4.4 Spills Analysis for Proposed Action

In the context of the impact analysis for TAPS, normal operations represent a constant, but relatively low, perturbation to the natural and human environment. Normal operations would not result in the release of oil or materials that would be hazardous to the environment or beyond permitted levels. In this section of the EIS, we examine accidental releases of oil to the environment. While highly unlikely, some of the oil spills could result in significant perturbations to natural systems. Oil spills are best examined separately from normal operations because the scenarios that generate accidental spills and the potential effects of those spills on the environment are of a different magnitude and type compared with normal TAPS operations.

Spills Analysis and Impact Definitions

A *spill scenario* is a description of a possible spill event, including the cause (e.g., earthquake), damage to containment vessel (e.g., crack in pipeline), the material and quantity spilled (e.g., crude oil), the location (e.g., MP 45), and how frequently such a spill would be expected to occur.

Spill frequency is a quantitative expression of the likelihood of a particular petroleum spill scenario. For example, if a corrosion leak along the length of the pipeline has a frequency of 1×10^{-3}/yr, this implies that a leak due to corrosion is expected to occur with a frequency of once in 1,000 years.

Spill volume is the quantity, usually expressed in barrels or gallons, of material released to the natural environment (e.g., escaping to soil outside of the facility).

Consequence is the associated impact on humans and/or the natural environment as a result of the release of material on soil, and/or into water and/or the air.

Risk is the product of the spill consequence and the associated frequencies. An example would be the risk associated with the frequency of occurrence of a sequence of events leading to the release, exposure, and resulting damaging effect on humans (e.g., second degree burn or lung damage) and the environment (e.g., loss of moose habitat).

4.4.1 Spill Scenarios

The prevention of a release or spill of petroleum products is inherent to the design of pipeline systems. Once the pipeline is operating, monitoring pipeline fluid flow parameters, instituting operational procedures and controls, and performing periodic maintenance procedures are typically used as industry spill prevention best practices. Spill prevention and response requirements specific to the TAPS are discussed in Section 4.1.4. As with all engineered systems, including pipelines, process or material failures and human error leading to material loss are expected occurrences. The environmental consequences from these occurrences, such as an accidental spill, cannot be evaluated without reference to a known or expected release of a specific size, location, and duration. The pipeline spill scenarios that have been developed for this spill analysis represent “credible” potential pipeline events, as defined in Appendix A, Section A.15, for use in assessing impacts from accidental releases or spills during TAPS operations.

The spill scenario environmental impacts assessed under the proposed action in this FEIS do not imply that these spills are “expected” pipeline events. In addition, a spill that actually occurs may or may not occur in the same sequence or combination of events as specified in the assessed spill scenarios. An underlying principle in this spills analysis is that conditions constantly change along the length of the TAPS. The spill volume and frequency vary as a function of milepost along the TAPS because of (1) varying conditions external to the pipeline system, such as topography, soil conditions, potential for damaging earth movements, and potential for third-party damages; and (2) varying pipeline system characteristics, such as pipe type, coating condition, operating pressures, maintenance practices, and types and dates of integrity validations. This spills analysis, therefore, considers the location-specific interaction of all critical variables in all failure modes, including to the extent possible, any risk-reducing measures taken by the operator.

This spill analysis focuses on potential spills associated with continued operation and maintenance of the TAPS from 2004 through 2034. Review of existing spill records contained in the TAPS Spills Database (TAPS Owners 2001b) established that the spills analysis should consider crude oil, gasoline, diesel fuel, and turbine fuel, on the basis of the projected continued pipeline transport and use of these materials in TAPS facility operations. The potential environmental impacts of the various types of petroleum products, such as gasoline and diesel fuel, are another measure by which the various petroleum products were considered for inclusion in the spills analysis. The TAPS pioneered the use of drag reducing agent, a long-chain hydrocarbon polymer injected into the pipeline to reduce pipeline friction and turbulent flow energy losses. Spills of drag reducing agent were discounted because of its high viscosity, slow environmental mobility, and relatively low toxicity compared with the petroleum spills covered by the analysis.

Potential spill scenarios were developed by using available literature concerning current TAPS operations (APSC 2001l; Capstone 2001; ARRT 2000). Recent NEPA documents for other pipeline projects (USFS and WEFSEC 1998; USFS 1999; CPUC and USFS 1996; CPUC 1998) were also reviewed to ensure consideration of a wide spectrum of spill scenarios consistent with current industry practice.

The severity and overall risk to the environment from petroleum product spills are direct functions of the following factors:

- Type of petroleum product spilled;
- Location, duration, and size of the spill;
- Frequency of spill events;
- Time of the year or the season in which the spill occurs;
- Local environmental conditions (e.g., wind or river speed, surface roughness, and porosity) at the time and place of the spill;
- Location and susceptibility of downstream or downwind receptors; and
- Effectiveness of emergency response and cleanup measures.

The first three factors, as they relate to the spill scenarios, are briefly discussed below, followed by identification and description of the spill events used in this analysis and their consideration in developing the spill scenarios. The last four factors are more related to the assessment of environmental impacts and are covered in the relevant consequence sections of this document.

The influence on the severity of impacts because of local conditions, receptor susceptibility, and effectiveness of emergency response measures is discussed in Sections 3.12, 4.4.4.9 through 4.4.4.12, and 3.1.2.1.6, respectively. The type and the associated characteristic properties of crude oil, refined petroleum, and the associated hazard materials used or generated as waste during TAPS operations were carefully considered in developing release scenarios that could pose a potential harm to the environment. These characteristics are discussed in further detail in Appendix A, Section A.15.

4.4.1.1 Pipeline and Valdez Marine Terminal Spill Scenarios and Locations

The developed spill scenarios took into account spill location, duration, magnitude, and frequency. Sensitive receptor locations and environmental media, such as rivers and streams, serving as spill transport-enhancing media to a sensitive receptor were identified as impacting factors along the pipeline. The spill magnitude and duration were computed in defining each spill scenario. Although large spills of relatively short duration may impose large to catastrophic environmental consequences, relatively long duration spills with release rates too small for detection with current technology could also pose large environmental consequences. Considering the extremely small frequencies of very large spills, such spills would be expected to represent a relatively small environmental risk (which takes into account frequency as well as consequence).

Frequency of occurrence, the fourth factor in the risk severity equation, allows the estimated environmental consequences from spill events to be put into perspective relative to likelihood of occurrence. The various spill scenarios developed for assessment in this EIS are forecast to occur at frequencies ranging from several times a year to once in 1 million years. In general, the greater the volume of material released and the greater the expected consequences, the more unlikely it would be for a spill to occur (the lower its probability). As discussed for the spills analysis methodology in Appendix A, Section A.15, each spill scenario was assigned to one of the following four frequency categories: *anticipated, likely, unlikely,* and *very unlikely*. The spill analysis computed frequencies for each pipeline scenario, and each scenario was assigned a likelihood category with frequency ranges given below:

- *Anticipated:* Spills estimated to occur one or more times every 2 years of TAPS operations (frequency ≥ 0.5 per year).
- *Likely:* Spills estimated to occur between once in 2 years and once in 30 years of TAPS operations (frequency = from 0.5 per year to 0.03 per year).
- *Unlikely:* Spills estimated to occur between once in 30 years and once in 1,000 years of TAPS operations (frequency = from 0.03 per year to 1×10^{-3} per year).
- *Very Unlikely:* Spills estimated to occur between once in 1,000 years and once in 1 million years of TAPS operations (frequency = from 1×10^{-3} per year to 1×10^{-6} per year).

The first two likelihood categories listed above have frequencies consistent with the historical operation of the TAPS, starting when the pipeline first began pumping crude oil from the North Slope on June 20, 1977. The 30- to 1,000-year range given for the third frequency category represents events that would be unlikely to occur within the renewal period of the TAPS. The once in a thousand year frequency boundary between the unlikely and very unlikely categories was set to be consistent with the TAPS design basis envelope (APSC 1996). The once in a million years frequency is set as the boundary between very unlikely events and events considered incredible.

Estimated pipeline spill frequencies for pipeline operations for each spill scenario were derived from data compiled from a number of available sources. Data on small- to moderate-sized spills with anticipated to likely frequencies were collected for all of the recorded spills that have occurred on the entire TAPS pipeline system over the 25 years from January 1977 to November 2001 (TAPS Owners 2001b). Frequencies for likely events also included data from DOT domestic natural gas transmission and gathering lines (DOT 2001a,b), and DOT domestic hazardous liquid pipelines (DOT 2001c). The spills analysis contained in the TAPS ROW Environmental Report (TAPS Owners 2001a) was used as an aid in identifying major spill events and in evaluating statistical distributions for the historical TAPS spill record.

Leaks resulting in pipeline spills may range from a small leak, where oil escapes the pipeline for an extended period of time until detected, to a large pipeline rupture, where crude oil is released into the environment over a relatively short time but in potentially large quantities. The volume of a leak depends on the size of the opening in the pipe, the crude oil density, the pipeline pressure, topography, and leak duration. The spill volumes for each scenario were determined by the duration of the release multiplied by the flow rate through an assumed hole size (barrels or gallons per hour), and the line draindown volume subsequent to shutdown of the line. The spill duration accounts for the time required to detect a leak, locate it if it is not immediately obvious, and shut down the pipeline (Capstone 2001). The draindown volume is the estimated quantity of crude oil that could be released from a pipeline rupture on the basis of topography, pipeline diameter, pressure, valve location, and response time.

The TAPS pipeline and Valdez Marine Terminal spill scenarios considered in this FEIS are outlined in Tables 4.4-1 and 4.4-2, respectively. One of three spill release duration ranges is assigned to each spill scenario identified in the tables. If a release is estimated to occur very quickly, with duration on the order of 1 hour or less, it is designated as an instantaneous release. Short duration releases are assumed to occur over periods of a few hours up to a day, and prolonged releases are assumed to take place over several days to several months.

Spills that occur very frequently (because of incorrect hose placement, equipment error, etc.) result in liquid releases in less than 1 hour. For example, a valve that is incorrectly turned could cause a leak, but the operator would notice the liquid on the ground and manually close the valve. Such a leak typically occurs in a time frame of less than 1 hour. Short duration releases include the “guillotine” break (complete break in the line) scenarios. A release from events such as an underground corrosion leak could occur over several days before it was noticed. In addition to giving the release duration, Tables 4.4-1 and 4.4-2 provide (1) a brief description of the spill scenario, (2) frequency range, (3) type of material spilled, (4) range in spill volume, (5) release point (above and/or below ground), and (6) release duration. The scenario spill frequencies given are specific to the entire pipeline (i.e., 800 mi) or to specific facilities within the Valdez Marine Terminal.

Although each of these spill scenarios poses an environmental risk, because of the potential volume of released material (upper end of spill ranges are greater than 15,000 bbl), Scenarios 16, 19, 20, and 21 would likely result in the largest environmental consequences. This observation, however, does not necessarily imply that these spills would represent the largest risk events for the TAPS ROW renewal. In this analysis, risk is taken to be the product of the annual frequency of a spill event and its severity consequences. Therefore, if a particular postulated event is calculated to potentially cause large consequences but occurs with low frequency, the calculated risk would be small. The development of the very unlikely catastrophic scenarios and their locations along the pipeline and at the Valdez Marine Terminal are described in Section 4.4.1.3.

4.4.1.1.1 Pipeline Spill Scenarios. Table 4.4-1 shows the 21 pipeline spill scenarios analyzed in this FEIS. The first group of TAPS pipeline events, Scenarios 1 through 8 in Table 4.4-1, was developed from consideration of more than 250 documented pipeline spills (TAPS Owners 2001b) during the first 25 years of pipeline operation. The scenarios include spills of North Slope crude and TAPS-related refined petroleum products (gasoline and diesel and turbine fuels), with a wide range of spill initiators or causes, ranging from equipment failure (e.g., faulty valves or drain plugs, sump pump failure, vent discharge) or human error (e.g., failure to follow maintenance procedures) to acts of vandalism. The spill volumes for these scenarios range from less than 1 to 1,800 bbl, and the durations are assumed to be short. The descriptions and locations of the top 12 spills, with spill volumes greater than 10,000 gal of crude oil, that have occurred along the pipeline, including the VMT, from 1977 through November 2001 are shown in Map 4.4-1. Although the historical record shows that these spills have occurred most frequently at PS 1 and 2 (about 30% of the spills) and along the pipeline segment between PS 4 and 5 (about 10% of the spills), they can generally be considered independent of pipeline location for spill scenario projections during the ROW renewal period. In light of the issues of pipeline aging and implementation of the RCM program for TAPS (APSC 2001k), these anticipated or likely spill projections appear to be reasonable to use in assessing the risk of these relatively small events over the ROW renewal period.

To avoid a double counting of spills associated with specific initiators considered under the likely to unlikely spill events, data for four specific spills reported in the TAPS Spills Database were screened from events composing Scenarios 1 through 8. Data for these spills were used in developing the sabotage/vandalism (Scenario 12) and ground settlement (Scenario 15) scenarios listed in Table 4.4-1. These events included the February 15, 1978, Steele Creek sabotage event involving an explosive detonation at MP 457 and the more

TABLE 4.4-1 Summary of Spill Scenarios for Continued Operation of the TAPS Pipeline

			Frequency Range				Release (spill) Characteristics			
Scenario No.	Scenario Description	Expected Frequency (per yr)	Anticipated (> 0.5/yr)	Likely (0.03 to 0.5/yr)	Unlikely (10^{-3} to 0.03/yr)	Very Unlikely (10^{-6} to 10^{-3}/yr)	Crude/ Oil Products	Spill Volume (bbl)	Release Point[a]	Release Duration[b]
1	Small leak of crude oil during pipeline or pump station operations	> 0.5	X				Crude oil	0 – 50	Above or below ground	Instantaneous
2	Small leak of diesel fuel during pipeline or pump station operations	> 0.5	X				Diesel fuel	0 –100	Above ground	Instantaneous
3	Small leak of gasoline during pipeline or pump station operations	> 0.5	X				Gasoline	0 – 3	Above ground	Instantaneous
4	Small leak of turbine fuel during pipeline or pump station operations	> 0.5	X				Turbine fuel	0 – 50	Above ground	Instantaneous
5	Moderate leak of crude oil during pipeline or pump station operations	0.5 – 0.03		X			Crude oil	50 – 1,800	Above or below ground	Instantaneous
6	Moderate leak of diesel fuel during pipeline or pump station operations	0.5 – 0.03		X			Diesel fuel	100 – 200	Above ground	Instantaneous
7	Moderate leak of gasoline during pipeline or pump station operations	0.5 – 0.03		X			Gasoline	3 – 100	Above ground	Instantaneous
8	Moderate leak of turbine fuel during pipeline or pump station operations	0.5 – 0.03		X			Turbine fuel	50 – 200	Above ground	Instantaneous

TABLE 4.4-1 (Cont.)

Scenario No.	Scenario Description	Expected Frequency (per yr)	Frequency Range: Anticipated (> 0.5/yr)	Likely (0.03 to 0.5/yr)	Unlikely (10^{-3} to 0.03/yr)	Very Unlikely (10^{-6} to 10^{-3}/yr)	Release (spill) Characteristics: Crude/ Oil Products	Spill Volume (bbl)	Release Point[a]	Release Duration[b]
9	Leak due to maintenance-related damage	4.0×10^{-2}		X			Crude oil	50 – 5,000	Above or below ground	Very Short
10	Leak due to overpressurization from inadvertent RGV closure	3.2×10^{-2}		X			Crude oil	1,000 – 3,000	Above or below ground	Short (hours)
11	Valve leak due to gasket failure or large packing leak	1.6×10^{-2}			X		Crude oil	1,000 – 10,000	Above ground	Prolonged (days)
12	Leak due to sabotage or vandalism	4.8×10^{-2}		X			Crude oil	900 – 10,000	Above ground	Prolonged (days)
13	Leak due to washout damage resulting from close proximity to a stream or river	5.4×10^{-4}				X	Crude oil	700 – 10,000	Above ground	Prolonged (days)
14	Leak due to corrosion-related damage	3.8×10^{-2}		X			Crude oil	200 – 10,000	Above or below ground	Prolonged (days)
15	Leak due to pipeline settlement (subsidence)	7.4×10^{-3}			X		Crude oil	50 – 5,000	Below ground	Short (hours)
16	Crack resulting from seismic fault displacements and ground waves	1.4×10^{-2}			X		Crude oil	3,000 – 16,000	Above or below ground	Short (hours)
17	Tank loss at TAPS pump station	1.1×10^{-5}				X	Crude oil	700	Above ground, on land, outside containment	Short (hours)

TABLE 4.4-1 (Cont.)

			Frequency Range				Release (spill) Characteristics			
Scenario No.	Scenario Description	Expected Frequency (per yr)	Anticipated (> 0.5/yr)	Likely (0.03 to 0.5/yr)	Unlikely (10^{-3} to 0.03/yr)	Very Unlikely (10^{-6} to 10^{-3}/yr)	Crude/ Oil Products	Spill Volume (bbl)	Release Point[a]	Release Duration[b]
18	Guillotine break due to impact of a large truck (18-wheeler)	1.7×10^{-4}				X	Crude oil	2,000 – 5,000	Above ground	Short (hours)
19a	Guillotine break due to aircraft crash without fire	8.6×10^{-3}			X		Crude oil	2,000 – 54,000	Above ground	Short (hours)
19b	Guillotine break due to aircraft crash with fire	2.6×10^{-3}			X		Crude oil	2,000 – 54,000	Above ground	Short (hours)
20	Guillotine break due to landslide (e.g., seismic initiated)	8.0×10^{-3}				X	Crude oil	2,500 – 47,000	Above or below ground	Short (hours)
21	Guillotine break due to impact of a helicopter	2.9×10^{-5}				X	Crude oil	2,000 – 54,000	Above ground	Short (hours)

[a] See Table 4.4-5 for the surface water bodies that guillotine break spills would be expected to reach. Depending upon terrain features and spill proximity, smaller spills may also reach surface water bodies. See Sections 4.4.4.3 and 4.4.4.4 for discussion of spill impacts on surface water and groundwater resources.

[b] An instantaneous release is defined as a final spill of duration on the order of 1 hour or less.

TABLE 4.4-2 Summary of Spill Scenarios for Continued Operations of the TAPS Valdez Marine Terminal

			Frequency Range				Release (Spill) Characteristics				
Event No.	Scenario Description	Estimated Frequency (per year)	Anticipated (>0.5/yr)	Likely (0.03 to 0.5/yr)	Unlikely (10^{-3} to 0.03/yr)	Very Unlikely (10^{-6} to 10^{-3}/yr)	Crude/ Oil Products	Spill Volume (bbl)	Release Duration	Release Point/ Environmental Media	Spill Reaches Water?
1	Small leak of crude oil during VMT[a] operations	~0.5	X				Crude oil	13.0	Short	Land, outside containment	No
								0.5	Short	Water (Port Valdez)	Yes
2	Small leak of diesel fuel during VMT operations	~0.5	X				Diesel fuel	15.0	Short	Land, outside containment	No
								0.02	Short	Water (Port Valdez)	Yes
3	Moderate leak of crude oil during VMT operations	3.0×10^{-2}		X			Crude oil	3,200	Short	Land, outside containment	No
								1,700	Short	Water (Port Valdez)	Yes
4	Moderate leak of diesel fuel during VMT operations	3.0×10^{-2}		X			Diesel fuel	300.0	Short	Land, outside containment	No
								0.7	Short	Water (Port Valdez)	Yes
5	Cargo tank vessel cracks discovered while loading crude oil	4.7×10^{-2}		X			Crude oil	500	Short	Water	Yes
6	Failure of loading system between terminal dock and ship	1.7×10^{-3}			X		Crude oil	80	Instantaneous (10 seconds)	Water	Yes

TABLE 4.4-2 (Cont.)

Event No.	Scenario Description	Estimated Frequency (per year)	Frequency Range: Anticipated (>0.5/yr)	Likely (0.03 to 0.5/yr)	Unlikely (10^{-3} to 0.03/yr)	Very Unlikely (10^{-6} to 10^{-3}/yr)	Release (Spill) Characteristics: Crude/ Oil Products	Spill Volume (bbl)	Release Duration	Release Point/ Environmental Media	Spill Reaches Water?
7	Diesel fuel line rupture	1.0×10^{-4}			X		Diesel fuel	450	Short	Land	No
8	Pipeline failure between the east tank farm and the west manifold	1.3×10^{-5}				X	Crude oil	11,300	Short	Land	No
								100	Short	Water	Yes
9	Pipeline failure between west metering and Berth 5	1.3×10^{-5}				X	Crude oil	5,900	Short	Land	No
								1,900	Short	Water	Yes
10	Aircraft crash into crude oil tank at East Tank Farm, w/fire	2.1×10^{-5}				X	Crude oil	382,500	Prolonged	Air (dike fire)	No
11	Catastrophic rupture of a crude oil storage tank (e.g., foundation or weld failure)	1.8×10^{-6}				X	Crude oil	50,350	Instantaneous	Land, outside containment	No
								143,450	Instantaneous	Water (Port Valdez)	Yes
12	Catastrophic rupture of a diesel fuel tank	2.2×10^{-6}				X	Diesel fuel	40,000	Short	Land	No

[a] VMT = Valdez Marine Terminal.

recent October 4, 2001, random vandalism act at MP 400 near Livengood. Two ground settlement-induced crude spills occurred in 1979. The first involved the melting of thick ice lenses in weathered bedrock beneath a section of buried pipe at Atigun Pass, and the other involved pipeline settlement near PS 12 caused by melting of ground ice in silty settlement. The locations of these two spills, along with 10 others, are shown in Map 4.4-1 as the 12 largest pipeline and Valdez Marine Terminal spills during TAPS operations.

Scenarios 9 through 12 and 14 through 16 were developed from data reported in previously identified TAPS-specific spill analyses or risk assessments and historical data compiled by the DOT for other pipeline systems. The seven likely or unlikely events, with spill totals ranging from 50 to 16,000 bbl of crude, included spills resulting from (1) damage from maintenance activity, (2) overpressurization from spike in hydraulic head, (3) flange or seal leaks, (4) vandalism or sabotage, (5) corrosion, (6) settlement or subsidence, and (7) cracks in the pipeline from seismic activity.

The last group of events, Scenarios 13, 17, 18, 20, and 21, summarized in Table 4.4-1, were developed from statistical data for potential spill event initiating activities along the pipeline and data or guidance from the DOT, DOE, and FAA. Crude oil releases from these types of events would generally be considered to lead to a catastrophic spill. These five scenarios were in the very unlikely event frequency category and included leaks from pipeline washout damage (Scenario 13) and from tank failure at a pump station (Scenario 17), and guillotine breaks from impact of a large truck (Scenario 18), a large landslide (e.g., seismic-initiated) (Scenario 20), and impact of a helicopter (Scenario 21). Pipeline milepost spill volumes for the guillotine break scenarios were estimated with the aid of the APSC Oil Spill Volume (OSV) Model (Carpenter 1997).

4.4.1.1.2 Valdez Marine Terminal Spill Scenarios. Table 4.4-2 shows the 12 Valdez Marine Terminal spill scenarios developed and analyzed in this FEIS. The Valdez Marine Terminal Scenarios 1 through 4 were developed from more than 250 documented spills at the terminal (TAPS Owners 2001b) during the first 25 years of operation of the pipeline. The scenarios covered spills of North Slope crude oil and diesel fuel. The spill volumes for these scenarios ranged from about 15 bbl of diesel fuel to 3,200 bbl of crude oil, all of short spill duration. Spill initiators or causes and spill size ranged from relatively small fuel line ruptures to large valve leaks at storage tanks.

Scenarios 5 through 7 were developed from data reported in previously identified Valdez Marine Terminal specific spill analyses or risk assessments and historical data compiled by DOT for other marine terminals. Scenario 5 is in the likely category, whereas Scenarios 6 and 7 have frequencies in the unlikely category, with spill totals ranging from 80 to 500 bbl of oil. The scenarios are as follows:

- Scenarios 5 and 6 are equipment-related failures occurring during loading operations at berths. Scenario 5 is a crack in the cargo tank of a vessel loading Alaskan crude oil. The majority of the oil is contained inside a boom. Scenario 6 is a leak in loading arm berths 3 through 5, which is assumed to take 10 seconds to discover and close the valves; most of the oil is contained inside a boom.

- Scenario 7 is a diesel fuel line rupture. The line is a 1,800-ft-long 16-in.-diameter pipeline connecting Berth 1 loading arms with the diesel tanks at the Valdez Marine Terminal.

Scenarios 8 and 9 are overpressurization pipeline ruptures caused by inadvertent valve closure. In Scenario 8, the rupture in the pipeline is between the East Tank Farm and the West Manifold, and in Scenario 9, it is between the west metering station and Berth 5.

The last three scenarios, 10 through 12, summarized in Table 4.4-2 were developed from statistical data for potential spill event initiating activities at the Valdez Marine Terminal and data or guidance from DOT, DOE, and the FAA. These types of events would generally be considered to lead to catastrophic spills. A total of three scenarios were developed as very unlikely events, including (1) aircraft crash with subsequent fire followed by a prolonged secondary containment area fire in the east tank farm, (2) a failure of a 510,000-bbl crude oil tank, and (3) a rupture of a diesel fuel tank.

4.4.1.2 Transportation-Related Spill Scenarios

Table 4.4-3 shows the seven proposed action transportation spill scenarios developed and analyzed in this FEIS. The first two events can be categorized as very unlikely truck accidents involving spills of turbine fuel and arctic-grade diesel. The last five have unlikely or very unlikely frequencies and involve truck accidents with spills of turbine fuel. Scenarios 1 through 4 were based upon data on Alaska hazardous material spills (ADEC 2001b) and from data available on large hazardous materials spills and spill rates per truck mile (USFS and WEFSEC 1998). Scenarios 3 through 7 were based on data in the DOT Hazardous Materials Information System Database (1990–1995) for highway transportation accidents involving fires and explosions (Brown et al. 2000). All of the scenarios involved spills initially contaminating land surfaces.

The seven *unlikely* and *very unlikely* hazardous material truck accidents can be summarized as follows:

- *Scenario 1:* A fuel truck carrying liquid turbine fuel from the Williams North Pole Refinery to PS 7 leaves the highway and overturns on Old Richardson Highway. Between 5,000 to 8,000 gal of turbine fuel is spilled.

- *Scenario 2:* A fuel truck carrying Arctic grade diesel fuel from the Williams North Pole Refinery to PS 12 leaves the highway and overturns on Richardson Highway. Between 5,000 to 8,000 gal of diesel fuel is spilled.

- *Scenario 3:* A fuel truck carrying liquid turbine fuel from the Petro Star Refinery in Valdez to PS 12 leaves the highway and overturns on either State Highway 4 or State Highway 1. Between 5,000 to 8,000 gal of turbine fuel is spilled.

- *Scenario 4:* A fuel truck carrying liquid turbine fuel from the Williams North Pole Refinery to PS 9 leaves the highway and overturns on State Highway 2. Between 5,000 to 8,000 gal of turbine fuel is spilled.

- *Scenario 5:* A fuel truck carrying liquid turbine fuel from the Petro Star Refinery in Valdez to PS 12 leaves the highway and overturns on either State Highway 4 or State Highway 1. Between 5,000 to 8,000 gal of turbine fuel is spilled. The spilled amount subsequently ignites and burns.

- *Scenario 6:* A fuel truck carrying liquid turbine fuel from the Williams North Pole Refinery to PS 7 leaves the highway and overturns on Old Richardson Highway. Between 5,000 to 8,000 gal of turbine fuel is spilled. The spilled amount subsequently ignites and burns.

- *Scenario 7:* A fuel truck carrying liquid turbine fuel from the Williams North Pole Refinery to PS 9 leaves the highway and overturns on State Highway 2. Between 5,000 to 8,000 gal of turbine fuel is spilled. The spilled amount subsequently ignites and burns.

4.4.1.3 Catastrophic Spills at Environmentally Important Pipeline or Valdez Marine Terminal Locations

The catastrophic events identified in Tables 4.4-1 and 4.4-2 are discussed in further detail below with reference to sensitive or important environmental or human health and safety receptor locations along the pipeline and in the vicinity of the Valdez Marine Terminal.

4.4.1.3.1 Catastrophic Pipeline Events. A total of six to eight aboveground crude oil relief, or “breakout,” tanks with storage capacities ranging from 55,000 to 210,000 bbl, are projected to serve five to seven TAPS pump stations under the proposed action alternative. A scenario involving catastrophic loss for these tanks is considered in Section 1.1.1 of the *TAPS Pipeline Oil Discharge Prevention and*

TABLE 4.4-3 Summary of Spill Scenarios for Continued Operation of the TAPS: Transportation Accidents

			Frequency Range				Release (Spill) Characteristics				
								Spill Volume (bbl)			
Scenario No.	Spill Scenario Description	Frequency (1/year)	Anticipated (> 0.5/yr)	Likely (0.03 to 0.5/yr)	Unlikely 10^{-3} to 0.03/yr)	Very Unlikely (10^{-6} to 10^{-3}/yr)	Spill Material	Low	High	Release Duration	Release Point
1	Overturn of a liquid turbine fuel truck between the North Pole Refinery to PS 7	$3.6 – 6.2 \times 10^{-5}$				X	Turbine fuel	119	190	Instantaneous	Above ground, on land
2	Overturn of a fuel truck carrying Arctic grade diesel between the North Pole Refinery to PS 12	$1.1 – 1.9 \times 10^{-4}$				X	Arctic grade diesel	119	190	Instantaneous	Above ground, on land
3	Overturn of a liquid turbine fuel truck between the Petro Star Refinery to PS 12	1.4×10^{-3}			X		Turbine fuel	119	190	Instantaneous	Above ground, on land
4	Overturn of a liquid turbine fuel truck between the North Pole Refinery to PS 9	$4.9 – 8.6 \times 10^{-3}$			X		Turbine fuel	119	190	Instantaneous	Above ground, on land
5	Overturn of a liquid turbine fuel truck with subsequent fire between the Petro Star Refinery to PS 12	1.6×10^{-4}				X	Turbine fuel	119	190	instantaneous	Above ground, on land, air
6	Overturn of a liquid turbine fuel truck with subsequent fire between the North Pole Refinery to PS 7	$4.2 – 7.3 \times 10^{-6}$				X	Turbine fuel	119	190	Instantaneous	Above ground, on land, air
7	Overturn of a liquid turbine fuel truck with subsequent fire between the North Pole Refinery to PS 9	$5.8 \times 10^{-4} – 1.0 \times 10^{-3}$				X	Turbine fuel	119	190	Instantaneous	Above ground, on land, air

Contingency Plan (CP-35-1) (APSC 2001l). Considerable data exist for aboveground storage tanks. An example (not related to TAPS) of such a failure occurred in 1988 when a catastrophic failure of a brittle tank spilled 750,000 gal of diesel fuel into adjacent storm sewers that emptied into a nearby river. Another large failure occurred in March 2000 when the entire contents of a tank owned by West Coast Aviation (Unalakleet, Alaska) spilled more than 84,000 gal. On the basis of a review of historical records of large tank failures, the *Guidelines for Chemical Process Quantitative Risk Analysis* (Center for Chemical Process Safety 2000) reports a mean catastrophic tank failure rate of 1.0×10^{-6}/tank-year. The conditional probability of secondary containment failure is on the order of 25%. On the basis of this value, the probability of a catastrophic tank failure for all of the TAPS pump station tanks is projected to be 1.1×10^{-5}/tank year (or with a frequency of about 1 occurrence every 100,000 years), which is considered a very unlikely event. It is estimated that 15,000 to 120,000 bbl of oil could spill from tanks at pump stations because of such an event. However, because of secondary containment around the tanks, only about 700 bbl of crude oil is estimated to spill beyond or outside of this containment at PS 3. On the basis of historical working volumes for the other pump station relief tanks (Norton 2002a), all of the oil is predicted to be captured by the secondary containment at these locations along the pipeline.

The pipeline is monitored from the air by helicopter. Knowing the number of miles of aboveground pipe and assuming about 100 helicopter overflights per year, the likelihood of a pipeline crash can be estimated from the statistical parameters (i.e., target area and crash rates per flight) relating to helicopter crashes with pipelines reported in DOE-STD-3014-96 (DOE 1996). (This analysis does not consider helicopter overflights of the TAPS for tourist sight-seeing trips and other non-APSC-related activities.) Because there are 418 mi of aboveground pipe, the crash frequency is conservatively estimated to be 2.9×10^{-5} per year. Thus, occurrence of such a crash during the renewal period of the TAPS would be considered a very unlikely event. As estimated from the OSV model, guillotine break volumes along the pipeline are estimated to range from 1,000 to 54,000 bbl.

The analysis of fixed-wing aircraft impacts is intended to provide a conservative analysis of the risk from an aircraft crash into the pipeline or other system facility. The approach used was based on guidance published in DOE-STD-3014-96 (DOE 1996). Actual and projected takeoff and landing data for 11 airports within 10 mi of the pipeline over a 21-year period from 1995 through 2015 were used in estimating crash frequencies and impact damage to the pipeline. The airports considered in this analysis are listed in Table 4.4-4. The analysis showed that the impact from a small, single-engine or

TABLE 4.4-4 Airports within 10 Miles of the Pipeline

Airport	City
Chandalar Shelf	Chandalar Shelf
Coldfoot	Coldfoot
Deadhorse	Deadhorse
Fairbanks International	Fairbanks
Galbraith Lake	Galbraith Lake
Gulkana	Gulkana
Porcupine Creek	Porcupine Creek
Prospect Creek	Prospect Creek
Valdez Airport	Valdez
Wainwright Air Force Base	Fairbanks/Fort Wainwright
Wiseman	Wiseman

multiengine aircraft weighing 12,500 lb may cause significant damage (e.g., at least a local pipe perforation) to the pipeline. It was assumed that the impact from a medium to large aircraft weighing between 12,500 to 300,000 lb would result in a guillotine break. The frequency of a guillotine break in the pipeline from air plane impact is unlikely, with an estimated frequency of occurrence of around once in 100 to 400 years (8.6×10^{-3}/yr). On the basis of the analysis supporting the DOE Waste Management Programmatic Environmental Impact Statement (Mueller et al. 1996) and Wall (1974), a conditional probability of 30% of a postcrash fire was assumed. This assumption resulted in an aircraft crash with a fire frequency of 2.6×10^{-3}/yr (once in 400 years).

For the “vehicle impact” scenario, the determination that the steel pipeline could be locally penetrated by an 18-wheeler carrying a heavy load (e.g., pipes) was estimated by using the formula from the Ballistic Research Laboratory (DOE 1996). The analysis conservatively assumes that the engine from a large truck would penetrate the pipeline. The frequency of occurrence of the truck penetration was estimated to be 1.7×10^{-4}, which classifies it as a very unlikely event.

The frequency of a seismically induced leak has been estimated by the superposition of leak risks described in Capstone (2001) and Technica, Inc. (1991). Superposition is justified because the failure mechanisms for these events are independent. The frequency estimate provided by Capstone assumes that an earthquake of sufficient magnitude to cause a crack would have a return period of 500 years. On the basis of expert judgment, this event might result in an occurrence of 2 leaks per 100 mi of pipeline in the affected region. The resulting base leak frequency is 40×10^{-6} leak per mile per year. This base frequency is adjusted for high-risk areas (bridge and fault crossings, aboveground sections, and geologic watch-list areas). By integrating this adjusted frequency over the pipeline path, the total leak frequency is estimated as 1.2×10^{-2} per year. This is consistent with results presented in Capstone (2001, Table 25). Technica, Inc. (1991) has identified an independent failure mode that may be active in the vicinity of the Denali Fault. That mechanism is pipe cracking caused by impingement of the pipeline against supports following displacement of the pipeline off of the supports during a severe seismic event. The additional frequency calculated for this event is 1.6×10^{-3}. The superposition of this event with the event reported in Capstone yields a total leak frequency of 1.4×10^{-2}. Spill volumes associated with these events are assumed to be between 3,000 and 16,000 bbl, on the basis of values suggested in the Technica assessment. The Capstone assessment does not postulate seismicity-induced spill volumes.

Landslides can be triggered by flood, earthquake, and other events. This spill analysis assumes that the initiator is a strong earthquake, as demonstrated by the historical significant seismic activity in Alaska (see discussion in Section 3.4). The frequency of a TAPS landslide-induced leak or spill resulting in a guillotine break was estimated by first recognizing that the most landslide prone soils have experienced landslides in the past. Analyses of soil cores taken at the centerline of the TAPS show that about 0.05% of the soil along the pipeline previously experienced landslide disturbance (Kreig and Reger 1982). Given that the susceptible soils are found only in the mountainous regions, the expectation would be to find all of the 0.05% of this soil occurring in those regions. Since the length of the pipeline through those regions is approximately 227 mi, the percentage of soil in the mountainous regions with past landslide exposure is estimated to be 0.176% (i.e., $0.05 \times 800/227$). Thus, the probability of an historical landslide area existing at any point along the route within the mountainous region is 0.00176. Assuming a 500-year return period[1] for an earthquake of sufficient magnitude to initiate a landslide, the probability of a landslide event triggered by the earthquake is $0.00176/500 = 3.5 \times 10^{-6}$. This

[1] It is assumed that an earthquake with a return period of 500 years is sufficient to induce a landslide because (1) it is known that landslides were triggered by the great Alaska earthquake in 1964 and the return period for such a quake has been estimated to be 700 years (Wesson et. al. 1999); (2) it is reasonable to assume that lesser earthquakes may trigger landslides, they certainly have in other areas; and (3) regional warming in Alaska may be increasing the susceptibility of soils to landslide (see Section 3.3).

probability is applied as the average over each milepost segment through the mountainous regions: the Brooks Range (MP 140–237), Alaska Range (MP 560–610), and Chugach Mountains (MP 720–800). Since the Brooks Range is in a less seismically active area than the other two mountainous regions, this probability estimate is relatively conservative. The overall probability of a landslide-initiated guillotine break over the entire length of the pipeline is 8.0×10^{-4} ($3.5 \times 10^{-6} \times 229$ mi).

Catastrophic spill volumes resulting from guillotine breaks have been assessed at or along 41 pipeline points or segments identified for assessing impacts that may pose the largest environmental consequences and/or impact environmentally important or sensitive receptors. The TAPS crosses widely varying terrain, including the broad Arctic Coastal Plain, three major mountain ranges, hilly uplands, hundreds of small streams, and several major rivers. The five river crossing locations identified in Table 4.4-5 were selected because the rivers are either classified as anadromous fish stream or are designated as Wild and Scenic, or both (Sections 3.7 and 3.28). They also represent rivers in three different portions of the TAPS ROW, as described in Section 3.7. Minton Creek was included because it would receive the largest quantity of crude oil in a guillotine break scenario. The identification of land-based areas included consideration of geology and seismicity. Catastrophic spill impacts are assessed in Section 4.4.4.1 for earthquake-prone areas in the Chugach Mountains (identified as MP 795 through 798, MP 727 through 735 in the table) and the southern edge of the Copper River Basin (MP 710 through 722). MP 587 through 590 and 593 through 600 are located in Wild and Scenic areas. Additional land-based locations were included to be representative of areas with different types of terrestrial wildlife habitats that occur along the TAPS, including lowland tundra, upland tundra, and boreal forest. The evaluated locations were also selected to represent locations where there are limited topographic features that would impede spreading of any spilled oil.

The spill volumes were estimated with the OSV model for three crude oil throughput levels: 0.3, 1.1, and 2.1 million bbl/d (see Appendix A, Section A.15). These crude oil spill volumes are specific to scenarios involving a guillotine-break of the TAPS pipeline and were taken from an APSC-supplied OSV model output file that gave the spill volumes at each survey point (over 100,000 points along the pipeline) for a given TAPS throughput (Norton 2001b, 2002b; Brown 2002). Table 4.4-5 provides the estimated spill volumes at various environmentally important areas along the TAPS pipeline as well as the estimated size of potentially oil-contaminated land surface. Because frequency estimates were developed on a per-mile basis for the spills analysis, mile-averaged guillotine break spill volumes were applied for the areas that encompassed one mile in length. The TAPS pipeline contains a large number of emergency shut-off valves that are located within various mile-long segments along the TAPS. In these cases, two guillotine break spill volumes were computed, one before the valve and the other after the valve. The higher of the two estimated spill volumes was conservatively applied for mile-long segments containing valves. For areas with lengths less than one mile, the maximum spill volume for the identified length of pipeline was applied, as a conservative measure, because the method of spill volume averaging by the OSV modeling results could not be readily ascertained.

Large spill events along these pipeline segment locations could have both land-based and/or water-based impacts. The locations (by name and pipeline milepost numbers) of specific water bodies and land-based sites, the predicted maximum computed crude oil spill quantities, and the estimated potentially contaminated areas are given in Table 4.4-5. These estimates conservatively assume that the spill would continue to spread on the basis that containment by spill response would not occur. Although one might expect larger spill volumes with higher pipeline operating throughputs, other factors may result in larger spill volumes at lower throughputs (see Table 4.4-5). These factors would include the location of the pipeline break relative to check or gate valves, the pipeline pressure at that location, and valve closing time.

Two approaches — parametric and objective analyses — were used to arrive at estimates of the area that may be potentially contaminated by

TABLE 4.4-5 Milepost-Specific Maximum Guillotine Break Crude Oil Spill Volumes

Geophysical Feature (name/type)	Approximate Pipeline Location (MP or MP Range)	Guillotine Break Volumes (bbl) by Pipeline Throughput Level			Estimated Maximum Spill Areas (acres) by Pipeline Throughput Level[a]									Objective Analysis
		0.3×10^6 bbl/d	1.1×10^6 bbl/d	2.1×10^6 bbl/d	0.3×10^6 bbl/d			1.2×10^6 bbl/d			2.1×10^6 bbl/d			
					1 in.	2 in.	3 in.	1 in.	2 in.	3 in.	1 in.	2 in.	3 in.	
Water-Based														
Sag River	83–85[b]	28,998	29,880	31,662	NA[c]	NA	NA	NA	NA	NA	NA	NA	NA	NA
Yukon River	353–354	20,477	21,246	17,676	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Tanana River	531	7,489	8,486	11,612	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Gulkana River	654–655	26,308	27,930	24,690	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Tazlina River	686–687	17,334	18,291	15,871	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Minton Creek	510	52,390	53,967	50,561	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Land-Based														
Spectacled eider, lowland tundra	1–12	22,168	23,228	24,552	34	17	11	36	18	12	38	19	13	NA
Upland tundra	86–88	27,077	27,946	29,687	42	21	14	43	22	14	46	23	15	6.1
Cultural resources	112–115	41,274	42,238	43,430	64	32	21	65	33	22	67	34	22	72.7
Upland tundra	129–130	20,931	21,734	22,757	32	16	11	34	17	11	35	18	12	NA
Brooks Range (cultural resources)	142–144	34,030	34,677	35,485	53	26	18	54	27	18	55	27	18	18.2
Brooks Range (cultural resources)	215–216	27,120	29,797	26,647	42	21	14	46	23	15	41	21	14	12.1
Brooks Range (cultural resources)	226–228	32,916	35,425	32,492	51	25	17	55	27	18	50	25	17	3.9
Boreal forest	253–254	19,233	21,379	18,995	30	15	10	33	17	11	29	15	10	12.7
Boreal forest	317–318	41,832	43,098	40,338	65	32	22	67	33	22	62	31	21	18.2
Boreal forest; Yukon Valley	358–360	28,726	29,419	25,639	44	22	15	46	23	15	40	20	13	12.1
Boreal forest	388–390	28,234	28,506	30,394	44	22	15	44	22	15	47	24	16	21.8

TABLE 4.4-5 (Cont.)

Geophysical Feature (name/type)	Approximate Pipeline Location (MP or MP Range)	Guillotine Break Volumes (bbl) by Pipeline Throughput Level			Estimated Maximum Spill Areas (acres) by Pipeline Throughput Level[a]									Objective Analysis
					0.3×10^6 bbl/d			1.2×10^6 bbl/d			2.1×10^6 bbl/d			
		0.3×10^6 bbl/d	1.1×10^6 bbl/d	2.1×10^6 bbl/d	1 in.	2 in.	3 in.	1 in.	2 in.	3 in.	1 in.	2 in.	3 in.	
Cultural resources	396–397[b]	31,722	31,582	32,180	49	25	16	49	24	16	50	25	17	12.1
Boreal forest	410–411	49,211	49,167	46,320	76	38	25	76	38	25	72	36	24	24.2
Land-based	450	40,172	44,544	45,964	62	31	21	69	34	23	71	36	24	0.2
Goldstream Creek	448–453[b]	47,460	52,155	53,565	73	37	24	81	40	27	84	41	28	NA
Air quality (near Fairbanks)	456–458	36,663	40,905	42,101	57	28	19	63	32	21	65	33	22	NA
Air quality (near Fairbanks)	475	12,002	15,047	15,156	22	11	7	29	14	10	30	15	10	NA
Land-based	480	35,506	38,400	38,229	55	27	18	59	30	20	59	30	20	0.2
Boreal forest	482–483	31,377	34,092	33,831	49	24	16	53	26	18	52	26	17	45.0
Boreal forest; Frank Tanana Valley	521–523	26,638	27,892	34,370	41	21	14	43	22	14	53	27	18	NA
Upland tundra, Alaska Range	557–558	17,894	18,752	19,949	28	14	9	29	15	10	31	15	10	48.5
Upland tundra, Alaska Range	565–567	14,043	14,916	16,200	34	17	11	35	17	12	37	18	12	54.5
Seismically active, Alaska Range	587–590	16,301	17,507	15,734	25	13	8	27	14	9	24	12	8	12.1
Seismically active, Alaska Range	593–600	24,830	26,119	26,891	37	19	12	39	20	13	41	20	14	24.2
Boreal forest	619–622	16,906	18,510	19,239	26	13	9	29	14	10	30	15	10	52.1
Boreal forest	632–635	39,348	41,196	42,026	61	30	20	64	32	21	65	33	22	7.3

TABLE 4.4-5 (Cont.)

Geophysical Feature (name/type)	Approximate Pipeline Location (MP or MP Range)	Guillotine Break Volumes (bbl) by Pipeline Throughput Level			Estimated Maximum Spill Areas (acres) by Pipeline Throughput Level[a]									Objective Analysis
					0.3×10^6 bbl/d			1.2×10^6 bbl/d			2.1×10^6 bbl/d			
		0.3×10^6 bbl/d	1.1×10^6 bbl/d	2.1×10^6 bbl/d	1 in.	2 in.	3 in.	1 in.	2 in.	3 in.	1 in.	2 in.	3 in.	
Boreal forest, Copper Plateau	660–680	40,260	41,596	39,614	62	31	21	64	32	21	61	31	20	NA
Land-based	692	13,322	14,198	12,060	21	10	7	22	11	7	19	9	6	5.5
Land-based	695	34,828	35,662	33,470	54	27	18	55	28	18	52	26	17	5.5
Boreal forest, Copper Plateau	700–705	37,624	38,359	36,317	58	29	19	59	30	20	56	28	19	55.8
Seismically active, Copper River Basin	710–718	32,940	33,530	31,691	51	25	17	52	26	17	49	25	16	22.4
Seismically active, Copper River Basin	719–722	26,600	27,054	25,253	–[d]	–	–	–	–	–	–	–	–	–
Seismically active, Chugach Mountains	727–729[b]	25,618	15,524	13,619	40	20	13	24	12	8	21	11	7	24.2
Seismically active, Chugach Mountains	730–735	32,110	20,950	19,010	–	–	–	–	–	–	–	–	–	–
Seismically active, Chugach Mountains	795–798[b]	21,679	35,893	26,258	–	–	–	–	–	–	–	–	–	–

a Based on spill volumes for three TAPS daily throughput levels and assumed parametrically adjusted pool depths of 1, 2, and 3 in.

b A portion of the pipe between the two mileposts indicated would be below ground. The spill areas indicated would not be applicable to those pipeline segments.

c NA = the objective analysis is not applicable for this particular pipeline location (see text discussion).

d A dash indicates a belowground pipeline segment, guillotine break from landslide is possible. See discussion of possible surface contamination in Section 4.4.4.1.

a crude oil or other petroleum product spill. Estimates of the extent of ground contamination based on the parametric approach are applicable to spill areas along the pipeline on essentially flat terrain. The objective analysis essentially applies to all other spill areas where terrain features would constrain the spread (e.g., terrain obstacles) of crude oil or influence the direction of that spread (e.g., terrain slope). The estimated spill areas and volumes for the guillotine break scenarios at the three simulated crude oil throughput levels are provided in Table 4.4-5 for the identified environmentally important milepost locations. Spill areas and volumes for locations along the pipeline that are given over MP ranges (e.g., MP 86–88) are the computed maximum values of milepost-to-milepost calculations.

Spill areas estimated with the parametric approach were simply calculated by dividing the projected spill volume by a parametric adjustment to an assumed crude oil spill depth. At the time when the crude oil stops spreading, the spilled liquid pool on the ground was assumed to have an average depth or thickness of 1, 2, or 3 in. To assure conservative estimates of spill areas, it was assumed that no crude oil losses occur from seepage into the underlying surface or from evaporation to the atmosphere. Evaporation alone could result in a loss in pool mass by as much as 15% within 24 hours.[2] This would result in a proportional reduction in the estimated contaminated areas, as determined by the parametric-derived values listed in Table 4.4-5. Since spill volume was not explicitly factored into the area estimates determined with the objective analysis, neglecting evaporation would have a nonproportional influence on those values (see further discussion below). Finally, the parametric method inherently maximizes the extent of the estimated contamination or spill area by conservatively neglecting surface roughness, viscous drag on the crude oil from contact with the surface, and liquid surface tension. All spill surfaces were conservatively assumed to be nonporous. In addition to the estimated areas for guillotine spills on flat terrain, as required, the spill areas were also estimated using the parametric approach for all of the other scenarios involving smaller spill volumes (see Section 4.4.4).

The use of the objective analysis method for estimating the size of a contaminated area on land is restricted to terrain constraining spill spread areas where significant terrain features can be clearly discerned from topographic maps, and for which spill volumes were large enough to sufficiently cover the area constrained by the topographic and/or hydrologic feature. This essentially restricted the application of the objective analysis to the guillotine break spill scenarios. The objective analysis takes advantage of site-specific land features, such as slopes, surface water bodies, access roads, workpads, and/or highways, that control the pathway of a plume and influence the extent of ground contamination from a surface release of liquid such as crude oil.

The objective analysis is based on three main assumptions. First, the land features at a release site are the sole controlling factors in determining the size of a contaminated area. Factors that would reduce the size of a contaminated area, such as evaporation and infiltration, are not included. Further, as stated above, the volume of oil released is assumed to be sufficient to cover the estimated area. The

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2 It is estimated that 13% by weight of a North Slope crude oil spill would evaporate to the atmosphere within 24 hours. This loss would primarily be in the light-end components and at ambient temperatures of around 15°C. This loss over the same 24-hour period is estimated to increase by around 2 to 3%, with a 10-degree rise in temperature. As the more volatile crude oil components evaporate, the rate of loss from the surface declines. These estimates are based on empirically derived expressions by Fingas (1996) who notes that for periods less than 5 to 10 days after a spill, evaporative losses seem to follow a power law square root function with time, and then a logarithmic function for the longer elapsed times. Therefore, for periods greater than 5 to 10 days after a spill it is estimated that around 18% of the oil would evaporate in one week, with only an additional 5% loss at the end of 8 weeks. These estimates assume a mean temperature of around 15°C. The equations specific to North Slope crude were used in calculating the evaporative losses reported above. These estimates are based on statistically derived empirical expressions by Fingas (1996), who measured and studied the evaporative characteristics of approximately 20 different crude oils, including North Slope crude, and several petroleum products (e.g., diesel fuel). Experimental and distillation data were reviewed, and "best-fit" equations were determined for estimating the rate of evaporation with temperature and time.

analysis assumes that the land features provide constraints that maximize the estimated area. If the volume of oil from a guillotine break is relatively small, say less than about 20,000 bbl, and the terrain of a spill site is flat or slopes gently, a plume might stop spreading before it reaches an interceptor. In this case, the method fails and the areas estimated with the parametric approach would be better used in assessing the environmental consequences.

Second, the objective analysis assumes that throughput-dependent milepost spill volumes can be ignored for large spills and reasonably close spread-constraining land features. This assumption is valid because the volume of a spill in a guillotine break is generally very large and the spill duration is very short (i.e., the release from the pipeline would be complete in less than 6 hours). With a few notable exceptions, many land features can control the spread of oil. However, in certain cases the estimated contaminated areas may be greatly over-estimated by not explicitly accounting for the milepost-dependent spill volumes.

Third, as crude oil is released from a guillotine break site, it follows the slope of the land surface and is guided by workpads, access roads, or roadbeds of highways to lowlands, ravines, creeks, streams, ponds, or lakes (or interceptors). Therefore, the land features would limit the size of a spill site that can be effectively estimated by multiplying the length of the plume by its width. On a site with a steep slope, the width of a plume is arbitrarily assumed to be 50 ft, whereas a site with a gentle slope has an assumed width of 100 ft.

Finally, the estimated areas computed with either the parametric method or with the objective analysis conservatively assume that the spill duration and/or spread time is much smaller than the time required for spill response and control. In other words, no spill mitigation is assumed for land spills.

In addition to the guillotine breaks at environmentally sensitive or important milepost-specific receptors, a range of spill volumes was estimated for small and moderate leaks, maintenance damage, sabotage or vandalism, washout, and valve leaks (Table 4.4-1). Spill areas for the small to moderate spills were estimated by multiplying the spill volume in barrels. by 0.001547 (units conversion factor, bbl to in.^{3}) for a 1-in. pool and dividing the result by 2 or by 3 for a 2-in. or 3-in.-deep pool. The estimated spill areas that maximize impacts at each environmentally important location along the pipeline were used in the consequence assessments. Impacts for the other estimated spill areas, either from the parametric approach or the objective analysis, were treated qualitatively.

4.4.1.3.2 Catastrophic Valdez Marine Terminal Events. The potential exists for a large release of soot and gaseous air contaminants as a result of an aircraft crash into the crude oil storage tanks at the Valdez Marine Terminal. The 18 crude oil storage tanks at Valdez Marine Terminal are located in two areas, the East and West Tank Farms, with individual tank storage capacities exceeding 0.5 million bbl. In this analysis, an aircraft accident was defined to be an event that results in destruction of the aircraft by the impact and subsequent fire. A methodology was used that takes into consideration items determined to be important to understanding the risk from an aircraft crash into fixed facilities (DOE 1996). These items include number of aircraft operations/flights, crash probabilities, aircraft characteristics, crash kinematics, impacting missiles, and structure characteristics. The current and projected future numbers of aircraft operations from the Valdez Airport were used in conjunction with national crash statistics to estimate the annual frequency of an aircraft crash into the crude oil tanks at the Valdez Marine Terminal. Structure characteristics (wall thickness, material properties), together with consideration of the various detached parts of an aircraft (e.g., engine) that can hit a target directly from the air or after skidding on the ground, were used to estimate the degree of local damage and whether the aircraft or aircraft part would penetrate the tank wall and cause tank failure.

Catastrophic storage tank failure or rupture is extremely rare. Eight cases of crude oil tank rupture are known from around the world — three caused by foundation failure, one caused by weld failure, one caused by impact of a rail truck, and three caused by flooding. Flooding is the only one of these initiators relevant to the

Valdez Marine Terminal. The chance of this happening is extremely remote since there is no large source of runoff water at the storage areas, and secondary containment drainage is good and well controlled. For the present purpose, however, the possibility is considered. If a tank were to rupture, the most likely consequence would be a major flow of oil to the secondary containment. In the case of a very large rupture (greater than about 5 ft in diameter), it is likely that the oil would wash over or break the dike wall. In this case, oil would disperse over the hillside below the tank farm and flow to surface drainage. The volume of spilled oil would almost certainly be greater than the capacity of diversion impounding, except the final dam at the outflow of No Name and Dayville Creeks (Emerald Consulting Group, Inc. 2001). The frequency of a storage tank failure spill event at the Valdez Marine Terminal is estimated to be 1.8×10^{-6}. Such tank failures were determined to be very unlikely events that could produce spill magnitudes ranging from approximately a 50,000-bbl spill on land outside secondary containment, to a spill of more than 143,000 bbl of crude oil into the Port of Valdez.

A 1989 American Petroleum Institute (API) survey indicated that there were approximately 700,000 aboveground diesel fuel storage tanks in the United States. Tank rupture accounted for only 5.4% of the 132 releases that occurred worldwide between 1970 and 1988. However, tank rupture accounted for almost 19% of the released material. This analysis considers a spill scenario involving a catastrophic rupture of tanks containing diesel fuel at the Valdez Marine Terminal. The frequency of such an event is estimated to be 1.1×10^{-6} per tank-year (Center for Chemical Process Safety 2000). Two tanks, each with a shell storage capacity of 40,000 bbl, store diesel fuel at the Valdez Marine Terminal.

4.4.2 Hydrological Analysis of Spill Events

Because the density of the crude oil transported through the TAPS is less than the density of water (about 0.8699 g/cm^3 for oil [Roehner 2001] and 1.0 g/cm^3 for water), oil spilled into water will tend to float on the surface and spread. If the water is moving, the oil will be transported downstream by the surface currents (advection). The combined motions of spreading and advection will produce an elongated oil slick. The slick will, in general, move downstream at the speed of the surface current; however, winds may alter the direction of transport. Wind-induced surface currents have been reported to vary between 1 and 6% of the wind speed, with 3% being the most widely used drift factor in oil slick trajectory models (Shen and Yapa 1988). Depending on the direction of the wind, the slick can be driven to one of river's banks, where it then can be recovered.

Oil Slick

A slick refers to oil spilled on the water that absorbs energy and dampens out surface waves, thus making the oil appear smoother, or slicker, than the surrounding water (NOAA 2001a).

Some light hydrocarbons in the crude oil may dissolve or evaporate. In turbulent water, some of the oil may be emulsified as small dispersed droplets (oil-in-water emulsions). It is now believed that the nonhydrocarbon fraction of oil is an important ingredient in emulsification. Under certain chemical and turbulent energy conditions, the emulsified oil can form a substance often referred to as "mousse." This "mousse" is a very viscous fluid that has significantly different physical properties than those of the parent oil (Overstreet and Galt 1995). These emulsified droplets may become dispersed because of the currents present, or they may become attached to suspended matter in the stream and slowly settle to the bottom. If formed, the oil-in-water emulsions can be long lived. The turbulence action can also cause water to become entrained in the oil, forming water-in-oil emulsions, which may weather further and form dense tar balls (Shen and Yapa 1988).

During an oil spill to water, an oil sheen is likely to develop. An oil sheen is a very thin layer of oil that floats on the water surface and is transported downstream with the current (NOAA 2001a). The color of the sheen corresponds with its thickness. Silver sheens have a thickness greater than 0.0001 mm, iridescent sheens have a thickness that is greater than 0.0003 mm, brown to black crude oil sheens have a thickness that is greater than 0.1 mm, and brown/orange water-in-oil emulsions are thicker than 1 mm (ITOPF 2002).

While moving as a slick, crude oil can be affected by a number of physical processes. These include advection (moving along with the current); mechanical spreading because of the balance among gravitational, viscous (viscosity is a measure of a fluid's internal resistance to flow), and surface-tension forces; horizontal turbulent diffusion (spreading driven by a difference in concentration); evaporation; dissolution; and shoreline deposition (Shen and Yapa 1988). In addition, photochemical reactions and microbial biodegradation are also possible. The effect of these processes depends on the properties of the oil and environmental conditions. Spreading, dissolution, evaporation, and photochemical reactions of the crude oil usually occur within hours after the spill. Evaporation and dissolution are particularly important processes for the light hydrocarbon components of the crude oil. For example benzene, toluene, ethylbenzene, and xylene (BTEX) will readily evaporate because of their high Henry's Law constants for volatilization and dissolve into the water column because of their large solubilities following a release to surface water (Lyman et al. 1992). They will then be transported downwind by the surrounding air and downstream by turbulent advection in the water. Light crude oils can lose as much as 75% of their original volume within the first few days after a spill; medium weight crudes might lose as much as 40% of their original volume. Heavy crude or residual oils, on the other hand, might only lose about 10% of their volume in the same period of time (Overstreet and Galt 1995). The formation of oil-in-water emulsions and sinking can require days. On the other hand, water-in-oil emulsions can require years to degrade.

Water near the center of a stream flows faster than water near its banks or bottom (Fischer et al. 1979). This difference in current speed and the resulting shearing forces between water layers is typically the major mixing mechanism that spreads oil as it moves downstream. The leading edge of the slick may move as a relatively sharp front; however, mixing will continuously exchange water and oil between the slower, near-bank regions and the faster-flowing, central regions of the river. Many river channel profiles (morphologies) are very irregular, with rapids at one extreme and quiet bays at the other. These features either accelerate or decelerate the average flow in the river and contribute to the shear in the current pattern, thus increasing the along-channel spreading of the oil (ESSO 2001).

Sometime after the spill event, oil will reach a shoreline and be deposited. In sands and gravels, the lighter-weight crude oil components may then penetrate the surface, contaminating deeper layers of soil and possibly the underlying groundwater. Some of this deposited oil will be reentrained by the water and transported farther downstream. Exposed headlands (high steep-faced promontories that extend into the water) rapidly lose deposited oil to the adjacent water (Shen and Yapa 1988). One-half of the original mass of oil deposited on a headland is lost back to the stream within one hour. At a sandy beach, it takes about 1 day to lose one-half of the original mass of oil. Sand and cobble beaches, sheltered rock shores, and sheltered marshes can take up to 1 year to lose half of the original mass of oil deposited. Such areas provide potential sources of oil for increases in the length of the original slick and long-term sources of future contamination.

Impacts of oil spills on rivers and streams can be severe. On August 1, 2000, in British Columbia an aging pipeline spilled about 10,700 bbl (449,400 gal) of crude oil into the Pine River (Reuters World Environment News 2000a,b). The 500-mi pipeline, which was built in 1962, carries crude oil from Taylor, British Columbia, to the Prince George Husky Oil Refinery. The spill affected fish, wildlife, and riverside vegetation, and compromised the town of Chetwynd's drinking water supply. A sheen more than 13 mi long was observed. Oil is expected to continue to be released from soil and gravel and the riverbed itself for years to come, causing potential contamination problems.

As discussed above, the transport of oil downstream following a spill is a very complex process and can be difficult to analyze. Computer models have been developed to estimate the behavior of oil slicks in rivers (Shen and Yapa, 1988; Yapa and Shen 1994; Overstreet and Galt 1995; Zhubrin 2001). However, these models, in general, require large quantities of field data unavailable for this project. Because such detailed information is not available, simplifying assumptions are made to evaluate the trajectory of the oil slicks and its geometry following a spill at an elevated bridge crossing (Appendix A, Section A.15.2).

4.4.3 Fire Analysis of Spill Events

Pool fires, flash or jet fires, and vapor cloud explosions are three possible types of energetic events involving crude oil and other flammable liquids associated with operation of a petroleum pipeline. Consideration of energetic events, such as a boiling liquid expanding vapor explosion, were excluded from analysis primarily because such events require the existence of pressurized storage vessels containing a saturated liquid/ vapor at temperatures well above its normal boiling point (at atmospheric pressure). Each of the tanks in the East and West Tank Farms have emergency venting (6 to 12 ventilation vent vapor breaks) and weak roof-to-shell seams that would prevent tank pressure buildup.

If the ignition of flammable vapors is delayed, an unconfined vapor cloud explosion or a flash fire could result. Crude oil movement in pipelines requires a pressurized flow. Crude oil movement in the pipeline requires pressurized flow. A hole or small crack in the pipeline would result in a pressurized crude oil leak generating suspended liquid droplets or an aerosol spray of crude oil. “Flash” vaporization of some of the volatile light petroleum compounds would also occur. If an ignition source was present, a flash fire to the source of the leak could occur and a jet fire would ensue. The recent vandalism act on the pipeline on October 4, 2001, involving a bullet rupture and a pressurized leak in the pipe at MP 400 near Livengood did not result in a fire. Response to events like this is very carefully planned, and special care is taken by the response team to prevent the introduction of an ignition source during the response in repairing the leak. Review of a long record of data from the Office of Pipeline Safety (DOT 2001c) shows no occurrence of explosions, fireballs, or jet/flash fires at crude oil pipelines or pump stations. Although the explosion and fire that occurred at PS 8 during start-up in July 1977 was associated with a spill, the installation of Halon fire suppression systems at all of the pump and metering stations, along with the continued RCM on these systems, has essentially eliminated the likelihood or greatly reduced the recurrence of such an event.

For a vandalism event, such as the Livengood incident, the ignition source required for a pipeline flash/jet fire is dependent on inadvertent introduction by the spill response team. Considering that there have not been any fire events associated with pipeline vandalism recorded in the data available from the Office of Pipeline Safety (DOT 2001c) and because of the special care taken by the APSC response team in responding to such events, a pipeline flash/jet fire was deemed to be an incredible event. However, analysis of the frequency of aircraft take-off and landings from the Valdez Airport and the Fairbanks International Airport show that an aircraft impact into the pipeline near Fairbanks or into a crude oil holding tank at the Valdez Marine Terminal could occur with frequencies of about once in 400 years and once in about 50,000 years, respectively (see Section 4.4.1 and Folga et al. 2002).

The spills analysis identified six spill scenarios involving fires that could be defined as credible events (frequency of occurrence greater than once in a million years). The first two crude oil fire events considered are those occurring at fixed pipeline facilities. Each of these events involves very large crude oil pool fires from an aircraft impact: one in the secondary containment dike at the Valdez Marine Terminal East Tank Farm (identified as Scenario 10 in Section 4.4.1), and one resulting from a pipeline guillotine break near Fairbanks (identified as Scenario 19b, Section 4.4.1). The last four fire spill scenarios are vehicle transportation accidents. Three of the scenarios involve rollovers of fuel tanker trucks carrying liquid turbine fuel during shipments between (1) Williams North Pole Refinery to PS 7, 3, (2) Williams North Pole Refinery to PS 9, and (3) Petro Star Refinery in Valdez to PS 12. The sixth transportation spill scenario involving a fire is a fuel truck shipment carrying arctic grade diesel from the Williams North Pole Refinery to Deadhorse. Because the transportation spill scenarios involved much smaller spill quantities compared with the Valdez Marine Terminal and pipeline fire scenarios, quantitative analysis of these events was not performed. The associated consequences and risk of truck accidents involving flammable and/or explosive materials can be found in the DOT National Transportation Risk Assessment (Brown et. al. 2000).

To estimate fire impacts, simulations were performed with two models: the Fire Dynamics Simulator (FDS) and FIREPLUME (see fire model descriptions in Appendix A, Section A.15.3). The near-field (distances less than 1 km from the dike fire) air quality impacts from this dike fire were assessed with the FDS model for locations near the dike and pipeline, and at distances from the fire where workers or nearby residences may be exposed. FIREPLUME was used to estimate soot and other combustion product impacts from a few kilometers to 50 km downwind of the dike fire. Considering the uncertainty in any model's predictions, a decision was made to err on the conservative side by using the results from the model producing the largest concentration estimates in the downwind range from 3 to 10 km.

The specific assumptions made in analyzing fire impacts for the Valdez Marine Terminal and pipeline fire scenarios are described below, along with a summary of the fire modeling results. The associated human health impacts from exposures to fire combustion products (e.g., soot) are discussed in Section 4.4.4.7.2.

4.4.3.1 Valdez Marine Terminal Fire Event (Valdez Marine Terminal Scenario 10)

Scenario 10 assumes that crude oil holding tank #2 in the East Tank Farm, as shown in Map 4.4-2, catastrophically fails as a result of a direct impact from an aircraft taking off from the Valdez Airport approximately 8.9 km from the Valdez Marine Terminal. The impact from the crash and the resulting fire was assumed to occur in the largest containment area and to be confined to this area. A large crude oil pool fire ignites in the diked area serving two 510,000-bbl storage tanks. Approximately 400,000 bbl of crude spills into the dike from the ruptured tank to a depth of around 2 m and engulfs the entire secondary containment area (~ 34,590 m^2) in fire. It is assumed that the contents of the second tank and the dike walls would not be affected by the spill-fire initiator. The tanks are 250 ft in diameter and 63 ft high. The footprint of each tank covers about 12% of the diked area. The tanks have conical fixed roofs and are connected to a vapor recovery system. Wall thickness is 1 1/8 in. at the bottom, increasing to 1/2 in. at the top.

On the basis of a spill of 382,500 bbl of crude oil, the average working level for holding tank #2 (Norton 2002c) into the diked area would cover an almost 9-acre area (adjusted for the area displaced by one of the remaining tanks in the two-tank-per-dike configuration at the East and West Tank Farms). Using this volume and the laboratory-reported North Slope crude oil density of 0.8699 g/mL (Roehner 2001), the total mass of the crude oil spill was calculated to be 5.3×10^7 kg. Using a burn density of 0.051 kg/m^2-s and a dike area of 34,500 m^2, the fire burn rate is calculated at 105,844 kg/min. Therefore, an unmitigated dike fire is estimated to burn for over 8 hours. The total heat release rate (HRR) generated from this fire would be about 74.1 GW (HRR = mass spilled (5.3×10^7 kg) $\times$ heat of combustion (42,000 kJ/kg)/burn time (29,880 s or 8.3 h). By comparison, the heat release rate for largest crude oil controlled burn in the 1994 Mobile experimental Burn Series (Walton et. al. 1993) is about 2 orders of magnitude smaller (estimated to be around 600 MW for a trial involving a spill of 107 bbl over a 231-m^2 area). Because of the high temperatures and velocities that accompany large fires in the gigawatt range, a very buoyant fire plume would be generated. Such a plume would easily penetrate low to moderate level inversions that would trap smoke above these layers.

Considering the very buoyant smoke plume generated from the large dike fire and the important role weather conditions play in transporting and dispersing this plume, careful consideration was made in selecting the meteorological conditions that would be expected to produce the largest ground-level concentrations of soot and other combustion products. For most cases, the buoyancy of the fire plume would be sufficient to penetrate the inversion layers typical to a coastal location like Valdez. A nighttime fire, during stable light wind conditions, would tend to keep the fire plume elevated for a long time, thereby producing a fanning plume shape with little vertical mixing that would result in near zero or extremely small ground-level soot and other combustion product concentrations. However, during such conditions impacts on visual range at long distances would occur on the order of over 30 to 50 km downwind, especially for the smaller size soot fraction. Strong to very strong winds, near or exceeding the vertical velocities of the hot very buoyant fire plume, would be needed to bend the plume over enough to minimize penetration of the inversion layer. A review of meteorological data processed (using EPA's RAMMET meteorological preprocessing program) from 6 years of surface measurements at the NWS station in Valdez and the same period of upper air observations from the NWS soundings at Anchorage show average mixing heights of 600 m during very unstable conditions (Pasquill-Gifford [PG] stability Class A) and average mixing heights of around 850 m during moderate to slightly unstable conditions (PG Class B and C). During neutral conditions (PG Class D), the average mixing heights are around 560 m. For the same period, the maximum boundary layer heights over consecutive hours during very unstable conditions and moderate to slightly unstable conditions are 500 and 3,000 m, respectively.

Taking these considerations into account, two meteorological conditions were modeled. For the far-field estimates using FIREPLUME, neutral atmospheric conditions with strong winds (10 to 12 m/s) were assumed for the first case (PG Class D) and conditions between a slightly unstable atmosphere and a neutral atmosphere (PG Class C/D). Near-field impacts with FDS were modeled assuming neutral atmospheric conditions (Class D, temperature lapse rate between -1.5 and -0.5°C/100 m) with moderate to strong wind speeds ranging from 12 m/s (~25 mph) from the south towards the Port of Valdez. The wind flow would be across the largest diked area dimension with thermal radiation greatest on the north end (nearest to the tank that is assumed to remain intact). The closest "safe" access by firefighters would be on the road just east of the dike (the dike dimensions are widest at the north end). Fire temperatures, thermal radiation hazard, and fire plume buoyancy parameters were estimated with the FDS model and used as fire buoyancy parameters for the far-field FIREPLUME simulations. The buoyancy parameters were computed over the dike at the pool fire flame height. This height was estimated using a simple empirical correlation for fuels burning as pool fires (NFPA 1997). The flame height was estimated to be 100 m. The FIREPLUME model predictions for the neutral condition case with 10 m/s wind speeds showed that the smoke and soot generated from the fire would be lifted high in the atmosphere and transported far downwind. The maximum predicted ground-level concentrations occurred over 50 km from the terminal. For the slightly unstable to neutral condition case with 7.5 m/s winds and a mixing height of 750 m (Case 1), the smoke and soot were not lifted as high and were brought to the ground closer to the fire than the neutral stability case with a 1,500-m mixing height (Case 2). The predicted FIREPLUME maximum soot and other combustion product concentrations and distances downwind from the Valdez Marine Terminal for these two cases are given in Table 4.4-6. The health impacts to the general public exposed to these concentration levels are discussed in Section 4.4.4.7.2. The averaging time for the estimated concentrations is based on the dike fire burn time. Assuming that the crude oil burn rate would be around 0.051 kg/m^2-s (38 lb/h-ft^2), consistent with the literature on crude oil fires and available field measurements, and assuming a confined dike fire with just the one tank involved, the fire would be estimated to burn for about 8 hours before self-extinguishing.

As noted, the FDS model was used to obtain estimates of the near-field (e.g., within a 3-km radius of the dike fire) soot and combustion product concentrations. The FDS is able to account for fire-induced winds that can influence ground-level concentrations close to the fire. The results from these calculations should be viewed

TABLE 4.4-6 Maximum Public Exposures to Soot and Fire Combustion Products

		Combustion Product (8-hour averages)[a]						
Case[b]	Downwind Distance (km)	TSP (mg/m^3)	PM_{10} (mg/m^3)	CO (mg/m^3)	NO_x (mg/m^3)	SO_2 (mg/m^3)	VOC (mg/m^3)	PAH (mg/m^3)
1	30.5	0.573	0.524	0.115	0.0039	0.096	0.0191	3.82×10^{-4}
2	50	0.29	0.26	0.06	1.9×10^{-3}	0.048	9.5×10^{-3}	1.9×10^{-4}

[a] The results reported in this table should be viewed with caution, considering the large heat generation rates for this fire and the large uncertainties associated with near-field fire modeling of soot and other combustion product concentrations.

[b] Case 1: Unstable atmospheric conditions with 7.5 m/s wind speeds and mixing layer heights of 750 m.

Case 2: Neutral to slightly unstable atmospheric conditions with 10.0 m/s wind speeds and mixing layer heights of 1,500 m.

with caution since the model has not been applied to very large fires (>1 GW) and has not been compared with field measurements close to fire (<1 km). The largest fire that the FDS has been applied to is in the Mobile mesoscale experiments conducted in 1991 (Fingas et al. 1996; McGrattan et al. 1995). The lowest of these burns was estimated to be between 600 and 700 MW. With these caveats, several FDS runs were performed with varying computational grid sizes. The results indicated that a grid spacing of 4.5 m was required to adequately resolve the fire physics. Memory constraints limited the number of grid points that could be modeled to approximately one million. Therefore, the largest computational domain possible (750 m in the downwind direction, 240 m in the cross-wind direction, and 500 m vertically) was selected while meeting these constraints. The number of grid points in the X, Y, and Z directions was 162, 54, and 108, respectively. Meteorological conditions were selected that would likely give the maximum downwind ground-level concentration of pollutants emitted from the fire. This would occur, assuming a neutral atmospheric lapse rate of -0.0097°C/m, with moderately strong winds of around 12 m/s.

The fire plume buoyancy parameters were calculated by time- and space-averaging conditions in a horizontal rectangular area 100 m above the fire. The height of 100 m was selected because significant heat was released per unit volume up to this level and thus could be used as the reference height for the FIREPLUME simulations of an elevated buoyant release. The rectangular area had the same dimensions as the secondary containment area (thus the fire), but was shifted 100 m downwind, which was the approximate distance (as measured by passive tracer particles) that the plume was advected as it rose to a height of 100 m. The FDS-computed average temperature, density, and vertical wind velocity above the fire were 411°C, 1.087 kg/m^3, and 14.42 m/s, respectively. The temperature around the surface of oil storage tank #1 was modeled using FDS. Once conditions stabilized, surface temperatures were found to range from 230 to 420°C. If tank #1 was assumed to fail due to thermal fatigue from the fire, its contents would be added to the oil already present in the secondary containment area. Assuming that tank #1 has an equivalent working level as tank #2, this would double the depth of the oil pool. This thermal tank failure would be expected to double the fire burn time and the combustion product burden to the atmosphere. A "boilover" event is also possible (see discussion below). However, it is assumed that fire fighting efforts would be directed to saving tank #1 (the crude oil tank not directly involved in the fire) and averting a tank fire and boilover event.

The near-field workers concentration exposure levels within the marine terminal boundaries, along with distances from the dike fire, are summarized in Table 4.4-7. These 15-minute average values were estimated with the FDS model. Possible worker-related health impacts from exposures to these concentration levels are discussed in Section 4.4.4.7.2.

The hottest pool temperature at a height around 100 m above the surface is predicted to reach about 430°C. Using an estimated flame temperature of 800°F, the thermal radiation intensity to a person outside the flame envelope was estimated with a simple “solid flame radiation” model (Mudan 1984). The thermal radiation hazard to fire fighters and nearby workers at the terminal is summarized in Table 4.4-8. Exposures at the 5-kW/m^2 thermal radiation level for less than 13 seconds are suggested as acceptable (40 CFR 193, 1980). Unprotected (e.g., exposed skin, no personal protective equipment [PPE]) exposures for greater than 40 s at this level can lead to second degree burns, while the same duration of exposure at the 10-KW/m^2 level can lead to 1% fatalities in the exposed population (Mudan 1984).

This scenario assumes a dike fire with a relatively shallow crude oil depth of around 6 ft (i.e., estimated assuming a spill of 382,500 bbl of crude oil over an area of ~34,600 m^2 [~372,000 ft^2]). “Shallow-layer” boiling effects from the liquid water present at the bottom of the dike would be of a relative small magnitude

TABLE 4.4-7 Maximum Worker Exposures to Soot and Fire Combustion Products, Valdez Marine Terminal Scenario 10

		Combustion Product (15-min averages)						
Location	Distance (m)	PM_{10} (mg/m^3)	CO (mg/m^3)	NO_x (mg/m^3)	SO_2 (mg/m^3)	VOC (mg/m^3)	PAH (mg/m^3)	CO_2 (mg/m^3)
Containment edge south	190	4.18	0.92	3.05×10^{-2}	7.63×10^{-1}	1.53×10^{-1}	3.05×10^{-3}	48.6
Containment edge north	196	4.18	0.93	3.05×10^{-2}	7.63×10^{-1}	1.53×10^{-1}	3.05×10^{-3}	48.6
E Manifold Receiving Building	340	1.46	0.32	1.07×10^{-2}	2.66×10^{-1}	5.33×10^{-2}	1.07×10^{-3}	17.0
Sludge pit	372	1.10	0.24	8.03×10^{-3}	2.01×10^{-1}	4.01×10^{-2}	8.03×10^{-4}	12.8
Offices	730	0.685	0.15	5.00×10^{-3}	1.25×10^{-1}	2.50×10^{-2}	5.00×10^{-4}	7.96
Ballast Water Treatment Facility	794	0.643	0.14	4.69×10^{-3}	1.17×10^{-1}	2.35×10^{-2}	4.69×10^{-4}	7.48
Maintenance/ warehouse	808	0.595	0.13	4.34×10^{-3}	1.09×10^{-1}	2.17×10^{-2}	4.34×10^{-4}	6.92
Emergency response/ laboratory building	973	0.462	0.10	3.37×10^{-3}	8.43×10^{-2}	1.69×10^{-2}	3.37×10^{-4}	5.37
Marine building	1,091	0.403	0.088	2.94×10^{-3}	7.35×10^{-2}	1.47×10^{-2}	2.94×10^{-4}	4.69

TABLE 4.4-8 Thermal Radiation Exposures, Valdez Marine Terminal Scenario 10

Location	Distance from fire (m)	Estimated Thermal Radiation Hazard (kW/m^2)
OCC Building	1,125	0.593
Sludge processing area "sludge pit"	250	6.27
East Manifold Building	180	13.5
Road around perimeter of dike	Very close to fire	37.5 to 75

compared with that of "deep layer" "boilovers"[3] that can and have occurred in large crude oil tanks (e.g., oil refinery, Milford Haven, South Wales, England, August 1983; oil terminal, Thessalonika, Greece, February 24, 1986). The magnitude of a boilover event is defined as the ratio of the maximum burning rate of crude when boiling occurs to the burning rate of the liquid at its steady state condition (Koseki and Mulholland 1991). Tank boilover events that have occurred have crude oil depths several times larger than what would be possible for dikes. The depth of crude oil is important relative to what would be necessary to generate a sufficient heat wave cycle. However, less violent effects can occur in dike fires, such as "slopover" or "frothing." "Frothover" is steady frothing of liquid over a tank rim or dike wall without a sudden or explosive event typical with boilover. "Slopover" is a short-duration froth over containment with usually minor intensity and small containment loss of liquid compared with a frothover or boilover event. "Slopover" or "frothing" can be easily contained with foam application and would therefore not be expected to spread the fire to the crude oil tanks in adjacent secondary containment areas at the East Tank Farm.

The dike fire scenario assumes that the fire protection measures already in place and existing firefighting response capabilities would prevent a crude oil tank fire and deep-layer "boilover" event. This assumption implies the availability of a high-level of industrial fire fighting capability from a well-trained and equipped Valdez Marine Terminal fire brigade with support, as necessary, from the Valdez Fire Department. Because of the uncertainties inherent in this assumption, several important factors need to be considered in evaluating what it would take to successfully contain dike fires and prevent escalation to adjacent terminal facilities.

First, it is likely that the vapor recovery system serving the tanks in the affected and adjacent dikes would fail either at the point of the initial aircraft impact into the affected tank or at some point during the subsequent dike fire. Without that system operating, flammable vapor would build up and be emitted from the roof vents as the tank was heated from the outside. North Slope crude has a flashpoint of -11.1^{o}C (12^{o}F) [APSC 2002c]. Under the intensely hot flames emanating from the dike fire, with temperatures in excess of 600^{o}C (1,112^{o}F) and with flame heights ranging from 50 to 100 m, ignition of the tank vent vapors would be highly likely. Because each of the fixed-roof pressure relief vents serving the tanks in the East and

3 Large fires involving volatile liquids such as crude can in time become very hot. The lighter and more volatile components (e.g., aromatics and PAHs) of crude on the surface are rapidly burned off and/or evaporated and burned. The less volatile components of the crude layer on top become denser and sink below the surface to be replaced by a more volatile layer, which is again burned off. This cycle, known as a "heat wave," continues, resulting in a deepening surface layer of very hot oil. The cycle terminates in an explosive boilover of the crude oil pool (as a result of the denser and hotter layer reaching water or water/oil emulsion at the bottom of the tank, which results in the superheated water or oil mixture subsequently flashing into steam and nearly explosive boiling).

West Tank Farms are equipped with flame arresters, subsequent ignition of the vapor space inside any of the tanks is not an immediate concern. As previously mentioned, the relief vents are primarily designed to prevent the occurrence of a boiling-liquid-expanding-vapor explosion in the holding tanks. However, over time, the weak tank rims typical in the design of fixed-roof holding tanks would likely collapse or partially collapse under the intense heat coming from the dike fire. After the roof collapsed, a tank fire would rapidly ensue. The resulting crude oil tank fire could develop into very large “boilover” event that could spread the dike/tank fire outside secondary containment and/or to adjacent containment dike(s) within the East Tank Farm.

The protection of the second tank in a two-tank dike configuration is fundamental to containing and eventually extinguishing dike fires that may occur in the East or West Tank Farms. This can be done through a well planned and executed firefighting response strategy. Although details would need to be developed, one strategy would be to divide the dike into three zones and target foam application to the standing tank within the dike fire. The goal would be to provide a foam/water application rate sufficient to keep the tank cool and thereby prevent tank thermal failure. A concurrent action to consider would be, if feasible, to rapidly empty the crude oil in the second tank to an available vessel in berth. This could be done in less than 2 hours if the tank volume was less than 150,000 bbl of crude. It is also assumed that the tank’s subsurface fire foam system[4] would be activated at the appropriate time to provide a surface vapor barrier on top of the crude oil in the tank. This barrier would reduce vapor emissions through the tank roof vents and prevent vapor ignition from the external fire. The Valdez Marine Terminal currently has a draft fire fighting strategy to keep adjacent tanks cool in a tank or dike fire (APSC 2002c).

The fire analysis presented in the FEIS analyzes an accepted, but very unlikely, scenario of a tank farm fire. The scenario is based on credible, current, and accepted assumptions on fires in tank farms, as well as on documented firefighting strategies and capabilities at the Valdez Marine Terminal. While it is maybe possible to speculate on other fire scenarios, information currently available is not adequate to conduct technical analyses of other worst-case events. Thus, the presentation of other worst-case fire scenarios would be highly speculative and uncertain and would not be supported with available, peer-reviewed technical information.

The BLM recognizes that regardless of the adequacy of industrial firefighting capabilities, including specific firefighting response and mitigation actions, the outcome of a large dike fire at marine terminals or oil refineries is uncertain. Thus, plans and capabilities are in place to ensure life and safety protection, including evacuation of the facility. Because of a large number of uncertainties and the small probabilities of large dike fires, attachment of specific firefighting mitigation actions or requirements to the TAPS renewal would be premature at this time. However, the review of response and mitigation of potentially large fires that are credible but *very unlikely* events would be appropriate and well suited to those JPO member agencies (including the State of Alaska Fire Marshal, ADEC, EPA, and BLM) that have oversight, as established under current regulatory authority, for Valdez Marine Terminal fire planning and response.

Given the presence of an ignition source and the presence of vapors (in the vapor space above a flammable liquid) at concentrations within their flammability limits, a boilover event can occur with a large crude oil tank fire. Although it is likely that the vapor recovery system serving tank #1 fails during the initial aircraft impact into tank #2, a fire and boilover in tank #1 is assumed not to occur. The basis for this assumption is that the firefighters at the Valdez Marine Terminal would have the necessary specialized training and equipment required to fight large dike fires. This would

[4] A subsurface fire foam system is installed at both the East and West Tank Farms. The system includes pumps and motor-operated valves designed to create and direct foam inside a tank in case of a fire. Fixed pipes at the bottom of the tank distribute foam radially through a “spider” piping system installed in each tank, near the tank bottom. This system is designed to disperse foam that would float to the top of the burning crude oil surface and extinguish a fire (APSC 2002b).

include having industrial-type fire fighting apparatus and associated equipment (e.g., cannons/pumps with industrial ratings) and aqueous fire fighting foam. The appropriate level of training, foam inventories, and the size and number of foam cannons are critical to producing and sustaining the foam/water discharge rates required to achieve foam runs that can contain and extinguish large fires. In addition to the fire fighting strategy that is employed, it is assumed that the tank's subsurface fire foam system, in addition to the targeted foam application to the standing tank within the dike fire, would be sufficient to keep the tank cool enough and thereby prevent tank thermal failure and/or prevent the ignition of flammable vapors that would be generated in the vapor space at the top of tank. The Valdez Marine Terminal currently has a draft fire fighting strategy to keep adjacent tanks cool in a tank or dike fire (APSC 2002c). The crude oil in tank #1 one was assumed to be unaffected by the fire because of the quick response from a well-trained and well-equipped Valdez Marine Terminal fire brigade, with support as necessary, from the Valdez Fire Department.

4.4.3.2 Pipeline Fire Scenario

Pipeline Scenario 19b assumes a guillotine break in the pipeline as the result of a direct impact from an aircraft taking off from the Fairbanks International Airport approximately 19 km from the pipeline. The impact from the crash and the resulting fire were assumed to occur somewhere between TAPS MP 456 through 458. A large crude oil fire ignites and burns as oil continues to spill from the break in the pipeline. A total of 42,101 bbl or 5.8 million kg of crude oil spills at this pipeline location and burns in a pool fire for about 30 min. The heat release rate from this fire is 141.2 GW. The spill is unconfined (i.e., no containment barriers, berms, bunds, or dikes) and is estimated to exit the broken pipe at a constant rate of 1,458.3 bbl/min (based on a 2.1-million bbl/d throughput, Folga et al. 2002). The extent of spill spread on the ground is limited by the North Slope crude oil burn rate of 0.051 kg/s-m^2. At the given continuous spill rate for the pipeline guillotine break, the crude oil would continue to spread until the total burning rate is equal to the spill rate. When this equilibrium is reached, the fire pool spread or pool diameter can be estimated with the empirical formula given by Mudan (1984).[5] The resulting equilibrium pool diameter is 289.7 m, with an estimated pool area of 65,912 m^2. This pool fire area is about twice the size of the confined dike fire spill in Scenario 10 for the Valdez Marine Terminal.

In contrast to weather conditions occurring at Valdez, more frequent unstable atmospheric conditions are observed at Fairbanks with larger mixing layer depths. Fire air quality impacts for four meteorological conditions were assessed with the FIREPLUME model. Case 1 assumed moderately unstable conditions (stability Class B) with a 2 m/s wind speed and a 2,400-m inversion layer height; Case 2 assumed slightly unstable conditions (stability Class C) with a 5 m/s wind speed and a 1,750-m boundary layer height. Case 3 was run with near neutral weakly stable conditions (stability class D/E) with a 10 m/s wind speed and a 1,500-m mixing height. Finally, Case 4 assumed slightly stable or weakly neutral conditions (stability Class E/D) with and a 7 m/s wind speed and a 700 m mixing height.

The buoyancy parameters derived from the Fairbanks FDS model assumed flame heights similar to the Valdez Marine Terminal fire. The FDS-computed average fire temperature at an effective release of 100 m was 223.5°C. The predicted FIREPLUME maximum soot and other combustion product concentrations and distances downwind from Fairbanks for these two cases are given in Table 4.4-9. The averaging time for the estimated concentrations is based on the dike fire burn time. Assuming the same crude oil burn rate of 0.051 kg/m^2-s (38 lb/h/ft^2), as used for the Valdez fire, the Fairbanks pipeline fire would be estimated to burn for around 30 min before self-extinguishing. The greatest soot and other combustion product impacts occur under moderately unstable conditions at distances greater than 30 km downwind of the pipeline guillotine break. The

5 The empirical formula to calculate the fire pool spread or pool diameter is given by Mudan (1984): $d_p = V_S/(\pi B_V)^{0.5}$, where V_S = 3.86 m^3/s is the crude oil volume spill rate and $B_V = 5.86 \times 10^{-5}$ m/s is the burn velocity.

TABLE 4.4-9 Maximum Public Exposures to Soot and Fire Combustion Products, Pipeline Scenario 19b

Case	Downwind Distance (km)	Combustion Product (30-min averages)							
		TSP (mg/m^3)	PM_{10} (mg/m^3)	CO (mg/m^3)	NO_x (mg/m^3)	SO_2 (mg/m^3)	VOC (mg/m^3)	PAH (mg/m^3)	CO_2 (mg/m^3)
1 (B2)[a]	37.5	0.608	0.555	0.122	4.05×10^{-3}	0.101	2.03×10^{-2}	4.05×10^{-4}	11.4
2 (C5)	> 50	3.03×10^{-2}	2.76×10^{-2}	6.05×10^{-3}	2.02×10^{-4}	5.05×10^{-3}	1.01×10^{-3}	2.02×10^{-5}	0.567
3 (D/E10)	> 50	0.106	9.66×10^{-2}	2.11×10^{-2}	7.05×10^{-4}	1.76×10^{-2}	3.52×10^{-3}	7.05×10^{-5}	1.98
4 (E/D7)	> 50	0.190	0.173	3.79×10^{-2}	1.26×10^{-3}	3.16×10^{-2}	6.32×10^{-3}	1.26×10^{-4}	3.55

[a] The information in parentheses is the stability class and wind speed.

predicted FDS model concentrations at the specified downwind distance from the fire are summarized in Table 4.4-10. These concentrations account for fire-induced wind-field effects on the smoke plume. Exposure health impacts to workers are discussed in Section 4.4.4.7.

4.4.4 Impacts of Spills on Environmental Receptors

4.4.4.1 Soils and Permafrost

Impacts of Oil Spills on Soils and Permafrost

Surface soil near the TAPS ROW could be affected by spills on the land. The most immediate potential impact would be direct contamination of the soil. Prompt cleanup efforts could reduce the spread of contaminants. However, the disturbance of surface vegetative cover during cleanup activities could impact the permafrost below. Depending on locations, spill volumes, and spill scenarios, the extent of contaminated land area due to a spill could range from 0.15 acre to 84 acres.

4.4.4.1.1 Spills on Land. Surface soil near the TAPS ROW could be affected by spills on the land. The most immediate potential impact would be direct contamination of the soil. Prompt cleanup efforts could reduce the spread of contaminants. However, the disturbance of surface vegetation cover during cleanup activities could impact the permafrost below (see Section 4.3.2). This section discusses the potential extent of land contaminated from spills under various spill scenarios.

Several factors control the spread of spilled crude oil on land. Once a spill occurs, the light components in the crude oil evaporate. For most crude oils (medium oils), about one-third of the oil can evaporate within 24 hours. The rate of evaporation can be affected by weather. Low temperatures reduce the evaporation rate, while high winds increase it. The terrain and the surface features of a spill site, as well as human response to a spill, control the spreading of the rest of the spilled oil.

On a sloped terrain, part of the spilled oil flows downslope; the remainder infiltrates to the subsurface or is absorbed or coats vegetation or snow. The downslope spreading of the oil is partly restrained by the viscous drag on the crude oil from contact with the ground surface and vegetation, liquid surface tension, and local depressions. Downward infiltration of the oil into the soil depends on the permeability of the ground surface, which, in turn, is controlled by the texture of local soil and the presence of snow, permafrost, and the water table. A frozen

TABLE 4.4-10 Maximum Public Exposures to Soot and Fire Combustion Products Close to the Fire, Pipeline Scenario 19b

	Centerline Concentrations (15-min averages)							
Distance (m)	PM_{10} Soot (mg/m^3)	TSP (mg/m^3)	CO (mg/m^3)	NO_x (mg/m^3)	SO_2 (mg/m^3)	VOC (mg/m^3)	PAH (mg/m^3)	CO_2 (mg/m^3)
150	43.1	47.2	9.44	0.315	7.86	1.57	3.15×10^{-2}	884
200	54.1	59.2	0.118	0.395	9.87	1.97	3.95×10^{-2}	111
250	42.7	46.8	9.35	0.312	7.79	1.56	3.12×10^{-2}	876
300	17.5	19.2	3.83	0.128	3.19	0.639	1.28×10^{-2}	359
350	6.27	6.9	1.37	4.58×10^{-2}	1.14	0.229	4.58×10^{-3}	129
400	3.67	4.0	0.804	2.68×10^{-2}	0.670	0.134	2.68×10^{-3}	75.3
450	1.48	1.6	0.324	1.08×10^{-2}	0.270	5.40×10^{-2}	1.08×10^{-3}	30.4
500	1.48	1.6	0.324	1.08×10^{-2}	0.270	5.40×10^{-2}	1.08×10^{-3}	30.4
600	0.82	0.90	0.180	5.99×10^{-3}	0.150	2.99×10^{-2}	5.99×10^{-4}	16.8
700	0.287	0.31	6.28×10^{-2}	2.09×10^{-3}	5.24×10^{-2}	1.05×10^{-2}	2.09×10^{-4}	5.89
800	0.123	0.13	2.69×10^{-2}	8.98×10^{-4}	2.24×10^{-2}	4.49×10^{-3}	8.98×10^{-5}	2.52
900	7.26×10^{-2}	7.95×10^{-2}	1.59×10^{-2}	5.30×10^{-4}	1.32×10^{-2}	2.65×10^{-3}	5.30×10^{-5}	1.49
1,000	2.71×10^{-2}	2.97×10^{-2}	5.93×10^{-3}	1.98×10^{-4}	4.95×10^{-3}	9.89×10^{-4}	1.98×10^{-5}	0.556
1,100	7.07×10^{-3}	7.74×10^{-3}	1.55×10^{-3}	5.16×10^{-5}	1.29×10^{-3}	2.58×10^{-4}	5.16×10^{-6}	0.145
1,200	1.37×10^{-3}	1.50×10^{-3}	3.00×10^{-4}	1.00×10^{-5}	2.50×10^{-4}	5.00×10^{-5}	1.00×10^{-6}	2.81×10^{-2}
1,300	5.44×10^{-4}	5.96×10^{-4}	1.19×10^{-4}	3.97×10^{-6}	9.93×10^{-5}	1.99×10^{-5}	3.97×10^{-7}	1.12×10^{-3}
1,400	3.26×10^{-4}	3.57×10^{-4}	7.14×10^{-5}	2.38×10^{-6}	5.95×10^{-5}	1.19×10^{-5}	2.38×10^{-7}	6.69×10^{-3}

soil has a low permeability that limits downward infiltration. Downslope spreading dominates the spreading process until the oil is intercepted by either human intervention or natural features, such as depressions, rivers, streams, ponds, or lakes. If an anthropogenic structure, such as a workpad, access road, or highway, is in the path of a migrating oil plume, it can divert the flow. In addition, spilled oil can spread laterally as it moves downslope. The magnitude of the lateral spreading increases with decreasing slope.

On a flat terrain, such as in the Arctic Coastal Plain, the slope is of less importance in controlling the spreading of a spill. Local surface features, such as depressions on patterned ground and vegetative cover, would control the extent of a spill.

The methodology used to estimate the size of a spill site on land is described in Section 4.4.1. In general, if the location of a spill is not specified, the size of the contaminated area created by the spill is estimated by dividing the volume of the spill by an assumed depth of the spilled liquid pool (1, 2, or 3 in.). If the TAPS milepost of a spill is specified, however, an objective analysis method (see Section 4.4.1) is used, if appropriate, to estimate the size of the spill area.

4.4.4.1.2 Impacts for Selected Spill Scenarios.

Anticipated Spills. *Anticipated* spills are defined as spills caused by events with an expected frequency range of 0.5/yr or more (Tables 4.4-1 and 4.4-2). The scenarios include six types of small leaks that could cause a land-based release of 0 to 50 bbl (0 to 2,100 gal) of crude oil, 0 to 100 bbl (0 to 4,200 gal) of diesel fuel, 0 to 3 bbl (0 to 126 gal) of gasoline, or 0 to 50 bbl (0 to 2,100 gal) of turbine fuel. The worst event among the anticipated spill scenarios would be an instantaneous leak of 100 bbl of diesel fuel during pipeline or pump station operations. On the basis of the parametric method, the maximum size of the potentially contaminated area would be about 0.15 acre. This level of impact on soils would be very small and local. Prompt cleanup would reduce the impacts to negligible.

Likely Spills. *Likely* spills are defined as spills caused by events with an expected frequency range of 0.03 to 0.5/yr (Tables 4.4-1 and 4.4-2). The scenarios evaluated represent 10 types of events that could cause a land-based release of 50 to 10,000 bbl (2,100 to 420,000 gal) of crude oil, 100 to 200 bbl (4,200 to 8,400 gal) of diesel fuel, 3 to 100 bbl (126 to 4,200 gal) of gasoline, or 50 to 200 bbl (2,100 to 8,400 gal) of turbine fuel. The worst event in this category would be a leak caused by sabotage or vandalism that might cause the release of 10,000 bbl of crude oil over a period of 48 hours (Table 4.4-1). This event is used to evaluate the maximum impact in the likely spill category.

To ensure that the evaluation results would not underestimate the consequences, a release of 10,000 bbl of oil onto the ground was assumed. The maximum extent of spreading would be expected if no interceptor was present near a spill site. On the basis of the parametric method (see Section 4.4.1), the maximum potentially contaminated area would be about 15 acres at an assumed oil pool depth of 1 in. Because of the small size, this impact on soils would be small and localized if prompt cleanup occurred after the spill.

Unlikely Spills. *Unlikely* spills are defined as spills caused by events with expected frequencies of 10^{-3} (0.001) to 0.03/yr (Tables 4.4-1 and 4.4-2). The scenarios evaluated include six types of events that could cause a land-based release of crude oil ranging from 50 to about 54,000 bbl (2,100 to 2,268,000 gal), depending on both the location of the spill and the throughput of the pipeline. The worst event in this category would be a guillotine break from the impact of an aircraft. Up to 54,000 bbl of crude oil could be released in a short period of time. This scenario was used to evaluate the maximum impact for the unlikely spill category.

For the unlikely spill scenarios, because the potential release volume would be the same as the volume for the very unlikely spill scenarios and because potential release sites are not specific, the maximum size of a potentially contaminated area would be expected to be the same (84 acres) as that evaluated below for the very unlikely spill category.

Very Unlikely Spills. *Very unlikely* spills are defined as spills caused by events with an expected frequency range of 10^{-6} (0.000001) to 10^{-3}/yr (Tables 4.4-1 and 4.4-2). The scenarios evaluated for this category of spill include nine types of events that could cause a land-based release of a volume of crude oil ranging from 700 to about 54,000 bbl (29,400 to 2,268,000 gal), depending on both the location of the spill and the throughput of the pipeline at the time of the spill. The worst event in the very unlikely spill category would be a guillotine break of the pipeline from the impact of a helicopter. Up to 54,000 bbl of crude oil could be released in a short period of time. This scenario is used to evaluate the maximum impact in the very unlikely spill category.

Table 4.4-5 summarizes the estimated maximum land-based spill areas in various locations, including earthquake-prone areas, wild and scenic areas, population centers, and representative areas with different types of terrestrial wildlife habitats along the TAPS. Among the locations, the Goldstream Creek area (MP 448–453) would experience the maximum release under the very unlikely spill scenario of a guillotine break of the pipeline: 53,565 bbl (2,249,730 gal) of crude oil released aboveground in a short time for a pipeline throughput of 2.1 million bbl/d (Table 4.4-5). On the basis of the parametric method of calculation (see Section 4.4.1), the estimated size of a potentially contaminated area would be 84 acres for the 2.1 million-bbl/d throughput and an assumed spill pool thickness of 1 in. (Table 4.4-5). However, the pipeline in this area is adjacent to a creek. Crude oil released in this area would drain into the creek, resulting in a smaller contaminated land area of about 0.2 acre (as reported in the results from using the objective analysis, see Section 4.4.1). The majority of the contaminated land would be confined along the creek and downstream.

To estimate the maximum size of a potentially contaminated land-based area for the very unlikely spill scenarios, both release volume and local terrain were considered. At locations with no nearby interceptors, the spreading of spilled oil would be limited by the quantity of a spill. The maximum volume of a land-based spill is estimated to be about 54,000 bbl (see above). On the basis of the parametric method, which ignores land surface features, vegetation, and snow presence, the maximum size of a potentially contaminated area is expected to be less than 84 acres for the very unlikely spill scenarios. The impact on soils would be small and localized if containment and cleanup was prompt after the spill.

4.4.4.2 Paleontology

In most cases, no adverse effects to paleontological resources are anticipated to result from oil spills from the pipeline or Valdez Marine Terminal operations. Although some paleontological resources have been discovered near the TAPS ROW, these materials, when they were Pleistocene or Holocene in age, were removed upon discovery. The greatest risk to any previously undiscovered paleontological material remaining in the vicinity of the TAPS would likely be from heavy machinery used during spill containment and remediation activities rather than from the spill itself. One potentially adverse effect from crude oil on nonpetrified paleontological materials would be from hydrocarbon contamination, which may preclude age determination by means of radiocarbon dating and other types of chemical analyses. The likelihood of such an effect is very low, given that (1) there are only two known locations where Pleistocene-age vertebrate fossils were found in proximity of the ROW, and (2) the general improbability of a spill at or near (and uphill or upstream from) those specific locations.

Impacts of Oil Spills on Paleontological Resources

Oil spills from the pipeline or Valdez Marine Terminal are not expected to adversely affect paleontological resources. There is a potential for oil contamination to adversely affect nonpetrified paleontological materials.

4.4.4.3 Surface Water Resources

4.4.4.3.1 Introduction. The spill scenarios evaluated for this FEIS were divided into four frequency ranges: *anticipated, likely, unlikely,* and *very unlikely* (Section 4.4.1.1). Because these ranges are applicable for the overall length of the pipeline, the frequency of occurrence for any spill scenario at a specific location would be much less than for the pipeline as a whole. For example, a guillotine break caused by a helicopter crash into the pipeline is estimated to occur at a frequency of approximately 2.9×10^{-5} along the entire length of the pipeline. However, the frequency of such an accident occurring in buried portions of the pipeline is zero. The frequency of occurrence along any 1-mi stretch of the aboveground portions of the pipeline is on the order of 1 in 10 million (6.9×10^{-8}), and the frequency of such a spill occurring at a bridge with a length of 300 ft would be (6.9×10^{-8}) × 300/5280), or about 3.9×10^{-9} (1 in 255 million). Similarly, the overall frequency of occurrence for a likely corrosion-related leak is 0.038 along the entire pipeline. However, the maximum frequency of a corrosion-initiated leak along any 1-mi stretch of the pipeline is much less, about 5×10^{-5}, or about 1 in 20,000.

Impacts of Oil Spills on Surface Water Resources

Anticipated accident scenarios involving small spill volumes could release sufficient crude oil to produce substantial contamination problems for such rivers as the Gulkana, which is designated as a Wild River. For these types of spills, impacts could be minimized by proper planning, training, surveillance, and timely implementation of contingency activities.

Impacts to surface waters could be major and extensive in the event of a guillotine break of the pipeline at an elevated river crossing. Scenarios were evaluated for such breaks caused by a helicopter or fixed-wing aircraft crashing into the pipeline at such a crossing. Such an event is judged to have a very low probability of occurrence. However, if it did occur, 54,000 bbl of crude oil could be released. Many miles of river banks and beds could be coated with oil, requiring long-term cleanup efforts.

Crude oil spills along the TAPS ROW could affect surface water resources, particularly if the spill occurred directly to water (e.g., at an elevated river or stream crossing), or in a location in which the spilled oil could enter a river or stream after flowing across a land surface. Because the impacts produced by a spill of a given volume would be greatest for a direct spill to water, the analyses presented here for surface water impacts assume that the spilled oil is discharged directly to water. Impacts to water for the same spill occurring over land followed by surface flow to water would be accordingly smaller because of losses of oil on the ground.

In northern areas, the presence of ice can complicate and modify the movement and spreading of an oil slick (Overstreet and Galt 1995) as well as an appropriate and timely response. Oil spilled under a solid ice sheet tends to form lenses that can remain relatively thick. Currents in the flowing water can move the oil lenses along the underside of the ice in paths that are difficult to analyze. If the ice is broken, oil can float up in the small water channels between pieces of ice and spread over large areas. Because of the inherent complexity of such situations and the need for site- and time-dependent information to calculate impacts, spills to broken ice or beneath ice sheets are not analyzed; however, the impacts would be bounded by the calculations performed for open water. Impacts of spills to the top of a thick ice sheet would be similar to impacts of a spill on frozen ground.

4.4.4.3.2 Impacts of Spill Scenarios. Impacts to surface water resources from the postulated spill scenarios are discussed in this section by their occurrence frequency, starting with impacts produced by spills that are *anticipated* (frequency of occurrence greater than 0.5/yr). Four scenarios that could affect inland surface waters are included in this range: a small leak of crude oil (Scenario 1); a small leak of diesel fuel (Scenario 2); a small leak of gasoline (Scenario 3); and a small leak of turbine fuel (Scenario 4). Of these four scenarios, a small leak (50 bbl) of crude oil is the only scenario that could directly affect surface water resources. The other spill scenarios would occur only at pump stations or at valves.

The second frequency analyzed is for accidents that are described as *likely* (frequency of occurrence of 0.03 to 0.5/yr). This category includes eight spill scenarios that could affect inland surface water resources: a moderate leak of crude oil (Scenario 5); a moderate leak of diesel fuel (Scenario 6); a moderate leak of gasoline (Scenario 7); a moderate leak of turbine fuel (Scenario 8); a leak resulting from maintenance-related damage (Scenario 9); a leak caused by pipeline overpressurization from inadvertent remote gate valve operation (Scenario 10); a leak caused by sabotage or vandalism (Scenario 12); and a leak caused by corrosion-related damage (Scenario 14). Two scenarios would produce the same and greatest impacts: a leak caused sabotage or vandalism (Scenario 12), and a leak caused by corrosion-related damage (Scenario 14). Both scenarios would have a maximum release of 10,000 bbl of crude oil over a prolonged period.

The third frequency range evaluated is for accidents that are *unlikely* (frequency of occurrence of 1×10^{-3} to 0.03/yr) (Section 4.4.1). Four accidents that could affect inland surface water resources are classified as unlikely: a valve leak caused by gasket failure or large packing leak (Scenario 11); a crack resulting from seismic fault displacements and ground waves (Scenario 16); a guillotine break caused by a fixed-wing aircraft crash without fire (Scenario 19a); and a fixed-wing aircraft crash with fire (Scenario 19b). Of these accidents, the one that would cause the greatest impact to surface water resources is the one that would release the largest volume of oil. This accident is a guillotine break of the pipeline from the impact of a fixed-wing aircraft (Scenario 19a). This accident would release a maximum of about 54,000 bbl of oil.

The last frequency range of spill scenarios is described as *very unlikely* to occur (frequency of occurrence of 1×10^{-6} to 1×10^{-3}/yr) (Section 4.4.1). Five scenarios are included in this frequency range that could affect inland surface waters: a prolonged leak caused by washout damage resulting from close proximity to a stream or river (Scenario 13); a catastrophic tank loss at a pump station (Scenario 17); a guillotine break of the pipeline caused by the impact of a large truck (Scenario 18); a guillotine break caused by a seismically induced landslide (Scenario 20); and a guillotine break caused by the impact of a helicopter (Scenario 21). Of these scenarios, a helicopter crash into the pipeline at an elevated river crossing would produce the largest impact to surface water resources because it would release the largest volume of oil (about 54,000 bbl). Because the volume of oil that would be released by this accident would be the same as that released by a fixed-wing aircraft crash into the pipeline (Scenario 19a), the impacts would be the same.

The analyses performed to determine the impacts of the spill scenarios mentioned above depend on a number of estimated and measured quantities: the volume of fluid spilled during an event, the time needed for the fluid to discharge to the environment, the velocity of the current in the receiving river that would transport the fluid downstream, and the response time required to initiate appropriate contingency measures (see Section 3.7).

It is assumed that once the crude oil was in flowing water, it would move downstream with distinct leading and trailing edges (plug flow) and a slick length that remained constant in time. Circular spreading is assumed to occur until the slick reaches a shoreline (Appendix A, Section A.15.2). Processes not considered in the analysis include multidimensional mechanical spreading caused by the balance between gravitational, viscous, and surface-tension forces; horizontal turbulent diffusion (spreading driven by a difference in concentration); evaporation; dissolution; shoreline deposition; and photochemical and biological degradation. In addition, the effectiveness of remediation activities once a slick is either contained or diverted to an appropriate containment site is not evaluated. Evaluation of the effectiveness of remediation activities at a containment site is not performed because of highly uncertain site- and time-specific input parameters, including the following: the flow velocity of water in the river, the presence or absence of waves, the amount of turbulence, the presence or absence of ice, channel morphology, the quantity and type of dissolved constituents, sediment load characteristics, the type of equipment available for the remedial action, and the experience of the remediation crew. Even under ideal conditions, it is unlikely that 100% of the oil in a river at a containment site would be removed by a remedial activity even if the response team were able to arrive at the containment site and set up its equipment prior to the arrival of the leading edge of the oil spill. Because of these uncertainties, the percentage of released oil subject to recovery is calculated as a measure of response effectiveness for each of the designated spill scenarios.

Anticipated Spill Events. The first frequency range of spill scenarios analyzed is described as *anticipated*. A small leak of crude oil would produce the greatest impact on surface water resources (Scenario 1) because it would release the greatest volume of oil to the environment (50 bbl, or 2,100 gal). Other spill scenarios in this category (e.g., spills of fuel oil and gasoline) would not produce direct impacts to surface water resources because they would occur at pump stations or valves that have no direct contact with rivers or creeks.

Table 4.4-11 lists some of the major and minor elevated river crossings where a direct spill to water could occur. Six of the elevated river crossings listed in Table 4.4.4.3-1 were selected for evaluation for this FEIS:

- Dan Creek/Sagavanirktok River (MP 85),
- Yukon River (MP 353–354),
- Minton Creek (MP 510),
- Tanana River (MP 531–532),
- Gulkana River (654–655), and
- Tazlina River (MP 686–687).

These crossings were selected because the rivers are classified as anadromous or Wild and Scenic, or both (see Section 3.7.1), and they represent rivers in different hydrologic regions of the TAPS ROW (North of the Brooks Range, the Interior, and Glennallen to Valdez Hydrologic Regions, (see Section 3.7). Minton Creek was included because it would receive the largest quantity of crude oil in a guillotine break scenario. Because the Dan Creek crossing is located very near to the Sagavanirktok River (less than 500 ft away), calculations were performed by using the properties of the Sagavanirktok River to obtain conservative results. The Gulkana and Tazlina Rivers were selected as important tributaries to the Copper River drainage.

Table 4.4-12 summarizes information on flows and physical characteristics for the six elevated crossings and on designated containment sites from the appropriate contingency plans (APSC 2001l). The containment site distance given in the table is the distance from the location of the spill to the location where the oil would be contained (i.e., the designated containment site provided in the contingency plan).[6] The velocities of the surface currents listed are assumed to be the same as the river velocities provided in the contingency plans.

The anticipated spill is assumed to occur instantaneously (very short duration spill). Spill times for analyses were obtained by dividing the release volume by the daily throughput of the pipeline. For throughputs of 0.3 million, 1.1 million, and 2.1 million bbl/d, the release times are about 14, 4, and 2 seconds, respectively. For this spill, the oil slick would be short under plug-flow assumptions. The longest slicks would occur on the Tanana and Tazlina Rivers. For a current velocity of 10 ft/s (Table 4.4-12), a 140-ft-long slick would be produced for a throughput of 0.3 million bbl/d.

The approximate times for a response team to get to the location of the designated containment site and initiate an appropriate response for an anticipated event are listed in Table 4.4-13 (Folga et al. 2002). The sequence

6 Responses are not restricted to these containment sites. Response activities would take place at suitable locations identified at the time of the spill. However, these designated sites are assumed for the purpose of the analysis presented here.

TABLE 4.4-11 Approximate Maximum Oil Discharges (bbl) at Major and Minor Elevated River Crossings Produced by a Guillotine Break in the Pipeline

		Maximum Oil Discharge (bbl) by Throughput Level (bbl/d)		
Name	Milepost	0.3×10^6	1.1×10^6	2.1×10^6
Dan Creek/Sagavanirktok River	85	28,998	29,880	31,662
Atigun River	141	27,916	28,573	29,393
Atigun River	147	17,521	18,506	19,737
Snowden River	198–199	34,932	37,846	33,922
Dietrich River/floodplain	200	34,932	37,846	33,922
Dietrich River	205–206	37,028	39,858	36,296
Middle Fork Koyukuk River/floodplain	208–213	23,730	26,519	23,057
Linda Creek	215	24,473	27,164	24,006
Sheep Creek	216–217	27,120	29,797	26,647
Nugget Creek	217	31,254	33,921	30,774
Middle Fork Koyukuk River/floodplain	221	32,726	35,336	32,257
Hammond River	222	20,595	23,187	19,834
Middle Fork Koyukuk River/floodplain	222–225	23,261	25,809	22,843
Minnie Creek	226	23,261	25,809	22,843
Middle Fork Koyukuk River/floodplain	228–233	35,310	37,792	34,889
Clara Creek	236	24,219	26,617	23,734
Middle Fork Koyukuk River/floodplain	242–246	32,804	35,075	32,241
South Fork Koyukuk River	256	26,479	28,591	25,959
Douglas Creek	270	23,041	24,964	22,323
Prospect Creek	277	36,610	38,430	31,940
Yukon River	353–354	20,477	21,246	17,676
Hess Creek	378–379	37,727	38,148	33,692
Erickson Creek	387–388	28,122	28,410	31,714
Lost Creek	392	32,561	32,779	28,467
Tolovana River	398–399	28,803	28,938	38,079
Tatalina River	412–413	23,723	23,662	27,823
Globe Creek	417	43,888	38,222	39,451
Aggie Creek	423–425	25,722	20,710	21,978
Washington Creek	431–432	18,584	30,440	31,518
French Creek	474–484	28,945	31,593	31,315
Little Salcha River	490–491	21,292	23,573	20,276
Redmond Creek	500	29,388	31,813	33,948
Minton Creek	510	52,390	53,967	50,561
Shaw Creek	520–521	23,550	24,828	31,833
Tanana River	531–532	7,489	8,486	11,612
Castner Creek	587–588	15,964	17,129	15,499
Lower Miller Creek	588	15,964	17,129	15,499
Miller Creek	589–590	13,143	14,336	12,737
Gulkana River	654–655	26,308	27,930	24,690
Tazlina River	686–687	17,334	18,291	15,871
Rock Creek	712	32,940	33,530	31,691
Squirrel Creek	717	20,468	20,992	19,260

TABLE 4.4-12 River Parameters for Spill Analyses

Location	Milepost	Contingency Area	Segment	Containment Site (CS) (mi)	Velocity (ft/s)	Discharge (ft^3/s)	Comments
Dan Creek/ Sagavanirktok River	85	Sagavanirktok River 2	2	CS 2-0 13.6 mi	2 to 8	2,000 to 28,000	CS2-1 containment site also possible, but very near crossing; heavy braiding; diversion booms with pits (low flows), underflow dams in side channels, blocking dams in high water channels.
Yukon River	353	Yukon	4	CS 5-26 1mi CS 5-29 4 mi	3 to 8	150,000 to 800,000	Single confined channel; Edward L. Patton Bridge; 1,500 to 4,000 ft wide; diversion booms.
Minton Creek	510	Salcha	5	CS 8-7A 12 mi	1 to 4	5 to 150	Incised channel; 2 to 20 ft wide with dense grass and willows and beaver dams; blocking dams and underflow dams.
Tanana River	531	Big Delta	3	CS 8-16 4 mi	3 to 10	15,000 to 60,000	Incised with narrow floodplain before Richardson Highway Bridge; braided after with several channels and gravel bars; 200 to 4,000 ft wide; diversion boom with underflow dams in small channels; contain in braided segment.
Gulkana River	654	Gulkana	3	CS 10-16 (17?) 20 mi at south abutment of old Richardson Highway Bridge	1 to 7	600 to 12,000	Near entry to Copper; 150 to 400 ft wide; meandering pattern with single channel; gravel bars at low flows; diversion booms and berms.
Tazlina River	686	Tazlina	4	CS 10-20 5 mi	2 to 10	2,000 to 26,000	6 mi to Copper; 250 to 600 ft wide; meandering pattern in broad valley; diversion booms and pits.

TABLE 4.4-13 Estimated Response Times for Various Spill Locations and a Guillotine Pipeline Break

Location	Nearest Milepost	Contingency Area	Nearest Pump Station	Distance to Nearest Pump Station (mi)	Estimated Response Time (h)		
					Worst Case	Average	Best Case
Dan Creek/ Sagavanirktok River	85	Sagavanirktok River 2	PS 3	33	12	5	5
Yukon River	353	Yukon	PS 6	4	9	3	3
Minton Creek	510	Salcha	PS 8	5	12	5	4
Tanana River	531	Big Delta	PS 9	20	14	7	7
Gulkana River	654	Gulkana	PS 11	13	10	4	4
Tazlina River	686	Tazlina	PS 12	35	10	5	4

of events involved in getting a response team to the designated containment site and initiating oil-recovery procedures is summarized as follows:

- Leak detection system goes into alarm,
- Dispatcher recognizes that a leak is occurring and notifies appropriate pump station
- The OCC requests the pump station to conduct reconnaissance,
- A helicopter is mobilized, or vehicles dispatched, as needed, for reconnaissance,
- Reconnaissance conducted to confirm the presence of an oil leak,
- The maintenance coordinator notifies the OCC and pump station personnel of leak and requests that containment equipment be dispatched,
- Pump station personnel and equipment are mobilized,
- Crews are dispatched from the pump station to containment site, and
- Booms and other equipment are deployed to contain the spill.

With the oil slick created by the spill traveling at the velocity of the river (Table 4.4-12), the leading edge of the slick could be many miles downstream of the break by the time containment and cleanup could be initiated for both high- and low-flow conditions in the receiving waters (Table 4.4-14). Because of the small volume of the spill, however, it is unlikely that the oil would be able to reach all of these containment locations, particularly those under high-flow conditions.

The percentages of oil subject to recovery at the containment sites were calculated on the basis of the assumptions of plug flow and volumetric balances as detailed in (Appendix A, Section A.15.2). The results are presented in Table 4.4-15. Except for the Dan Creek/ Sagavanirktok River, Minton Creek, and the Gulkana River crossings at low flow, all of the containment sites would fail to capture the crude oil if it flowed downstream as a plug flow. For

TABLE 4.4-14 Location of the Leading Edge of the Oil Slick at Estimated Average Response Times

Water Body	Distance (mi) Downstream of Release Point	
	High-Flow Conditions	Low-Flow Conditions
Dan Creek/ Sagavanirktok River	27.5	7.0
Yukon River	16.5	6.3
Minton Creek	13.5	3.4
Tanana River	47.6	14.7
Gulkana River	19.2	2.8
Tazlina River	34.0	7.0

TABLE 4.4-15 Summary of Spill Results for a Worst-Case Anticipated Spill Scenario

Location	Average Response Time (h)	High-Flow Velocity (mph)	Low-Flow Velocity (mph)	CS (mi)	Time to Reach CS for High Flow (h)	Time to Reach CS for Low Flow (h)	Spill Duration (h)	Percentage of Spill Subject to Recovery at CS for High Flow	Percentage of Spill Subject to Recovery at CS for Low Flow
Dan Creek/ Sagavanirktok River	5	5.5	1.4	13.6	2.5	9.7	0	0	100
Yukon River	3	5.5	2.1	4	0.7	1.9	0	0	0
Minton Creek	5	2.7	0.7	12	4.4	17.1	0	0	100
Tanana River	7	6.8	2.1	4	0.6	1.9	0	0	0
Gulkana River	4	4.8	0.7	20	0.6	28.6	0	0	100
Tazlina River	5	6.8	1.4	5	4.2	3.6	0	0	0

Dan Creek/Sagavanirktok River, Minton Creek, and the Gulkana River, 100% of the released fluid would be subject to capture.

Because the crude oil would not move downstream as a plug, the physical size of the contaminated zone would be larger than the length of the plug-flow slick because of hangup along the flow path, mixing, entrainment, and remobilization. Although the volume of oil released is very small compared with the other spill scenarios, it would still be sufficient to create contamination problems downstream of the break, particularly in the Gulkana National Wild River.

Likely Spill Events. The second frequency class analyzed was for spill scenarios described as *likely*. The scenarios in this category that would produce the greatest impact on surface water resources would be a leak caused by sabotage or vandalism (Scenario 12) and a leak resulting from corrosion-related damage (Scenario 14). These scenarios would produce the greatest impacts because they would release the largest volume of oil — 10,000 bbl (420,000 gal) over a prolonged release period. For purposes of analysis, the oil is assumed to spill directly into one of the previously discussed six rivers or streams at an elevated crossing.

Table 4.4-16 summarizes the duration of these spills and the response times for recovery at the six river crossings. The spill times range from 10 to 102 hours for a corrosion-related spill and from 11 to 105 hours for vandalism. The range of time is determined by the size of the hole in the pipeline (Folga et al. 2002). The spill times for the oil for the two scenarios are assumed to be the same (approximately 10 to 100 hours). Under average conditions, the response times listed in Table 4.4-16 range from 2 to 6 hours; under worst-case conditions (i.e., the spill is not readily detected), the response times are much longer, 31 to 36 hours.

Because the response times for a likely spill event (Table 4.4-17) (Folga et al. 2002) are different from those of an anticipated spill event (Table 4.4-13), the leading edge of the oil spill would be at a different locations for the given response times. For high-flow conditions, these distances are 22.0, 11.0, 10.8, 40.8, 14.4, and 27.2 mi for the Dan Creek/Sagavanirktok River, Yukon River, Minton Creek, Tanana River, Gulkana River, and Tazlina River, respectively. Under low-flow conditions, the distances would be 5.6, 4.2, 2.8, 12.6, 2.1, and 5.6 mi, respectively. The slicks would be wide enough to extend from bank-to-bank for all of the rivers and creeks evaluated (Appendix A, Section A.15.2). The tails of the slicks would not pass the containment sites for at least 10 hours, the minimum duration time of the spill, if the containment site was located at the spill location.

The percentage of oil subject to capture at the containment sites was again calculated by using plug-flow assumptions and volumetric balances (Appendix A, Section A.15.2). For these calculations, an average response time for the initiation of recovery was assumed. This assumption is reasonable for the likely spill scenarios because detection of oil spilling directly into one of the six rivers would be readily detected. The results of this analysis for a small hole (an emptying time of about 100 hours) are given in Table 4.4-17. On the basis of plug-flow assumptions, at least 95% of the released oil would be subject to recovery at the containment sites for each river. In the worst case (Tanana River and high-flow conditions), 50 bbl (2,100 gal) of oil would flow beyond the containment site without being subject to recovery. If the response time increased to the worst-case values, less of the oil would be subject to capture. For example, at Minton Creek the percent of spilled oil subject to recovery at the containment site would decrease from 100% to 70% if the response time increased from an average value of 4 hours to a worst-case value of 34 hours.

Table 4.4-18 shows the results of the calculations for the likely spill scenarios for a large-diameter hole (emptying time of 10 hours) with all of the other factors remaining the same. Under high-flow conditions on the Tanana River, 46% of the spilled oil would be subject to recovery at the containment site under conditions of plug flow, but 5,400 bbl (226,800 gal) would potentially move past the containment point before initiation of recovery. The percentage of oil subject to recovery at the other rivers would all be higher than that for the Tanana River crossing. Increasing the response

TABLE 4.4-16 Estimated Response Times for Various Spill Locations for a Likely Spill Scenario

Location	Nearest Milepost	Contingency Area	Duration of Leak due to Corrosion (h)		Duration of Leak due to Vandalism (h)		Estimated Response Time (h)		
			Large Hole	Small Hole	Large Hole	Small Hole	Worst Case	Average	Best Case
Dan Creek/ Sagavanirktok River	85	Sag River 2	10	102	11	105	34	4	3
Yukon River	353	Yukon	10	102	11	105	31	2	1
Minton Creek	510	Salcha	10	102	11	105	34	4	2
Tanana River	531	Big Delta	10	102	11	105	36	6	5
Gulkana River	654	Gulkana	10	102	11	105	32	3	2
Tazlina River	686	Tazlina	10	102	11	105	32	4	3

TABLE 4.4-17 Summary of Spill Results for a Worst-Case Likely Spill Scenario and a Small Hole

Location	Average Response Time (h)	High-Flow Velocity (mph)	Low-Flow Velocity (mph)	CS (mi)	Time to Reach CS for High Flow (h)	Time to Reach CS for Low Flow (h)	Spill Duration for a Small Hole (h)	Percentage of Spill Subject to Recovery at CS for High Flow	Percentage of Spill Subject to Recovery at CS for Low Flow
Dan Creek/ Sagavanirktok River	4	5.5	1.4	13.6	2.5	9.7	100	99	100
Yukon River	2	5.5	2.1	4	0.7	1.9	100	99	100
Minton Creek	4	2.7	0.7	12	4.4	17.1	100	100	100
Tanana River	6	6.8	2.1	4	0.6	1.9	100	95	96
Gulkana River	3	4.8	0.7	20	4.2	28.6	100	100	100
Tazlina River	4	6.8	1.4	5	0.7	3.6	100	97	100

TABLE 4.4-18 Summary of Spill Results for a Worst-Case Likely Spill Scenario and a Large Hole

Location	Average Response Time (h)	High-Flow Velocity (mph)	Low-Flow Velocity (mph)	CS (mi)	Time to Reach CS for High Flow (h)	Time to Reach CS for Low Flow (h)	Spill Duration for a Large Hole (h)	Percentage of Spill Subject to Recovery at CS for High Flow	Percentage of Spill Subject to Recovery at CS for Low Flow
Dan Creek/ Sagavanirktok River	4	5.5	1.4	13.6	2.5	9.7	10	85	100
Yukon River	2	5.5	2.1	4	0.7	1.9	10	87	99
Minton Creek	4	2.7	0.7	12	4.4	17.1	10	100	100
Tanana River	6	6.8	2.1	4	0.6	1.9	10	46	59
Gulkana River	3	4.8	0.7	20	4.2	28.6	10	100	100
Tazlina River	4	6.8	1.4	5	0.7	3.6	10	67	96

time would, again, decrease the percentage of oil subject to recovery. For example, if the response time at Minton Creek increased from an average value of 4 hours to a worst-case value of 34 hours (Table 4.4-16), the percentage of oil subject to recovery would decrease to zero at the containment site. The magnitude of the change in the potential percentage of capture is much greater in this case because of the short pipeline emptying time used in the calculations (10 hours).

The results show that impacts from a likely spill event would be much more severe, and the area impacted could be larger, than discussed above for an anticipated spill event.

Unlikely Spill Events. Of the unlikely spill scenarios considered, a guillotine break in the pipeline caused by the impact of a fixed-wing aircraft would produce the largest oil release to inland waters (53,967 bbl, or 2,267,000 gal for a throughput of 1.1 million bbl/d). Because a guillotine break would release the largest quantity of oil, it is used as representative and bounding for the spill scenarios in the unlikely category.

For conservative results, the guillotine break for Scenario 21 was assumed to discharge oil directly into flowing water at the six elevated river crossings. Impacts from guillotine breaks in elevated pipeline segments over land could also impact nearby surface water resources, but the impacts to surface water would be less because some of the oil would remain on and in the ground while traveling from the location of the break to the water. Table 4.4-11 lists the volumes of oil that would be released following a guillotine break at major and minor elevated river crossings along the TAPS ROW. The volume would depend both on the location and the throughput of the pipeline. For the three throughputs considered in this FEIS (0.3 million, 1.1 million, and 2.1 million bbl/d), the greatest release of crude oil along the TAPS ROW for a guillotine break would occur at Minton Creek (MP 510). These release volumes would be 52,390 bbl (2,200,000 gal), 53,967 bbl (2,267,000 gal), and 50,561 bbl (2,250,000 gal) for throughputs of 0.3 million, 1.1 million, and 2.1 million bbl/d, respectively.

Table 4.4-19 summarizes spill volumes associated with a guillotine break at each of the six elevated crossings. These spills are all described as having a short duration. Because of the length of the pipeline between valves that would be closed in the event of a guillotine break to stop flow in the pipeline, a small amount of time would be needed to close the appropriate valves safely and discharge the oil in the affected pipe segment. Details on this calculation are provided in Folga et al. (2002). Estimates of these times required are provided in Table 4.4-19.

The largest predicted spill volumes and duration times for the guillotine break spill scenario would occur at Minton Creek. For a throughput of 0.3 million bbl/d, about 4.2 hours would be needed to close the appropriate valves and discharge the contents of the broken pipe section into the creek. The smallest release volumes and emptying times would occur at the Tanana River. The differences in release volumes is primarily a function of the location of valves in the pipeline relative to the location of the guillotine break.

While the spill event was in progress, oil discharged to the river would flow downstream at the velocity of the river current, forming a slick. For plug flow, the length of the slick can be estimated as the product of the velocity and the duration time of the spill. Because the flow of water in a river or stream is variable (e.g., the flow velocity in the Dan Creek/Sagavanirktok River varies from about 2 to 8 ft/s [Table 4.4-12]), the higher flow values in the flow ranges provide conservative estimates of the slick lengths given in Tables 4.4-20 and 4.4-21 for high- and low-flow conditions, respectively. The longest slick produced by a guillotine break during the discharge period would be 12.7 mi on the Dan Creek/Sagavanirktok River for a throughput of 0.3 million bbl/d. The shortest slick would be 0.9 mi on the Tanana River for a throughput of 2.1 million bbl/d. For each of the six rivers, the longest slicks would occur for the lowest throughput value (0.3 million bbl/d) because the drain time would be the longest for that throughput level.

Once a spill to water was detected, a spill response team would be sent to the containment sites identified in the contingency plans

TABLE 4.4-19 Summary of Spill Volumes, Rates, and Drainage Times for River Crossings under Different Throughputs

Location	Milepost	Volume Released (bbl)	Initial Spill Rate (bbl/min)	Drainage Time (h)
0.3 million bbl/d Throughput				
Dan Creek/ Sagavanirktok River	85	28,998	208	2.3
Yukon River	353	20,477	208	1.7
Minton Creek	510	52,390	208	4.2
Tanana River	531	7,489	208	0.6
Gulkana River	654	26,308	208	2.1
Tazlina River	686	17,334	208	1.4
1.1 million bbl/d Throughput				
Dan Creek/ Sagavanirktok River	85	29,880	764	0.65
Yukon River	353	21,246	764	0.47
Minton Creek	510	53,967	764	1.18
Tanana River	531	8,486	764	0.19
Gulkana River	654	27,930	764	0.61
Tazlina River	686	18,291	764	0.40
2.1 million bbl/d Throughput				
Dan Creek/ Sagavanirktok River	85	31,662	1458	0.37
Yukon River	353	17,676	1458	0.22
Minton Creek	510	50,561	1458	0.58
Tanana River	531	11,612	1458	0.13
Gulkana River	654	24,690	1458	0.28
Tazlina River	686	15,871	1458	0.18

(Table 4.4-13) (APSC 2001g), and recovery activities would begin. Under average conditions, the total response time would vary from 3 hours for the Yukon River crossing to 7 hours for the crossing on the Tanana River. By the time the response team reached any of the containment sites and initiated an appropriate response, the entire predicted volumes of oil would have been released to the rivers (Table 4.4-19), and the leading edge of the slick would have traveled downstream beyond the containment site for all rivers except the Gulkana. Assuming small losses during the initial phase of transport, the leading edge of the slick could be almost 50 mi downstream on the Tanana River before cleanup activities started (Table 4.4-14).

The percent of oil subject to recovery at the containment sites was estimated by using simple volumetric balances and plug-flow assumptions (Appendix A, Section A.15.2). These results are given in Table 4.4-20 for high flow conditions. For the Gulkana River, 100% of the slick would be subject to recovery activities consisting of use of diversion booms and berms (Table 4.4-12).

TABLE 4.4-20 Summary of Spill Analyses for a Worst-Case Unlikely Guillotine Break during High-Flow Conditions for Three Pipeline Throughput Levels

		Slick Length (mi) by Pipeline Throughput			
Location	Milepost	0.3×10^6 bbl/d	1.1×10^6 bbl/d	2.1×10^6 bbl/d	Location of Leading Edge of Slick at Average Response Time (mi)
Dan Creek/ Sagavanirktok River	85	12.7	3.7	2.0	27.5
Yukon River	353	9.0	2.6	1.2	16.5
Minton Creek	510	11.3	3.2	1.6	13.5
Tanana River	531	4.1	1.4	0.9	47.6
Gulkana River	654	10.1	3.0	1.3	19.2
Tazlina River	686	9.6	2.7	1.2	34.0

	Location of Trailing Edge, if Plug Flow (mi)				Distance from Trailing Edge to Containment Site (mi)			Percent of Oil Subject to Capture		
Location	0.3×10^6 bbl/d	1.1×10^6 bbl/d	2.1×10^6 bbl/d	Distance to CS (mi)	0.3×10^6 bbl/d	1.1×10^6 bbl/d	2.1×10^6 bbl/d	0.3×10^6 bbl/d	1.1×10^6 bbl/d	2.1×10^6 bbl/d
Dan Creek/ Sagavanirktok River	14.8	23.8	25.5	13.6 (CS2-0)	1.2	10.2	11.9	0	0	0
Yukon River	7.5	13.9	15.3	4.0 (CS5-29)	3.5	9.9	11.3	0	0	0
Minton Creek	2.2	10.3	11.9	12 (CS8-7A)	-9.8	-1.7	-0.1	87	87	6
Tanana River	43.5	46.2	46.7	4 (CS8-16)	39.5	42.2	42.7	0	0	0
Gulkana River	9.1	16.2	17.9	20 (CS10-16)	-10.9	-3.8	-2.1	100	100	100
Tazlina River	24.4	31.3	32.8	5 (CS10-20)	19.4	26.3	27.8	0	0	0

TABLE 4.4-21 Summary of Spill Analyses for a Worst-Case Unlikely Guillotine Break during Low-Flow Conditions for Three Pipeline Throughput Levels

		Slick Length (mi) by Pipeline Throughput			
Location	Milepost	0.3×10^6 bbl/d	1.1×10^6 bbl/d	2.1×10^6 bbl/d	Location of Leading Edge of Slick at Average Response Time (mi)
Dan Creek/ Sagavanirktok River	85	3.2	0.9	0.5	7.0
Yukon River	353	3.6	1.0	0.5	6.3
Minton Creek	510	2.9	0.8	0.4	3.4
Tanana River	531	1.3	0.4	0.3	14.7
Gulkana River	654	1.5	0.4	0.2	2.8
Tazlina River	686	2.0	0.6	0.3	7.0

	Location of Trailing Edge, if Plug Flow (mi)				Distance from Trailing Edge to Containment Site (mi)			Percent of Oil Subject to Capture		
Location	0.3×10^6 bbl/d	1.1×10^6 bbl/d	2.1×10^6 bbl/d	Distance to CS (mi)	0.3×10^6 bbl/d	1.1×10^6 bbl/d	2.1×10^6 bbl/d	0.3×10^6 bbl/d	1.1×10^6 bbl/d	2.1×10^6 bbl/d
Dan Creek/ Sagavanirktok River	3.8	6.1	6.5	13.6 (CS2-0)	-9.8	-7.5	-7.1	100	100	100
Yukon River	2.7	5.3	5.8	4.0 (CS5-29)	-1.3	1.3	1.8	36	0	0
Minton Creek	0.6	2.7	3.1	12 (CS8-7A)	-11.4	-9.3	-8.9	100	100	100
Tanana River	13.4	14.3	14.4	4 (CS8-16)	9.4	10.3	10.4	0	0	0
Gulkana River	1.3	2.4	2.6	20 (CS10-16)	-18.7	-17.6	-17.4	100	100	100
Tazlina River	5.0	6.4	6.7	5 (CS10-20)	0	1.4	1.7	0	0	0

(Booms would be used to divert the flow of oil toward one of the river banks, rather than trying to contain the oil directly because of the high-velocity current of the river.) For the other river crossings, the tail of the slick would move past the containment point before the initiation of recovery operations if the oil moved downstream as plug flow. Recovery would be effective in the Gulkana River because the location of the front of the oil slick would not reach the containment site before the initiation of a recovery response; the Gulkana River has a small current (7 ft/s) relative to the other rivers, and its containment site is located farthest downstream of the break (20 mi). Although 100% of the oil would be subject to recovery on the Gulkana River, the downstream region between the pipeline break and containment site would be subject to major impacts from oil coating (approximately 20 mi of shoreline, part of which is along a wild river corridor).

For the Minton Creek elevated river crossing, approximately 87% of the initial oil slick would be subject to capture for a throughput of 0.3 million bbl/d (Table 4.4-20). Lesser quantities would be subject to capture at higher throughputs because of shorter drain times. Once the slick had moved beyond the containment site, it could continue to move downstream, contaminating additional portions of the river channel.

Because of spreading, the slick would get wider as it moved downstream. If the slick spread circularly (Yapa and Shen 1994), the slicks downstream of all of the elevated river crossings evaluated would be sufficiently wide to extend from bank-to-bank, even under conditions of high flows (Appendix A, Section A.15.2).

The above analyses assumed that the spilled crude oil would move downstream as a plug of crude oil with sharp leading and trailing edges and would not be in any way impeded. However, because of mixing, emulsification, entrainment, deposition, channel variations, rapids, encounters with boulders, islands, braiding, weather, and other factors, the oil slick would not move downstream as plug flow. Nonetheless, it is clear that for all rivers except the Gulkana, oil could be downstream of the containment sites before cleanup was initiated.

Impacts to the rivers and creek under high-flow conditions for the postulated guillotine break scenario would be major, and subsequent cleanup could take considerable time and effort because it is unlikely that the response teams could capture a significant portion of the spilled oil. Many miles of shoreline, as well as the bottom of the channel, could be affected. Because of the remoteness of the rivers and lack of easy access, these cleanup activities could be very difficult to accomplish.

Table 4.4-21 shows the results of similar calculations performed for low-flow conditions at the same elevated river crossings. For these conditions, 100% of the slicks would be subject to recovery for spills at the Dan Creek/ Sagavanirktok River, Minton Creek, and Gulkana elevated crossings. No capture would be predicted for elevated guillotine breaks and pure plug flow at river crossings on the Tanana and Tazlina Rivers. For the Yukon River crossing, 36% of the released oil would be subject to capture. As in the case of high flows, factors such as mixing, emulsification, entrainment, deposition, channel variations, rapids, encounters with boulders, islands, braiding, and weather would prevent the oil from being transported as a plug. However, a substantial portion of the initial release could be downstream of the containment sites before cleanup was initiated for at least two of the river crossings evaluated (Tanana and Tazlina Rivers).

Because the leading edge of the oil slick would pass the containment location prior to the arrival of the response team, impacts could occur to the Copper River. Plans are being developed to mitigate such impacts (see text box on following pages).

Very Unlikely Spill Events. Of the very unlikely spill scenarios, a guillotine break of the pipeline at an elevated river crossing resulting from a helicopter crash would produce the largest oil release (53,967 bbl, or 2,267,000 gallons) to inland waters for a throughput of 1.1 million bbl/d. Because a guillotine break would release the largest quantity of oil, it was used as representative and bounding for the very unlikely spill scenarios.

Oil Spill Planning for the Copper River Drainage

The Copper River drainage is one of several major drainages traversed by the Trans-Alaska Pipeline System (TAPS). Several individuals and organizations commenting on the DEIS expressed concern about the impacts that would be associated with a potential oil spill in the Copper River drainage, and APSC's plans to prevent or respond to such a spill. This text box identifies various risk management components that either prevent or mitigate the potential impacts for this type of a spill in the Copper River drainage.

JPO Oil Spill Planning

The Joint Pipeline Office (JPO) oil spill planning and prevention program is a large-scale, multiagency endeavor. Each of five participating agencies [Alaska Department of Environmental Conservation (ADEC), Environmental Protection Agency (EPA), Bureau of Land Management (BLM), Alaska Department of Natural Resources (ADNR), and the Office of Pipeline Safety (OPS)] has a particular focus; however, their individual objectives are considered collectively in the JPO TAPS oil spill response and planning group. This interagency group meets monthly and maintains a continuous monitoring program on TAPS oil spill planning and related issues.

The emphasis of the five agencies is the prevention of spills. Spill prevention is accomplished through a combination of (1) oversight of spill contingency planning (including 64 exercises conducted on TAPS annually) and, (2) JPO's comprehensive TAPS operations oversight and monitoring of issues that could contribute to a spill in the future. In the event a spill does occur, however, JPO has a number of highly trained individuals who are prepared to respond quickly and effectively.

Oil Spill Analysis in the EIS

Existing mitigation measures, including the JPO oversight, design features intended to prevent and/or detect potential leaks, monitoring and surveillance activities, oil discharge and contingency plans, and other social, cultural, and economic mitigation features are discussed in Section 4.1 of the EIS. Section 4.4 of the EIS discusses the spill scenarios and their potential impacts considered along the pipeline, including the Copper River drainage area, and at the Valdez Marine Terminal. Consideration of spill scenarios and impacts in the Prince William Sound and on the North Slope is included in Section 4.7 of the EIS.

Likelihood of a Spill into the Copper River Drainage

As part of the process for planning for oil spills, the risks of pipeline spills are analyzed on a linewide basis (i.e., considering the full length of the pipeline – 800 mi). The most recent analysis was completed by Capstone Engineering Services Inc., in December 2001 (Capstone Engineering Services 2001).* Factors considered in the analysis include internal corrosion data, age of the pipe, information on vulnerability of aboveground sections to sabotage, seismic information, TAPS leak data, and pipeline industry historical data.

The Capstone report ranked the most significant leak initiators as sabotage, maintenance (errors), corrosion, hydraulic events, and mechanical defects. Seven additional initiators were included in the assessment, including seismic events, washouts, and vehicle/aircraft impacts. The assessment looked at each mile of pipeline and applied the worst-case probability of occurrence within that segment to the entire mile.

* On the basis of historical pipeline spill data for spills of 50 bbl or greater, the TAPS has a rate of leaks of about 0.4 per 1,000 mi of pipeline per year, compared with the U.S. average of 1.1 per 1,000 mi of pipeline per year.

Continued

The results of the Capstone assessment do not show a disproportionately high frequency of oil spills threatening the Copper River. The frequency rankings at the five major stream crossings in the area (Gulkana, Tazlina, Klutina, Squirrel, and Tonsina) range between 0.00016 (1.6×10^{-4}) and 0.00037 (3.7×10^{-4}) per mile per year (or between approximately 1 and about 4 in 10,000 years for a given mile segment of TAPS.) Spills occurring at this frequency are considered to be very unlikely (Section 4.4). Of the 10 highest ranked sites for risk (for which frequencies range from 0.00081 [8.1×10^{-4}] to 0.00091 [9.1×10^{-4}] per year), four are in the Copper River drainage; however, all are distant from significant stream crossings that drain into the Copper River. (Note that these probabilities are not for the worst-case spills described below, but for spills of greater than 50 bbl anywhere along a 1-mi segment of TAPS.) Because these probabilities of occurrence are calculated on a per-mile basis, the actual frequencies of occurrence are less because the length of the pipeline crossings over most streams is much less than 1 mi. (The site-specific probability of occurrence for any one stream is equal to the probability of occurrence for the mile segment that contains the stream crossing multiplied by the length of pipeline that occurs directly over the water in the stream divided by 1 mi.)

Although the frequencies of occurrence for spills in the Copper River drainage are small and considered to be very unlikely, the risks of such spills could be significant. As discussed in Section 4.4, risk is the product of the probability of occurrence times the consequences. The consequences of oil spills in the Copper River drainage could be large, depending on the volume of oil released; the location, duration, and size of the spill; the time of year or the season in which the spill occurs; local environmental conditions; the location and susceptibility of downstream receptors; and the timeliness and effectiveness of the cleanup measures.

For the EIS, analyses were performed for four spill frequencies: *anticipated, likely, unlikely,* and *very unlikely* (Table 4.4-1). Specific calculations were performed for the Gulkana (MP 654–655) and Tazlina (MP 686–687) Rivers, both of which are part of the Copper River drainage. For an unlikely worst-case spill scenario (helicopter crash into an elevated pipeline river crossing that produces a guillotine break of the pipeline and a direct release of oil into the rivers) and a very unlikely spill scenario (a fixed-wing aircraft crash into an elevated river crossing that produces a guillotine break of the pipeline and a direct release of oil into the rivers), impacts on the Tazlina River would be major because the leading edge of the spill would move beyond the oil containment site before a response team could arrive there and initiate cleanup activities. This oil could produce significant impacts on the Copper River system. For the Gulkana River, 100% of the oil would be subject to capture at the designated containment site (approximately 20 mi downstream of the river crossing) (Section 4.4.4.3). Depending on conditions, some of the oil could escape containment and flow into the Copper River.

Prevention

The majority of significant leak originators (e.g., corrosion) are already subject to linewide programs, often under the heading of pipeline integrity. They include a corrosion prevention and detection program, slope stability program, maintenance procedures, and a security program. These programs are closely monitored by multiple government agencies.

Measures to Limit Environmental Damage

Should a leak occur, several mitigating measures are in place to limit the environmental damage that might result.

On the basis of U.S. Department of Transportation regulations and the Federal and State Lease for the ROW, main-line valves are located near each major river crossing to limit the amount of oil released from a pipeline leak. All potential spill volumes are listed in the *Trans-Alaska Pipeline System Pipeline Oil Discharge Prevention and Contingency Plan, CP-35-1 GP*, prepared in 2001 by the Alyeska Pipeline Service Company (C-Plan). The highest spill volume is not in the Copper River drainage, but north of the Alaska Range. In the case of the Klutina River crossing (MP 696.9 to 698.8), the dynamic spill volume that would result from a guillotine break is up to 43,336 bbl. For the Gulkana River crossing (MP 654.3 to 654.4), the dynamic spill volume is approximately 13,000 bbl.

Continued

Another mitigating factor is the recent construction of berms near the banks of crossings at the Gulkana, Tazlina, and Klutina Rivers to prevent oil flowing along the ROW from directly entering the rivers. These berms are unique to the Copper River tributaries.

Spill Response Capabilities

The C-Plan provides for significant resources, including equipment, trained personnel, and effective organization, to respond if oil spills from the pipeline.

Response crews and equipment for initial deployment are stationed at PS 9, Glennallen, PS 12, and Valdez. The entire region crossed by the pipeline has been characterized with respect to the potential flow of spilled oil. Appropriate containment tactics are described in the C-Plan, with site-specific descriptions for each identified containment site.

The Region 5 plan, which contains all contingency areas that could affect the Copper River, lists 12 contingency areas and 38 segments. Priority control actions and specific containment instructions are identified for each of the 38 segments. Each regional plan includes tables detailing materials and equipment available for oil spill response at all stations and containment sites.

A primary objective of these strategies is to contain oil before it reaches the Copper River. The C-Plan provides for establishing containment at the point of entry into the Copper River if oil were to travel that far. Discussions of control actions to take if oil reaches the Copper River are limited; however, there are descriptions of suitable strategies, tactics, personnel, and equipment for containment and recovery of oil for the river.

Limitations

In the General Provisions Section 2.4, “Realistic Maximum Response Operating Limits,” the C-Plan describes environmental conditions that could occur that would adversely impact the effectiveness of a response. The described conditions would potentially delay the deployment of mechanical containment and recovery equipment, or present a threat to the safety of the responders.

C-Plan Section 1.7.4.1.6, “Crude Oil and Suspended Solids Interaction in Silty Rivers” discusses impacts of silt on an oil spill. The Copper River and several of its tributaries have a seasonal silt loading sufficient to remove a significant portion of a surface oil slick. The amounts of oil removed from the surface slick would depend on the amount and rate of oil released in the river, the amount of solids in the river, the volume of water discharge rate, the mixing energies available downstream of the release, and the composition of the crude oil (lighter elements would vaporize from the water surface).

The surface slick may break up into small droplets, bind with silt particles, and be suspended in the water column. The aggregate particles would travel along the course of the river channel. Particles remaining in suspension would be widely dispersed downstream of the release point and would not resurface. Particles having negative buoyancy would be expected to widely disperse along the river bottom and in side eddies. The small size and distribution of these particles make them ideally available for biodegradation. An important factor affecting the potential for oil and silt interaction is the volume of water in the river. The discharge rate of the Tonsina River is 1,930 ft^3/s for summer compared to the Copper River summer discharge rate of 140,000 ft^3/s.

Continued

Local Involvement

Ahtna Construction & Primary Products Corporation is a primary response action contractor for APSC. The team comprises six personnel based at the Glennallen PS 11 area. The crew consists of a combination of teamsters, operators, and laborers. Ahtna is required by contract to provide a minimum three-person response team capability on a 24 hours per day, 7 days per week basis. The team would be mobilized at PS 11 and prepared for deployment within 3 hours of notification.

TCC is a primary response action contractor for APSC, based at Valdez. TCC works as part of the SERVS Initial Response Team. The team consists of eight personnel, made up of a combination of SERVS and TCC personnel available on a 24-hour per day basis.

Houston/Nana Joint Venture is APSC's pipeline maintenance contractor providing vehicle maintenance, pipeline facilities maintenance, and baseline crew staffing. All pipeline facilities and vehicle maintenance assigned personnel have collateral oil spill response duties and are available at various locations from PS 1 to Valdez. Baseline crew members are assigned primary oil spill response duties and are available at PS 1, 3, 4, 5, 6, 7, 9, and 12.

APSC has contracts with three local boat handlers for local knowledge of operations on area rivers and to augment response by providing expanded logistics support.

Continual Improvement

Listed below are activities designed to reduce the potential of a spill into the Copper River drainage, and if a spill does occur, to reduce the potential consequences. Several of these actions have already been completed; others are either underway or being planned.

- Construct berms on river banks in areas of aboveground pipe and defined drainage on the Gulkana, Tazlina, and Klutina Rivers – *[complete]*.
- Purchase a LCM-style support boat and an on-board skimmer system *[complete]*.
- Increase area responders by staffing a Glennallen-based response team *[complete]*.
- Deliver to PS 11 new response trailers and a 45-ft van to improve overall response *[complete]*.
- Develop a rapid containment boom deployment system on the lower Tonsina River *[underway]*.
- Conduct a number of containment-site evaluations and training sessions in the region *[complete]*.
- Develop three additional Gulkana River access sites *[complete]*.
- Locate an equipment connex at the Gulkana River/Richardson Highway bridge *[complete]*.
- Add 12,000 ft of smaller dimension fast-water boom (2,400 ft is located within the PS11/12 area) *[complete]*.
- Develop pre-deployed anchor systems on the Klutina, Gulkana, and Tazlina Rivers *[planned]*.
- Develop boat access for the Copper River *[planned]*.

It is anticipated that the oil spill prevention and response measures already in place (C-Plan) and new measures being instituted as discussed above will reduce both the likelihood and the consequences of potential spills in the Copper River drainage area.

For this spill scenario, release volumes for the six river crossings would be the same as those discussed above for the unlikely spill scenario for the guillotine break caused by a fixed-wing aircraft crash (Scenario 19a). Because the spill volumes and other parameters would be same as for those used to evaluate the unlikely spill scenario, the impacts associated with the guillotine break under this very unlikely spill scenario would be the same as those discussed above.

4.4.4.4 Groundwater Resources

4.4.4.4.1 Introduction. Groundwater resources along the TAPS ROW could be affected by spills, particularly if a spill occurred directly, or close, to underlying groundwater. This type of spill could occur along buried segments of the pipeline. Impacts to groundwater for the same spill occurring along aboveground pipeline segments would be, accordingly, smaller because oil would be lost on the land surface.

Four spill scenarios were analyzed for their effects on groundwater resources. Each is representative of one of the four spill-frequency categories. The first category consists of spills that are *anticipated*. Only one of these scenarios, (Scenario 1) would discharge oil below the ground surface. This spill would result from a small leak and would involve a maximum oil release of 50 bbl.

Impacts of Oil Spills on Groundwater

For anticipated spill events, the volume of oil spilled would be low (e.g., 50 bbl), and impacts to groundwater resources would be small and local. In the event of a very low probability accident involving a larger spill (e.g., an underground guillotine break of the pipeline that is initiated by a landslide and releases 46,000 bbl of crude oil), impacts to groundwater would range from small in magnitude and local in the Brooks and Alaska Ranges to very large in magnitude and extensive in the Chugach Range. Impacts of direct spills to groundwater could be minimized by proper planning, training, surveillance, and timely implementation of contingency plans.

The second category involves spills considered to be *likely*. Of the eight spill scenarios in this category, four could directly affect groundwater resources: Scenario 5 — a moderate, instantaneous leak of crude oil; Scenario 9 — a very short-duration leak caused by maintenance-related damage; Scenario 10 — a short-duration (10 hours) leak caused by overpressurization from inadvertent remote gate valve closure; and Scenario 14 — a prolonged (2 days) leak resulting from corrosion-related damage. Of these scenarios, Scenario 14 was evaluated because it would release the largest volume of oil (10,000 bbl) to the environment.

The third analysis was performed for spill scenarios that are considered to be *unlikely*. Of the five scenarios in this category, two could impact groundwater resources: a leak resulting from pipeline settling (Scenario 15); and a crack resulting from seismic fault displacement and ground waves (Scenario 16). Because of its larger release volume (16,000 bbl), Scenario 16 was analyzed.

The last analysis was performed for a *very unlikely* spill scenario. It consists of an underground guillotine break caused by a seismically induced landslide (Scenario 20). This spill would release a maximum of about 47,000 bbl of crude oil.

4.4.4.4.2 Impacts of Spill Scenarios.

Anticipated Spills. Scenario 1, an *anticipated* spill event (Section 4.4.1.1), would discharge oil below the ground surface from a small leak. The volume of oil released is assumed to be 50 bbl, and the release period is assumed to be instantaneous.

An underground release can only occur along buried sections of the pipeline. Three general regions have been identified along the TAPS ROW where an underground leak might occur: MP 140 to 255 in the Brooks Range, MP 560 to 610 in the Alaska Range, and MP 720 to 800 in the Chugach Range. Impacts are analyzed at MP 178 for the Brooks and Alaska Ranges, and at MP 741 for the Chugach Range. These locations were selected because they coincide with the locations of maximum oil releases for more severe, less frequent accidents discussed below.

Because the volume of oil released for the anticipated scenario would be very small (50 bbl), it is unlikely that any of the oil would emerge at the surface, although it would be released under pressure. Within the Brooks and Alaska Ranges, the 50 bbl of oil released would be in a region where permafrost is usually present. Because of the presence of permafrost, the oil would probably stay within the pipeline's gravel pack and affect the quality of water contained in thaw bulbs present at the location of the leak. Impacts would thus be small and local.

In the Chugach Range, permafrost is assumed to be absent at the location of the leak. For this case, the released oil could migrate downward under the influence of gravity and contaminate the local groundwater system. Because of the small volume of oil released, impacts to the groundwater system would be small and local.

Likely Spills. For the *likely* category of spills, a prolonged leak resulting from corrosion-related damage was selected for analysis because it would release the greatest volume of oil (10,000 bbl over a 2-day period). Because this type of leak could occur anywhere along the ROW where the pipeline is buried, evaluations of the impacts to groundwater were made for the same locations as those selected for the anticipated spill scenarios — the Brooks and Alaska Ranges (represented by a spill at MP 178), and the Chugach Range (represented by a spill at MP 741).

For the Brooks and Alaska Ranges, the volume of oil released (10,000 bbl) would be much greater than that discussed for the anticipated spill scenario (50 bbl). Impacts to the groundwater system in the Brooks and Alaska Ranges would be small and local because of the presence of permafrost that would prevent oil from migrating to deep groundwater systems, if present.

In the Chugach Range, the volume of oil released would be much larger than that released for the anticipated spill scenario discussed above. Impacts would occur when the oil infiltrated the soil column and reached the underlying groundwater. The 2-day duration of the spill would allow some response activities to commence and limit the amount of oil available for infiltration. These impacts would, however, be potentially very large because of the volume of oil released.

Unlikely Spill Events. The third analysis was for a release of oil through a pipeline crack resulting from seismic fault displacements and ground waves (Scenario 16). This spill is considered to be *unlikely* (frequency of occurrence of once in 1,000 years to once in about 30 years). Because of its association with faulting, this spill scenario is assumed to occur at MP 590 in the area of the Denali Fault in the Alaska Range. It would release 16,000 bbl of oil over a short period (hours).

In the Alaska Range, permafrost is discontinuous. Because of the proximity of the Delta River to the pipeline in the vicinity of MP 590, permafrost is assumed to be absent. As with the spill scenarios analyzed above, crude oil released from a crack would be under pressure (about 1,180 psi). Because of the volume of oil released and the system pressure, it is probable that the released oil would rapidly migrate to the surface and contaminate the land. Even with losses to the land surface, the underlying groundwater system could experience severe water quality impacts because of the large volume of oil released.

Very Unlikely Spill Events. An instantaneous, underground guillotine break resulting from a landslide was analyzed for the *very unlikely* spill scenarios (Scenario 20). This type of event would be expected to occur only between once in 1 million years to once in 1,000 years. Three general regions have been identified along the pipeline where this event might occur: MP 140 to 255 in the Brooks Range, MP 560 to 610 in the Alaska Range, and MP 720 to 800 in the Chugach Range. These regions are all within mountain ranges where landslides are possible. However, a belowground guillotine break is only feasible in regions in which the pipeline is buried. These locations and their associated maximum release volumes are listed in Table 4.4-22. The predicted maximum volume of crude oil that would be released varies with both location and throughput. Table 4.4-23 summarizes the information for the three mountain ranges.

The largest volume of oil that would be released for the very unlikely spill scenario would be 46,994 bbl in the Brooks Range at MP 178 for a pipeline throughput of 2.1 million bbl/d. This location is near Atigun Pass (MP 166). This spill was used to establish an upper bound of impacts for other guillotine breaks with smaller release volumes in the Brooks and portions of the Alaska Ranges in which permafrost is present (permafrost is discontinuous in the Alaska Range).

A separate evaluation was performed for a belowground guillotine break in the Chugach Range at MP 741. This location maximizes the volume of oil that would be released (38,773 bbl for a pipeline throughput of 0.3 million bbl/d) between MP 720 and 800. This second evaluation was performed because of physical differences in the landforms present. In the Brooks and Alaska Ranges, permafrost is continuous and stable (Brooks Range), or discontinuous (Alaska Range). In the Chugach Range, permafrost is either sporadic or absent (TAPS Owners 2001a). The presence or absence of permafrost can affect the vertical migration of spilled oil toward underlying groundwater resources.

The first evaluation is for a guillotine break of the belowground segment of the pipeline at MP 178. On the south side of Atigun Pass (MP 166), the pipeline descends steeply and loses 1,200 ft in elevation at the head of the Chandalar River basin and then loses another 700 ft to the headwaters of the Dietrich-Koyukuk River system (approximately MP 185) (TAPS Owners 2001a). The upper Dietrich River valley is narrow with a steep gradient (change in elevation with distance); steep, intersecting fans occur on its side slopes. Permafrost is continuous in this region and is relatively cold (-3 to -7°C). During the winter, the active layer (a thin, seasonally thawed layer that lies on top of the permafrost) freezes to the top of the permafrost, which is located about 1.5 ft below the ground surface. Bedrock is near the surface.

A guillotine break of the buried pipeline at MP 178 would discharge oil to the trench and gravel pack around the pipeline and to any thaw bulbs that might have developed because of the presence of warm oil flowing through the pipe. Contact with any deeper groundwater, if present, beneath the permafrost would not occur because the permafrost is very thick and would prevent vertical migration of the oil. In addition, deep groundwater may not be present in this location because of the presence of near-surface rock.

Oil from the guillotine break would flow in the gravel pack of the trench downhill toward the Dietrich River floodplain. Because the oil is much warmer than the surrounding permafrost (oil temperature at PS 1 is about 116°F, at PS 6 it is about 66°F, and at the Valdez Marine Terminal the temperature of the crude is about 63°F [APSC 2001i]), some of the permafrost would melt, and the oil would move downhill in the pipeline trench. The energy required to melt the permafrost would come from the warm oil, thereby reducing the oil's temperature (Sears 1953). As the warm oil melted the permafrost, the viscosity of the oil would increase as its temperature dropped. This increase in viscosity would decrease the mobility of the oil. However, the presence of drag reducing agent in the pipeline could help maintain the fluidity of the oil.

During construction, the underground segments of the pipeline were buried in a trench that is about 8 ft wide and of variable depth. The depth of the trench was sufficient to bury the pipeline on top of a gravel pad and to accommodate at least 4 ft of overburden. The thickness of the overburden above the pipeline is variable (APSC 2001i). The normal thickness is about 4 ft. However, there are some areas of deep burial (e.g., Wilbur Creek, where the overburden thickness approaches 40 ft). The thickness of the overburden ranges between 4 and 20 ft in most areas (Norton 2002d).

At MP 178, the buried pipeline and trench are shallow because of the presence of stable permafrost and shallow bedrock. Although the physical size of the trench is small, a thaw bulb with a radius of 30 ft is assumed to have formed because of the flow of warm oil through the frozen soil (Appendix A, Section A.15.2). If a guillotine break occurred in this environment, pressurized oil would be released to the thaw

TABLE 4.4-22 Belowground Segments of Pipeline in the Brooks, Alaska, and Chugach Ranges and Their Maximum Releases of Oil for a Guillotine Break

Location	Milepost Range (MP)	Belowground Segment Range (MP)	Location of Break for Maximum Oil Release (MP)	Maximum Release by Pipeline Throughput Level			Comments
				0.3×10^6 bbl/d	1.1×10^6 bbl/d	2.1×10^6 bbl/d	
Brooks Range	140–255	157–169	157	33,723	34,852	36,059	Along Atigun River, crosses Continental Divide, steep terrain
		171–175	171	26,671	29,976	32,819	Along Chandalar River, Chandalar Airstrip, steep terrain to the south
		177–178	178	41,061	44,271	46,994	Along headwaters of Dietrich River
		178–190	182	NA	NA	33,269	Along Dietrich River floodplain
			190	31,685	34,728	NA	
		191–196	196	32,533	35,489	31,304	Dietrich River floodplain
		205–206	205	37,028	39,858	36,296	Middle Fork Koyukuk River buried crossing
		211–212	211	30,080	32,826	29,469	Middle Fork Koyukuk River buried crossing
		215–216	216	27,120	29,797	26,647	Gold Creek buried crossing
		231–236	231	34,852	37,320	34,401	Floodplain Koyukuk River
		243–245	243	28,345	30,645	27,790	Floodplain Koyukuk River
Alaska Range	560–610	568–569	568	33,166	34,081	35,328	Unnamed buried stream crossing
		572–589	582	27,942	29,035	NA	Delta River floodplain, steep areas near MP 585 - Flood Creek and Michael Creek
			585	NA	NA	21,876	

TABLE 4.4-22 (Cont.)

Location	Milepost Range (MP)	Belowground Segment Range (MP)	Location of Break for Maximum Oil Release (MP)	Maximum Release by Pipeline Throughput Level			Comments
				0.3×10^6 bbl/d	1.1×10^6 bbl/d	2.1×10^6 bbl/d	
		590–593	593	24,139	25,385	26,328	Delta River floodplain
		599–602	599	28,300	29,575	30,329	Phelan Creek, some steep slopes
		603–610	603	18,502	19,834	20,661	Isabel Pass, Summit Lake
Chugach Range	720–800	720–721	720	13,870	14,352	12,687	Nearby steep slopes to the south
		724–725	724	12,080	12,506	10,591	Tonsina River buried river crossing
		730–735	730	32,110	20,950	19,010	Floodplain Little Tonsina River
		736–800	741	38,773	36,415	37,585	Many steep slopes

TABLE 4.4-23 Maximum Release Volumes and Locations for a Belowground Guillotine Break Caused by a Landslide

Location	Milepost Marker Range (MP)	Location of Maximum Release (MP)	Maximum Release by Pipeline Throughput Level		
			0.3×10^6 bbl/d	1.1×10^6 bbl/d	2.1×10^6 bbl/d
Brooks Range	140–237	178	41,061	44,271	46,994
Alaska Range	560–610	568	33,166	34,081	35,328
Chugach Range	720–800	741	38,773	36,415	37,585

bulb. Because the pressure in the pipeline exceeds hundreds of pounds per square inch (APSC 2001i), it is likely that the released oil would emerge from below the ground and spill onto the land surface. Such belowground spills would have less impact than a direct spill onto the surface because of oil losses to the subsurface.

If the spilled oil remained underground in the thaw bulb along the pipeline, it would initially occupy a length of about 300 ft on the basis of mass conservation (Appendix A, Section A.15.2). Once the oil was in the trench and thaw bulb, it would continue to move downhill until the elevation increased sufficiently to reduce the velocity to zero, the oil found a path to the surface, or response activities stopped the oil from flowing farther. For these conditions, impacts to groundwater resources would be small and local.

In addition to contaminating the water in thaw bulbs along the TAPS ROW, oil released from an underground guillotine break could melt some of the surrounding permafrost. This melting would occur because the crude oil in the pipeline is warmer than the ice. For a spill volume of 46,994 bbl of oil at an initial temperature of 110°F, about 65,000 ft^3 of ice could be melted (Appendix A, Section A.15.2). If the initial radius of the thaw bulb was 30 ft, the impact of melting the surrounding permafrost would be to increase its radius by 1 ft over its calculated length of 300 ft. This impact would be negligible.

For the Chugach Range, the maximum release of oil from a belowground guillotine break would occur at MP 741. The maximum volume (38,773 bbl) would be released for a pipeline throughput of 0.3 million bbl/d (Table 4.4-23). At this location, the buried pipeline is in a region with either sporadic or no permafrost; this evaluation assumes that no permafrost is present. This assumption is also appropriate for areas of the Alaska Range in which permafrost is absent and the groundwater is shallow.

As before, the buried trench is assumed to have a width of 8 ft. However, the depth of the trench is assumed to be 12 ft, consistent with burial in a region with a thicker surficial soil. The flow of oil after the release is assumed to be primarily through the more permeable gravel pack of the trench, although vertical infiltration through underlying soil could also occur. The effective flow area of the fill material with a porosity of 0.3 is calculated to be about 15 ft^2 (Appendix A, Section A.15.2). For a spill volume of 38,773 bbl, the oil could fill the gravel pack for a distance of about 2.5 mi if there were no vertical infiltration (Appendix A, Section A.15.2) or pathway to the surface. The actual length of trench containing oil would depend on the depth of the pipeline, impediments to flow (e.g., interaction with valve structures, contact with surface water, etc.), properties of the fill material, properties of the crude oil and drag reducing agent, and properties of the surrounding soils and rock. If the material below the pipeline was alluvial fan deposits and glacial till, the oil could readily move down toward the water table. Because of the presence of numerous streams in this area, the water table could be shallow, and the oil could contaminate this groundwater resource. Impacts to the quality of the groundwater system could be potentially very large.

4.4.4.5 Physical Marine Environment

As discussed in Section 4.4.1, 12 scenarios for spills at the Valdez Marine Terminal were developed for analysis in this DEIS. The spill scenarios were developed on the basis of statistical data on potential spill-event-initiating activities; data or guidance from the DOT, DOE, and FAA; and assumptions about the continued operation and maintenance of the TAPS from 2004 through 2034. Section 4.4.1.1 and Table 4.4-2 describe each spill scenario, the types of chemicals spilled, the total amount released, the amount of the spill that would stay on the land, and the amount that would reach the physical marine environment. Nine of the 12 spills that could occur at the Valdez Marine Terminal could reach the waters of Port Valdez; these are represented by Scenarios 1, 2, 3, 4, 5, 6, 8, 9, and 11. In two scenarios, contaminants would be released directly into water. In seven scenarios, the initial release of crude would be on land and then the oil would flow overland to the waters of Port Valdez. Five of these would involve release of crude oil, and two would involve a release of diesel fuel.

The spills that would reach Port Valdez waters can be divided into four groups according to the volume of contaminant that reaches the marine environment. The first group of spills would have volumes of less than 1 bbl. These are represented by Scenarios 1, 2, and 4, with volumes of 0.5, 0.02, and 0.7 bbl, respectively. Scenarios 2 and 4 involve diesel fuel, and Scenario 1 involves crude oil. The second group of crude oil spills would have volumes ranging from 80 to 500 bbl. These are represented by Scenarios 5, 6, and 8, with spill volumes of 500, 80, and 100 bbl, respectively. The third group is represented by Scenarios 3 and 9, in which the crude oil spill volumes reaching the physical marine environment would be 1,900 and 1,700 bbl, respectively. The fourth group is represented by Scenario 11, with a crude oil spill volume of 143,450 bbl reaching the water.

The spill scenarios can also be grouped by expected frequency into the four categories shown in Table 4.4-2. The first category is the *anticipated* spill scenarios, with occurrence frequencies of 0.5/yr or more. Scenarios 1 and 2 are in this group, with volumes of 0.5 and 0.02 bbl, respectively. The second category is the *likely* spill scenarios, which occur from 0.03 up to 0.5/yr. Scenarios 5, 3, and 4 are in this group, with volumes of 500, 1,700, and 0.7 bbl, respectively. The third category is the *unlikely* spill scenarios, which occur from 10^{-3} (0.001) up to 0.03/yr. Only Scenario 6, with an expected release of 80 bbl, falls into this category. The fourth and last category is *very unlikely* spill scenarios, which occur from 10^{-6} (0.000001) up to 10^{-3}/yr. Scenarios 8, 9, and 11 have expected occurrence frequencies in this range, with volumes of 100, 1,900, and 143,450 bbl, respectively.

4.4.4.5.1 Spill Locations. In the majority of the spill scenarios for the Valdez Marine Terminal, the initial release would be on land, and the spilled North Slope crude oil would flow over land until it reached the waters of Port Valdez. (Two diesel fuel spills and two crude oil spills would release contaminants directly into the water.) The volume of the initial releases would be significantly larger than the volume of the spill that would reach the water. All these overland spills would occur in, or near, the storage tank area or in the western portion of the Valdez Marine Terminal. The topography of this area is such that all these spills would flow into Unnamed Valdez Marine Terminal Creek and down to the waters of Port Valdez. Unnamed Valdez Marine Terminal Creek discharges into Port Valdez near Berth 4 and the small boat harbor, and it is the drainage for nearly all of the Valdez Marine Terminal area. The discharge location for Unnamed Valdez Marine Terminal Creek is shown on Map 3.9-1. It is assumed that the discharge point for Unnamed Valdez Marine Terminal Creek is the release point for all of the spills that begin with a land release that are evaluated in this section.

Nine Scenarios of Oil Spills that Could Reach Port Valdez

In two scenarios, contaminants would be released directly into water.

In seven scenarios, the initial release of crude would be on land, then the oil would flow over land to the waters of Port Valdez; five would involve the release of crude oil, and two would involve the release of diesel fuel.

The release point for all spills would be near Berth 4 and the mouth of the unnamed Valdez Marine Terminal creek.

The four scenarios that represent the release of contaminants directly into the water — crude oil spill Scenarios 5 and 6 and diesel fuel spill Scenarios 2 and 4 — would occur during the loading of a tanker vessel. All these scenarios would have release points within the boomed area that is created around berthed tankers during loading and ballast water unloading procedures. These release points would most likely be at Berths 4 or 5. However, Berths 1 and 3 could potentially be used to load tankers and could also be a discharge point for a spill. The use of Berth 1 would be unlikely. Berths 3, 4, and 5 are relatively near the discharge point of Unnamed Valdez Marine Terminal Creek. It is assumed that all the Valdez Marine Terminal spill scenarios that could potentially affect physical marine resources would have release points in essentially the same area, which is the discharge point of Unnamed Valdez Marine Terminal Creek, shown on Map 3.9-1.

4.4.4.5.2 Spill Model. The movement and spread of oil in the waters of Port Valdez were evaluated by using the General NOAA Oil Modeling Environment (GNOME) model developed by the Hazardous Materials Response Division of the NOAA, Office of Response and Restoration (NOAA 2000). GNOME is publicly available. It is an oil spill trajectory model that simulates oil movement in marine environments due to winds, currents, tides, and spreading. GNOME predicts how winds, currents, and other processes might move oil spilled on the water and spread it. It uses site-specific data, such as data on local currents and bathometry, in addition to other local data. In addition to providing best estimates of oil movement on the basis of these local parameters, GNOME also predicts how oil trajectories might be affected by inexactness ("uncertainty") in observations and forecasts of winds and currents. GNOME also models the physical and chemical changes to oil (weathering) that can occur while the oil remains on the ocean surface (NOAA 2000).

The GNOME model uses a method to incorporate uncertainty called the "minimum regret" approach (Galt et al. 1996). This source notes that trajectory models cannot be considered deterministic because of the uncertainties associated with the various data they require, the sensitivity of model parameters, and various model assumptions. It states, "The minimum-regret strategy can identify less likely, but extremely dangerous or expensive, scenarios that may require the development of alternate protection strategies" (Galt et al. 1996). A minimum-regret strategy tries to minimize the consequences of various response actions by identifying sensitive areas that might be less likely to be impacted by a spill and by ensuring that these areas are also protected, even though best estimates of spill trajectories might indicate that these areas would not be impacted.

To implement the minimum-regret approach, a modeling method called "trajectory analysis" (rather than trajectory modeling) is used (NOAA 1996). Trajectory analysis essentially requires evaluating uncertainty in various parameters, especially wind and weather, and treating the model as a trajectory model that generates estimates of potential oil spill movement rather than as a deterministic model that generates a best estimate of actual oil spill movement.

4.4.4.5.3 Properties of North Slope Crude Oil. Oils are generally classified into five groups for purposes of spill contingency planning (Michel et al. 1994). North Slope crude is classified as a Group III oil, which is termed "medium oils and intermediate products." Some examples of Group III oils are North Slope crude, South Louisiana crude, intermediate fuel oils,

North Slope Crude Oil

North Slope crude oil is a Group III oil. It tends to emulsify quickly, and 15-20% evaporates within 24 hours of a spill. The rest forms a stable mousse containing up to 75% water. Its viscosity increases, and sticky streaks, patches, and balls result, making cleanup difficult. Recovery from the water and shoreline is most effective early in a spill response.

and lube oils. Group III oils have the following properties (Michel et al. 1994):

- They are moderately volatile (flash point higher than 125°F/52°C).
- Up to one-third of the oil will evaporate.
- They have moderate to high viscosity.
- Their specific gravity is 0.85 to 0.95; their API gravity is 17.5 to 35.
- Their acute toxicity is variable, depending on the amount of light fraction.
- They can form stable emulsions.
- They will coat and penetrate the substrate; heavy subsurface contamination is likely.
- Stranded oil tends to smother organisms.
- Recovery from the water and shoreline cleanup are most effective early in the response.

Crude oil is a mixture of various hydrocarbons that can vary greatly in chemical composition (NOAA 2001b). The variations depend on the crude's geographical origin and any chemicals, such as surfactants, that might be mixed with the oil to aid production or transport. These additives can also affect the way a crude oil behaves when it is spilled (NOAA 2001b).

In addition to the general features that describe Group III oils presented above, NOAA (2001b) provides a list of important features for a marine spill that are specific to North Slope crude blends. These descriptions of features are adapted from NOAA (2001b):

- North Slope crude blends tend to emulsify quickly, forming a stable emulsion (or mousse). The rate of emulsification is known to be accelerated by wind mixing and is thought to be related to the blend's wax content. North Slope crude is thought to form a mousse after about 14% of the lighter components evaporate.
- From 15 to 20% of North Slope crude evaporates in the first 24 hours of a spill, depending on the wind and sea conditions. Very little oil is dispersed into the water column during this time. After 24 hours, the weathered oil then starts to form a stable mousse with up to 75% water content. This process can increase the oil-slick volume up to four times. During this change, the physical characteristics of the North Slope crude change dramatically.
- The viscosity of the oil-in-water mixture increases rapidly, and the color usually turns from dark brown and black to lighter browns and rust. As the water content of the emulsion increases, weathering processes (e.g., dissolution and evaporation) slow down.
- The "sticky" mousse behaves differently from a fluid and may react to additional weathering forces by forming a surface skin, creating a nonhomogenous material with a crust of slightly more weathered mousse surrounding a less weathered core.
- As the mousse is subjected to increased mixing from energetic wave action, the crusts can be torn or ruptured, and the less weathered mousse can be released. The continued exposure of weathered mousse to wave action continues to stretch and tear patches of mousse into smaller bits, resulting in a field of streaks, streamers, small patches, and, eventually, small tarballs.
- The oil-in-water emulsion is very sticky and makes cleanup and removal more difficult. When the emulsion is stranded on the shoreline, the degree of adhesion varies,

depending on the substrate type. For example, this mousse will not penetrate far in finer sediments.

4.4.4.5.4 Spill Impacts. The impact analyses in this section are based on the assumption that a spill response would be successful — sufficient equipment would be available and it would be deployed and operated correctly. The analyses further assume that weather conditions at the time of the spill would not significantly change the effectiveness of the spill response action. If these conditions were not met, the potential impacts from an oil spill could be larger, and the impacted areas larger, than those presented in the following analyses for the various accident scenarios. For the larger-volume spill events analyzed, unfavorable weather conditions could cause any spill response action to be ineffective, thus resulting in significant impacts over very large areas.

Anticipated Spills. The *anticipated* spill category includes Scenario 1, a 0.5-bbl leak of crude oil directly into the waters of Port Valdez, and Scenario 2, a 0.02-bbl leak of diesel fuel directly into the waters of Port Valdez. These spills would occur close to the shoreline, and it is assumed that they would have a short duration (Table 4.4-2). Impacts to the water column would be minimal because the volume of oil or diesel fuel released to the harbor would be small. Impacts near the shore could be significant, but they would be relatively short-lived. The nearshore environment could be impacted for several tens to hundreds of feet, but all significant impacts would be relatively close to the release point. Because of the small volume of these spills, cleanup and mitigation measures would be able to minimize the magnitude and spatial extent of the impacts. These spills would occur during operations at the Valdez Marine Terminal. Frequent observation of areas near the shore that might be impacted by these types of spills could result in shorter response and containment times, minimizing any impacts from the spills.

Impact of Anticipated Spills on the Physical Marine Environment

These spills would occur during operation and probably be noticed quickly, resulting in a short response time. Impacts would be confined to the nearshore environment near the loading berths.

Likely Spills. The *likely* spill category includes Scenario 5, a crack in a tanker vessel during loading; Scenario 3, a moderate leak of crude during Valdez Marine Terminal operations; and Scenario 4, a moderate leak of diesel fuel during Valdez Marine Terminal operations. Spill volumes reaching the waters of Port Valdez would be 500, 1,700, and 0.7 bbl, respectively.

Impact of Likely Spills on the Physical Marine Environment

Scenario 5 involves a release during tanker loading that would be contained by booms placed around the ship to present significant quantities of oil from reaching the shore.

Potential impacts from Scenario 4, the 0.7-bbl leak of diesel fuel, would be similar to the impacts from the *anticipated* spill category discussed above.

Scenario 5 would involve the introduction of significant volumes of North Slope crude oil (500 bbl) into the waters of Port Valdez. The leak would occur during tanker loading, and the crude oil released to the port waters would be contained by the booms that are placed around tankers before loading begins. This containment would minimize the area impacted by the spill and prevent significant quantities of oil from reaching the shore. As noted above, in the first 24 hours, North Slope crude does not significantly dissolve in the water column, and any oil that does dissolve is diluted quickly. Impacts from Scenario 5 would be short lived, on the order of a few days to a few weeks. Mitigation would involve following required operating procedures, such as boom deployment, during tanker loading and quickly responding to any spills.

Scenario 3 would involve the release of 1,700 bbl of crude oil into Port Valdez. Since this spill would result from Valdez Marine Terminal operations, it is assumed that it would be released to Port Valdez waters at the mouth of Unnamed Valdez Marine Terminal Creek. This release scenario is almost the same as Scenario 9 in the *very unlikely* category. Impacts from these spills were estimated by the GNOME model (NOAA 2000) and are discussed in detail in the *very unlikely spill* section below.

Unlikely Spills. The *unlikely* spill category only contains one spill, Scenario 6, which would involve a failure of the loading system between the dock and the ship, resulting in the release of 80 bbl of North Slope crude into the waters of Port Valdez. This spill would occur during loading operations, after the tanker had been enclosed with a protective boom. The 80-bbl spill volume would be contained by these booms. As noted above, North Slope crude does not significantly dissolve in 24 hours. However, there would be some dissolution of the lighter crude fractions, which would be quickly diluted by tides and currents in the harbor. Impacts to the area within the boom would be short-lived. Mitigation would involve following required operating procedures, such as boom deployment, during tanker loading and quickly responding to and cleaning up any spills.

Impact of Unlikely Spills on the Physical Marine Environment

An unlikely spill would occur within the booms placed around tankers during loading, which would minimize the area impacted.

Very Unlikely Spills. The *very unlikely* spill category includes three scenarios: Scenario 8, a pipeline failure between the east tank farm and the west manifold, resulting in 100 bbl of North Slope crude reaching the waters of Port Valdez; Scenario 9, a pipeline failure between West Metering and Berth 5, resulting in 1,900 bbl of North Slope crude reaching the waters of Port Valdez; and Scenario 11, the catastrophic rupture of a crude oil storage tank, resulting in 143,450 bbl of North Slope crude reaching the waters of Port Valdez. In addition, since Scenario 3 is very similar to Scenario 9, it is evaluated in this section. These scenarios would all have release points into Port Valdez at the mount of Unnamed Valdez Marine Terminal Creek near Berth 4 and the small boat harbor.

Impact of Very Unlikely Spills on the Physical Marine Environment

For very unlikely spills, it is assumed that large volumes of crude oil would be released to the waters of Port Valdez and would not be contained for 2 hours. During that time, the plumes could expand and impact up to 2 mi of shoreline. Impacts would be mostly restricted to that area.

The GNOME computer program was used to estimate the spread of oil from the mouth of Unnamed Valdez Marine Terminal Creek after a release. The GNOME program uses input data from location files for specific local conditions. These estimates used data in the Prince William Sound location file compiled by NOAA (2002). These data include the effects of five current patterns to simulate the circulation and tides in Prince William Sound and Port Valdez. NOAA (2002) states:

> "The tides at Hinchinbrook Strait, Port Wells, Montague Strait, and Valdez Arm are each simulated with separate current patterns. The tidal circulation of Latouche Passage, Elrington Passage and Prince of Wales Passage are all simulated with two current patterns: (1) a modified portion of the Montague Strait current pattern and (2) a background current pattern. The background current pattern models the net surface currents through each of these passages: Latouche Passage (-0.3 knots); Elrington Passage (0.3 knots); and Prince of Wales Passage (-0.9 knots). The tidal current pattern for Montague Strait was extended to each of these passages with relative amplitudes that approximate the residual tides. Since the phase differences between these areas were on the order of an hour, this approximation was considered acceptable."

The *very unlikely spill* scenarios assume that the North Slope crude oil would be released at the mouth of Unnamed Valdez Marine Terminal Creek and that it would spread for 2 hours before response and containment occurred. The actual response time could be very different because unforeseen circumstances could occur. For example, because all these hypothetical spills would initially occur on land and flow to Port

Valdez, marine response actions could begin before the North Slope crude reached the port waters, resulting in significantly shorter response times than those assumed in the scenario. It is also assumed that these spills would occur under nonextreme weather conditions. However, there is a possibility that these spills could occur under extreme weather conditions, and the winds and currents could be different from those used in the model. These differences could result in a larger area being impacted by oil spills. If response times were longer than those assumed for this analysis, the area affected by a spill could be larger.

Prevailing winds in Port Valdez are generally from the northeast at speeds up to 15 knots. The other prevalent wind direction in Port Valdez is from the southwest at about 12 knots (TAPS Owners 2001a). Both of these prevailing wind speeds were used in the model runs to estimate the impacts of the various spill scenarios. The results of these model runs are summarized in Table 4.4-24. As the table shows, the majority of the model runs used a wind from the southwest at a speed of 12 knots. While this wind direction is not as prevalent as that from the northeast, it would move the oil slick away from the shore, into Port Valdez. This difference can be seen in the estimates for Scenario 11a and 11b. The only difference between these scenarios is the wind direction and speed. Winds from the northeast result in more of the North Slope crude oil being beached, while winds from the southwest result in more oil floating in the water 2 hours after the release. For Scenarios 11a and 11b, the amount of North Slope crude that is still floating 2 hours after the release changes from 16% of the spill to 52% of the spill, respectively. In addition to the effects of wind variability, the differences in currents at different times of the day were also evaluated. The model runs were all based on a release date of February 20, 2003 (this was arbitrarily chosen). Most runs used a release time of 1:00 a.m., when it was assumed the longer 2-hour response time was more likely. Scenarios 11b and 11c evaluated the impacts of different release times on the behavior of the spill. Scenario 11b had a release time of 1:00 a.m., while Scenario 11c had a release time of 1:00 p.m. Although there were some differences in the results for the different release times, those differences were not significant relative to the inherent model uncertainties.

TABLE 4.4-24 GNOME Model Results for Spills to Port Valdez from the Valdez Marine Terminal[a]

Parameter	Spill Scenario 8	9	11a[b]	11b	11c
Volume of spill (bbl)	100	1,900	143,450	143,450	143,450
Release time	1:00 a.m.	1:00 a.m.	1:00 a.m.	1:00 a.m.	1:00 p.m.
Wind direction[c]/speed	SW/12 knots	SW/12 knots	NE/15 knots	SW/12 knots	SW/12 knots
Volume of oil floating (bbl)	16 (15.6%)	987 (51.5%)	23,526 (16.4%)	73,877 (51.5%)	75,455 (52.5%)
Volume of oil beached (bbl)	81 (81.2%)	861 (45.3%)	115,334 (80.4%)	64,983 (45.3%)	63,405 (44.2%)
Volume of oil evaporated/ dispersed (bbl)	3 (3.2%)	61 (3.2%)	4,590 (3.2%)	4,590 (3.2%)	4,590 (3.2%)

a Release date for all scenarios was arbitrarily selected as February 20, 2003, for these modeling purposes.

b Scenario 11 was evaluated for variations in wind and tide conditions and, therefore, is presented as Scenarios 11a, 11b, and 11c.

c SW = southwest, NE = northeast.

For all the release scenarios modeled, the oil slick moved out from the shore and expanded radially. The general direction of the movement is dependent on the wind direction. For wind directions from the southwest, the oil slick moved generally to the northeast, but more north than east because of the influence of the point of land where Berth 3 is located. When winds were modeled as coming from the northeast, the oil moved along the shoreline to the west of the Valdez Marine Terminal.

All the modeled releases for Scenarios 3, 9, and 11 predicted that the shoreline would be oiled from Berth 3 to Berth 5. The scenarios with winds from the northeast predicted that the shoreline would be oiled as far west as the mouth of Sawmill Creek, while the scenarios with winds from the southwest did not predict the oil would reach that far. These scenarios predicted that the shore would be oiled from about Berth 1 to Berth 5, with the oil moving in a more northeasterly direction. The model predicts that the oil slick could move up to 6 mi from the release point in a northeast direction and up to 1 mi in a northwest direction.

Scenario 11 would result in the greatest amount of oil being released, and up to 2 mi of shoreline would be significantly impacted during the 2 hours before the response. It is assumed that at the 2-hour point, the spill would be contained, and further spreading would be stopped. However, for Scenario 11, it is likely that some oil would escape the initial containment, and it could impact other areas in Port Valdez. Outside the containment area, these impacts would be small and localized. Within the containment area, the impacts would be significant. It is assumed that once the oil was contained, removal actions would begin. As noted above, North Slope crude does not significantly dissolve into the water column during the first 24 hours after a spill, but dissolution does take place. Dissolved constituents resulting from the spill could have minor local impacts, but dilution effects would limit the impacts away from the spill areas. As noted in Section 3.9.3 on marine environment, the waters of Port Valdez are well mixed, with a complete flushing occurring, conservatively, every few weeks (usually quicker). During winter storms, the waters can be completely flushed within a few days.

The model predicts that the areas immediately around the release point near the mouth of Unnamed Valdez Marine Terminal Creek would be significantly impacted from the release of 143,450 bbl of oil, as postulated under Scenario 11. Approximately 2 mi of shoreline would be heavily oiled, and the waters immediately around the area would also be impacted. If this release was contained within 2 hours, the impacts would be localized. Impacts to the waters of Port Valdez would likely be relatively short-lived, on the order of a few weeks, due to flushing. Impacts to the oiled shoreline would be expected to last significantly longer. The oil on the shoreline could also continue to impact the waters of Port Valdez in the immediate area, but because of dilution and the existing hydrocarbon background concentrations, these impacts would be minimal. The potential exists for impacts in other areas of Port Valdez; these impacts would likely be small and localized. As noted in Section 3.11.3, a significant background concentration of hydrocarbons already exists in Port Valdez waters.

Scenario 8 would be confined to the immediate vicinity of the release point near the mouth of Unnamed Valdez Marine Terminal Creek. Scenarios 9 and 3 would result in the shoreline from Berth 3 to Berth 5 being oiled, causing significant impacts in this area. Impacts from these scenarios to the waters of Port Valdez would be localized and short-lived, on the order of a few weeks at most. Impacts to the shoreline could last longer, as discussed above.

Mitigation for these postulated releases could include minimizing response time and minimizing the time required to contain a release. For all these land-based releases, if a marine response was initiated when a leak was first detected on land, the response times could be significantly shortened. The majority of land-based leaks at the Valdez Marine Terminal would have the same release point to the waters of Port Valdez: the mouth of Unnamed Valdez Marine Terminal Creek. The quick deployment of containment systems at this location could reduce the probability that a land-based spill would have a large impact on the physical marine environment.

4.4.4.6 Air Quality

This section describes the estimated potential air quality impacts in the vicinity of the TAPS ROW that could result from accidental releases or spills of crude oil and petroleum products, such as diesel fuel, under the proposed action. The topics of the discussion include:

- Spill scenarios selected for air quality impact assessments;
- Estimates of emissions of HAPs and other toxic pollutants that would result from the evaporation of volatile components (e.g., benzene, toluene, and hydrogen sulfide [H_2S]) of spilled crude oil and petroleum products;
- Dispersion modeling; and
- Ambient concentrations that would result from these emissions at receptor locations of interest.

Spills of crude oil and petroleum products may or may not involve fire. This section evaluates potential air quality impacts due to spills not involving fire. Potential air quality impacts of spills involving fire are discussed in Section 4.4.3.

4.4.4.6.1 Spill Scenarios. Spill scenarios, their expected frequencies of occurrence, the materials being spilled, and estimated spill volumes, release points, and release durations are described in Section 4.4.1. Spill volumes were estimated for four categories of expected frequencies of occurrence (anticipated, likely, unlikely, and very unlikely) under three levels of pipeline crude oil throughput (0.3, 1.1, and 2.1 million bbl/d).

Assessments of potential air quality impacts due to spills were limited to their implication on public health impacts discussed in Section 4.4.4.7. Thus, the assessments of air quality impacts focused on spills near population centers: Fairbanks at MP 456 (land-based spills), Valdez Marine Terminal (land- and marine-based spills), and the Yukon River from MP 353 to 354 (river-based spills). Potential spills on roadways due to accidents involving tanker trucks carrying turbine fuel or arctic grade diesel fuel were also included in ambient air quality impact assessments. The maximum spill volumes estimated for crude oil and petroleum products at these locations for the four frequency categories are listed in Table 4.4-25.

The potential maximum volumes of spills from the TAPS pipeline at MP 456 cover the following range: 100 bbl of diesel fuel for anticipated events (small leak during pipeline operations); 10,000 bbl of crude oil for likely events (moderate leak due to corrosion-related damage, sabotage, or vandalism); 42,101 bbl of crude oil for unlikely events (spill due to guillotine break resulting from a fixed-wing aircraft crash); and 42,101 bbl of crude oil for very unlikely events (spill due to guillotine break resulting from a helicopter crash) (see Tables 4.4-1 and 4.4-5).

The river-based spill site selected for evaluation of potential air quality impacts is the Yukon River from MP 353 to 354. The potential maximum volumes of spills from the pipeline at this location cover the following range: 50 bbl of crude oil for anticipated events (small leak during pipeline operations); 10,000 bbl of crude oil for likely events (moderate leak due to corrosion-related damage, sabotage, or vandalism); 21,246 bbl of crude oil for unlikely events (spill due to guillotine break resulting from a fixed-wing aircraft crash); and 21,246 bbl of crude oil for very unlikely events (spill from guillotine break resulting from a helicopter crash) (see Tables 4.4-1 and 4.4-5).

The potential maximum volumes of spills from Valdez Marine Terminal cover the following range: 15 bbl of diesel fuel for anticipated events (small leak of diesel fuel during Valdez Marine Terminal operations); 4,900 bbl of crude oil (3,200 bbl remain on land and 1,700 bbl drain to Port Valdez) for likely events (moderate leak of crude oil during Valdez Marine Terminal operations); 450 bbl of diesel fuel for unlikely events (due to diesel fuel line rupture); and 510,000 bbl of crude oil (about 316,000 bbl remain within the secondary containment, 50,350 bbl spread outside the secondary

TABLE 4.4-25 Spill Scenarios without Fire, Frequencies, Spill Volumes, and Receiving Media at Selected Spill Locations

Spill Location	Frequency Range[a]	Spilled Material	Receiving Medium	Max. Spill Vol. (bbl)	Spill Area (acres)[b]	Release Duration	Spill Scenario
Fairbanks (MP 456)	Anticipated	Diesel fuel	Land	100	0.16	Instantaneous	Small leak during pipeline or pump station operation (Scenario 2)[c]
	Likely	Crude oil	Land	10,000	15	Prolonged (days)	Leak due to corrosion, sabotage, or vandalism (Scenarios 12, 14)[c]
	Unlikely	Crude oil	Land	42,101	65	Short (hours)	Guillotine break due to aircraft crash or landslide (Scenarios 19a, 20)[c,d]
	Very unlikely	Crude oil	Land	42,101	65	Short (hours)	Guillotine break due to impact of a helicopter (Scenario 21)[c,d]
Yukon River (MP 353–354)	Anticipated	Crude oil	River	50	Variable[e]	Instantaneous	Small leak during pipeline operations (Scenario 2)[c]
	Likely	Crude oil	River	10,000	Variable[e]	Over 2 days	Leak due to corrosion, sabotage or vandalism (Scenarios 12, 14)[c]
	Unlikely	Crude oil	River	21,246	Variable[e]	Short	Guillotine break due to aircraft crash (Scenarios 19a, 20)[c,d]
	Very unlikely	Crude oil	River	21,246	Variable[e]	Short	Guillotine break due to impact of a helicopter (Scenario 21)[c,d]
Valdez Marine Terminal	Anticipated	Diesel fuel	Land	15	0.02	Short	Small leak during Valdez Marine Terminal operations (Scenario 2)[f]
			Marine	0.02	1×10^{-5}		
	Likely	Crude oil	Land	3,200	5	Short	Moderate leak during Valdez Marine Terminal operations (Scenario 3)[f]
			Marine	1,700	1		
	Unlikely	Diesel fuel	Land	450	0.7	Short	Fuel line rupture (Scenario 7)[f]
			Marine	0	0		
	Very unlikely	Crude oil	Land	316,000[g]	10	Instantaneous	Catastrophic rupture of storage tank (Scenario 11)[f]
				50,350	15		
			Marine	143,340	86		

TABLE 4.4-25 (Cont.)

Spill Location	Frequency Range[a]	Spilled Material	Receiving Medium	Max. Spill Vol. (bbl)	Spill Area (acres)[b]	Release Duration	Spill Scenario
Roadway	Unlikely	Turbine fuel	Land	190	0.3	Instantaneous	Overturn of fuel truck (Scenarios 3 and 4)[h]
	Very unlikely	Turbine/ diesel fuel	Land	190	0.3	Instantaneous	Overturn of fuel truck (Scenarios 1, 2, 5, 6, 7)[h]

a Anticipated (> 0.5/yr); likely (0.03–0.5/yr); unlikely (10^{-3}–0.03/yr); very unlikely (10^{-6}–10^{-3}/yr).

b Based on 1-in.-thick spills on land. Thickness of the plug flow of oil spilled into rivers is estimated on the basis of channel width, current speed, and the rate of oil release for the Valdez Marine Terminal. Thicknesses of oil in the containment area and in a marine environment are assumed to be 2.6 and 49.9 in., respectively.

c See Table 4.4-1.

d See Table 4.4-5.

e Spill area changes as a function of the rate of the spill release, the channel width, and the time elapsed since the start of the spill.

f See Table 4.4-2.

g Of the total volume (510,000 bbl) of a storage tank, about 316,000 bbl remain in the secondary containment, about 190,000 bbl escape secondary containment, and about 143,000 bbl reach Port Valdez.

h See Table 4.4-3.

containment, and 143,450 bbl flow into Port Valdez) for very unlikely events (spill from the catastrophic failure of a storage tank, such as a foundation or weld failure) (see Table 4.4-2).

The potential maximum roadway accident-related spills are estimated to be 190 bbl of turbine or diesel fuel for likely to very unlikely events (overturn of a tanker truck carrying the fuel at various roadway locations) (see Table 4.4-3).

4.4.4.6.2 Estimation of Emissions. Emissions of 11 HAPs and other toxic air pollutants from evaporation of crude spilled oil and petroleum products were estimated: benzene, cyclohexane, ethyl benzene, n-heptane, hexane, naphthalene, n-octane, styrene, toluene, xylene, and hydrogen sulfide. The vapor pressures and weight percent (wt%) of these HAPs and other toxic air pollutants in North Slope crude oil, turbine fuel, and arctic grade diesel fuel are listed in Table 4.4-26.

TABLE 4.4-26 Vapor Pressures and Weight Percents of Hazardous and Other Toxic Air Pollutants in North Slope Crude Oil, Turbine Fuel, and Arctic Grade Diesel Fuel

Species	Vapor Pressure (mm Hg)[a]	Weight % North Slope Crude Oil[b]	Weight % Turbine Fuel[c]	Weight % Arctic Grade Diesel Fuel[c]
Benzene	61.7	0.36	0.05	0.24
Cyclohexane[d]	69.5	0.94	–[e]	–
Ethyl benzene	5.2	0.06[e]	–	0.09
n-Heptane	31	1.64	–	–
n-Hexane	103.4	0.94	–	–
Naphthalene	0.05	0.10[f]	–	0.34
n-Octane[d]	10.3	1.90	–	–
Styrene	3.6	0.50[g]	–	–
Toluene	18.1	0.81	0.30	0.50
Xylene	5.2	0.50[g]	–	0.53
Hydrogen sulfide[d]	11,893	0.006[h]	–	–

a At 60°F. Source: Yaws (1994).

b Roehner (2001).

c MAPCO (2002).

d These toxic air pollutants are not included in the list of hazardous air pollutants defined by Section 112(b) of the Clean Air Act.

e A dash indicates that no data exist. When data for turbine fuel and arctic grade diesel oil were not available, data for North Slope crude oil were used in spill emission estimations.

f Riley et al. (1980).

g National Research Council (1985).

h OGJD (2000).

The emission rate of a HAP or other toxic air pollutant from a spill area is a function of the temperature and surface area of the spill, molecular weight and partial pressure of individual HAP or other tox air pollutant species, wind speed, and the time elapsed since the spill (IT Alaska 2001). The surface area and thickness of a pool formed by a land-based spill would depend on many factors, such as the degree and variability of slope, surface roughness, and porosity of the receiving land. After the initial formation of the pool, the surface layer of the pool would be subjected to weathering that would alter the composition of spilled oil. To estimate ambient air quality impacts, three thicknesses (1, 2, and 3 in.) were assumed, and associated surface areas were calculated. Emission rates of HAPs and other toxic air pollutants from land-based spills were computed according to the procedures described in IT Alaska (2001) for wind speeds of 1.5 and 3 m/s.

Estimating the behavior and fate of crude oil and petroleum products spilled into running waters is quite complicated (see Section 4.4.4.3). Many factors can affect the size and speed of an oil slick produced from a spill, including the width of the river channel, speed of the surface current, and speed and direction of the surface wind. While flowing downstream, the oil slick can be affected by processes such as advection, mechanical spreading, emulsification, evaporation, dissolution, shoreline deposition, photochemical reactions, and biodegradation. To obtain rough estimates of potential air quality impacts, the oil slick was assumed to form instantaneously and travel at the speed of surface current as a plug flow (rectangular-shaped) defined by the channel width of the stream. The surface current speed of the Yukon River at the spill location was assumed to be 8 ft/s, and the channel width was assumed to be 2,750 ft. The size and the center position of the rectangular-shaped oil slick were determined on an hourly basis from the time of the spill, and the corresponding hourly emission rate of each HAP or other toxic air pollutant was computed for wind speeds of 1.5 and 3 m/s. Emission rates for selected spills during the first hour after the spill when the wind speed is 3 m/s are listed in Table 4.4-27.

4.4.4.6.3 Dispersion Modeling.

Ambient concentrations of HAPs and other toxic air pollutants caused by evaporative emissions from spills were estimated at the locations of interest (e.g., residential areas) in the vicinity of spill sites by using the Industrial Source Complex (ISC-3) model or ALOHA model as appropriate. The ISC-3 model is recommended by the EPA for estimating ambient impacts of stationary point and area sources with hourly meteorological data input. It was used for estimating ambient impacts due to spills at Fairbanks (MP 456), Yukon River (MP 353–354) and the Valdez Marine Terminal. Typical meteorological conditions[7] (neutral stability [D class] and 3-m/s wind speed) and worst-case meteorological conditions (stable stability [F class] and 1-m/s wind speed) were used as the input to the ISC-3 model. The ALOHA model is a screening model also recommended by the EPA for estimating short-term ambient impacts from accidental releases. This model was used for estimating ambient impacts from transportation-related accidents. Meteorological conditions conducive to maximum ambient concentrations (i.e., a stable [Category F] atmospheric condition and 1.5-m/s wind speed were assumed).

Emissions of highly volatile VOCs from a crude oil spill are generally negligible about 24 hours after the spill, although emissions of less volatile VOCs would persist for a longer period of time at very low rates. Therefore, air quality impacts due to emissions from spills were estimated in terms of short-term concentration (1-hour average concentration). The 1-hour average ambient concentrations of HAPs caused by these emissions were estimated at the downwind boundary of the spill area for the spills (in the direction parallel to the largest dimension of the spill area) at Fairbanks, Yukon River, and Valdez Marine Terminal.

7 The most important meteorological parameters that affect ground-level concentrations of air pollutants include atmospheric stability, which determines how quickly pollutants are dispersed in the atmosphere, and wind speed, which determines how quickly pollutants are transported away from a given location. The atmospheric stability classes from the highest to lowest degree of dispersion are very unstable (Class A), unstable (Class B), slightly unstable (Class C), neutral (Class D), slightly stable (Class E), stable (Class F), and very stable (Class G).

4.4.4.6.4 Ambient Concentrations. The estimated maximum 1-hour average concentrations of various HAPs and other toxic air pollutants in the vicinity of spills that would result from the selected maximum spills with anticipated, likely, unlikely, and/or very unlikely frequencies of occurrence at Fairbanks MP 456), Yukon River (MP 353–354), and Valdez Marine Terminal and on the roadway are listed in Tables 4.4-29 through 4.4-32. Potential impacts of these concentration levels with respect to public health are assessed in Section 4.4.4.7.2.

4.4.4.7 Human Health and Safety

The assessment of potential human health and safety impacts from spills under the proposed action considers pipeline, Valdez Marine Terminal, and transportation spills, as outlined in Section 4.4.1. The assessment addresses four exposure categories: (1) potential for impacts from exposures to soils and groundwater contaminated due to spills to land; (2) impacts from inhalation exposures resulting from pipeline spills to land or rivers, Valdez Marine Terminal spills, transportation spills, or hazardous material spills; (3) impacts from inhalation exposures resulting from fires; and (4) impacts from foodchain exposures subsequent to spills to water.

Impacts of Oil Spills on Human Health and Safety

Health and safety impacts were assessed for spills along the pipeline (both onto land and into rivers), at the Valdez Marine Terminal, along transportation routes, and for large spill-associated fires. A key endpoint evaluated for short-term impacts was the "impact distance," defined as the distance from the spill boundary out to which there is the potential for serious adverse health impacts from inhalation of contaminants emitted from spills or fires. For spills and fires in the unlikely/very unlikely category, the maximum impact distances estimated ranged from 4 to 13 km. People who remain within the impact area could experience serious health effects from spills.

For spills to rivers or Port Valdez, there is a concern about exposures from eating contaminated fish, shellfish, or marine mammals. Spills can cause tainting of large numbers of these species, making them noticeably unfit for human consumption (e.g., the fish would have visible oil on the surface or smell of oil). However, in cases where the food is not noticeably contaminated, this assessment showed that adverse health effects would not be expected from eating fish, shellfish, or marine mammals from a spill area.

In general, the spill scenarios considered were the pipeline and Valdez Marine Terminal scenarios in each of four frequency categories (i.e., *anticipated*, *likely*, *unlikely*, and *very unlikely*) that would result in the highest impacts. Spills of crude oil, diesel, or turbine fuel are included in this assessment, as well as spills of other hazardous materials stored or transported. In general, the volumes of spills of refined oil products considered were smaller than those of crude oil spills. The highest impacts of the spills generally would be associated with the spill in each frequency category with the highest volume. Hypothetical spill locations were selected to be close to actual human populations. For example, the inhalation impacts from pipeline spills were assessed for the pipeline location nearest to a residential area of Fairbanks (MP 456).

The assessment of human health and safety impacts from spills is limited to impacts to the general public and does not include occupational exposures for cleanup workers or TAPS employees at the pump stations or Valdez Marine Terminal. Protection of these workers is regulated under the Occupational Health and Safety Act and is beyond the scope of this assessment. However, it is important to emphasize that minimizing the exposures of spill cleanup workers is a very important consideration. For example, allegations have been made of serious, chronic health effects to workers who participated in the cleanup of the Exxon Valdez oil spill in 1989 (Murphy 2001). Former workers allege that during the massive cleanup operation, appropriate protective equipment was not always available and procedures to protect worker health were not always followed. Some former workers claim that the oil and solvent exposures have resulted

TABLE 4.4-27 Estimated Emission Rates of Hazardous and Other Toxic Air Pollutants from Evaporation of Spilled Materials without Associated Fire

	Maximum Emission Rate (lb/h)[a] per Type and Location of Spill and Expected Frequency Range of Spill (A, L, UL, and U/VU)[b]											
	Pipeline Spills at Fairbanks (Land)			Pipeline Spills on Yukon River (MP 353–354) (river)			Valdez Marine Terminal Spills (land/marine)				Roadway Spills (land)	
Chemical	A[c]	L[d]	U/Vu[e]	A[f]	L[g]	U/Vu[h]	A[i]	L[j]	UL[k]	VU[l]	U/VU - Turbine[m]	U/VU - Diesel[m]
Benzene	56.8	8,522	35,880	55.9	1,119	23,769	8.5	3,292	256	61,260	22.5	108
Cyclohexane[n]	245	24,450	102,938	146	2,921	62,063	36.7	9,443	1,100	175,753	465	465
Ethylbenzene	1.6	108	455	9.3	186	3,961	0.2	41.7	7.3	777	2.1	3.1
n-Heptane	180	17,952	75,579	255	5,096	108,280	26.9	6,934	808	129,041	341	341
Hexane	292	29,212	122,984	146	2,921	62,063	43.8	11,738	1,315	259,421	555	555
Naphthalene	0.1	1.6	6.8	3.2	110	73.8	0.01	0.6	0.2	11.7	0.03	0.1
n-Octane[n]	66	6,615	27,850	295	5,904	125,446	9.9	2,555	298	47,551	126	126
Styrene	6.3	627	2,642	78	1,554	28,338	0.9	242	28.2	4,510	11.9	11.9
Toluene	33	5,324	22,414	126	2,517	53,480	4.9	2,056	148	38,268	37.5	62.4
Xylene	10	901	3,791	78	1,554	33,012	1.4	348	43.0	6,473	17.1	18.1
Hydrogen sulfide[n]	1.8	175	738	0.9	17.5	373	0.3	86.0	7.9	8,941	3.3	3.3

a Emission rate during the first hour after a spill at 60°F oil temperature and 3-m/s wind speed. The emission rate at 1.5 m/s would be about ≥58% of the listed values.

b A = anticipated event (>0.5/yr); L = likely event (0.03 to 0.5/yr); U = unlikely event (10^{-3} to 0.03/yr); and VU = very unlikely event (10^{-7} to 10^{-3}/yr).

c Small leak during pipeline or pump station operation; 1-in.-thick, 0.16-acre pool area.

d Leak due to sabotage, vandalism, or corrosion; assumption of 2.1-million-bbl/d throughput; 1-in.-thick, 15-acre pool area.

e Guillotine break due to a fixed-wing aircraft crash or seismic event; assumption of 2.1-million-bbl/d throughput; 1-in. thick, 65-acre pool area.

f Small leak during pipeline operation.

Footnotes continued on next page.

TABLE 4.4-27 (Cont.)

[g] Leak due to sabotage, vandalism, or corrosion; assumption of 2.1-million-bbl/d throughput.

[h] Guillotine break due to aircraft crash or impact of a helicopter; assumption of 2.1-million-bbl/d throughput.

[i] Small leak during Valdez Marine Terminal operations; 1-in.-thick, 0.02-acre pool area.

[j] Moderate leak of crude oil during Valdez Marine Terminal operations; total spill is 4,900 bbl, 3,200 bbl on ground (1-in.-thick, 7.5-acre pool area), 1,700 bbl in Port Valdez (2.6-in.-thick, 1.0-acre slick area).

[k] Spill due to fuel line rupture; 1-in.-thick, 0.7-acre pool area.

[l] Catastrophic storage tank rupture at Valdez Marine Terminal due to foundation or welding failure; total spill is 510,000 bbl, of which 316,000 bbl remain in secondary containment (49.9-in.-thick, 10-acre pool area), 50,350 bbl reach land outside secondary containment (5.2-in.-thick, 15-acre pool area), and 143,450 bbl reach Port Valdez (2.6-in.-thick, 86-acre slick area).

[m] Rollover of a tanker truck carrying turbine or diesel fuel; 1-in.-thick, 0.3-acre pool area.

[n] These toxic air pollutants are not included in the list of hazardous air pollutants defined by Section 112(b) of the Clean Air Act.

in a wide range of respiratory and other illnesses. Out of 15,000 workers involved in the cleanup, 25 have filed suit for damages. Of these claims, 7 have been settled, 8 have been dismissed, and 10 are pending (Murphy 2001).

4.4.4.7.1 Impacts from Exposures to Contaminated Soils and Groundwater Resulting from Spills to Land. Spills of crude oil, diesel, gasoline, or turbine fuel to land could occur at any point along the pipeline, at the pump stations, at the Valdez Marine Terminal, or along transportation routes (see scenarios presented in Section 4.4.1). Projected spill volumes range from about 10 to 50,000 bbl; the highest volumes are projected for crude oil spills and are associated with unlikely or very unlikely scenarios.

The potential for ingestion or dermal exposure of the general public to soils and groundwater contaminated because of spills is very low, because of extensive regulation of the containment and cleanup of spill sites. Public access to spill sites is restricted, and in most cases, contamination of groundwater is prevented by timely removal of soil contamination. If groundwater contamination does occur, measures are taken to prevent public use of the water. Potential inhalation exposures to contaminants volatilizing from a spill are addressed below in Section 4.4.4.7.2. Details on State of Alaska containment and cleanup requirements after a spill occurs are provided in the following paragraphs.

The State of Alaska cleanup program seeks to identify the risks associated with each contaminated site and to prioritize sites for cleanup on the basis of the risks posed. State involvement in the cleanup may range from total control to simple oversight of the responsible parties. Liability for state costs and damages are assigned to the persons identified as responsible for the contamination (ADEC 2001a).

Alaska statutes require the ADEC to prescribe general methods and procedures for containment and cleanup of hazardous substance releases. This state guidance is contained in numerous documents[8] that detail specific aspects of the required actions for contaminated site remediation. Overall, the process involves the following elements or phases: site discovery, site characterization, cleanup decision, cleanup, and site closure.

The *site discovery phase* involves collection and confirmation of information regarding the extent and severity of contamination. It also may involve emergency actions to protect human health. If there is risk to the public, notification takes place at this stage. A preliminary risk rank is assigned to the site based on the risk to both the public and the environment. Responsible parties are identified, and the management responsibility for site remediation is established.

The *site characterization phase* involves more detailed information gathering on the site and contaminants, including field sampling and investigation. Potential risks to human health and the environment are evaluated, as are potential cleanup technologies. The responsible parties are required to submit a report that details the conclusions regarding the nature and extent of contamination, the human and environmental hazards, calculation of cleanup levels, and recommendation of cleanup technologies to be applied.

Five criteria are specified for consideration of cleanup alternatives: protectiveness of human health and the environment; practicability; short- and long-term effectiveness; compliance with state and federal regulations; and community input. Generic State of Alaska cleanup levels have been established for soil, groundwater, and surface water. The generic cleanup levels for oil-related contaminants are listed in Table 4.4-28. Site-specific cleanup reports must specify whether generic State of Alaska cleanup levels are recommended or whether alternative levels are sought on the basis of site-specific calculations or a risk assessment. The ADEC specifies four methods for developing site-specific alternate cleanup levels. These methods vary, depending on whether or not Arctic Zone soils are involved and whether the contaminants are limited to petroleum hydrocarbons or not.

8 The guidance documents are available on the Internet at http://www.state.ak.us/local/akpages/ENV.CONSERV/dspar/csites/ind_docs.htm.

TABLE 4.4-28 Alaska Cleanup Levels for Hydrocarbon-Contaminated Soil[a,b]

		Cleanup Level (mg/kg)	
Product	Parameter/ Constituent	Method 1[c]	Method 2[d]
Gasoline	GRO (C6-C10)	50–1,000	260–1,400
	(C6-C10) Aliphatic hydrocarbons		240–1,000
	(C6-C10) Aromatic hydrocarbons		130–1,000
	Benzene		0.02–390
	Toluene		4.8–27,400
	Ethyl benzene		5.0–13,700
	Xylenes		69–274,000
	Naphthalene		38–5,500
Diesel	GRO (C6-C10)	50–1,000	260–1,400
	(C6-C10) Aliphatic hydrocarbons		240–1,000
	(C6-C10) Aromatic hydrocarbons		130–1,000
	DRO C10-C25	100–2,000	230–12,500
	C10-C25 Aliphatic hydrocarbons		6,400-10,000
	C10-C25 Aromatic hydrocarbons		90–5,000
	Benzene		0.02–390
	Toluene		4.8–27,400
	Ethylbenzene		5.0–13,700
	Xylenes		69–274,000
	PAHs:		
	Naphthalene		38–5,500
	Fluorene		240–5,500
	Anthracene		3,900–41,000
	Pyrene		1,400–4,100
	Benzo(a)anthracene		5.5–15
	Acenaphthene		190–8,200
	Chrysene		550–1,500
	Benzo(a)pyrene		0.9–3
	Dibenzo(a,h)anthracene		0.9–6
	Benzo(b)fluoranthene		9–20
	Benzo(k)fluoranthene		93–200
	Indeno(1,2,3-c,d)pyrene		9–54
Waste Oil	GRO (C6-C10)	50–1,000	260–1,400
	(C6-C10) Aliphatic hydrocarbons		240–1,000
	(C6-C10) Aromatic hydrocarbons		130–1,000
	DRO C10-C25	100–2,000	230–12,500
	C10-C25 Aliphatic hydrocarbons		6,400–10,000
	C10-C25 Aromatic hydrocarbons		90–5,000
	RRO C25-C36	2,000	9,700–22,000
	C25-C36 Aliphatic hydrocarbons		20,000
	C25-C36 Aromatic hydrocarbons		2,500–10,000

TABLE 4.4-28 (Cont.)

		Cleanup Level (mg/kg)	
Product	Parameter/ Constituent	Method 1[c]	Method 2[d]
	Benzene		0.02–390
	Toluene		4.8–27,400
	Ethyl benzene		5.0–13,700
	Xylenes		69–274,000
	PAHs:		
	Naphthalene		38–5,500
	Fluorene		240–5,500
	Anthracene		3,900–41,000
	Pyrene		1,400–4,100
	Benzo(a)anthracene		5.5–15
	Acenaphthene		190–8,200
	Chrysene		550–1,500
	Benzo(a)pyrene		0.9–3
	Dibenzo(a,h)anthracene		0.9–6
	Benzo(b)fluoranthene		9–20
	Benzo(k)fluoranthene		93–200
	Indeno(1,2,3-c,d)pyrene		9–54
	Metals:[e]		
	Arsenic		1.8–8
	Barium		982–9,600
	Cadmium		4.5–140
	Chromium		23–680
	Chromium(III)		83,000–>106
	Chromium(VI)		23–680
	Lead: residential		400
	Lead: industrial		1,000
	Nickel		78–2,700
	Vanadium		580–3,400

[a] Soil cleanup levels are from the Oil and Hazardous Substances Pollution Control Regulations, 18 AAC 75, Article 3.

[b] There are also site-specific methods for determining alternate soil cleanup levels.

[c] Method 1 involves a table to determine the soil cleanup level for three different hydrocarbon ranges:

GRO: gasoline range organics
DRO: diesel range organics
RRO: residual range organics

[d] Method 2 involves soil cleanup levels that were designed to protect humans from three different potential exposure pathways: direct ingestion of soil, inhalation of volatile contaminants, and migration from soil to groundwater and the subsequent ingestion of contaminated groundwater.

[e] Metals analyses required on a site-by-site basis.

based on a detailed risk assessment that considers potential pathways of exposure to assess the likelihood of adverse human health or environmental effects. Procedures for conducting such risk assessments are specified in the Risk Assessment Procedures Manual (ADEC 2000). The manual sets out detailed requirements for identifying exposure pathways, assessing toxicity, and characterizing health risks.

On the basis of the information provided, during the *decision phase* the ADEC develops a decision document that specifies the cleanup requirements. The *cleanup phase* includes development of a detailed cleanup plan, followed by implementation of the cleanup under ADEC oversight. Completion is documented in a report. Finally, in the *site closure phase*, sites are either completely closed out of the supervision process or designated for longer-term monitoring, depending on the effectiveness of the cleanup.

Because spills onto gravel or soil surfaces must be cleaned up according to these ADEC requirements, there should be no complete exposure pathways or elevated concentrations remaining after remediation of these types of spill sites and, therefore, no long-term health impacts from exposure to contaminants in soil. In particular, the risk assessments conducted for these sites under the ADEC Site Contamination Program are intended to ensure that spills to soil will not result in potential human health risks from the exposure pathways of direct contact or leaching to groundwater. For example, APSC has used the above procedures in assessing the potential for adverse impacts to human health or the environment from construction-era releases at Happy Valley Camp and recommending risk-based corrective action (OASIS Environmental 1998).

4.4.4.7.2 Impacts from Inhalation Exposures Resulting from Spills. This section assesses the potential for adverse health impacts resulting from inhalation of contaminants volatilized from spills along the pipeline, spills at the Valdez Marine Terminal, spills during transportation accidents, and spills to rivers along the pipeline (see Section 4.4.1; Tables 4.4-1 through 4.4-5). Spill scenarios along the pipeline and at pump stations encompass maximum volumes of 100 bbl of diesel for *anticipated* events (e.g., small leak during operations), 10,000 bbl of crude oil for likely events (e.g., corrosion or sabotage), and 42,101 bbl of crude oil for *unlikely* or *very unlikely* events (e.g., a guillotine break due to aircraft crash or seismic landslide). Spill scenarios at the Valdez Marine Terminal encompass maximum volumes of 15 bbl of diesel for *anticipated* events, 3,200 bbl of crude oil to land and 1,700 bbl to Port Valdez for *likely* events, 450 bbl of diesel for *unlikely* events, and a *very unlikely* aircraft crash into a storage tank in which about 316,000 bbl is released into a containment area, 50,000 bbl is released outside of containment, and 143,000 bbl flows into Port Valdez. Transportation spill scenarios involve release of 190 bbl of turbine fuel for *unlikely* events and 190 bbl of diesel or turbine fuel for *very unlikely* events. River spill scenarios assessed involve release of 10,000 bbl of oil for *likely* events and 21,246 bbl of oil for *unlikely/very unlikely* events.

Potential inhalation was modeled for the volatile components of spilled substances for the various scenarios and volumes. A range of conditions was assessed, including typical and worst-case meteorological conditions (D atmospheric stability and 3 m/s wind speed for typical case; F stability and 1.5 m/s wind speed for worst case), and, where appropriate, a 1- to 3-in. oil pool depth. A method to estimate air emissions to aid in spill response procedures developed for APSC (IT Alaska 2001) and using the EPA's ISCST3 (EPA 1995) to model downwind ambient levels was employed in this analysis. The method allowed estimation of maximum 1-hour average contaminant concentrations downwind of spill areas. The shortest averaging time that the ISCST3 model predicts for is 1 hour.

Ten volatile crude oil, diesel, and turbine fuel components of greatest concern with respect to toxicity were identified (Goldstein et al. 1992). The assumed percent composition of these substances in the current TAPS crude oil mix was not available, so existing information was used to estimate the composition. Percent composition values used in this assessment, as well as emission estimates for modeled spills, are presented in Section 4.4.4.6.

In general, there are no federal or state standards for evaluating the impacts of isolated exposures resulting from accidental releases. However, two groups have analyzed available toxicological data for various chemicals and have derived levels of concern for short exposures of the general public to these chemicals. Emergency response planning guideline (ERPG) levels have been derived by the American Conference of Governmental Industrial Hygienists (AIHA 2002) for about 100 substances, and temporary emergency exposure limits (TEELs) have been derived by a DOE working group for about 1,700 additional substances (Westinghouse Safety Management Solutions 2002). The ERPG levels are specifically derived for comparison with exposures of 1-hour duration or less; the TEEL values are derived for comparison with exposures of 15 minutes or less. To evaluate short-term inhalation exposures to the toxic volatile components of crude oil, diesel, and turbine fuel, the use of ERPG levels was preferred in this assessment, because these levels incorporate more chemical-specific toxicity data and have received a greater degree of review.

To assess whether adverse impacts would be associated with inhalation of the volatile components of a spill, the estimated maximum concentrations at the boundary of the spill area were compared with a range of levels that could cause health effects ranging from mild transient adverse effects up to serious irreversible effects that could impair an individual's ability to take protective action (ERPG and TEEL values; see footnotes to impact tables cited below for complete definitions). The assessment also provides an impact distance for the oil spills, defined as the distance from the boundary of the spill area to the location where the ambient air concentration drops below the ERPG-2 or TEEL-2 value. It would be recommended that any members of the general population within the impact distance downwind of an oil spill be evacuated for a period of several hours up to 24 hours until the plume caused by the emitted air pollutants could dissipate. (It is estimated that VOC emissions from a crude oil spill are generally negligible about 24 hours after the initial spill [IT Alaska 2001].)

Pipeline Spills. For pipeline spills, a spill near a Fairbanks residential area at MP 456 was modeled because it was considered to represent the worst-case exposure situation along the pipeline (that is, the place where members of the general public would be closest to the spill location). At this aboveground pipeline location, residences are located about 33 m (0.02 mi) from the pipeline. For the *unlikely* or *very unlikely* guillotine break scenarios, the maximum spill volume for this location was at a throughput of 2.1×10^6 bbl/d, and was estimated to be 42,101 bbl. Although for the scenarios modeled, a specific pipeline location was assumed (i.e., MP 456 near Fairbanks), these impact estimates can be considered bounding for similar spill volumes at any location along the pipeline.

For *anticipated* spills along the pipeline, the assessment examined a spill of 100 bbl of diesel. Because this spill volume is relatively small, only a 1-in. diesel pool depth was modeled (this results in a larger pool size and higher estimated air concentrations than when assuming a 3-in. diesel pool depth). For this spill under maximum hazard weather conditions (F stability, 1.5 m/s wind speed), maximum concentrations of benzene and toluene in the first hour after the spill (330 and 190 mg/m^3,

Hazard Conditions

For the assessment of inhalation impacts from spills, typical weather conditions are represented by a meteorology of Class D atmospheric stability and 3 m/s wind speeds, and worst-case weather conditions are represented by Class F atmospheric stability and 1 m/s wind speed. Minimum hazard conditions are represented by the combination of typical weather conditions (D stability, 3 m/s wind speed) and a 3-in. oil pool depth. Maximum hazard conditions are represented by the combination of worst-case weather conditions (F stability, 1.5 m/s wind speed) and a 1-in. oil pool depth.

TABLE 4.4-29 Inhalation Impacts of Pipeline Spills: Maximum 1-Hour Pollutant Concentrations and Impact Distances

	Maximum Hazard[a]				Minimum Hazard[a]				
	Very Unlikely or Unlikely Scenario[b] (42,101 bbl)		Likely Scenario[c] (10,000 bbl)		Very Unlikely or Unlikely Scenario[b] (42,101 bbl)		Likely Scenario[c] (10,000 bbl)		
Compound	Maximum 1-Hour Concentration (mg/m^3)	Impact Distance[d] (km)	Maximum 1-Hour Concentration (mg/m^3)	Impact Distance[d] (km)	Maximum 1-Hour Concentration (mg/m^3)	Impact Distance[d] (km)	Maximum 1-Hour Concentration (mg/m^3)	Impact Distance[d] (km)	Comparison Concentration[e] (mg/m^3)
Volatile organic compounds									
Benzene	1,250	0.17	1,000	0.06	490	-[f]	400	-	150–500
Cyclohexane	3,600	-	2,900	-	1,400	-	1,200	-	3,000–4,000 (TEEL)
Ethyl benzene	16	-	13	-	6.2	-	5.1	-	500 (TEEL)
n-Heptane	2,600	0.06	2,200	0.02	1,000	-	850	-	1,500 (TEEL)
n-Hexane	5,300	1.3	4,300	0.44	2,100	0.1	1,700	0.04	500–750 (TEEL)
Naphthalene	0.2	-	0.2	-	0.1	-	0.1	-	75–150 (TEEL)
n-Octane	970	-	790	-	380	-	310	-	1,500 (TEEL)
Styrene	92	-	76	-	36	-	30	-	200–1,000
Toluene	780	-	640	-	300	-	250	-	150–1,000
Xylene	130	-	110	-	51	-	43	-	600–750 (TEEL)
Inorganic compounds									
Hydrogen sulfide	44	0.01	36	-	30	-	25	-	20[g]–40

See footnotes on next page.

TABLE 4.4-29 (Cont.)

a Maximum and minimum hazards reflect differences in assumed oil pool depth and meteorological conditions at the time of the spill. Maximum hazards occur under meteorological conditions of F stability with 1.5 m/s wind speed and an oil pool depth of 1 in., whereas minimum hazards occur under D stability with 3 m/s wind speed and an oil pool depth of 3 in.

b Guillotine break due to aircraft crash or seismic event at MP 456. For maximum hazard scenario, the length and area of the spill are 0.35 km and 65 acres; for minimum hazard scenario, length and area of the spill are 0.2 km and 22 acres. Maximum concentration locations are at the boundary of spill area.

c Leak resulting from sabotage or corrosion at MP 456. For maximum hazard scenario, length and area of the spill are 0.2 km and 15 acres; for minimum hazard scenario, length and area of the spill are 0.1 km and 5 acres. Maximum concentration locations are at boundary of spill area.

d Impact distance is the distance from the boundary of the spill area to the location where the ambient air concentration drops below the ERPG-2 or TEEL-2 value.

e The range is from Emergency Response Planning Guideline 1 (ERPG-1) to ERPG-2, where ERPG values are available (AIHA 2002). Otherwise, Temporary Emergency Exposure Limit 1 (TEEL-1) and TEEL-2 values were used. ERPG and TEEL definitions are almost identical, except ERPGs are for 1-hour exposures, while TEELs are for 15-minute exposures. Definitions: ERPG-1 (TEEL-1) = the maximum concentration in air below which it is believed nearly all individuals could be exposed for up to 1 hour (up to 15 minutes) without experiencing other than mild transient adverse health effects or perceiving a clearly defined objectionable odor. ERPG-2 (TEEL-2) = the maximum concentration in air below which it is believed nearly all individuals could be exposed for up to 1 hour (up to 15 minutes) without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action. It is recommended that for application of TEELs, concentration at the receptor point of interest be calculated as the peak 15-minute time-weighted average concentration. Therefore, the comparison with TEELs may be underprotective (see text for discussion).

f A dash indicates predicted concentrations are lower than the ERPG-2 or TEEL-2 comparison levels over the entire modeling domain.

g For hydrogen sulfide, the TEEL-1 value was used instead of the ERPG-1 value because ERPG-1 was odor-based rather than toxicity-based.

respectively) would exceed the comparison levels for mild adverse effects at the edge of the spill area, but the concentrations of both would be less than the comparison values for serious effects at the edge of the spill area (see Table 4.4-29 for comparison concentrations). The compound n-hexane would have a maximum concentration of 2,100 mg/m^3 and an impact distance of 0.02 km. Under more typical, minimum hazard weather conditions (D stability, 3 m/s wind speed), the maximum concentrations of benzene, toluene, and n-hexane would decrease to 240, 150, and 820 mg/m^3, respectively, and the impact distance for hexane would decrease to less than 0.01 km.

The impacts of *likely* spills were assessed by assuming a 10,000 bbl release. Impact estimates for that release are given in Table 4.4-29. Under maximum hazard conditions, concentrations of benzene, n-heptane, hexane, toluene, and hydrogen sulfide would exceed the comparison concentrations at the edge of the spill area in the first hour after the spill, with the maximum impact distance extending to 0.44 km (0.3 mi) downwind of the spill area. Under minimum hazard conditions, benzene, toluene, and hydrogen sulfide would exceed the comparison levels for mild adverse effects, but the concentrations would be less than the comparison values for serious effects at the edge of the spill area. The impact distance for n-hexane would be 0.04 km.

The impacts for the *unlikely* and *very unlikely* scenarios (guillotine breaks) are also summarized in Table 4.4-29. Under maximum hazard conditions, concentrations of benzene, cyclohexane, n-heptane, n-hexane, toluene, and hydrogen sulfide would exceed the comparison concentrations at the edge of the spill area in the first hour after the spill, with the maximum impact distance extending to 1.3 km (0.8 mi) downwind of the spill area. For minimum hazard conditions, benzene, toluene, and hydrogen sulfide would exceed the comparison levels for mild adverse effects, but the concentrations would be less than the comparison values for serious effects at the edge of the spill area. The impact distance for n-hexane would be 0.1 km (0.06 mi).

For substances without ERPG values available, an uncertainty associated with this assessment is the comparison of post-spill maximum 1-hour average concentrations with TEEL values. The TEEL values are intended to be compared with peak 15-minute time-weighted average concentrations. As a rough cut to account for this uncertainty, the 1-hour concentrations were compared with adjusted TEEL values (i.e., TEEL values divided by four — since the estimated exposure duration could be four times longer than that usually compared with TEEL values). For the pipeline spills presented in Table 4.4-29, this would result in cyclohexane and n-octane (in addition to the other substances previously listed) exceeding the adjusted TEEL-values, with impact distances of less than 1 km (0.6 mi). It would also increase the impact distance for n-hexane from a maximum of 1.3 km (0.8 mi) out to 8 km (5 mi). The approach of using adjusted TEEL values is likely to be conservative (that is, to overestimate the impact distance).

Valdez Marine Terminal Spills. For Valdez Marine Terminal scenarios, diesel spills for the *anticipated* and *unlikely* scenarios were postulated to occur outside of containment (except for the release of less than a gallon to Port Valdez for the *anticipated* scenario, which was assumed to have negligible impacts with respect to inhalation). The areas covered for a 1-in. oil pool depth for *anticipated* and *unlikely* scenarios were 0.02 acres and 0.7 acres, respectively. For the *likely* scenario of a moderate leak during Valdez Marine Terminal operations, volatilization from two areas was accounted for: a 5-acre land area where the oil pool would have a 1-in. thickness, and a 1-acre area of Port Valdez to which about 1,700 bbl of oil would flow. For the *very unlikely* scenario of a catastrophic rupture of a crude oil storage tank, volatilization from three areas was accounted for: a 10-acre containment area, a 15-acre additional land area for overflow oil outside of containment, and an 86-acre area of Port Valdez to which about 143,000 bbl of oil would flow. For modeling the Port Valdez contaminated areas, it was assumed that booms would be used, thus containing the oil to a concentration of about 1.69 gal/ft^2 (APSC 2001h), corresponding to about a 2.6-in. thickness on the surface of the water. For Valdez Marine Terminal spills, the impact distances were compared with the distance to residential areas of Valdez, located as close as 3.2 km (2 mi) from the Valdez Marine Terminal.

For *anticipated* spills, the assessment examined a spill of 15 bbl of diesel. Because this spill volume is relatively small, only a 1-in. diesel pool depth was modeled. For this spill under maximum hazard weather conditions, the concentration of benzene at the edge of the spill area (220 mg/m^3) in the first hour after the spill would exceed the comparison level for mild adverse effects, but it would be less than the comparison value for serious effects. The compound n-hexane would have a maximum concentration of 1,400 mg/m^3 and an impact distance of less than 0.01 km (0.006 mi). Under more typical weather conditions (D stability, 3 m/s wind speed), the maximum concentration of n-hexane at the edge of the spill area (560 mg/m^3) would exceed the comparison level for mild adverse effects, but it would be less than the comparison value for serious effects. This spill would not affect residential areas of Valdez.

The impacts of *likely* spills are summarized in Table 4.4-30. Under maximum hazard conditions, concentrations of benzene, n-heptane, n-hexane, toluene, and hydrogen sulfide would exceed the comparison concentrations at the edge of the spill area in the first hour after the spill, with the maximum impact distance extending to 0.2 km (0.1 mi) downwind of the spill area. Under minimum hazard conditions, benzene and toluene would exceed the comparison levels for mild adverse effects, but the concentrations would be less than the comparison values for serious effects at the edge of the spill area. The impact distance for n-hexane would be 0.02 km (0.01 mi). This spill would not impact residential areas of Valdez.

The *unlikely* spill at the Valdez Marine Terminal is for 450 bbl of diesel, a substantially lower volume than for the *likely* spill assessed. As would be expected, the modeled impacts are lower. (Therefore, the impacts are not shown in Table 4.4-30.) Under maximum hazard conditions, 1-hour concentrations of benzene, toluene, and hydrogen sulfide (430, 250, and 23 mg/m^3, respectively) would exceed the comparison concentrations for mild impacts, but not for serious impacts. The impact distance for n-hexane (maximum concentration of 2,700 mg/m^3) would be 0.05 km (0.03 mi), so the plume would be very small and would not reach Valdez residential areas.

The impacts for the *very unlikely* scenario (catastrophic rupture of crude oil storage tank) are also summarized in Table 4.4-30. Under maximum hazard weather conditions, concentrations of benzene, cyclohexane, n-heptane, n-hexane, toluene, and hydrogen sulfide would exceed the comparison concentrations at the edge of the Port Valdez spill area in the first hour after the spill. The highest impact distance could extend up to 4.0 km (2.5 mi) downwind of the Port Valdez spill area. For an assumed contained oil area on Port Valdez extending approximately 0.8 km (0.5 mi) north of the Valdez Marine Terminal, this impact distance would intersect the residential areas of Valdez (if the wind were blowing toward the city). Under the more typical minimum hazard weather conditions, the maximum impact distance would be 0.3 km (0.2 mi), and the plume would not reach Valdez residential areas.

As noted under **Pipeline Spills**, an uncertainty associated with this assessment is the comparison of post-spill maximum 1-hour average concentrations with TEEL values (for substances with no ERPG values available). The TEEL values are intended to be compared with peak 15-minute time-weighted average concentrations. As a rough cut to account for this uncertainty, the 1-hour concentrations were compared with adjusted TEEL values (i.e., TEEL values divided by four). For the very unlikely Valdez Marine Terminal spill presented in Table 4.4-30 and assuming maximum hazard weather conditions, this would result in all substances except ethylbenzene, naphthalene, and styrene exceeding comparison concentrations at the edge of the spill area. It would also increase the impact distance for n-hexane from a maximum of 2.1 km (1.3 mi) out to 13 km (8 mi). This plume would intersect Valdez residential areas. Assuming minimum

TABLE 4.4-30 Inhalation Impacts of Valdez Marine Terminal Spills: Maximum 1-Hour Pollutant Concentrations and Impact Distances

	Maximum Hazard[a]				Minimum Hazard[a]				
	Very Unlikely or Unlikely Scenario[b] (510,000 bbl)		Likely Scenario[c] (4,900 bbl)		Very Unlikely or Unlikely Scenario[b] (510,000 bbl)		Likely Scenario[c] (4,900 bbl)		
Compound	Maximum 1-Hour Concentration (mg/m^3)	Impact Distance[d] (km)[e]	Maximum 1-Hour Concentration (mg/m^3)	Impact Distance[d] (km)	Maximum 1-Hour Concentration (mg/m^3)	Impact Distance[d] (km)	Maximum 1-Hour Concentration (mg/m^3)	Impact Distance[d] (km)	Comparison Concentration[e] (mg/m^3)
Volatile organic compounds									
Benzene	1,500	0.38	870	0.02	600	0.02	400	-[f]	150-500
Cyclohexane	4,200	0.01	2,500	-	1,700	-	1,200	-	3,000–4,000 (TEEL)
Ethyl benzene	18	-	11	-	7.7	-	5.1	-	500 (TEEL)
n-Heptane	3,100	0.15	1,800	0.01	1,300	-	850	-	1,500 (TEEL)
n-Hexane	6,100	2.1	3,700	0.2	2,600	0.31	1,400	0.02	500-700 (TEEL)
Naphthalene	0.28	-	0.17	-	0.12	-	0.08	-	75-150 (TEEL)
n-Octane	1,100	-	670	-	470	-	310	-	1,500 (TEEL)
Styrene	110	-	64	-	44	-	30	-	200–1,000
Toluene	910	-	540	-	380	-	250	-	150–1,000
Xylene	150	-	92	-	64	-	43	-	600–750 (TEEL)
Inorganic compounds									
Hydrogen sulfide	500	4.0	31	-	110	0.13	8.3		20[g]–40

a Maximum and minimum hazards reflect differences in assumed meteorological conditions at the time of the spill. Maximum hazards occur under meteorological conditions of F stability with 1.5 m/s wind speed; minimum hazards occur under D stability with 3 m/s wind speed.

b Catastrophic storage tank rupture caused by aircraft crash (includes 316,000 bbl oil released into containment area [10 acres], 50,350 bbl released to secondary containment [15 acres], and 143,450 bbl released to water but contained by booms [86 acres]). Maximum concentration location is at boundary of spill area (about 0.8 km north of the Valdez Marine Terminal in Port Valdez); air modeling accounts for each component of spill area.

Footnotes continued on next page.

TABLE 4.4-30 (Cont.)

[c] Moderate leak during operations of 3,200 bbl crude oil outside containment (5 acres) and 1,700 bbl to water but contained by booms (1 acre). Maximum concentration location is at boundary of spill area (about 0.2 km north of the Valdez Marine Terminal in Port Valdez); air modeling accounts for each component of spill area.

[d] Impact distance is the distance from the boundary of the Port Valdez spill area to the location where the ambient air concentration drops below the ERPG-2 or TEEL-2 value.

[e] The range is from Emergency Response Planning Guideline 1 (ERPG-1) to ERPG-2, where ERPG values are available (AIHA 2002). Otherwise, Temporary Emergency Exposure Limit 1 (TEEL-1) and TEEL-2 values were used. ERPG and TEEL definitions are almost identical, except ERPGs are for 1-hour exposures while TEELs are for 15-minute exposures. Definitions: ERPG-1 (TEEL-1) = the maximum concentration in air below which it is believed nearly all individuals could be exposed for up to 1 hour (up to 15 minutes) without experiencing other than mild transient adverse health effects or perceiving a clearly defined objectionable odor. ERPG-2 (TEEL-2) = the maximum concentration in air below which it is believed nearly all individuals could be exposed for up to 1 hour (up to 15 minutes) without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action. It is recommended that for application of TEELs, concentration at the receptor point of interest be calculated as the peak 15-minute time-weighted average concentration. Therefore, the comparison with TEELs may be underprotective (see text for discussion).

[f] A dash indicates predicted concentrations are lower than the ERPG-2 or TEEL-2 comparison levels over the entire modeling domain.

[g] For hydrogen sulfide, the TEEL-1 value was used instead of the ERPG-1 value because ERPG-1 was odor-based rather than toxicity-based.

hazard weather conditions and adjusted TEEL values, the maximum impact distance would be 2.4 km (1.5 mi), and the plume would not reach Valdez residential areas. The approach of using the adjusted TEEL values is likely to be conservative (that is, overestimate the impact distance).

Transportation Spills. Impacts of transportation spills are summarized in Table 4.4-31. For the *unlikely* scenario (190 bbl of turbine fuel), only n-hexane exceeds the comparison values, with an impact distance ranging from 0.003 to 0.03 km (0.002 to 0.02 mi), depending on the hazard conditions at the time of the accident. For the *very unlikely* scenario (190 bbl of diesel), n-hexane exceeds the comparison values with an impact distance ranging from 0.003 to 0.03 km. Toluene and benzene also exceed the comparison value for mild impacts.

As noted under **Pipeline Spills**, an uncertainty associated with this assessment is the comparison of post-spill maximum 1-hour average concentrations with TEEL values (for substances with no ERPG values available). The TEEL values are intended to be compared with peak 15-minute time-weighted average concentrations. As a rough cut to account for this uncertainty, the 1-hour concentrations were compared with adjusted TEEL values (i.e., TEEL values divided by four). For the Transportation spills presented in Table 4.4-31, this would result in cyclohexane, n-heptane, and n-octane exceeding the comparison values (in addition to the other substances previously listed). It would also increase the impact distance for n-hexane from a maximum of 0.03 km (0.02 mi) out to 0.19 km (0.12 mi). The approach of using the adjusted TEEL values is likely to be conservative (that is, overestimate the impact distance).

Inhalation Exposure Impacts from Spills to Rivers. To assess whether spills to rivers could result in adverse impacts from inhalation of volatile components for receptors along the river banks, spills representing a range of possible impacts were evaluated. The modeling of this scenario is somewhat complex because the source would be moving away from the receptor with the river current. Modeling assumptions are provided in Section 4.4.4.6. For each scenario modeled, the receptor was assumed to be at the aboveground river crossing release point, which would be the location of maximum air concentrations of contaminants.

On the basis of the discussion of possible spills to rivers provided in Section 4.4.4.3 and the modeling for *likely* and *unlikely/very unlikely* categories (see below), spills in the *anticipated* category (up to 100 bbl of diesel) were considered to have negligible inhalation impacts and were not assessed quantitatively.

For the *likely* category spill, a 10,000 bbl slow leak from the pipeline into the Yukon River was assessed. This spill would spread over a large surface area because the oil release occurs slowly over an extended time period. Because of the large surface area over which the spill could spread (the width of the Yukon ranges from 1,500 to 4,000 ft), the modeled air concentrations from a spill to the Yukon would be higher than for the narrower rivers. Table 4.4-32 summarizes the impacts from the likely spill into the Yukon. No comparison values would be exceeded at the river bank for any of the volatile contaminants modeled.

For the *unlikely/very unlikely* spill categories, a guillotine break releasing 21,246 bbl of crude oil to the Yukon River was assessed. (Again, although the spill volumes to other rivers could be higher, the Yukon's large surface area would result in higher air concentrations of contaminants.) Under maximum hazard weather conditions, concentrations of benzene, n-heptane, n-hexane, toluene, and hydrogen sulfide would exceed the comparison concentrations. The highest impact distance could extend up to 1.2 km (0.75 mi) from the river bank. For minimum hazard conditions, concentrations of benzene and toluene would exceed the comparison levels for mild impacts, and the impact distance for n-hexane could extend up to 0.03 km (0.02 mi) from the river bank.

As noted under **Pipeline Spills**, an uncertainty associated with this assessment is the comparison of post-spill maximum 1-hour average concentrations with TEEL values (for substances with no ERPG values available). The TEEL values are intended to be compared with peak 15-minute time-weighted average concentrations. As a rough cut to account for this

TABLE 4.4-31 Inhalation Impacts of Transportation Spills: Maximum 1-Hour Pollutant Concentrations and Impact Distances

	Maximum Hazard[a]				Minimum Hazard[a]				
	Unlikely Scenario[b] (190 bbl turbine fuel)		Very Unlikely Scenario[c] (190 bbl diesel)		Unlikely Scenario[b] (190 bbl turbine fuel)		Very Unlikely Scenario[c] (190 bbl diesel)		
Compound	Maximum 1-Hour Concentration (mg/m^3)	Impact Distance[d] (km)	Maximum 1-Hour Concentration (mg/m^3)	Impact Distance[d] (km)	Maximum 1-Hour Concentration (mg/m^3)	Impact Distance[d] (km)	Maximum 1-Hour Concentration (mg/m^3)	Impact Distance[d] (km)	Comparison Concentration[e] (mg/m^3)
Volatile organic compounds									
Benzene	76	-[f]	370	-	37	-	180	-	160–500
Cyclohexane	1,600	-	1,600	-	760	-	760	-	3,000–4,000 (TEEL)
Ethyl benzene	7.0	-	10	-	3.4	-	5.1	-	500 (TEEL)
n-Heptane	1,200	-	1,200	-	560	-	560	-	1,500 (TEEL)
n-Hexane	2,300	0.03	2,300	0.03	910	0.003	910	0.003	500–750 (TEEL)
Naphthalene	0.10	-	0.36	-	0.05	-	0.17	-	75–150 (TEEL)
n-Octane	430	-	430	-	210	-	210	-	1,500 (TEEL)
Styrene	40	-	40	-	20	-	20	-	200–1,000
Toluene	130	-	210	-	62	-	100	-	150–1,000
Xylene	58	-	61	-	28	-	30	-	600–750 (TEEL)
Inorganic compounds									
Hydrogen sulfide	19	-	19	-	5.5	-	5.5		20[g]–40

[a] Maximum and minimum hazards reflect differences in assumed meteorological conditions at the time of the spill. Maximum hazards occur under meteorological conditions of F stability with 1.5 m/s wind speed, whereas minimum hazards occur under D stability with 3 m/s wind speed. A 1-in. oil pool depth was assumed for all scenarios.

[b] Overturn of a liquid turbine fuel truck between the Petro Star Refinery to PS12, or between the North Pole Refinery to PS 9. For both maximum and minimum hazard scenarios, the length and area of the spill are 24 m and 0.3 acres. Maximum concentration locations are at the boundary of spill area.

Footnotes continued on next page.

TABLE 4.4-31 (Cont.)

[c] Overturn of a fuel truck carrying arctic grade diesel between the North Pole Refinery to PS 12. For both maximum and minimum hazard scenarios, the length and area of the spill are 24 m and 0.3 acres. Maximum concentration locations are at boundary of spill area.

[d] Impact distance is the distance from the boundary of the spill area to the location where the ambient air concentration drops below the ERPG-2 or TEEL-2 value.

[e] The range is from Emergency Response Planning Guideline 1 (ERPG-1) to ERPG-2, where ERPG values are available (AIHA 2002). Otherwise, Temporary Emergency Exposure Limit 1 (TEEL-1) and TEEL-2 values were used. ERPG and TEEL definitions are almost identical, except ERPGs are for 1-hour exposures while TEELs are for 15-minute exposures. Definitions: ERPG-1 (TEEL-1) = the maximum concentration in air below which it is believed nearly all individuals could be exposed for up to 1 hour (up to 15 minutes) without experiencing other than mild transient adverse health effects or perceiving a clearly defined objectionable odor. ERPG-2 (TEEL-2) = the maximum concentration in air below which it is believed nearly all individuals could be exposed for up to 1 hour (up to 15 minutes) without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action. It is recommended that for application of TEELs, concentration at the receptor point of interest be calculated as the peak 15-minute time-weighted average concentration. Therefore, the comparison with TEELs may be underprotective (see text for discussion).

[f] A dash indicates predicted concentrations are lower than the ERPG-2 or TEEL-2 comparison levels over the entire modeling domain.

[g] For hydrogen sulfide, the TEEL-1 value was used instead of the ERPG-1 value because ERPG-1 was odor-based rather than toxicity-based.

TABLE 4.4-32 Inhalation Impacts of Spills to Rivers: Maximum 1-Hour Pollutant Concentrations and Impact Distances

	Maximum Hazard[a]				Minimum Hazard[a]				
	Likely Scenario[b] (10,000 bbl)		Unlikely/Very Unlikely Scenario[c] (21,246 bbl)		Likely Scenario[b] (10,000 bbl)		Unlikely/Very Unlikely Scenario[c] (21,246 bbl)		
Compound	Maximum 1-Hour Concentration (mg/m^3)	Impact Distance[d] (km)	Maximum 1-Hour Concentration (mg/m^3)	Impact Distance[d] (km)	Maximum 1-Hour Concentration (mg/m^3)	Impact Distance[d] (km)	Maximum 1-Hour Concentration (mg/m^3)	Impact Distance[d] (km)	Comparison Concentration[e] (mg/m^3)
Volatile organic compounds									
Benzene	40	-	840	0.07	20	-	410	-	150–500
Cyclohexane	130	-	2,900	-	51	-	1,100	-	3,000–4,000 (TEEL)
Ethyl benzene	0.92	-	23	-	0.29	-	7.4	-	500 (TEEL)
n-Heptane	100	-	2,100	0.05	38	-	980	-	
n-Hexane	200	-	4,200	1.2	51	-	1,100	0.03	500–750 (TEEL)
Naphthalene	0.31	-	0.34	-	0.12	-	0.14	-	75–150 (TEEL)
n-Octane	44	-	990	-	17	-	360	-	1,500 (TEEL)
Styrene	7.7	-	130	-	1.7	-	53	-	200–1,000
Toluene	32	-	680	-	12	-	260	-	150–1,000
Xylene	7.7	-	190	-	2.4	-	62	-	600–750 (TEEL)
Inorganic compounds									
Hydrogen sulfide	2.4	-	51	0.03	0.61	-	13	-	20[g]–40

a Maximum and minimum hazards reflect differences in assumed meteorological conditions at the time of the spill. Maximum hazards occur under meteorological conditions of F stability with 1.5 m/s wind speed, whereas minimum hazards occur under D stability with 3 m/s wind speed.

b A leak of 10,000 bbl to the Yukon River resulting from sabotage or vandalism or from corrosion-related damage. For both maximum and minimum hazard scenarios, the surface area of the spill would be about 1,800 acres. The surface area is high because the oil release would occur slowly over an extended time period. Maximum concentration locations are at boundary of spill area but are chemical specific (see Section 4.4.4.6).

Footnotes continued on next page.

TABLE 4.4-32 (Cont.)

c A spill of 21,246 bbl to the Yukon River resulting from a guillotine break. For both maximum and minimum hazard scenarios, the surface area of the spill would be about 840 acres. Maximum concentration locations are at boundary of spill area but are chemical specific (see Section 4.4.4.6).

d Impact distance is the distance from the boundary of the spill area to the location where the ambient air concentration drops below the ERPG-2 or TEEL-2 value.

e The range is from Emergency Response Planning Guideline 1 (ERPG-1) to ERPG-2 where ERPG values are available (AIHA 2002). Otherwise, Temporary Emergency Exposure Limit 1 (TEEL-1) and TEEL-2 values were used. ERPG and TEEL definitions are almost identical, except ERPGs are for 1-hour exposures while TEELs are for 15-minute exposures. Definitions: ERPG-1 (TEEL-1) = the maximum concentration in air below which it is believed nearly all individuals could be exposed for up to 1 hour (up to 15 minutes) without experiencing other than mild transient adverse health effects or perceiving a clearly defined objectionable odor. ERPG-2 (TEEL-2) = the maximum concentration in air below which it is believed nearly all individuals could be exposed for up to 1 hour (up to 15 minutes) without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action. It is recommended that for application of TEELs, concentration at the receptor point of interest be calculated as the peak 15-minute time-weighted average concentration. Therefore, the comparison with TEELs may be underprotective (see text for discussion).

f A dash indicates predicted concentrations are lower than the ERPG-2 or TEEL-2 comparison levels over the entire modeling domain.

g For hydrogen sulfide, the TEEL-1 value was used instead of the ERPG-1 value because ERPG-1 was odor-based rather than toxicity-based.

uncertainty, the 1-hour concentrations were compared with adjusted TEEL values (i.e., TEEL values divided by four). For the Spills to Rivers presented in Table 4.4-32, this would result in cyclohexane, n-octane, and xylene exceeding the comparison values (in addition to the other substances previously listed). It would also increase the impact distance for n-hexane from a maximum of 1.2 km (0.8 mi) out to 6.7 km (4.2 mi). The approach of using the adjusted TEEL values is likely to be conservative (that is, overestimate the impact distance).

Uncertainties in the Inhalation Impacts Assessment. Several areas of conservatism and uncertainty in the assessment of ambient air concentrations and estimation of impact distances exist that should be noted. As discussed in Section 4.4.1.3, the method used to calculate the on-land spill areas results in overestimates, primarily because absorption into the soil and terrain features are not accounted for. Also, the modeling relies on estimates of percent composition of the individual substances modeled in the crude oil (see Section 4.4.4.6). Data for the current TAPS crude mix were not available, so several sources of data were combined for this assessment (Roehner 2001; National Research Council 1985; Riley 1980). For cyclohexane, n-hexane, n-heptane, and n-octane, only the percent compositions for the total 6-carbon, 7-carbon, and 8-carbon components in the TAPS mix crude were available (Roehner 2001). In the absence of chemical-specific percent composition data, each of the four substances was assumed to make up 50% of its corresponding carbon component (e.g., the percent composition of cyclohexane was assumed to be 50% of the total C6 fraction, reported as 1.925%). A chemical-specific laboratory analysis of the current TAPS crude oil mix would allow much more accurate estimation of the expected downwind concentrations for each of the modeled substances.

For the substances for which ERPG values were not available, an additional uncertainty was introduced in that the TEEL values are actually derived for comparison with 15-minute exposure levels. Therefore, comparison of the maximum 1-hour estimated ambient concentrations with the TEEL values may be underprotective.

Spills of Hazardous Materials Stored or Transported. Approximately 50 different hazardous materials are stored in association with TAPS activities, including drag reducing agent, fire-fighting foams, lubricating oils, and solvents. Under EPCRA, the TAPS Owners are required to submit an annual report of the quantities stored and their storage locations (see Appendix C). To address the possible adverse health outcomes of spills of these stored materials, a screening assessment was conducted to evaluate the toxicity and quantity stored of each. Chemicals with low toxicity (i.e., TEEL-1 values > 50mg/m^3) or low single-container storage volumes (i.e., less than 10 gal per container) were assumed not to present a significant risk from accidental spills. After screening out chemicals with low toxicity or storage volumes, only six substances remained in the hazardous materials storage inventory for further assessment: ethanolamine (a component of citrikleen, up to 900 lb stored at Anchorage Operations Support Facility), ethylene glycol (up to 280,000 lb stored at the Valdez Marine Terminal), fluoroprotein foam (up to 496,000 lb stored at the Valdez Marine Terminal), lubricating oils (up to 80,000 lb stored at pump stations and the Valdez Marine Terminal), sodium hydroxide (up to 159,000 lb stored at the Valdez Marine Terminal), and sulfuric acid (up to 53,000 lb stored at the Valdez Marine Terminal).

Although these substances are stored in large quantities at one or more TAPS facilities, these substances do not represent a large risk from accidental spills. This is because none of the substances are very volatile, so inhalation exposures would be minimal after a spill. In fact, none of the substances are present in the database for the ALOHA model (EPA and NOAA 1999), which is commonly used to assess the impacts of accident releases of chemicals. Therefore, it is concluded that the accidental spill of hazardous materials used in association with TAPS operations would not represent a potential adverse human health impact.

4.4.4.7.3 Health Impacts from Fires. As discussed in Section 4.4.3, impacts from two fire scenarios were assessed: an aircraft crash into the pipeline at MP 456 resulting in a release of up to 41,101 bbl of oil, and an aircraft crash into a storage tank at the

Valdez Marine Terminal, releasing 382,500 bbl of crude oil (average working level of tank #2 in East Tank Farm, see discussion in Section 4.4.3). Emissions of particulate matter (soot), PAHs, carbon monoxide, carbon dioxide, nitrogen dioxide (as NO_x), and sulfur dioxide from these fires are assessed. Two assessments are provided, an estimation of the ambient levels of these pollutants at locations near the fire (near-field impacts out to about 3 km from the fire), and an estimation of concentrations at more distant locations (ranging from about 3 to 50 km from the fire), because the high temperature of a fire contributes to plume buoyancy that can transport contaminants for long distances. Large fires are expected to have higher far-field impacts, because the high temperatures contribute to plume buoyancy. Smaller fires generally have higher near-field impacts.

The FDS model was used to assess the near-field air quality impacts, and the FDS results were also used in the FIREPLUME model to assess the far-field air quality impacts. For the far-field modeling, two or more meteorological conditions were modeled in order to estimate the complete range of possible impacts. Details on the modeling assumptions are provided in Section 4.4.3.

Near-Field Impacts. The near-field modeling resulted in estimates of the maximum 15-minute average concentrations at various receptor locations around the fires at Fairbanks and the Valdez Marine Terminal. The estimated concentrations for the Fairbanks fire are compared with ERPG and TEEL values in Table 4.4-33 (see Section 4.4.4.7.2 for discussion of the ERPG and TEEL values). For the Fairbanks fire, the nearest modeled location at 0.15 km (0.09 mi) from the fire had the highest concentrations of the contaminants. The modeled concentrations indicate that the SO_2 concentration could exceed the comparison concentration for serious adverse effects at 0.2 km (0.1 mi) from the fire; the impact distance (distance from the fire to which the concentration equals or exceeds the ERPG-2 value) is between 0.2 and 0.3 km (0.1 and 0.2 mi) from the fire. PM_{10} concentrations could exceed the comparison level for mild adverse effects out to 0.25 km (0.16 mi) from the fire.

Table 4.4-33 also shows the near-field modeling results for the Valdez Marine Terminal fire. This is a fire of long duration (approximately 8 hours). Therefore, modeled near-field peak 15-minute concentrations were compared with longer-term comparison levels (8- or 24-hour NAAQS, and 8-hour time-weighted average threshold limit values [ACGIH 2000]). Comparing a short-term (e.g., peak 15-minute average) modeled ambient concentration with a longer term comparison level (e.g., 8-hour average) is protective, in that if the model calculated an 8-hour average level, it would likely be much lower than the peak 15-minute average. Using the longer-term comparison level accounts that exposures from a long-burning fire extending over several hours. Although 8-hour TWA TLVs are guideline values for routine 40-hour per week occupational exposures and are not generally applicable to short-term exposures of the workers, they are used here for comparison purposes.

The nearest modeled location (containment edge #4, 0.2 km [0.1 mi] from the fire) had the highest concentrations of the contaminants. The two contaminants that exceeded the comparison values at this location were PM_{10}, with a concentration of 4.2 mg/m^3 (comparison levels of 0.15 and 3 mg/m^3), and SO_2, with a concentration of 0.76 mg/m^3 (comparison levels of 0.37 and 5.2 mg/m^3). At the next nearest Valdez Marine Terminal receptor location at 0.3 km (0.2 mi) from the fire (the E Manifold Receiving Building), the concentrations would decrease to 1.5 mg/m^3 PM_{10} and 0.27 mg/m^3 SO_2. Persons likely to be at these close distances to the fire would be emergency response personnel with respiratory protection equipment. At the distance of 0.3 km, the TLVs, which are allowable levels for chronic occupational exposures, are no longer exceeded; therefore, the concentrations at this distance or farther may be a regulatory concern (that is, they exceed NAAQS), but are unlikely to be a health hazard for a single 8-hour exposure.

Far-Field Impacts. To assess the far-field impacts, the 30-minute average concentrations of emitted substances were estimated for the Fairbanks pipeline fire, because the fire was estimated to last for 30 minutes. For the Valdez Marine Terminal

TABLE 4.4-33 Near-Field Impacts of Crude Oil Spills with Associated Fire

	Very Unlikely Pipeline Scenario[a] (53,000 bbl)		Very Unlikely Valdez Marine Terminal Scenario[b] (510,000 bbl)	
Pollutant	Peak 15-min Concentration (mg/m^3)	Comparison Concentrations – ERPGs and TEELs[c] (mg/m^3)	Peak 15-min Concentration (mg/m^3)	Comparison Concentrations – NAAQS and TLVs[d] (mg/m^3)
PM_{10}	54	30–50 (TEEL)	4.2	0.15 (3)
PAH	0.04	0.6–1 (TEEL)	0.0031	(0.2)
CO	12	200–400	0.93	10 (29)
CO_2	1,100	50,000 (TEEL)	49	(9,800)
NO_2	0.40	7.5 (TEEL)	0.031	0.09 (5.6)
SO_2	9.9	0.75–7.5	0.76	0.37 (5.2)

[a] Guillotine break resulting from aircraft crash with subsequent fire at MP 449, assuming 2.1×10^6 bbl/d throughput, and near-field concentrations modeled at receptor locations ranging from 150 m to 3 km, highest concentrations are at 200 m from the fire and are given in this table.

[B] Catastrophic storage tank rupture at Valdez Marine Terminal resulting from aircraft crash with subsequent fire, ignition of 510,000 bbl crude oil, near-field concentrations modeled at receptor locations ranging from 196 m to 3 km. Highest concentrations are those closest to fire and are given in this table.

[c] The range is from Emergency Response Planning Guideline 1 (ERPG-1) to ERPG-2 where ERPG values are available (EPA 2001c). Otherwise, Temporary Emergency Exposure Limit 1 (TEEL-1) and TEEL-2 values were used. ERPG and TEEL definitions are almost identical, except ERPGs are for 1-hour exposures while TEELs are for 15-minute exposures. Definitions: ERPG-1 (TEEL-1) = the maximum concentration in air below which it is believed nearly all individuals could be exposed for up to 1 hour (up to 15 minutes) without experiencing other than mild transient adverse health effects or perceiving a clearly defined objectionable odor. ERPG-2 (TEEL-2) = the maximum concentration in air below which it is believed nearly all individuals could be exposed for up to 1 hour (up to 15 minutes) without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action. It is recommended that for application of TEELs, concentration at the receptor point of interest be calculated as the peak 15-minute time-weighted average concentration. Comparison of estimated peak 15-minute concentrations with ERPG values is protective.

[d] For PM_{10}, CO, and SO_2, the NAAQS are for short time periods of 8 to 24 hours and are not to be exceeded more than once per year. For PM_{10}, 0.15 mg/m^3 is the 24-hour average limit; for CO, 10 mg/m^3 is the 8-hour average; for SO_2, 0.37 mg/m^3 is the 24-hour average; for NO_2, 0.09 mg/m^3 is the annual average limit (no shorter averaging time NAAQS available). Values in parentheses are 8-hour time-weighted average threshold limit values (ACGIH 2000).

far-field impacts, the 8-hour average concentrations of emitted substances were estimated, corresponding to the duration of that fire. Various comparison levels were used to evaluate these far-field concentrations, depending on the length of the fire (and therefore, the length of exposure) that was being assessed. For the Fairbanks fire the 30-minute averages were compared with ERPG and TEEL levels, which are appropriate for evaluating short-term exposures. For the Valdez Marine Terminal fire, the 8-hour averages were compared with 8- to 24-hour NAAQS (when available) and with 8-hour time-weighted average threshold limit values (TLVs) (ACGIH 2000). Although TLVs are guideline values for routine 40-hour per week occupational exposures and are not generally applicable to short-term exposures of the general public, they are used here for comparison purposes only. Far-field impacts are given in Table 4.4-34.

For far-field impacts, no comparison values were exceeded for the Fairbanks fire. For the Valdez Marine Terminal fire, the only comparison value that would be exceeded would be the 24-hour NAAQS level for PM_{10}. This exceedance would likely be a regulatory concern, but not a health hazard for a single 8-hour PM_{10} exposure (note that the allowable level for chronic occupational exposures is 3 mg/m^3, well above the modeled value).

4.4.4.7.4 Impacts from Foodchain Exposures Resulting from Spills to Water. Many of the assessments of impacts from potential spills in this FEIS are based on projected spill volumes and locations, as detailed in Section 4.4.1.1. However, much information on potential risks from foodchain pathways can be obtained from measured edible tissue contaminant levels in seafood and other species obtained from areas impacted by the Exxon Valdez oil spill in March 1989. The volume of this spill was very large (about 11 million gal, or 260,000 bbl), and many subsequent measures have been taken to ensure that such a large spill would not occur again. Therefore, it can be assumed that in general, the foodchain impacts estimated on the basis of tissue contamination levels associated with the Exxon Valdez oil spill would bound the impacts from any future spills into Prince William Sound during the renewal period. Foodchain impacts from potential spills into rivers along the pipeline will be discussed at the end of this section.

In response to the March 1989 Exxon Valdez oil spill in Prince William Sound, the Alaska Oil Spill Health Task Force (OSHTF) was formed to evaluate the potential health impacts from exposure to the spilled oil (Field et al. 1999). Part of the work of the OSHTF included an extensive study of the degree of oil contamination in subsistence resources contaminated by the spill. This work was conducted by the NOAA's Northwest and Alaska Fisheries Center. The OSHTF also included toxicologists from the U.S. Food and Drug Administration (FDA). Their role was to conduct a health risk assessment addressing the subsistence diet of many Alaska Natives by using the data on fish, shellfish, and marine mammals obtained by the NOAA.

The boundary of the watershed area affected by the Exxon Valdez oil spill is shown in Map 4.4-3. Between 1989 and 1991, NOAA staff collected about 258 finfish muscle tissue samples, 1,100 shellfish samples, and samples of blubber, liver, and muscle from about 40 marine mammals (seals and sea lions) from this area. The samples were analyzed for approximately 20 aromatic compounds, mostly PAHs. PAHs are the constituent of crude oil generally of most concern with respect to food chain impacts from oil spills (Bolger and Carrington 1999). PAHs are also formed during the incomplete combustion of coal, oil, gas, wood, garbage, or other organic substances, and are present in tobacco smoke and charbroiled meat; thus people are exposed to this class of compounds through many sources. There are more than 100 different PAHs. They generally occur as complex mixtures (e.g., as soot), not as single compounds. The adverse health effect most associated with exposure to PAHs is increased cancer risk. About 10 to 15 individual PAH compounds have been identified as carcinogens by various U.S. and international health agencies. Although other adverse health effects can be caused by PAH exposures (e.g., reproductive and immune system effects), these other effects generally do not occur at environmental exposure levels. Therefore, protecting an exposed population from

TABLE 4.4-34 Far-Field Impacts of Crude Oil Spills with Associated Fire

	Very Unlikely Pipeline Scenario[a] (53,000 bbl)		Very Unlikely Valdez Marine Terminal Scenario[b] (510,000 bbl)	
Pollutant	Peak 30-min Average Concentration (mg/m^3)	Comparison Concentrations – ERPGs and TEELs[c] (mg/m^3)	Peak 8-h Average Concentration (mg/m^3)	Comparison Concentrations – NAAQS and TLVs[d] (mg/m^3)
PM_{10}	0.555	30–50 (TEEL)	0.52	0.15 (3)
PAH	0.0004	0.6–1 (TEEL)	0.0004	(0.2)
CO	0.12	200–400	0.12	10 (29)
CO_2	11	50,000 (TEEL)	11	(9,800)
NO_2	0.004	7.5 (TEEL)	0.004	0.09 (5.6)
SO_2	0.10	0.75–7.5	0.096	0.37 (5.2)

[a] Guillotine break resulting from aircraft crash with subsequent fire, at MP 449 assuming 2.1×10^6 bbl/d throughput, concentrations modeled at maximum concentration location (38 km, or 24 mi downwind). Assumes D2 stability meteorological conditions; other meteorological conditions resulted in estimated concentrations a factor of 5 or more lower than those presented. The fire is estimated to last about 30 minutes, so short-term comparison levels (ERPGs and TEELS) are appropriate.

[b] Catastrophic storage tank rupture at Valdez Marine Terminal resulting from aircraft crash with subsequent fire, ignition of 510,000 bbl crude oil, far-field concentrations modeled at maximum concentration location (31 km, or 19 mi downwind). Assumes C/D stability meteorological conditions, for which concentrations were about twice those estimated when assuming D stability. The fire is estimated to last about 8 hours, so longer-term comparison levels (NAAQS and TLVs) are appropriate.

[c] The range is from Emergency Response Planning Guideline 1 (ERPG-1) to ERPG-2 where ERPG values are available (AIHA 2002). Otherwise, Temporary Emergency Exposure Limit 1 (TEEL-1) and TEEL-2 values were used. ERPG and TEEL definitions are almost identical, except ERPGs are for 1-hour exposures while TEELs are for 15-minute exposures. Definitions: ERPG-1 (TEEL-1) = the maximum concentration in air below which it is believed nearly all individuals could be exposed for up to 1 hour (up to 15 minutes) without experiencing other than mild transient adverse health effects or perceiving a clearly defined objectionable odor. ERPG-2 (TEEL-2) = the maximum concentration in air below which it is believed nearly all individuals could be exposed for up to 1 hour (up to 15 minutes) without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action. It is recommended that for application of TEELs, concentration at the receptor point of interest be calculated as the peak fifteen-minute time-weighted average concentration. Therefore, the comparison of TEELs with peak 30-minute average concentrations may be underprotective (see text). Comparison of ERPGs with estimated maximum 15-minute concentrations is protective.

[d] For PM_{10}, CO, and SO_2, the NAAQS are for short time periods of 8 to 24 hours and are not to be exceeded more than once per year. For PM_{10}, 0.15 mg/m^3 is the 24-hour average limit; for CO, 10 mg/m^3 is the 8-hour average; for SO_2, 0.37 mg/m^3 is the 24-hour average; for NO_2, 0.09 mg/m^3 is the annual average limit (no shorter averaging time NAAQS available). Values in parentheses are 8-hour time-weighted average threshold limit values (ACGIH 2000).

unacceptable increased cancer risk is protective for all adverse effects.

Shellfish (e.g., mussels, chitons, and clams) were the primary focus of the NOAA sampling effort, because it was known that fish and mammalian species have the ability to rapidly metabolize and excrete aromatic contaminants. As expected, the laboratory data showed that finfish and marine mammals rapidly metabolized PAHs to polar compounds that were excreted in the bile, and, therefore, PAH levels in edible muscle and blubber tissues were very low, even in specimens that had been exposed to high levels of contamination. The FDA health risk assessment based on the subsistence specimens collected concluded the following: (1) the risk associated with the consumption of salmon or other finfish that are not smoked is insignificant relative to that associated with consuming smoked salmon, because the process of smoking significantly increases PAH levels, and (2) the increased cancer risk from consumption of unsmoked salmon, other finfish, crustaceans, and oil-contaminated shellfish is low (FDA 1990). The upper-bound lifetime cancer risk for an individual ingesting shellfish reported in the FDA assessment was 2×10^{-6}; this was compared with a risk of 2×10^{-4} for ingestion of smoked salmon.

Updated Foodchain Risk Assessment*.* Primarily because some toxicity evaluation factors for PAHs have changed since the time of the FDA assessment of the Exxon Valdez oil spill impacts, additional risk calculations were conducted to support the foodchain health risk evaluation presented here. Risk calculations were conducted for ingestion of shellfish, but not for finfish or mammalian species, because the data discussed above were sufficient to conclude that risk from ingestion of these species would be negligible (Hom et al. 1999).

The results of the risk assessment for shellfish ingestion are summarized in Table 4.4-35. The assumed rate of shellfish ingestion (i.e., average of 30 g/d [0.5 lb per week] by a 60-kg individual), is the maximum from two surveys of consumption patterns among isolated Alaska Natives in the village of Chenega Bay and on Kodiak Island (FDA 1990). Most of the shellfish eaten by these populations are butter clams, only about 2 g/d are mussels (butter clams showed lower levels of PAH contamination in the NOAA studies, see below).

Two data sets were used for the assessment, each from NOAA analyses in association with the OSHTF (Varanasi et al. 1993). One was the data for mussels collected at Windy Bay in July 1989. The three samples collected from that location contained the highest levels from among the 13 subsistence use areas investigated as a result of the Exxon Valdez oil spill. Levels in mussel tissue collected at Windy Bay were considerably higher than levels in chiton or snail, so the averages for the three mussel samples were used to bound the ingestion concentrations. The second data set was for nine mussel samples collected at Windy Bay in April 1991. The PAH levels observed in these samples were much lower than those collected in the summer after the oil spill, in fact, many of the PAH compounds were not detected in these samples. Consequently, the maximum level (not the average) of each PAH compound detected was used in evaluating the 1991 data. The sum of the 15 PAHs for the 1989 data set was 5,300 ppb; the sum of the PAHs for the 1991 data set was 34 ppb. The combination of shellfish tissue contamination data and average ingestion rate was used to estimate the average daily intake of 15 PAHs for Alaska Natives on a subsistence diet.

To bound the risk from ingestion, it was assumed that the more highly contaminated shellfish could be ingested for up to 10 years. This time period was used to allow comparison with the FDA results, which were reported above. However, the 1991 data showed that contamination levels declined significantly within just 2 years; thus, 10 years of exposure at the elevated levels would be unlikely. An assessment of the risks from ingestion of the moderately contaminated shellfish (1991 data) over a lifetime of 70 years was also included. It was considered reasonable to include a prolonged possible exposure period because the PAH compounds are relatively persistent, and significant oil contamination was still found in some mussel beds 10 years after the Exxon Valdez oil spill (Fall 1999b).

Benzo[a]pyrene is the PAH with the most toxicity data available to use as a basis for

TABLE 4.4-35 Foodchain Risk from Ingestion of PAH-Contaminated Shellfish Compared with Risk from Ingestion of Smoked Salmon

Scenario	PAH-Associated Risk[a]
Ingestion of highly contaminated shellfish for 10 years[b]	3×10^{-5}
Ingestion of moderately contaminated shellfish for a lifetime (70 years)[c]	1×10^{-6}
Ingestion of highly contaminated shellfish for 10 years – FDA 1990 estimate[d]	2×10^{-6}
Ingestion of smoked salmon for 10 to 70 years[e]	$3 \times 10^{-5} - 2 \times 10^{-4}$

a PAHs measured in shellfish and included in the quantitative risk assessment (toxic equivalency factors [TEFs] used in parentheses) were: benzo[a]pyrene (1), dibenz[a,h]anthracene (5), benzo[a]anthracene (0.1), benzo[b]fluoranthene (0.1), benzo[k]fluoranthene (0.1), indeno[1,2,3-cd]pyrene (0.1), benzo[g,h,I]perylene (0.01), chrysene (0.01), acenaphthene (0.001), acenaphthylene (0.001), fluoranthene (0.001), fluorene (0.001), naphthalene (0.001), phenanthrene (0.001), and pyrene (0.001).

b Contaminant levels are average of three samples obtained in July 1989 from most highly contaminated fishing grounds (Windy Bay 1).

c Contaminant levels are maximums from nine samples obtained in April 1991 (Windy Bay 1).

d Contaminant levels from most highly contaminated fishing grounds; different slope factor and TEFs applied in risk calculation account for this risk estimate being smaller than that calculated in this study.

e Contaminant levels are averages of four salmon samples obtained from Tatitlek and Old Harbor in October 1989 that were subsequently smoked. The lower end of the range is for 10 years of exposure; the upper end is for a lifetime of 70 years.

developing quantitative estimates of cancer risk. An ingestion slope factor of 7.3 $(mg/kg\text{-}d)^{-1}$ for benzo[a]pyrene has been developed by the EPA (2001c). (See Section 3.17.2.3 to review the use of slope factors in estimating increased cancer risks.) This slope factor value is higher than the value of 1.75 $(mg/kg\text{-}d)^{-1}$ used by the FDA in its assessment (Bolger et al. 1996) and would result in higher risk estimates. An approach for estimating the cancer-causing potential of complex mixtures of PAHs based on “toxic equivalency factors” (TEFs) of specific PAHs relative to benzo[a]pyrene is recommended by the EPA (1993) and has been applied in this assessment of risk from ingestion for subsistence diets. The TEFs used are those reported by Nisbet and LaGoy (1992); these values also differed somewhat from those used in the FDA assessment (Bolger et al. 1996) and were specifically more conservative (i.e., resulted in higher risk estimates) for the PAH dibenzo[a,h]anthracene.

On this basis, the bounding estimates of increased lifetime cancer risk associated with 10 years of ingestion of highly contaminated shellfish is 3×10^{-5}, the increased risk from an additional 70 years of ingestion of moderately contaminated shellfish is 1×10^{-6}, for a total lifetime increased risk of about 3×10^{-5}. This risk is within the 10^{-6} to 10^{-4} risk range specified by the EPA as generally not requiring mitigating actions (1990).

For additional perspective, the increased cancer risk can be compared with that from eating smoked salmon. The NOAA study used for shellfish contamination levels also included analyses of four smoked salmon samples from two of the Alaska Native villages. These samples contained an average of 15,000 ppb total carcinogenic PAHs in edible tissue (Varanasi et al. 1993). Assuming 10 to 70 years of salmon ingestion at about 45 g/d (0.7 lb/wk) (Bolger et al. 1996), the increased cancer risk from smoked salmon ingestion alone would range from 3×10^{-5} to 2×10^{-4}. Clearly, extended ingestion of smoked fish would be as great or greater a source of risk as ingestion of contaminated shellfish. The lower end of the risk range is the same as the maximum risk reported above for ingestion of contaminated shellfish.

As in any quantitative risk assessment, there are several gaps in the toxicological database that result in uncertainties in the assessment results. First and foremost, the quantification of risk included only 15 PAHs, although crude oil contains about 100 different PAHs, and other potentially toxic substances (e.g., dibenzo-thiophenes, trace metals). The toxicological response to exposure to these types of mixtures is much more difficult to predict that the response to a single chemical exposure. Studies show an imperfect correlation between PAH content and the degree of carcinogenicity in various petroleum fractions, suggesting that the cancer-causing potential of some crude oil constituents has not yet been identified (Bolger and Carrington 1999).

A class of compounds present in crude oils and of particular interest is organosulfur compounds, especially condensed thiophenes, which are structurally similar to the carcinogenic PAHs but contain a sulfur atom in the ring structure. Some of these compounds have been found to be mutagenic, with potencies similar to that of benzo[a]pyrene (Kropp and Fedorak 1998). The NOAA shellfish samples used in this risk assessment were analyzed for the condensed thiophene dibenzothiophene and for alkylated dibenzothiophenes. In the Windy Bay 1 PAH-contaminated samples assessed, the dibenzothiophenes constituted about one-third of the concentration of low molecular weight aromatic carbons detected. To date, dibenzothiophene has not been shown to be mutagenic (Kropp and Fedorak 1998). However, the analyses for condensed thiophenes did not include some compounds that have been found to be mutagenic, so some compounds with mutagenic activity may also have been present. If these mutagenic compounds were present in the edible tissues, it would mean that the carcinogenic risk for ingestion of the shellfish was underestimated. To address this data gap, the mutagenic condensed thiophenes would need to be included in tissue sample analyses, and more complete investigation of their potencies relative to benzo[a]pyrene would be needed.

It is of interest to note that the rate of stomach cancer among Alaska Natives is three times higher than that of the U.S. White population (Lanier et al. 2000). Stomach cancer would be the type of cancer most likely to be elevated in association with ingestion of carcinogenic PAHs. The cause of the increased stomach cancer incidence among Alaska Natives is not known but perhaps is associated with frequent ingestion of smoked foods. With the increased rate of stomach cancer in this population, any additional exposures to PAHs should be avoided where possible. With this in mind, it is fortunate that, in general, after an oil spill the most highly contaminated shellfish beds can be visually identified and avoided, thus minimizing the likelihood of prolonged PAH exposure through the foodchain.

An oil spill could also occur into one of the many rivers crossed by the pipeline. The potential impacts of spills to rivers are discussed in Section 4.4.4.7.2. A spill would have adverse impacts on fish species used for food by Alaska Natives for a period of time. Fish passing through the contaminated area would be oiled and not suitable for ingestion. However, it is believed that because of the rapid metabolism and excretion of PAH compounds by fish, once the spill was contained and cleaned up to the extent practicable, the muscle tissue of fish that were not noticeably contaminated (e.g., visible oil on surface, odor of contamination) would be edible, and ingestion would not present an increased cancer risk.

4.4.4.8 Biological Resources Overview

The direct and indirect impacts of spills on biological resources are discussed in the sections that follow (through Section 4.4.4.12). The impacts on biological resources of spills would vary according to the material spilled, volume of the spill, and the location of the spill. Spills could contaminate soils, surface water, and groundwater and affect biological resources associated with these media. For the most part, spills that are anticipated or likely to occur would be small and affect only areas within the existing ROW or facility areas. The largest potential catastrophic spill to land (resulting from a guillotine break in the pipeline) would affect about 84 acres. If such a spill occurred at one of the rivers crossed by the TAPS, a considerable length of the river downstream of the spill site could be affected. The area affected would depend on river flow at the time of the spill and cleanup response time. The largest spill at the Valdez Marine Terminal could affect about 2 mi of shoreline and up to about 2 mi^2 in Port Valdez.

The impacts of a large spill to land would be expected to have localized effects on vegetation communities; bird and mammal populations; and threatened, endangered, and protected species populations, but would not noticeably affect regional vegetation patterns or animal populations. Such a spill could have localized effects on fish populations in adjacent water bodies. Containment and cleanup of a land spill are expected to be rapid and effective and would substantially reduce the magnitude and duration of impact.

A large spill to water (either at one of the rivers crossed by the TAPS or at Port Valdez) could have more widespread effects on biological resources. Unless quickly contained, a large spill to a river could affect a large portion of the river's fish population, much of the shoreline riparian vegetation, and riverine wildlife (e.g., waterfowl, river otters). Listed and protected species would not be affected by a river spill. A large spill to Port Valdez could affect shoreline vegetation, fish communities, and a number of listed and protected species (a variety of marine mammals) that occur in Port Valdez. The magnitude and duration of the impact would depend on the ability to contain and remove spilled oil.

4.4.4.9 Terrestrial Vegetation and Wetlands

Operation of the TAPS may result in accidental spills of oil or other materials over the course of the renewal period. Such spills could contaminate soils, surface water, and groundwater in the vicinity. Depending on the volume of the spill and time of year, vegetation could be injured or killed, and its reestablishment may be impeded or delayed because of residual soil contamination. Small spills onto level soil surfaces of the ROW that are immediately cleaned up would likely have minimal impacts other than the removal of vegetation in the immediate vicinity of the spill. After being cleaned up, these areas can be backfilled, regraded, and revegetated. Depending on the source, soils used for backfilling may contain seeds or other propagules of plant species that are not native to the area of the spill and may, therefore, provide an opportunity for introduction of exotic species. The use of native seed specifically grown for revegetation projects would reduce the incidence of exotic species introduction.

Impact of Oil Spills on Vegetation and Wetlands

Small spills, such as those that might be anticipated during the renewal period, would impact a relatively small area and would not be expected to have long-term impacts to terrestrial vegetation and wetlands. Large spills would be unlikely, but if they did occur, might have long-term effects on terrestrial vegetation and wetlands.

Spilled fluids that are not immediately cleaned up may migrate to lower soil strata and groundwater. The presence of oil on the ground surface may result in the development of thermokarst, as ice-rich shallow permafrost becomes warmed and thaws. Thermokarst may also result from soil exposure following removal of vegetation and the surface organic mat during cleanup activities. Areas of some vegetation communities may be eliminated as areas of thermokarst subsequently become inundated.

Some vegetation may survive low levels of oil contamination, or recolonize oil-damaged soils following applications of fertilizer (McKendrick 1987; McKendrick and Mitchell 1978a,b). Vegetation communities on drier soils may be more sensitive to the effects of oil than communities on wet or saturated soils (Walker et al. 1978), while some species such as willows or sedges (Walker et al. 1978) or cottongrass (Collins et al. 1994), may be less sensitive.

Spills of diesel fuel tend to have a greater effect on vegetation than crude oil. Vegetation that comes in contact with diesel fuel is killed, even on wet soils (Walker et al. 1978). Submerged wetland vegetation is less affected by either crude oil or diesel fuel, and has the greatest potential for recovery after a spill. Most areas receiving spilled oil, however, would remain poorly vegetated or unvegetated for many years if the oil contamination was not remediated or efforts were not undertaken to restore vegetation (Collins et al. 1994; McKendrick 1987; McKendrick and Mitchell 1978a,b; Mitchell et al. 1979). Spills onto frozen ground during winter generally have a low degree of soil penetration (McKendrick and Mitchell 1978b, Collins et al. 1994). The limited soil infiltration by the spilled material and dormancy of plants generally result in lesser effects from winter spills that are remediated quickly (McKendrick and Mitchell 1978b), although oil remaining on the surface can have severe effects (Collins et al. 1994). It is expected that remediation of spill areas would include the removal of vegetation and contaminated soils. These areas would be backfilled with clean soil and revegetated. Reestablishment of natural communities in these areas may be difficult and require extended periods of time if soil types used for restoration are different than the original soils. Restoration efforts would evaluated by the Authorized Officer (AO) and State Pipeline Coordinator (SPC), and methods would be designated on a site-specific basis to reestablish natural communities in affected areas.

A number of scenarios were developed to analyze potential impacts from oil spills for the proposed action (see Section 4.4.1). The analysis of impacts to vegetation evaluated pipeline leaks or breaks resulting in overland flow of oil, breaks occurring near elevated river crossings, and spills and breaks at the Valdez Marine Terminal. The relative frequencies of occurrence of spills and breaks were designated as *anticipated* (occurring more often than 0.5/yr), *likely* (0.03 to 0.5/yr), *unlikely* (1×10^{-3} to 0.03/yr), or *very unlikely* (1×10^{-6} to 1×10^{-3}/yr). The spill scenarios discussed below were selected for analysis because they would have the greatest potential impacts within their frequency range.

An example of an *anticipated* spill would be a small leak of diesel fuel during pipeline operations, resulting in up to 100 bbl of diesel fuel being spilled (Scenario 2, Table 4.4-1). If spread evenly over the landscape at a thickness of 1 in., the diesel fuel could cover an area of up to about 0.2 acre. A spill occurring in winter might cover a larger area than a similar spill during summer (Collins et al. 1994). Uneven ground surfaces, penetration of oil into the soil, and intervening vegetation and debris might restrict the spread of the spilled oil and result in a smaller area covered at a greater thickness or depth. An area of about 0.05 acre would be covered by a 3-in.-deep spill.

A spill from a pipeline leak caused by vandalism would be designated as *likely* (Scenario 12, Table 4.4-1). From 900 to 10,000 bbl of crude oil might be spilled in such an event. The spill would cover 1.4 to 15 acres at a depth of 1 in. and 0.5 to 5 acres if the depth was 3 in.

A spill caused by a guillotine break as the result of a crash of fixed-wing aircraft into the pipeline would be considered an *unlikely* event (Scenario 19a, Table 4.4-1). Under this scenario, from 2,000 up to about 54,000 bbl of crude oil would be spilled. The spilled oil would potentially cover an area of 3 to 84 acres at 1 in. depth, or an area of 1 to 28 acres if the spilled oil was 3 in. deep. A scenario considered *very unlikely* would be a guillotine break of the pipeline caused by the impact of a helicopter (Scenario 21, Table 4.4-1). The volume of crude oil spilled and the area covered would be the same as for the fixed-wing aircraft crash scenario. Although, the volume of a spill and the area covered might be less at any given location than that postulated under Scenarios 19a and 21, that volume and area represent a worst case, or bounding analysis, for evaluation of maximum impacts to terrestrial vegetation or wetlands along the ROW from a spill.

As noted above, various factors would influence the extent of impacts to terrestrial vegetation and wetlands in the event of a spill or pipeline break. The impacts of the spills evaluated for the various scenarios would depend on site-specific factors at the location and at the time of the spill, such as the material spilled, the intensity of the spill (lightly or heavily oiled ground), season, soil moisture level, degree of soil infiltration, and type and amount of vegetation present. However, any vegetation affected by a spill under any of these scenarios would generally be expected to be injured or killed, with lower survival of vegetation from a diesel fuel spill than from an oil spill.

Under the worst-case scenarios (Scenarios 19a, and 21, Table 4.4-1) in an area of lowland tundra, up to 84 acres of tundra could be impacted by a crude oil spill. Impacted vegetation communities would likely be primarily previously undisturbed wet sedge meadow communities, which are abundant on the Arctic Coastal Plain in the vicinity of the TAPS. Effects of oil contamination and remediation of the impacted soils would result in the elimination of these communities from the affected areas. Although revegetation efforts would be expected to eventually successfully establish native lowland tundra vegetation cover (McKendrick 1987, 1997; McKendrick and Mitchell 1978a), a number of years might be required for natural community development. The diversity of community types present in undisturbed lowland tundra may be absent or reduced in remediated areas.

A crude oil spill onto upland tundra might also impact up to 84 acres of previously undisturbed vegetation communities. The vegetation types affected might include tussock tundra communities, primarily in the northern foothills of the Brooks Range, or dwarf shrub tundra and low shrub tundra in alpine areas of the Brooks Range, Alaska Range, or Coastal Mountains. Reestablishment of these native communities might be difficult on steep slopes, and a number of years might be required for community development.

A worst-case spill in an undisturbed boreal forest area might impact up to 84 acres of forest communities, including white spruce forest and black spruce forest. Reestablishment of these forest communities might require substantial periods of time, particularly in areas where underlying permafrost was affected by the spill (Collins et al. 1994) or where natural soil was removed in cleanup efforts. Tall shrub and deciduous forest communities might become the dominant vegetation types on remediated sites before reestablishment of spruce forest communities.

A crude oil spill in a coastal forest might also impact up to 84 acres of previously undisturbed communities, primarily western hemlock-Sitka spruce forest. Reestablishment of these forest communities might also require substantial periods of time. As in the boreal forest area, tall shrub and deciduous forest communities might become the dominant vegetation types on remediated sites prior to reestablishment of hemlock-spruce forest communities.

Crude oil spilled into a river or stream would be transported downstream and would be subject to mixing and emulsification in the water and attachment to bottom sediments (Section 4.4.4.3). Oil in sediments might be transported downstream over time and cause continuing long-term contamination of downstream areas. Spilled oil would also be deposited along the shoreline, where it might penetrate sands and gravels, potentially reaching lower layers of substrate. Deposited oil might later reenter the stream current and become a source of future contamination. Depending on conditions at the time of the spill, vegetation along the impacted streams might become covered with oil and may be injured or killed by direct contact or by contamination of soil and water. Reestablishment of these vegetation communities might be difficult because of streambank contamination. Losses of riparian vegetation may increase the potential for soil erosion along streambanks, which might also affect the reestablishment of riparian communities.

Spill scenarios were developed for six TAPS river crossings (Section 4.4.4.3) and describe *unlikely* or *very unlikely* spill events involving a guillotine break. Under those scenarios, pipeline breaks could result in direct discharges of crude oil to rivers. The river crossings evaluated were over the Gulkana River, Minton Creek, Dan Creek/Sagavanirktok River, Yukon River, Tazlina River, and Tanana River.

On the Gulkana River, the spilled oil would not be expected to pass the containment area, postulated to be 20 mi downstream of the spill location, and 100% of the oil spilled would be subject to recovery upstream of the containment site. Therefore, the primary effects of the spill would occur along the 20-mi river segment downstream from MP 654. Riparian vegetation along this river segment, including scrub-shrub and forested wetlands, could be killed or injured.

Under high-flow conditions on Minton Creek, from 6 to 87% of the oil would be subject to recovery at the containment site 12 mi downstream of the spill. Although the effects of the spill would be greatest upstream of the containment site, many miles of the downstream areas could become contaminated by oil. Extensive areas of forested and scrub-shrub wetlands, as well as smaller areas of emergent wetlands, could be impacted downstream.

No recovery of oil would be expected from a spill into the Dan Creek/Sagavanirktok River at MP 85, the Yukon River at MP 353, the Tazlina River at MP 686, or the Tanana River at MP 531. Potentially affected wetlands downstream of the spill on these four rivers include scrub-shrub wetlands, as well as emergent wetlands along the Sagavanirktok River, forested wetlands along the Tazlina and Tanana Rivers, and smaller areas of emergent wetland along the Tanana River. Riparian vegetation could be killed or injured for many miles downstream as the oil slick continued to spread and deposit oil on the shorelines. Under low flow conditions, 100% of the oil would be subject to recovery at the containment site on the Sagavanirktok River, Minton Creek, and the Gulkana River, while 0 to 36% of oil released on the Yukon River and 0% on the Tazlina or Tanana Rivers would be recovered (Section 4.4.4.3).

Spill scenarios involving a transportation accident (overturn of a fuel truck) were also developed (Section 4.4.1, Table 4.4-3) and included accidents in the *unlikely* and *very unlikely* frequency range. Under these scenarios, between 119 and 190 bbl of turbine fuel or diesel fuel would be spilled on land. At a thickness of 1 in., the fuel would potentially cover an area of 0.2 to 0.3 acre, or an area of 0.06 to 0.1 acre for a 3-in. deep spill. Most or all terrestrial or wetland vegetation coming in contact with the fuel would be eliminated. Wetland vegetation entirely submerged below the water surface during the spill would likely show the greatest recovery following remediation.

A number of spill scenarios were also developed for Valdez Marine Terminal operations (Section 4.4.1, Table 4.4-2). Spills onto land would likely flow into a creek near the terminal. The creek, in turn, flows into Port Valdez near Berth 4 (Section 4.4.4.5.1). Spills that enter the water of Port Valdez might reach wetlands located along the shoreline. Vegetation along the path of the spill would be injured or killed, including wetland vegetation along the creek and on the Port Valdez shoreline. The largest spill in the *very unlikely* frequency range would be a release of crude oil resulting from a catastrophic rupture of a storage tank (Scenario 11, Table 4.4-2). About 194,000 bbl of crude oil would spill outside the secondary containment, with 143,450 bbl reaching the water of Port Valdez and 50,350 bbl remaining on land. Depending on a number of factors at the time of the spill (such as wind direction), up to about 80% of the oil released to the water might reach the shoreline. Up to 2 mi of shoreline might become heavily oiled, with small amounts of oil potentially reaching other shoreline areas. Oil reaching the shoreline might persist for extended periods of time and slow or reduce vegetation recovery.

4.4.4.10 Fish

The effects of an oil spill on fish primarily depend on the location of the spill relative to the location of fish and their habitat, the type of petroleum (e.g., crude oil vs. refined products) involved, the concentration of oil present, the stage of fish development exposed to the oil (eggs, larvae, and juveniles are most sensitive), and the duration of exposure. Depending on the quantity spilled, oil can affect aquatic organisms in several ways. Physically coating a fish in oil, especially its respiratory surfaces (i.e., gills), can cause immobilization or suffocation. If concentrations of certain chemical constituents of the oil are sufficiently high, exposed fish will die. Lower concentrations may have sublethal effects, such as reduced growth, reduced reproduction, or altered behavior. Elevated concentrations of oil may also indirectly affect fish if impacts of the oil on other organisms (such as invertebrates) reduce the availability of prey for fish. The presence of oil may also cause some fish to avoid areas traditionally used for reproduction, feeding, overwintering, or as migration corridors. In addition, oil spills have the potential to affect commercial, sport, and personal use/subsistence fisheries because fish contaminated with oil pose a potential risk to people who eat them. As a consequence, fisheries in the vicinity of oil spills are often closed until testing shows that fish are no longer contaminated.

Impacts of Oil Spills on Fish

A major spill of oil from TAPS into a waterway as a result of a failure or guillotine break in the pipeline could result in severe effects on fish, depending upon the size of the receiving stream, the nature of fish community in the stream, and the season of the year. Such spills are considered very unlikely to unlikely. Smaller spills would have less effect on fish resources but would have a higher probability of occurrence.

Different types of oil have different characteristics that affect their potential for adverse effects on fish. Fuel oils, such as gasoline and diesel fuel, are very light oils. Light oils are very volatile (i.e., they evaporate relatively quickly), so as they spread on the surface of the water, they usually do not remain in the aquatic environment very long (typically no longer than a few days). However, light oils also tend to be more acutely toxic to organisms than heavier oils. In contrast, very heavy oils (such as bunker oils, which are used to fuel ships) look black and sticky and evaporate slowly. As a consequence, heavier oils can remain in the water for a long time (weeks, months, or even years). While these oils can be very persistent, they are generally considerably less acutely toxic than light oils. Instead, the initial threat from heavy oils comes from their ability to smother organisms by restricting the exchange of oxygen. After days or weeks, some heavy oils will harden. In this hardened state, heavy oils are less likely to harm animals or plants that come in contact with them. North Slope crude oil, such as that transported in the TAPS, falls in between these extremes of light and heavy oils and has toxicity levels between the extremes described above.

Some components of oils will dissolve in water and can have lethal or sublethal effects on aquatic organisms, including fish and planktonic and benthic invertebrates. Of particular concern are polycyclic aromatic hydrocarbons (PAHs), which, depending upon the type of PAH, can have effects on aquatic organisms at relatively low concentrations. While many of these soluble components would become dispersed into the water column shortly after an oil spill, crude oil that becomes stranded in shallow areas and on beaches can enter the interstitial spaces in sediments. Such oil may remain relatively unaltered for a considerable period of time (years in some cases), allowing soluble oil components to enter the water column whenever the sediments are disturbed (e.g., by wave action during storms) (Carls et al. 2001). Concentrations of PAHs will often be higher in the interstitial spaces of contaminated sediments, where burrowing invertebrates and fish eggs of some species (such as salmon), may become exposed. In addition, some PAHs taken up by organisms (including zooplankton, fish eggs, and fish larvae) can become more toxic than indicated by initial concentrations when exposed to ultraviolet radiation (e.g., sunlight) (Eisler 2000; Barron et al. 2002; Duesterloh et al. 2002).

Depending upon the concentrations and the forms of PAHs that are present, such contaminants can affect survival, growth, and reproduction of fish, especially eggs and larvae. In addition, different types and species of organisms have different sensitivities to these contaminants (Eisler 2000). Effects on eggs of Pacific herring were detected at concentrations as low as 0.7 ppb total aqueous PAHs (Carls et al. 1999), and effects on pink salmon embryos were observed at concentrations as low as 1 ppb total aqueous PAHs (Heintz et al. 1999). Survival of pink salmon larvae was affected when they ingested food containing approximately 1,305 ppm of PAHs derived from Alaska North Slope crude oil, and reduced growth was observed at food PAH concentrations of approximately 13 ppm (Carls et al. 1996). These findings indicate that bioconcentration of PAHs in tissues of invertebrates and fish could serve as a potential exposure pathway to other species.

This section discusses the potential impacts to fish from scenarios involving potential oil spills from the TAPS. Included in the evaluation are potential impacts from spills that enter freshwater or marine habitats in the vicinity of the TAPS ROW or the Valdez Marine Terminal. The potential volumes of oil released and estimated frequencies of occurrence associated with each of the evaluated spill scenarios are described in Section 4.4.1. Information about the degree to which oil from each spill scenario would be distributed in freshwater and marine habitats is provided in Sections 4.4.4.3 and 4.4.4.5, respectively.

Essential fish habitat consultation with NMFS was completed (Kurland 2002), including preparation of an EFH assessment that analyzed the effects of reasonably foreseeable spills on EFH (BLM 2002). In the EFH assessment, BLM concluded that while the proposed action might have short-term effects on EFH, the potential for such effects can be adequately avoided, minimized, and mitigated by measures associated with the proposed operation of the TAPS (BLM 2002b).

4.4.4.10.1 TAPS ROW. Although it is very difficult to precisely predict the effects of each spill scenario on fish in streams associated with the pipeline, in general, the effects of a crude oil spill from the TAPS would be a function of the amount of oil spilled (relative to stream discharge), the duration of exposure to spilled oil, and the sensitivities of the fish species and life stages present at the time of the spill. Thus, the relative level of adverse impacts for different spill scenarios was inferred on the basis of the volume of oil that would be introduced by a particular scenario, the length of stream habitat that the oil would travel through before containment, the length of time it would take the oil spill to pass through a particular area, the depth of the stream, and the fish resources present. The magnitude of oil spill effects to fish populations in a particular stream would also be related to the degree to which containment was effective at restricting downstream movement and recovering the spilled oil. The effects of an oil spill on freshwater habitats varies according to the rate of water flow and the habitat's specific characteristics. Standing water such as marshes or swamps with little water movement are likely to incur more severe impacts than flowing water because spilled oil tends to pool in the water and can remain there for long periods of time.

The portions of streams potentially affected by spilled oil under various spill scenarios, are identified in Section 4.4.4.3.

Spill scenarios with frequencies of greater than 0.5/year (described in Section 4.4.1 as *anticipated*) include smaller spills with volumes up to about 100 bbl. These scenarios include spills of crude oil, gasoline, turbine fuel, or diesel fuel and would occur over very short periods of time. As reported in Section 4.4.4.3, such a spill could produce a slick up to approximately 300 ft long in rivers such as the Tanana or Tazlina. Because of the smaller size and the short exposure duration as the oil slick passes through a particular reach, it is anticipated that such spills would have less effect on fish than would the larger spills described below unless the spill was into a very small stream. It is considered unlikely that such a spill would block or preclude movement of migrating fish or affect overwintering areas. However, because migrating salmon rely, in part, on chemical cues in water to identify natal streams, there is a possibility that even small oil spills could affect migration. In the event of a spill, APSC would likely use temporary structures, such as dams, portable Dunklee dams, inclined culverts, deflection booming (at culverts), underflow devices, and overflow dams to intercept and facilitate recovery of spilled oil. Such devices could also temporarily prevent or deter migration of fish during oil spill responses.

As identified in Section 4.4.1, the largest potential spill from a scenario considered *likely* (occurrence frequency of 0.03 to 0.5/year for the entire length of the pipeline) would be Scenarios 12 or 14 (Table 4.4-1). Under these scenarios, up to about 10,000 bbl of crude oil could be released over a prolonged period as a result of corrosion-related damage to the pipeline. A spill of this magnitude would be likely to cause moderate impact to fish in the affected portion if the oil was to enter a relatively small waterway. A spill of about 10,000 bbl of crude oil into the Pine River in British Columbia reportedly resulted in some fish mortality within the oiled area (Reuters World Environment News 2000a,b), although impacts to lower reaches of the river were reduced by containment efforts. However, impacts to streams along the TAPS could be greater if such a spill occurred during a sensitive period, such as migration or spawning, or if it occurred in a smaller stream.

Scenarios considered *unlikely* to *very unlikely* (as defined in Section 4.4.1) would involve a guillotine break in the pipeline caused by the crash of a helicopter or airplane (Scenarios 19a, 19b, and 21; Table 4.4-1). Such events would cause the largest spills to freshwater areas along the TAPS ROW and, presumably, the greatest impacts to fish. Depending on the rate of flow of individual streams and the time needed for spilled oil to drain from the pipeline, it is estimated that the length of oil slicks resulting from guillotine breaks in the pipeline would range from approximately 1 mi in the case of the Tanana River to about 13 mi in the case of the Sagavanirktok River (Table 4.4-15). It is estimated that the leading edge of the resulting oil slicks would travel between 13 and 48 mi downstream of the breaks during the average amount of time needed for oil spill response (Table 4.4-15). On the basis of the analysis provided in Section 4.4.4.3, it appears that containment of oil at designated containment sites will be incomplete or ineffective in some cases because the slick could completely pass by the designated containment sites before containment equipment could be deployed. In such cases, the portion of the stream in which fish could potentially be affected may be considerably longer.

If the assumption is made that the spilled oil would completely mix throughout the water column of the affected stream or river, an estimate of the proportion of oil to water can also be derived. Although this estimate may give some indication of potential concentrations in shallow streams, the ability of such an analysis to estimate concentrations in deeper rivers is limited because of the tendency of oil to float on the water surface. Thus, while oil may become distributed throughout a large proportion of the water depth in small streams (e.g., Minton Creek), only a small potion of the water column is likely to become mixed with oil in deeper streams (e.g., the Yukon River). With these limitations in mind, the estimated proportions of oil to water in the streams for guillotine break spill scenarios were developed by calculating the water volume passing a spill location during the drainage time required for the spill to be completed (Table 4.4-36). These calculations (which are based on the largest of the spill volumes for the three TAPS throughput cases) indicate that under scenarios with guillotine breaks in the pipeline, spilled oil would constitute a large proportion of the total volume in the smaller, shallower streams and somewhat smaller proportions of larger streams and rivers.

It is estimated that a guillotine break in the crossing over Minton Creek would result in 14 times more oil than water in the oil slick area under low-flow conditions and a mixture of 47% oil under high-flow conditions. It is clear that a very large proportion of the aquatic organisms located within the spill zone would be killed under such conditions. If this event occurred during the migration, spawning, or incubation periods for salmon, a whole year's production for the affected stream could be lost, and residual effects of the oil contamination would likely persist for years afterward.

If the oil became thoroughly mixed in the water column, it is estimated that a guillotine break in the pipeline at the river crossing over the Gulkana River would result in a mixture of about 11% oil under low-flow conditions and about 0.6% oil under high-flow conditions in the main slick (up to 1.5 mi long under low-flow and 10.1 mi long under high-flow conditions). As with the Minton Creek scenario, it is estimated that a considerable proportion of the fish in the affected stretch of the stream would be impacted under low-flow conditions. Because the Gulkana River is an important anadromous fish stream and supports a large fishery for both anadromous and resident fish species, such a spill could be especially severe. Similarly, the Copper and Lowe Rivers are especially important for salmon production in the vicinity of the southern portion of the TAPS ROW. If a large oil spill entered those rivers, severe impacts to salmon and the salmon fisheries supported by those rivers would likely result.

In the Yukon River, a similar scenario would result in about 0.05% oil under low-flow conditions and about 0.01% oil under high-flow conditions, with slick lengths of up to 4 to 9 mi

TABLE 4.4-36 Estimated Proportions of Oil to Water under High- and Low-Flow Conditions for Hypothetical Guillotine Breaks at Selected River Crossings

				Low Flow			High Flow		
Location	Milepost	Oil Spill Drain Time (s)	Volume of Spilled Oil (ft^3)	Discharge (ft^3/s)	Water Volume (ft^3)	Percent Oil in Water	Discharge (ft^3/s)	Water Volume (ft^3)	Percent Oil in Water
Sagavanirktok River	85	1,320	177,758	2,000	2,640,000	6.73	28,000	36,960,000	0.48
Yukon River	353	1,680	119,280	150,000	252,000,000	0.05	800,000	1,344,000,000	0.01
Minton Creek	510	4,260	302,983	5	21,300	1422.46	150	639,000	47.42
Tanana River	531	480	65,192	15,000	7,200,000	0.91	60,000	28,800,000	0.23
Gulkana River	654	2,220	156,805	600	1,332,000	11.77	12,000	26,640,000	0.59
Tazlina River	686	1,440	102,690	2,000	2,880,000	3.57	26,000	37,440,000	0.27

under low- and high-flow conditions, respectively. In larger and deeper waterways, such as the Yukon River, most of the oil discharged during a large oil spill would be located on the water surface and many of the fish and bottom-dwelling invertebrates would not be exposed to the oil as it passed over. However, organisms located in shallower shorelines of the affected rivers and eggs or larvae located near the water surface could still be affected by the spilled oil, and some mortality would be expected during an extremely large oil spill. In addition, the potential exists for adverse effects to fish and invertebrates from the aqueous phases of oil components (e.g., PAHs), which have the potential to become mixed through a greater portion of the water column.

In contrast, virtually all of the aquatic organisms in the contaminated portions of small streams such as Minton Creek and shallower rivers, such as the Gulkana, would probably be exposed to elevated and potentially lethal concentrations of crude oil in the event of a large break in the pipeline at or near a river crossing. However, as identified in Section 4.4.1, it is considered unlikely or very unlikely that such an event would occur.

This analysis indicates that fish and food resources in the immediate area of a spill could receive lethal or sublethal doses of oil, particularly if a spill occurred where and when fish were migrating, in overwintering areas during winter, or in small water bodies with limited water exchange. If an oil spill of sufficient size occurred in a small water body with restricted exchange, lethal and sublethal effects would be expected for most of the fish and food resources in that water body, and recovery could take several years. Sublethal effects could include changes in growth rates, feeding rates, fecundity, survival rates, and displacement of individuals. Other possible effects could include interference with movements to feeding, overwintering, or spawning areas, in addition to localized reduction in food resources and effects from consumption of contaminated prey.

4.4.4.10.2 Prince William Sound. Although large spills resulting from tanker accidents are not evaluated as part of TAPS operations (they are considered in the cumulative analysis, Section 4.7.4.4), the potential impacts from an unlikely catastrophic rupture of a crude oil storage tank at the Valdez Marine Terminal was evaluated. Under this scenario, it is estimated that a maximum of 143,000 bbl of crude oil could reach Port Valdez at the Valdez Marine Terminal (see Section 4.4.1.3.2). Hydrological modeling used to estimate the potential movement of the spilled oil in Prince William Sound indicated that the spilled oil would probably move up to 2 mi before it could be contained (Section 4.4.4.5). The model also indicated that between 44 and 80% of the spilled oil would become beached.

In open water, such as Prince William Sound, fish have the ability to avoid a spill by going deeper in the water or farther out to sea, thereby reducing the likelihood that they will be harmed by even a major spill. Fish that live closer to shore are at risk from oil that washes onto beaches or from consuming oil-contaminated prey. In shallow waters, oil may also harm invertebrates used as food or sea grasses and kelp beds that are used for feeding, shelter, or nesting sites by many different fish species. In addition, the Solomon Gulch Fish Hatchery is located near the Valdez Marine Terminal, and an oil spill in the vicinity could affect adult salmon returning to the hatchery or juvenile salmon leaving Solomon Creek.

There are concerns that oil deposited along the shoreline or that enters small streams in the vicinity of the Valdez Marine Terminal could affect fish populations, especially pink salmon that spawn within the intertidal zone. Following the Exxon Valdez oil spill, extensive field research was conducted along the shorelines and in the streams of Prince William Sound to evaluate whether the spill caused measurable impacts on the health or condition of aquatic organisms. Brannon et al. (1995) found no substantial effects on eggs, fry, or juvenile life stages of pink salmon from 1989-1991. Maki et al. (1995) found no significant relationship between the levels of polynuclear aromatic hydrocarbons and salmon escapement levels from 1989-1992 and were unable to detect significant differences in numbers of returns of spawning adult pink salmon between oiled and unoiled streams over the same period. Other studies (Sharr et al. 1994; Bue et al. 1996) reported that there were indications of higher pink salmon egg mortality in oiled streams, although results may have been confounded by the sampling protocol used (Brannon et al. 2001).

While long-term impacts to pink salmon may not have occurred as a result of the Exxon Valdez oil spill, research has indicated that relatively low concentrations of PAHs in water and sediments has a potential to affect aquatic organisms, and a major oil spill in the vicinity of the Valdez Marine Terminal could affect survival, reproduction, and growth of some species for a number of years. While other factors make it difficult to discern whether the Exxon Valdez oil spill is solely responsible, the Exxon Valdez Oil Spill Trustee Council considers a number of aquatic species and habitats in Prince William Sound as still not recovered from the spill (see Section 3.19.1.3).

4.4.4.11 Birds and Terrestrial Mammals

The impacts to wildlife from an oil spill would depend on such factors as the time of year and volume of the spill, type and extent of habitat affected, and home range or density of the wildlife species. For example, as the size of a species' home range increases, the effect of the oil spill generally decreases (Irons et al. 2000). Similarly, oil spill impacts are harder to detect for species with low densities. Section 4.4.4.1 provides information for land-based and Port Valdez spills, and Section 4.4.4.3 provides information for potential surface-water spills. The following discussion addresses the potential effects of oil spills on birds and terrestrial mammals. Potential impacts to marine mammals and listed species are addressed in Section 4.4.4.12.

The potential effects to wildlife from oil spills could occur from direct contamination of individual animals, contamination of habitats, and contamination of food resources (ADNR 1999). Acute (short-term) effects usually occur from direct oiling of animals; chronic (long-term) effects generally result from such factors as accumulation of contaminants from food items and environmental media (e.g., water) (Irons et al. 2000). Moderate to heavy contact with oil is most often fatal to wildlife. In aquatic habitats, death occurs from hypothermia, shock, or drowning. In birds, chronic oil exposure can reduce reproduction, cause pathological conditions, reduce chick growth, and reduce hatching success (MMS 1998). Even small quantities of oil on the surface of a bird egg can kill the embryo (Clark 1984). The reduction or contamination of food resources from an oil spill could also reduce survival and reproductive rates (MMS 1998). Oil ingestion during preening or feeding may impair endocrine and liver functions, reduce breeding success, and reduce growth of offspring (TAPS Owners 2001a).

Impacts of Oil Spills on Birds and Terrestrial Mammals

An oil spill would be expected to have a population-level adverse impact only if the spill was very large or contaminated a crucial habitat area where a large number of individual animals were concentrated. The potential for either event to occur is very unlikely. For a comparable oil-spill volume, a water-based spill would be expected to have a more extensive impact to wildlife than a land-based spill, because of the spatial extent of contamination within, and higher degree of difficulty to cleanup, a water spill.

The susceptibility of birds to an oil spill would depend upon a number of factors, including species and season. For example, some species may be most vulnerable during molt if they are not flight capable. Species that nest in concentrated colonies may be more vulnerable than species that have widely dispersed nests. Wintering concentrations of birds, especially in marine areas, could also be adversely affected if energetic needs are high and food becomes limited because of an oil spill. Oiling of feathers would also increase energetic demands (Anderson 2002). Oil reaching ponds or lakes can have long-term effects on invertebrate prey populations and emergent vegetation. These effects could reduce food availability, nesting habitat, and escape cover for birds in the area affected by the spill (Barsdate et al. 1980). A large spill in an area such as a lake used by geese during molting could affect hundreds of birds (BLM 1998). Piatt et al. (1990)

estimated that 100,000 to 300,000 birds were killed as a result of the Exxon Valdez spill; while Ford et al. (1996) estimated that 375,000 birds were directly killed by the EVOS, with a 5% lower bound and 95% upper bound range of 300,000 to 645,000, respectively.

A population-level impact from an oil spill could occur if (1) the spill was very large, and/or (2) caused a high loss of individuals of a species that has low reproductive rates, that congregates in only a few areas, that is rare, or that is already stressed (Piatt et al. 1990; MMS 1998). For example, although the Exxon Valdez oil spill killed only 1,000 to 2,000 Kittlitz's murrelets, that was a substantial fraction of a world population that may have numbered only a few tens of thousands. On the basis of survey data, the status for the recovery of Kittlitz's murrelet from the Exxon Valdez oil spill is still considered unknown (Exxon Valdez Oil Spill Trustee Council 2002).

The effects of EVOS on birds were most apparent shortly after the spill. Recovery of most species was well underway by late 1991. Most seabird habitat had returned to prespill conditions in all but a few localized areas by mid-1991. Seabird communities appear to have considerable resiliency to severe, but relatively short-term, perturbations, possibly because they can move over a regional scale (Wiens et al. 1996).

Bird species most susceptible to oil pollution of water bodies include loons, cormorants, grebes, sea ducks, auklets, murrelets, murres, guillemots, and puffins because they spend much of their time on the water surface, often congregate in dense flocks, depend on intertidal habitats close to shore, or may be flightless while undergoing a complete molt (Piatt et al. 1991). Some species that migrate at sea (e.g., red phalaropes) concentrate in areas such as tide rips, convergence lines, leads in ice, along spits, and in lagoons that are also the types of areas where spilled oil tends to concentrate (Troy 2000). Generally, species that dive for food were negatively affected by the Exxon Valdez spill, whereas those that feed on the surface were not affected (Irons et al. 2000).

Recovery of an affected population from a large oil spill could take one to two generations (two to six years) for common bird species or for species with high reproductive rates. Recovery would take longer for species that have a low reproductive rate (e.g., guillemots and murres) (MMS 1996; Golet et al. 2002). On the basis of survey data, the following conclusions have been reached regarding recovery of birds from the effects of the Exxon Valdez oil spill: (1) fully recovered — bald eagle, black oystercatcher, common murre; (2) recovering — marbled murrelet; (3) not recovering — common loon, cormorants (pelagic, red-faced, and double-crested), harlequin duck, and pigeon guillemot; and (4) recovery unknown — Kittlitz's murrelet (Exxon Valdez Oil Spill Trustee Council 2002). The lack of recovery for several species may be due to persistent oil remaining in the environment and reduced forage fish abundance, coupled with the lack of sufficient reproduction, survival, or immigration (Irons et al. 2000).

Oil spills that occur in aquatic systems could also affect some terrestrial mammals. For example, if a spill entered waters in the Gulf of Alaska during the middle of winter, Sitka black-tailed deer that forage heavily on kelp and other tidal vegetation during this time could be adversely affected. However, the Sitka black-tailed deer that feed on kelp are usually in a poor state of health and would be expected to die of starvation anyway. Deer in good health would not likely be on the beach (Ballard and Whitlaw 2002). A summer or fall spill that contaminated coastal streams, beaches, mudflats, or river mouths could be detrimental to brown bears that feed on fish during these seasons. River otter, beaver, muskrat, and mink are among terrestrial mammal species more vulnerable to the direct effects of oiling. They would have similar sensitivities as sea otters to a loss of thermal insulation and are also likely to ingest contaminants while attempting to clean their fur (MMS 1995). Survey data indicate that the river otter has recovered from the effects of the Exxon Valdez oil spill (Exxon Valdez Oil Spill Trustee Council 2002).

Terrestrial mammals exposed to oil are not as likely as birds to suffer from the loss of insulation. While most herbivores would avoid consuming oiled plants, contaminants could be absorbed through the skin, inhaled, or ingested (e.g., while trying to clean their fur) (MMS 1998). Duffy et al. (1996) reported that after exposure to crude oil, individual animals might exhibit acute and/or chronic immune system responses. They suggested that any subsequent secondary infections or tissue damage could lower individual survivorship and thus impact the population. Long-term, low-level contamination of food resources and habitats could cause chronic toxicity of terrestrial mammals because of the accumulation of hydrocarbon residues that may adversely affect physiology, growth, reproduction, and behavior (MMS 1995).

The Exxon Valdez incident caused the largest water-based oil spill (10.9 million gal) in Alaska history. The effects of that spill have been summarized in several key references, including (1) *Exxon Valdez Oil Spill: Fate and Effects in Alaskan Waters* (Wells et al. 1995), and (2) *Proceedings of the Exxon Valdez Oil Spill Symposium* (Rice et al. 1996). No comparably large land-based oil spills have occurred. Nevertheless, potential effects of land-based oil spills have been summarized in various oil and gas lease sale EISs (e.g., ADNR 1999; MMS 1995, 1996, 1998).

For purposes of analysis, a number of postulated surface-water spill scenarios have been identified for the proposed action. These scenarios include spills into a number of rivers and streams from the pipeline (Section 4.4.1) and spills into Port Valdez from the Valdez Marine Terminal (Section 4.4.1.2). Generally, small to moderately large pipeline spills (<100 to 10,000 bbl) would be *anticipated* (>0.5/yr) or *likely* (0.03 to 0.5/yr), respectively. In contrast, a large, catastrophic spill of up to 54,000 bbl (e.g., from a pipeline guillotine break) would be *unlikely* (10^{-3} to 0.03/yr) or *very unlikely* (10^{-6} to 10^{-3}/yr) (Section 4.4.1). A small to moderate spill at the Valdez Marine Terminal (0.02 to 1,700 bbl) into Port Valdez would be anticipated or likely; whereas the largest potential catastrophic spill of 143,450 bbl would be very unlikely. In addition to the volume and rate of the oil spill, the length of stream reach impacted would depend on stream flow rate and width for a spill to a river or stream, or on weather and tidal conditions for a Port Valdez spill. The longest slick from the maximum postulated spill into a river would be up to 3.2 mi long under low-flow conditions and up to 12.7 mi long under high-flow conditions. However, the stream length that would be contaminated by the slicks as it flows downstream cannot be predicted with certainty, although it would undoubtedly be a much greater length.

In contrast to a surface-water oil spill, which could be transported by the water, a land-based oil spill from the pipeline would contaminate a limited area. A number of land-based spill scenarios have also been identified for continued operations of the TAPS (Table 4.4-1). Generally, small to moderately large spills (≤100 to ≤10,000 bbl) would be anticipated to occur more than once every 2 years, to 0.03 to 0.5 times per year. Depending on the thickness of the spill, small to moderate spills would affect an area of 0.1 to <16 acres (0.0002 to 0.025 mi^2). In contrast, a large, catastrophic land-based oil spill of up to 54,000 bbl (e.g., from a guillotine break) would be unlikely to very unlikely, but if it did occur, it could contaminate an area from 1 to 84 acres (0.002 to 0.13 mi^2).

Given the estimated area potentially affected, a land-based oil spill would affect relatively few individual animals and a relatively limited portion of the habitat or food resources for large-ranging mammal species (e.g., moose, caribou, bear, and wolf) (ADNR 1999). A land-based spill would not cause significant impacts to movement (e.g., migration) or foraging activities at the population (herd) level, largely because of the vast amount of surrounding habitat that would remain unaffected (MMS 1998). The area impacted for even the largest potential spill from a guillotine break (i.e., 0.13 mi^2 [84 acres]) would be very small compared with the home range occupied by the larger wildlife species. For example, the Nelchina caribou herd occupies about 20,000 mi^2 (12.8 million acres), while in GMU 13 there is about 16,600 mi^2 (10.6 million acres) of wolf habitat, or about one wolf per 33 mi^2 (one wolf per 21,120 acres) (ADNR 2000b). Impacts to large mammals could result if an oil spill occurred in an important use or concentration area, such as denning sites, calving grounds, or insect relief sites. However, it is doubtful that more than a few individuals of any given species would be impacted by a land-based spill. Apparently no wildlife mortality from TAPS oil spills has been reported (Stephenson and Hunter 1999).

Generally, the small mammal species that have small home ranges and/or high densities per acre would be most affected by a land-based oil spill. Potential impacts to mammals can be estimated by comparing the spill area to the species' home range or density. For example, the maximum contaminated area of (0.13 mi^2) 84 acres could be inhabited by more than 6,100 shrews or more than 10,000 brown lemmings (Nowak 1991). Squirrels and other arboreal species would be able to avoid direct oiling, although portions of their habitat would be contaminated by the oil or otherwise impacted from spill response and restoration activities.

APSC has several response strategies to protect wildlife from an oil spill: (1) hazing birds and mammals to cause them to leave the area; (2) collecting dead, oiled wildlife to protect scavengers from feeding on contaminated carcasses; and (3) capturing and treating oiled birds (APSC 2000c). As necessary, any bird species can be hazed; the mammal species that can be hazed are caribou, musk ox, moose, brown bear, black bear, Dall sheep, American bison, mountain goat, gray wolf, Arctic fox, and red fox. Yearly permits from the Alaska Department of Fish and Game are required to haze wildlife, and hazing can only be performed by trained individuals. Hazing can also be performed to protect oil spill response workers from wildlife at spill sites, field camps, staging areas, waste disposal sites, and other areas. Wildlife hazing is allowed 2 mi to either side of the TAPS corridor, 2 mi to either side of Richardson and Dalton Highways, nonmarine areas within the Valdez Marine Terminal, one-half mile to either side of a river that is perpendicular to the TAPS or the highways (for a downstream distance of 30 mi), and 2 mi to either side of a river with portions that parallel within 2 mi of the TAPS or the highways (ADF&G 2002a,b).

Human presence and activities associated with response to spills of oil and other hazardous substances would also disturb wildlife in the vicinity of the spill site and spill-response staging areas. Such activities could be more intensive and prolonged than normal pipeline maintenance and operation and could disturb and displace larger numbers of animals. In addition to displacing wildlife from areas undergoing oil cleanup activities, habitat damage could also occur from cleanup activities. For surface water spills, birds could be disturbed by vessel traffic on the water and from other oil spill cleanup activities within their nesting, foraging, staging, or molting areas. Such activities could contribute to reduced reproductive success.

Disturbance could last for one or two seasons during cleanup operations, causing displacement of wildlife (e.g., caribou, musk ox, wolves, and wolverines) within 1 mi of these activities (MMS 1996). Some species, such as foxes and bears, could be attracted to human activity because of the possibility of finding food (ADNR 1999), although hazing would be conducted to protect workers. Avoidance of contaminated areas by wildlife during cleanup due to disturbance or hazing would minimize the potential for large herbivores to graze on the oiled vegetation before site cleanup is completed.

In summary, a spill would exclude large, wide-ranging terrestrial mammals from relatively small portions of their home ranges, although behavioral disturbance by spill response activities would extend the functional loss of habitat area. Temporary loss of available habitat would occur for birds and small mammals. Such losses would encompass a negligible portion of habitat available within the distributional range of such species. Wildlife habitat would be impacted for the length of time it takes for cleanup and restoration. This period could range up to several years or more.

4.4.4.12 Threatened, Endangered, and Protected Species

Spills that could occur as a result of the proposed action have the potential to affect threatened, endangered, and protected species. Impacts to these species can occur either directly through external contact (oiling) or ingestion or indirectly through the contamination of habitats or food supplies. These types of impacts were described previously in Section 4.4.4.9 (impacts to terrestrial vegetation and wetlands), Section 4.4.4.10 (impacts to fish), and Section 4.4.4.11 (impacts to birds and terrestrial mammals). This section examines the expected relative magnitude of impacts on threatened, endangered, and protected species that could occur when oil is spilled either on land or in the water. The assessment is based on the frequency, location, and volume of spills and the area that would be affected by spills. A summary of potential impacts is presented in Table 4.4-37.

The spill scenarios described in Section 4.4.1 serve as the basis for this analysis. The scenarios evaluated are representative of the range of spill volumes that could occur as a result of a variety of initiating factors including human error, equipment failure, corrosion, sabotage, natural events (e.g., washout, earthquakes), transportation accidents, and catastrophic accidents, such as a plane crash. Spills are categorized as *anticipated, likely, unlikely,* or *very unlikely*. It is important to recognize that, for pipeline spills, these probabilities represent the probability of occurrence for the entire pipeline, regardless of location. The probability of occurrence at any specific location (e.g., on the North Slope, where many of the threatened, endangered, and protected species occur, or at a particular river crossing) is much lower. In addition, the magnitude of impact to threatened, endangered, and protected species would be affected by the time of year in which the spill occurred. Spills that occurred during periods when these species were not present in the area would have less impact than if the spill occurred during the period of residence.

On the basis of the distribution of listed and protected species in the project area, spills are discussed for the North Slope (including the Beaufort Sea), the Interior Alaska, and Prince William Sound. Few of the listed or protected species are found in more than one of these regions. Spills are further categorized as spills to land or to water.

Spills to land on the North Slope have the potential to affect spectacled eider, Steller's eider, Arctic peregrine falcon, and polar bear. Impacts of a land spill could result from direct oiling of individuals (especially eiders), effects on the food base of species, and habitat impacts, such as reduced productivity and changes in the species composition of plant communities. The largest *anticipated* spill is 100 bbl, which could contaminate an area up to 0.15 acre. The largest *likely* spill is 10,000 bbl, which could contaminate an area up to 15 acres. Spills that are considered *unlikely* or *very unlikely* could be as large as 54,000 bbl (resulting from a guillotine break of the pipeline) and contaminate an area up to 84 acres. Although the amount of oil spilled in these scenarios is quite large, the size of the area that would be contaminated and require cleanup is relatively small, thus reducing the likelihood of impact to listed or protected species.

Spills to water bodies on the North Slope would have the potential to affect spectacled eider, Steller's eider, Arctic peregrine falcon, bowhead whale, beluga whale (Beaufort and Chukchi stocks), bearded seal, ribbon seal, ringed seal, spotted seal, Pacific walrus, and polar bear. For the most part, only very unlikely spills (e.g., the maximum release of 54,000 bbl to the Dan Creek/Sagavanirktok River resulting from a guillotine break of the pipeline) would have an important impact on listed or protected species and then only if the spill could not be contained before it entered the Beaufort Sea. Of these species, the spectacled eider, Steller's eider, Arctic peregrine falcon, beluga whale, spotted seal, and polar bear are the most likely to be adversely affected because they can occur along North Slope rivers and near the coast, where the impacts of a spill would be greatest. Other listed and protected species would not likely be adversely affected by even the worst-case spill because they use habitats farther from the coast where the effects of a spill would be minimal.

A number of factors would reduce the likelihood of adverse effects to listed or protected species from land spills associated with the proposed action:

- Any spills that occurred at the pump stations would be contained entirely within the pump station boundaries.
- Some, and perhaps most, oil leaked from the pipeline would remain on the graveled workpad.
- Underground leaks would not likely affect these species unless the oil ultimately

TABLE 4.4-37 Potential Impacts of Oil Spills on Threatened, Endangered, and Protected Species

Species	Status[a]	Time of Year	Locations	Potential Effect of Spill: Spill to Land	Potential Effect of Spill: Spill to Water
Birds					
American peregrine falcon	ESA-DM AK-SC	April – Sept.	Near rivers and lakes south of Brooks Range (MP 240–800)	Low-volume spills that are anticipated or likely to occur are not expected to have population-level effects. A high-volume, but very unlikely, spill could affect up to 84 acres of habitat but is not expected to result in a measurable change in the population.	Low-volume spills that are anticipated or likely to occur are not expected to have population-level effects. A high-volume, but very unlikely, catastrophic spill to a river could affect a large segment of the river and would affect habitat and the species' primary food supply (waterfowl).
Arctic peregrine falcon	ESA-DM AK-SC	April – Oct.	Near Sagavanirktok River (MP 0–110)	Same as American peregrine falcon.	Same as American peregrine falcon.
Blackpoll warbler	AK-SC	April – Oct.	Coniferous and mixed forest south of Brooks Range (MP 240–800)	Same as American peregrine falcon.	No effect because species is not dependent on aquatic or riparian habitats.
Eskimo curlew	ESA-E AK-E	NA	NA	No impacts anticipated because species is probably extinct.	
Gray-cheeked thrush	AK-SC	May – Oct.	Coniferous and mixed forest south of Brooks Range (MP 240–800)	Same as American peregrine falcon.	Same as blackpoll warbler.
Olive-sided flycatcher	AK-SC	April – Oct.	Coniferous forest south of Brooks Range (MP 240–800)	Same as American peregrine falcon.	Same as blackpoll warbler.

TABLE 4.4-37 (Cont.)

				Potential Effect of Spill	
Species	Status[a]	Time of Year	Locations	Spill to Land	Spill to Water
Spectacled eider	ESA-T AK-SC	May – Sept.	Wetlands and ponds of Arctic Coastal Plain (MP 0–40)	Low-volume spills that are anticipated or likely to occur are not expected to have population-level effects. A high-volume, but very unlikely, spill could affect up to 84 acres of habitat but is not expected to result in a measurable change in the population. Impacts of such a spill could result from loss of wetland habitat, effects on food base (aquatic invertebrates and plants), possible oiling of individual birds, and incidental ingestion of oil.	Low-volume spills that are anticipated or likely to occur are not expected to have population-level effects. A high-volume, but very unlikely, catastrophic spill to the Sagavanirktok River could affect a large segment of the river, including habitat in the river's delta in the Beaufort Sea. Impacts could result from habitat loss (shoreline wetlands), impacts to the food base (aquatic invertebrates and plants) and possibly oiling of individual birds. The generally low number of birds in the affected area would limit population-level impacts.
Steller's eider	ESA-T AK-SC	May – Sept. along ROW; winter in Prince William Sound	Wetlands and ponds of Arctic Coastal Plain (MP 0–40); Prince William Sound	Same as spectacled eider.	Same as spectacled eider.
Townsend's warbler	AK-SC	April – Oct.	Coniferous forest in Yukon River valley (MP 540–800)	Same as American peregrine falcon.	No effect.
Mammals					
Bearded seal	MMPA-P	All year	Beaufort Sea	No effect.	Low-volume spills that are anticipated or likely to occur are not expected to have population-level effects. A high-volume, but very unlikely, catastrophic spill to the Sagavanirktok River could affect this species if the spill were not contained before it entered the Beaufort Sea. Impacts to the species could result from impacts to the food base, oiling of individual animals, and incidental ingestion of oil.
Beluga whale Beaufort Sea and Chukchi stocks	MMPA-P	Summer	Beaufort Sea	No effect.	Same as bearded seal.

TABLE 4.4-37 (Cont.)

Species	Status[a]	Time of Year	Locations	Potential Effect of Spill: Spill to Land	Potential Effect of Spill: Spill to Water
Beluga whale Cook Inlet stock	MMPA-D	Winter	Prince William Sound	No effect.	Spills at the Valdez Marine Terminal are not expected to affect species because spill response and cleanup actions are expected to limit the area affected within Port Valdez.
Bowhead whale	ESA-E MMPA-D AK-SC	Summer	Beaufort Sea	No effect.	Same as bearded seal.
Dall's porpoise	MMPA-P	All year	Prince William Sound	No effect.	Same as beluga whale, Cook Inlet stock.
Fin whale	ESA-E MMPA-D	April – June	Prince William Sound	No effect.	Same as beluga whale, Cook Inlet stock.
Gray whale	ESA-D MMPA-P	Late spring and early fall	Prince William Sound	No effect.	Same as beluga whale, Cook Inlet stock.
Harbor porpoise	MMPA-P	All year	Prince William Sound	No effect.	Same as beluga whale, Cook Inlet stock.
Harbor seal	MMPA-P	All year	Prince William Sound	No effect.	Low-volume spills that are anticipated or likely to occur at the Valdez Marine Terminal are not expected to have population-level effects. A high-volume, but very unlikely, spill resulting from a catastrophic rupture of a crude oil storage tank at the Valdez Marine Terminal could affect the population inhabiting Port Valdez through food base effects, oiling individual animals, incidental ingestion of oil, and contamination of shoreline habitats.
Humpback whale	ESA-E MMPA-D AK-E	Summer	Prince William Sound	No effect.	Same as beluga whale, Cook Inlet stock.
Killer whale	MMPA-P	All year	Prince William Sound	No effect.	Same as beluga whale, Cook Inlet stock.

TABLE 4.4-37 (Cont.)

Species	Status[a]	Time of Year	Locations	Potential Effect of Spill: Spill to Land	Potential Effect of Spill: Spill to Water
Minke whale	MMPA-P	Summer	Prince William Sound	No effect.	Same as beluga whale, Cook Inlet stock.
Pacific walrus	MMPA-P	Summer	Beaufort Sea	No effect.	Same as bearded seal.
Pacific white-sided dolphin	MMPA-P	All year	Prince William Sound	No effect.	Same as beluga whale, Cook Inlet stock.
Polar bear	MMPA-P	All year	Beaufort Sea	Low-volume spills that are anticipated or likely to occur are not expected to have population-level effects. A high-volume, but very unlikely, spill could affect up to 84 acres of habitat but is not expected to result in a measurable change in the population. Impacts would result from habitat loss (tundra), possible oiling of individuals, and incidental ingestion of oil.	Low-volume spills that are anticipated or likely to occur are not expected to have population-level effects. A high-volume, but very unlikely, catastrophic spill to the Sagavanirktok River could affect this species if the spill were not contained before it entered the Beaufort Sea. Impacts to the species could result from impacts to the food base, oiling of individual animals, incidental ingestion of oil, and impacts to riverine shoreline habitat.
Ribbon seal	MMPA-P	All year	Beaufort Sea	No effect.	Same as bearded seal.
Ringed seal	MMPA-P	All year	Beaufort Sea	No effect.	Same as bearded seal.
Sea otter	MMPA-P	All year	Prince William Sound	No effect.	Same as harbor seal.
Spotted seal	MMPA-P	July to Oct.	Beaufort Sea	No effect.	Similar to bearded seal. Potential impact greater than for other seals because spotted seal uses coastal and river mouth habitats.
Steller sea lion	ESA-E MMPA-D AK-SC	All year	Prince William Sound	No effect.	Same as harbor seal.

[a] Notation: ESA = listed under the Endangered Species Act with the following qualifiers: E = endangered, T = threatened, D = delisted, DM = delisted but being monitored; AK-SC = Alaska species of special concern; MMPA = listed under the Marine Mammal Protection Act with the following qualifiers: D = depleted, P = protected.

entered surface water or came to the ground surface.

- The probability that a spill would occur in areas where listed or protected species are present on the North Slope is only 14% of the probabilities for the entire pipeline.
- For land spills, the maximum area that could be affected is small and, because the estimate is based on very conservative assumptions, the spill area is likely to actually be much smaller.
- Spill response actions described in Section 4.2 would reduce the area affected by a spill and result in cleanup and restoration of the spill area.
- Most species are present in the project area for only a portion of the year, thus reducing the likelihood of any direct spill effects such as oiling.
- Listed and protected species occur in low densities in the project area, which greatly reduces the number of individuals that could be affected by a spill.

No federally listed species occur along or in the vicinity of the pipeline in the interior, between the Brooks Range and Prince William Sound (MP 240 to 800). Several species in this region, however, are considered species of special concern by the State of Alaska. These species include American peregrine falcon, blackpoll warbler, gray-cheeked thrush, olive-sided flycatcher, and Townsend's warbler. The American peregrine falcon was recently removed from the federal list of threatened and endangered species.

Low-volume spills, considered anticipated or likely during the 30-year renewal period, would generally be expected to have only very small, if any, impact if the spill occurred on land because of the relatively limited area that could be affected (0.15 acre or less). High-volume spills, considered unlikely or very unlikely to occur, are expected to have minor impacts because these spills also would affect relatively small areas of land (84 acres or less). All of the species occupy forested areas and spend little, if any, time on the ground. They are, therefore, unlikely to come into contact with spilled oil. An impact would only be expected if spilled oil resulted in the loss or modification of forest habitat used by the species.

Spills to water bodies in the interior are not likely to have an effect on any of the species of concern except for the American peregrine falcon. The falcon could be affected by a high-volume spill into a river such as the Yukon River or Tanana River. Such a spill is likely to contaminate large stretches of river and shoreline because the flow in these high volume rivers would carry spilled oil far downstream before the spill could be contained. The impact to the peregrine falcon of a high-volume spill into a river is potentially large because it could affect waterfowl, which are an important food of the falcon. The probability of a high-volume spill occurring somewhere along the pipeline is considered unlikely or very unlikely. The probability of such a spill occurring at a river crossing is much smaller still because river crossings are a small portion of the entire pipeline.

Threatened, endangered, and protected species in Prince William Sound include Steller's eider, beluga whale (Cook Inlet stock), Dall's porpoise, harbor porpoise, Pacific white-sided dolphin, killer whale, fin whale, gray whale, humpback whale, minke whale, harbor seal, Steller sea lion, and sea otter. These species would only be affected by a spill at the Valdez Marine Terminal if oil entered Port Valdez. Several of the scenarios examined would result in oil or fuel entering Port Valdez. Anticipated spills would result in very small volumes (0.5 bbl or less) entering Port Valdez. Spills of this size are expected to have negligible impact on listed and protected species. The largest likely spill (frequency of 3 in 100 years or 1 during the renewal period) would result in the release of 1,700 bbl of oil into Port Valdez. A spill of this volume would contaminate a limited area near the Valdez Marine Terminal and could result in minor short-term impacts to listed and protected species. Spill response, containment, and cleanup would limit the duration of exposure and impact.

Catastrophic rupture of a crude oil storage tank (e.g., foundation or weld failure) at the Valdez Marine Terminal could result in a release of 143,450 bbl into Port Valdez. A spill of this magnitude would be expected to move less than 2 mi before it was contained (see Section 4.4.4.5) and 70% of the oil would remain near the shoreline. Species most likely to be affected by such a spill include harbor seal, Steller sea lion, and sea otter, which utilize shoreline habitats. Other species (whales, porpoises, and dolphins) might be able to avoid the spill area in response to the spilled oil and increased human activity in response to the spill and thus would be less likely to be affected. Impacts would result from impacts to the food base, possible oiling of individuals, incidental ingestion of oil, and contamination of shoreline habitats. Because of the limited area that would be affected by this "worst-case" spill, impacts to listed and protected species would be expected to be reduced.

4.4.4.13 Economics

The economic impacts associated with spills include the impacts that might result both directly from degradation of land and other natural resources, and indirectly to state and local governments as a result of lost oil revenues during periods when the pipeline would be shut down for repair and cleanup activities following a spill. The potential direct economic impacts of spills include impacts to recreation, tourism, and fishing mainly in rural locations, and the impacts on property values and local economic activity, primarily in urban locations. The relative importance of the direct and indirect impacts of potential pipeline spills would depend on the size and, to a lesser extent, the location of the spill. For smaller spills that would not require suspending pipeline operations, direct impacts would be primarily a local concern because these impacts would occur in the immediate vicinity of the spill location. Larger spills requiring shutdown of the TAPS would have far more substantial and far-reaching impacts in terms of losses of oil tax revenues to the state and local governments. Offsetting these losses would be the additional employment and income generated if cleanup activities required the hiring of additional spill response staff. Discussion of the impacts of the Exxon Valdez spill and the potential impacts of spills in Prince William Sound are included in Section 4.7.8.3.

4.4.4.13.1 State and Local Oil Revenues. The state and local governments benefit from a variety of tax revenues levied on oil production and transportation through the TAPS. At the state level, production taxes and royalties produce approximately 75% of state oil revenues and roughly 30% of the overall state budget. Other sources of oil revenue include bonuses, rents, corporate income taxes, and property taxes (Section 3.23.3.5). At the local level, oil revenues constitute approximately 10% of overall revenues, with 40% of property tax revenues coming from the oil industry. Local governments also receive substantial transfers from the state that would also be affected by any fall in oil revenues collected by the state.

Impacts of Oil Spills on State and Local Revenues

A spill from TAPS that would result in lost throughput could have an important impact on state revenues, with production taxes and royalties currently producing about 75% of state oil revenues. At the state level, with a throughput level of 1.1 million bbl/d, shutting down TAPS for a single day could mean that almost $3.5 million in royalties and production taxes would be lost. At the local level, spills would directly impact property taxes, and would also indirectly affect transfers made to local governments from revenues collected by the state.

Table 4.4-38 shows the impact that a spill could have on state revenues for a single day in 2004. In order to bound the impacts of all potential spills from the TAPS, impacts are shown for three representative throughput levels corresponding to (1) the design capacity of the pipeline (2.1 million bbl/d), (2) the minimum economic capacity (0.3 million bbl/d), and (3) the base case (1.1 million bbl/d). While it may be the case that pipeline throughput could be increased to compensate for oil losses, the likelihood, timing, and quantity of any increases is not certain. The analysis therefore assumes that spills that occur lead to losses in revenues that are not subsequently recovered from increased throughput in order to provide an upper bound to the analysis. The year 2004 was chosen in order

TABLE 4.4-38 Impacts of Spill Scenarios on Daily State Revenues in 2004 (thousands of 2000 dollars except where noted)

	No TAPS Throughput[a]	State Revenues, per TAPS Throughput Level ($\times 10^6$ bbl/d)			Percent % of State Revenues Lost by Throughput Level ($\times 10^6$ bbl/d)		
	0.0	2.1	1.1	0.3	2.1	1.1	0.3
Total oil revenues	289	6,649	3,787	1,569	96	92	82
Royalties	157	3,786	1,958	541	96	92	71
Production taxes	44	2,140	1,107	306	98	96	85

[a] Production at Cook Inlet only.

to present impacts in the year that would have a forecasted throughput value (1.086 million bbl/d) (Section 4.3.19.1) closest to the base case used for the analysis (1.1 million bbl/d).

Table 4.4-38 shows daily state oil revenues at the three throughput levels, together with a reference minimum case corresponding to revenues collected by the state only from production at Cook Inlet, with no North Slope production or TAPS operation. Only the major sources of revenue — royalties and production taxes — are shown in detail; the other sources of revenue are included in the total. The percentage of state revenues lost at each of the three throughput levels are shown. At the 1.1 million bbl/d level, for example, shutting down the pipeline for a single day could mean that almost $3.5 million in royalties and production taxes would be lost. Pipeline spills that result in periods of lost throughput that last longer than a single day can be estimated by multiplying these impacts by the number of days of lost operation.

4.4.4.13.2 Recreation and Tourism. Numerous locations in the pipeline corridor are used for hunting, fishing, and other forms of recreation and general tourist activity, particularly areas north of Fairbanks. Many of these areas have developed because they are easily accessible from the Richardson/Elliott/ Dalton Highway complex. There is also significant recreation in the vicinity of Valdez in the Wrangell-St. Elias NPP and in Prince William Sound. Activities in these areas could be affected by spills, depending on the location and extent of the spill, length of cleanup time, and extent to which land, water, and scenic resources were returned to prespill conditions.

Smaller spills would be likely to significantly affect only limited amounts of land used for recreation and tourism. However, given the limited road network in many of the areas through which the pipeline passes, spill response and cleanup might effectively close the road network for periods of time and therefore limit access to areas frequently used for recreation and tourism. Larger spills might not only limit access to the affected area but also produce long-term damage to larger portions of a particular type of environment not found in areas with similar road access, thus potentially impacting visitor rates in these areas.

For both smaller and larger spills, the economic impact of any decline in visitor rates in tourist and recreational areas would be likely to be small. Visitors would not be present in any great numbers in any of these areas, and as long as the road network was not closed for significant periods and there was no long-term damage to broad areas of natural resources or landscape, long-term trends in visitor rates

Economic Impacts on Recreation and Tourism

The overall economic impact of spills on recreation and tourism would likely be small, although there might be impacts at the local level. Apart from the visitor centers, few visitors go to many of the areas in which the pipeline is located, and the majority of spills would not be likely to have any long-term effect on road networks or damage natural resources or types of landscape that are not present elsewhere in the state.

Impacts of Oil Spills on Property Values and Overall Economic Activity

While spills might affect property values in all areas along the pipeline, impacts might only be measurable in locations where the market value of land and real estate can be established. Spills might affect property values in Fairbanks, where there are a number of alternate local uses of potentially affected land. In the North Slope Borough and in Valdez, however, for much of the land, there is little established alternate use, consequently limiting possible impacts on property value. Spills might affect overall economic activity if critical infrastructure was affected and if local labor and other resources were diverted into cleanup activities. Positive employment and income effects might occur if additional cleanup staff was required.

would not likely be affected. The local and state economic impacts of potential spills to recreational resources or tourism would therefore likely be minimal. More information on the impact of spills on land use and recreation in specific locations along the pipeline is provided in Sections 4.4.4.17 and 4.4.4.18.

4.4.4.13.3 Property Values and Changes in Economic Activity. Contamination of land or buildings resulting from a spill has the potential to affect property values in a particular location and overall economic activity in a wider geographic area. The nature and extent of the impact would depend on the location of the spill, the extent and nature of the damage, and the time taken for the cleanup process to return the affected property or activities to normal.

While property values could potentially be adversely affected at all locations along the pipeline, measurement of these losses might be possible only in locations where land has a clearly established market value and where the value of property is estimated for the assessment of property taxes. Property taxes are collected at three jurisdictions along the pipeline — Fairbanks North Star, North Slope, and Valdez-Cordova. The potential impacts of spills to property values would largely depend on the proximity of the pipeline to other local economic activities. These areas are mostly in population centers and in commercial and industrial developments that might be located in either urban or rural areas. The pipeline ROW is adjacent to a population center only in Fairbanks, where it is located within the city limits; to a much lesser extent, in Valdez, where it is located some 12 road miles from the Valdez Marine Terminal; and in Prudhoe Bay, where it is located approximately 5 mi from the community of Deadhorse.

A spill in Fairbanks has the potential to affect property values, since some commercial and residential activities are located close to the pipeline ROW within the city limits and along the Richardson/Elliott Highway north and east of the city. However, this area contains relatively low-density development; the main population center is located about 7 mi to the southwest of the pipeline itself. The likelihood of a spill producing long-term effects to many buildings or on more than a small number of land parcels is relatively small. In the North Slope Borough and in Valdez-Cordova, there are few other economic uses for land in the vicinity of the pipeline ROW. It is therefore unlikely that a spill would have any significant impact on local property values in either area.

In addition to the impacts on property values, spills might also impact overall economic activity in a location. Smaller spills would be more likely to affect economic activity if key resources, such as local agricultural products, industrial materials, and other supplies, were temporarily unavailable, since spill response and cleanup activities have priority over local road networks. Critical infrastructure, such as bridges, key road segments, port facilities, or an airport, might also be taken out of use as a result of the spill or subsequent cleanup. While the impacts of small spills such as these might create a certain amount of disruption in the local economy, the effects on employment, income, and tax revenues would likely be minor and short term. In addition, since the existing labor force would probably be able to provide teams to handle spill response and cleanup, there would likely be little or no additional impact on local employment, income, and tax revenues.

Larger spills might create additional problems if the demand for local resources for spill response and cleanup efforts was such that economic resources were diverted from normal uses. Fuel, water, or other supplies, for example, might be needed to deal with a larger spill, and use of these resources for spill control and cleanup might be given priority over normal local uses. Temporary losses of employment, income, and tax revenues might occur as a result. Spill response teams might need to hire additional people for spill response and cleanup. While this would offset losses in employment and income elsewhere in the local economy, additional burdens might also be placed on state and local government budgets if a large spill response or cleanup workforce moved into an area, thereby impacting the ability of local authorities to continue to provide public services at current levels.

Impacts of Oil Spills on Subsistence Resources

Severe negative impacts to subsistence fisheries would accompany high-volume spills in rivers or streams under certain conditions (shallow river or stream, low flow, key period in resident or anadromous fish life cycle).

Impacts to subsistence fisheries also are possible from spills of smaller volumes (e.g., 10,000 bbl) in rivers or streams, although such impacts would be more dependent on the nature of the waterway and the timing of the spill than would the consequences of a large spill.

Negative impacts to terrestrial subsistence activities could result from large spills that produced high, population-level impacts on birds and terrestrial mammals. However, the tendency towards geographic dispersion of many terrestrial subsistence resources, coupled with the geographic size of terrestrial subsistence use areas and the distance of much (or all) of each such areas from the TAPS, suggests that impacts likely would be small.

Under the spill scenarios considered for Prince William Sound for the proposed action, as much as 143,000 bbl of oil could reach the water from a catastrophic tank failure at Valdez Marine Terminal. Current spill response practices likely would limit the dispersal of such a spill to less than 2 mi of coastline. Anticipated subsistence impacts would be limited, given this small area and the location of the spill with respect to known subsistence use areas.

4.4.4.14 Subsistence

Certain spill scenarios presented in Section 4.4.1 have important implications for subsistence along the TAPS ROW. How spills would affect subsistence resources and activities generally varies for different categories of geographic settings — with spills in terrestrial settings differing in important, fundamental ways from spills in rivers and spills in Prince William Sound. Spills would also vary in frequency, or likelihood of occurrence, and magnitude. Less probable events would tend to yield larger-volume spills compared with more likely events. The spill scenarios summarized in Tables 4.4-1 and 4.4-2 present four categories of spills — *anticipated* (>0.5/yr), *likely* (0.03 to 0.5/yr), *unlikely* (10^{-3} to 0.03/yr), and *very unlikely* (10^{-6} to 10^{-3}/yr) — with accompanying estimates of spill volumes.

This section examines spills in each of the three main types of geographic settings and for each spill frequency category separately. The evaluation also considers impacts of transportation-related accidents, summarized in Table 4.4-3, that could affect both terrestrial and river settings. However, because the spill volumes for transportation accidents all would be well below those described for pipeline operations, their impacts on subsistence would be less than the impacts of the other scenarios considered.

Terrestrial spills could occur in all four frequency categories and as a result could involve a wide range of release volumes — from a few barrels of oil to tens of thousands of barrels (see Table 4.4-1). Small terrestrial spills, including those in the *anticipated* and *likely* frequency categories and those based on lower pipeline throughput, although often more probable than large-volume spills, would have smaller impacts on terrestrial subsistence resources than the larger releases discussed in the following paragraphs.

Under a worst-case accident, a guillotine break in the pipeline could produce a spill as large as 54,000 bbl of crude oil under both *unlikely* and *very unlikely* scenarios (see Table 4.4-1). Shallow (1-in.-deep) oil coverage in relatively flat terrain during the highest pipeline throughput considered could affect up to 84 acres (see Table 4.4-5). Although this large coverage was estimated to occur in a particular area along the TAPS (MP 410 to 411), its precise location has little importance in terms of key terrestrial subsistence resources. Impacts would be small in comparison to the terrestrial resources relied upon available to by any of the rural communities examined in the FEIS (see Section 3.24, Appendix D). Although subsistence resources might be damaged, they would primarily be those that could not move or otherwise avoid the effects of the spill, primarily plant resources (berries, wood for fire or construction, etc.) (see Section 4.4.4.9) and smaller animals with limited home ranges (see Section 4.4.4.11). Most of the subsistence resources found in terrestrial settings that are important to rural Alaskans, namely small and large mammals and birds, for the most part could avoid the impact area with little or no effect on their populations or areas of activity. Access to terrestrial subsistence resources thus would change little, and overall impacts would likely be quite small, even when large spills were involved.

In the analysis of impacts on birds and terrestrial mammals resulting from a large spill, it is concluded that high, population-level negative impacts could occur should the spill affect a large concentration of animals (see Section 4.4.4.11). Although a large-scale impact of this nature could have serious adverse implications for terrestrial subsistence, the tendency for key terrestrial subsistence resources to be geographically dispersed, coupled with the large size of subsistence-harvest areas (enabling hunters to easily avoid spill areas) and the distance of much (or all) of each area from the TAPS, suggest that impacts to subsistence likely would be small. This conclusion assumes that the main impact would be a need to relocate subsistence activities to avoid an area with a maximum extent of 84 acres — possibly an inconvenience, but certainly possible given modern transportation technology and the tendency for subsistence users to range over large areas.

In contrast to spills on land, spills into rivers could have much more serious consequences for subsistence. The evaluation of spills on fish provides a sense of the impacts under various conditions (see Sections 4.4.4.3 and 4.4.4.10). Impacts would vary considerably under different conditions — the key variables being spill volume, waterway characteristics (primarily amount of water flowing through a river and water depth), and timing of a spill with respect to life cycles of the affected subsistence resources. The most serious conditions would be a large spill in a small waterway under low-flow conditions during a sensitive period of anadromous or resident fish life cycles (e.g., spawning, overwintering), although any of these circumstances individually could have serious consequences for subsistence fisheries. If such impacts on subsistence resources occur as a result of the TAPS, compensation for damages could be available under Section 30 of the Federal Grant (see Appendix B).

Small, more probable spills would have lesser impacts on subsistence resources in rivers than would large, less likely spills. The particular conditions surrounding the spill would play an important role in the magnitude and nature the impacts experienced. Small volume spills of the *anticipated* frequency would have lesser subsistence impacts than would the larger spills associated with lower-probability events. However, the consequences of these (as well as larger) spills could include changes in growth rates, feeding rates, reproduction, survival, and displacement of individual fish — all with potentially important, although delayed, implications for subsistence. Spill scenarios considered under *likely* probabilities could lead to releases of up to 10,000 bbl. Such a spill could have moderate to serious impacts on fish, and hence subsistence fishing, if it occurred during a sensitive period in the life cycle of the fish species involved or occurred in a small stream or shallow river (see Section 4.4.4.10).

The highest volume spills would occur under an *unlikely* or *very unlikely* scenario — a guillotine break in the pipeline caused by a fixed-wing airplane crash or helicopter crash (up to 54,000 bbl released). The amount of river affected would depend on rate of stream flow and time required for the oil to drain from the pipeline. Estimated lengths of stream affected, depending on spill response time and effectiveness of response, could exceed 47 mi in the case of the Tanana River (see Table 4.4-14). A broad range of possible spill conditions has been projected in Section 4.4.4.10, from Minton Creek (low water volume, yielding high oil-to-water concentrations) to the Yukon River (large water volume, yielding low oil-to-water concentrations). Impacts on subsistence fisheries would vary accordingly.

In larger, deeper rivers, such as the Yukon, impacts of relatively low concentrations of oil (because of large water volume) likely would be limited to organisms located near the shoreline and eggs and larvae on the surface of the exposed area. Subsistence impacts in such a situation would be limited, although fear of contamination might cause subsistence users upstream and downstream to avoid salmon (despite its importance). In contrast, in small streams and shallower rivers (e.g., the Gulkana River), concentrations of crude oil from a spill of the magnitude considered here likely would be lethal to virtually all aquatic organisms. Subsistence impacts for these smaller-volume or shallower waterways would be large. In the case of the Gulkana River, people in the communities of Copper Center, Gakona, Glennallen, Gulkana, Kenny Lake, Paxson, Tazlina, and Tonsina all rely to one degree or another on this body of water for subsistence and thus would experience impacts from such a spill (Appendix D). Moreover, such a spill could affect subsistence upstream as well as downstream from the event, if nothing else through perceived damage to subsistence resources. That stated, once again is it is very unlikely that such an event would occur. For example, as discussed in Section 4.4.4.3.1 the likelihood of a helicopter crash presented in Table 4.4-1 (2.9×10^{-5}) is for the entire length of the pipeline. The likelihood of such a crash involving a specific 300-ft length of bridge crossing a particular river or stream would be much less — about 1 in 255 million.

Oil spills into Prince William Sound from the TAPS constitute a third category of potential accidents that could result in subsistence impacts. Note that subsistence impacts of tanker spills are not considered in this section, but in Section 4.7.8.1 (cumulative impacts). Spills of the *anticipated, likely,* and *unlikely* frequency categories would be more probable than would a *very unlikely* spill event but would yield much smaller impacts than those discussed below for the *very unlikely* category. However, even for the more frequent, lower volume spill categories, perceived problems with various resources might preclude subsistence activity in a geographic area larger than that actually affected by a spill, although in the cases of these more probable spills, the areas actually affected would be quite small (see Fall 1999a; Fall and Utermohle 1999).

The *very unlikely* spill scenario involving a catastrophic rupture of a crude oil storage tank could allow more than 143,000 bbl of oil to reach the waters of Port Valdez at the Valdez Marine Terminal (see Table 4.4-2). Despite this large volume, hydrological analysis suggests that the spilled oil likely would affect 2 mi or less of shoreline before containment by spill response efforts, with about 70% of the oil remaining close to the shoreline (see Section 4.4.4.5.4). Various subsistence resources — fish, invertebrate marine species, seabirds and shorebirds, and possibly certain marine mammals (e.g., sea otters) — could all be adversely affected by such a spill. However, given the limited spatial dispersal of oil under this scenario, the area affected would be small relative to the entire Prince William Sound and its coastline. The subsistence resources likely subjected to the greatest impacts would be those that could not avoid the oil, primarily those living near the shore and unable to move quickly, such as certain marine invertebrates, and those living at or near the affected shoreline. In all such situations, impacts should be limited by the expanse of the spill and by response capabilities. Impacts to subsistence resources are not expected to be large, because of the relatively small geographic dispersal of the spill, the small subsistence harvest area near the spill site (a small salmon fishing site for Tatitlek — see Map D-24), and the likely ability of subsistence users to shift their activities (if necessary) to avoid the relatively small area affected. Any relocations should not be so large as to add much to the time spent in subsistence travel, and the amount and types of resources affected should not require changes in species harvested, as occurred following the Exxon Valdez oil spill (Fall and Utermohle 1999). Finally, the magnitudes of subsistence impacts from even a large spill in Prince William Sound under the scenarios considered here should not be sufficient to disrupt exchange patterns or the instruction of young persons in subsistence activities (see IAI 2001), once again as occurred following the Exxon Valdez spill. That stated, the perception that subsistence resources are dangerous or otherwise unusable might have a broader geographic impact, recalling issues associated with scientific evaluations and perception once again associated with the Exxon Valdez spill (Fall 1999a). Moreover, adjustments to a spill in the form of modified use areas would introduce impacts themselves, such as increased cost of travel (in terms of fuel and time) and increased absence from the home community.

It is important to acknowledge that subsistence impacts of any spill would in part be a function of the magnitude and location of the spill and in part a function of the timing and thoroughness of spill response. The APSC maintains spill response plans for a range of such eventualities (APSC 2001l). Rapid, efficient implementation of these plans would serve to reduce impacts to subsistence resources and hence to subsistence.

Impacts of Oil Spills on Sociocultural Systems

High-volume spills in rivers or streams under certain combinations of conditions (shallow river or stream, low flow, key period in resident or anadromous fish life cycle) could have severe impacts on river resources and could lead to possible major disruption in economies emphasizing subsistence. Use of local crews to conduct spill cleanup could provide wage employment to rural Alaskans for whom such employment often is difficult to find. Both of these impacts could affect Alaska Native and as well as rural non-Native sociocultural systems.

4.4.4.15 Sociocultural Systems

Spills evaluated for the proposed action could have varying effects on a range of resources upon which Alaska Native and rural non-Native sociocultural systems rely and, depending on the situation, could possibly affect the sociocultural systems themselves.[9] Impacts of spills on sociocultural systems, as discussed below, largely are anticipated to be small, although some could be large under certain *unlikely* and *very unlikely* spill scenarios. In general, impacts would vary with the size of area affected, the duration of the effects, and the amount of critical resources affected. The magnitude of sociocultural impacts likely would differ between terrestrial spills, spills in rivers, and spills in Prince William Sound, primarily because of their potential for geographic dispersal, the availability of alternative resources, and the potential to generate long-term adaptive changes. Accordingly, the evaluation here discusses these three major geographic settings separately, exploring the four main frequency ranges in each.

Terrestrial spills, even the largest events categorized as *likely* or *very unlikely*, are not expected to have major effects on sociocultural systems. Such systems comprise the collection

9 Impacts on other resources with possible sociocultural corollaries are discussed elsewhere in Section 4.4.4, including a variety of biological resources (Sections 4.4.4.8 through 4.4.4.12), the economy (Section 4.4.4.13), and subsistence (Section 4.4.4.14).

of beliefs, ideas, behavioral patterns, and tools that humans use to adapt to their physical and social surroundings. By their very nature, sociocultural systems adapt to changing conditions. Although a large terrestrial spill might indeed devastate a piece of ground as large as 84 acres (see Section 4.4.4.1) and have large negative impacts on local bird or terrestrial mammal populations (see Section 4.4.4.11), current estimates do not indicate that even the largest spill would directly affect any Alaska Native villages or rural non-Native communities considered in this FEIS. Even if a spill affected land relied upon by some or all members of an Alaska Native or non-Native community, the area affected would be small enough to enable those individuals affected to shift their activities to avoid the spill area and focus on terrestrial resources elsewhere without undue difficulty. Shifts in adaptive patterns would not occur, except possibly as relatively in the form of minor geographic changes in areas exploited. Similarly, even if a culturally important locality were affected, the consequences of such an occurrence should not translate into impacts on a sociocultural system (changing economic orientation, kinship patterns, authority structures, etc.). Noteworthy negative sociocultural impacts are not anticipated in such a situation. Smaller spills described as *unlikely* and *very unlikely*, as well as more probable *likely* and *anticipated* events, would have a lesser impact on sociocultural systems than their larger counterparts because fewer resources would be affected over smaller areas.

Spills into rivers would have a much greater potential to impact sociocultural systems than would spills on land. The most important consequences of such spills would be effects on subsistence. Although potential effects on harvests are discussed elsewhere (see Section 4.4.4.14), the degree to which subsistence impacts would be sufficiently severe to alter a sociocultural system is important for consideration here — perhaps altering the economic system as a whole, causing major changes in a key component of a sociocultural system (e.g., causing a shift in status recognition away from persons with strong subsistence skills), or generating more intangible impacts because of the key role played by subsistence in rural (especially Alaska Native) sociocultural systems. Moreover, the impacts of such a spill to riverine resources could last for several years. Impacts on resources with sociocultural implications may take the form of reductions in fish populations as well as perceived damage to subsistence fisheries even after scientific examinations have declared the resources safe, as occurred following the Exxon Valdez oil spill in Prince William Sound (see Fall 1999a).

Smaller, more probable spills in rivers would have lesser impacts on sociocultural systems than their large counterparts. The particular conditions associated with the spill would play an important role in determining impacts, because spills occurring under *likely* probability scenarios could have moderate to high negative impacts on a riverine subsistence fishery if they occurred in shallow, low-volume rivers at a key time in fish reproduction (for instance). Smaller-volume spills, generally associated with *anticipated* events, would have reduced impacts on sociocultural systems by virtue of their lessened impact on local economies and related components of those economies (e.g., exchange patterns). However, the consequences of these (as well as larger) spills could include changes in fish growth patterns, feeding rates, reproduction, survival, and displacement of individual fish — all with potential, though delayed, negative impacts on those components of local rural economies heavily reliant on subsistence fisheries.

The impacts of large spills, on the other hand, could be substantial for local manifestations of sociocultural systems where part of the seasonal round relies on fishing in a particular river or stream devastated by a spill, and where fishing provides a large amount of subsistence resources or involves a large percentage of the population (which is often — see Tables 3.24 -1 and 3.24-2 and Appendix D). In particular, large-volume spills (especially 54,000-bbl releases) in shallow waterways under low-flow conditions during sensitive periods in anadromous or resident fish life cycles (e.g., spawning) would have large severe impacts on subsistence fisheries. However, such spill scenarios are highly improbable in general (see Table 4.4.1-1), less likely to affect a river (about 1 in 255 million chance for a guillotine break caused by a helicopter crash; see

Section 4.4.4.3), and still more unlikely under the flow conditions and life-cycle timing conditions discussed above. Moreover, given the inherent adaptability of sociocultural systems and the broad areas exploited for fishing (Appendix D), the severity of such impacts might well be lessened by subsequent adjustments, such as shifts of subsistence activities to other rivers or other portions of an affected river. The difficulty (and utility) of making such adjustments would vary considerably. For instance, a large spill into the Gulkana River would affect not only an important subsistence fishery, but one relied heavily upon by residents from no fewer than eight of the rural communities considered in this EIS (see Section 4.4.4.14, Appendix D).

The third geographic category of spills considered in assessing impacts on sociocultural systems is oil releases into Prince William Sound. Spill scenarios for Prince William Sound under the *anticipated, likely,* and *unlikely* categories would have greater frequencies of occurrence than a *very unlikely* spill event, but would yield much smaller volumes of spilled material affecting much smaller areas than the maximum release scenario discussed below. Impacts to Alaska Native and rural non-Native sociocultural systems should be similarly small, because of the limited effect on key subsistence and commercial fishing resources (many spills would not even be expected to reach the water of the sound — see Table 4.4-2).

The scenario generating the greatest volume of oil would be a very unlikely catastrophic rupture of a crude oil storage tank, with 143,000 bbl of crude oil entering the water at the Valdez Marine Terminal (see Tables 4.4-2, 4.4-24). Fisheries and other marine and (particularly) shoreline subsistence resources likely would be adversely affected by such a spill, even assuming relatively limited dispersal and rapid containment. The greatest impacts would be are expected to occur close to shore in a relatively small area, thereby leaving open-water fisheries and the great majority of shallow-water and shoreline catchment areas generally unharmed.

Such a spill should not have a large impact on sociocultural systems in the Prince William Sound area for several reasons:, because of the limited geographic impacts; the lack of impact on known subsistence use areas (with the possible exception of a small area used for salmon fishing by Tatitlek–see Map D-24); and the ability of peoples in the region relying on subsistence fishing, hunting and gathering, and commercial fishing to avoid the relatively confined impact area. Once again, however, some impacts might occur because of perceived dangers of consuming resources taken from near the spill area, even after scientific examinations have declared them safe — as occurred during the Exxon Valdez spill (see Fall 1999a) and possibly exacerbated by prior experience with that event. In addition, a sociocultural cost is incurred by subsistence users having to travel further, and hence be absent longer from their home community.

The impact of perceived damage to resources could extend beyond subsistence resources to commercial fisheries, thereby endangering a key component of the cash economy of both Alaska Native and rural non-Native sociocultural systems near the spill area. Duration of sociocultural impacts could vary with the sociocultural system concerned. If the Exxon Valdez spill experience was indicative of the type and duration of impacts under the large, *very unlikely* spill, many sociocultural impacts likely would not be large or last a long time (see Wooley 1995) despite the large negative effects on local economies and other aspects of sociocultural systems in the short term (IAI 2001). Moreover, because of the limited effects of such a spill, extended impacts on subsistence (including effects on its economic, sociocultural, and ceremonial roles), disruption of status hierarchies, extended absence of local residents traveling further in pursuit of subsistence, and interruption of teaching young residents subsistence skills should not occur — as they did for a period of time following the Exxon Valdez spill in 1989 (see also Fall and Utermohle 1999).

Regardless of the likelihood of a spill or the major geographic setting where a release occurred, larger-volume events would require cleanup responses that might involve use of local labor — particularly in more isolated settings and in situations where communities (notably Alaska Native villages) already have a hiring commitment from APSC for such activities. Four types of impacts on sociocultural systems might accompany such cleanup activities (see IAI 2001). One is a the possible impact caused by from an influx of outsiders to a rural setting, introducing or further establishing ideas or behavior patterns originating in other sociocultural environments as well as exacerbating certain social problems, such as substance abuse and crime. The general familiarity of rural Alaskans with more modern settings (such as urban Alaska), coupled with the limited duration of cleanup activities for most of the spill scenarios considered here, likely would yield only small sociocultural impacts from the influx of nonlocal people and behavior patterns. A second potential impact would emerge from extended absence by local residents involved in cleanup activities, and the sociocultural disruption resulting from the absence of possibly key individuals in community activities. A third possible impact is the sociocultural disruption from differential involvement in spill cleanup activities — associated with competition for jobs as well as modifications in recognized status of individuals based on their roles in cleanup efforts. Finally, local involvement in cleanup activities would generate cash income, an important component in mixed rural economies and hence a positive impact for sociocultural systems accustomed to (and in many ways reliant upon) periodic infusions of cash. Again, the likely short duration of cleanup responses would mean that the cash introduced to local economies would be similarly limited, although its impacts in general would likely be positive.

4.4.4.16 Cultural Resources

Given the proximity of certain cultural resources to the pipeline and other TAPS components (such as the Valdez Marine Terminal), the potential exists for adverse impacts as the result of a spill. Although the uncertainty of possible spill locations and, in many cases, site characteristics, makes it impossible to establish with certainty the nature of those impacts, high-volume spills and those affecting large areas along portions of the pipeline close to cultural resources likely would damage such resources, possibly including sites listed on the National Register of Historic Places.

Impacts of Oil Spills on Cultural Resources

High-volume oil spills affecting large areas near either known or unreported cultural resources could damage those resources, possibly including sites listed on the National Register of Historic Places. However, because the projected frequency of spills large enough to cause major damage is low, the overall risk to cultural resources would also be expected to be low.

The likelihood of such spills is very low (see Section 4.4.1), suggesting that overall risk to cultural resources would be similarly low. However unlikely, there is a potential for adverse impacts to cultural resources as the result of a major spill.

Several specific locations were examined to establish the potential effect of a spill on key cultural resources. The nature and specific locations of the sites are protected under the Archaeological Resources Protection Act and thus cannot be provided in this document. Each of the four spill categories discussed in Section 4.4.1 — *anticipated*, *likely*, *unlikely*, and *very unlikely* — was considered. The anticipated effects of the various scenarios on cultural resources range widely, depending on the amount and location of the spill relative to a specific site. Location is the key factor for determining whether an adverse impact would occur for all scenarios. The magnitude of impacts was consistent for all categories except for the *anticipated* spills category, consisting of smaller-volume releases, for which the likelihood of a noteworthy impact is considerably less. The smaller spills in this category generally would be confined to the ROW, where sites may exist but where the majority of past earthmoving activities during TAPS construction and maintenance were concentrated — increasing the possibility that any sites present already have been heavily disturbed.

Analyses of the other three spill categories found that noteworthy impacts were possible under certain conditions. If a spill occurred upslope from an archaeological site or traditional cultural property, the possibility of damaging the site increased, while a spill downslope from a site decreased the likelihood of an impact.

If a spill actually involves a cultural resource, two types of damage would be possible. One would involve oil coming in contact with archaeological material, which could destroy some types of archaeological information, such as that obtained by radiocarbon dating or floral analysis. Contact with oil could also increase the deterioration of an object or structure in an archaeological site. The second type of impact would involve disturbance from containment and remediation activities, such as from driving heavy machinery through the site, ditching for containment, soil removal, and similar operations. Such activities could destroy part or all of a site or a traditional cultural property. Impacts to historic structures are unlikely, but could potentially occur during containment and remediation activities such as those listed above.

In the case of spills affecting cultural resources, a programmatic agreement (DOI et al. 1997) in place since 1997 creates a special situation not found in other issue areas. This agreement states that cultural resources will not be considered during spill containment on dock staging areas less than 50 years old; gravel, paved, or graded roads; parking areas; causeways; airport runways; or drilling mats. The agreement requires that area contingency plans be in place detailing the procedure for contacting an archaeologist and assessing the impact of a spill and the resulting cleanup on historic properties, taking into consideration areas covered by exclusions and conditions for revoking exclusions. Exclusions can be revoked if a spill is greater than 100,000 gal or if the SHPO indicates that a historic property will be affected by the spill. APSC has spill contingency plans in place (APSC 2001g) and has contracted an archaeologist who would be contacted in the event of an emergency, thereby meeting the requirements of the programmatic agreement.

4.4.4.17 Land Uses and Coastal Zone Management

Continued operation of the pipeline entails the risk of land or water-based oil spills that could potentially affect land use and coastal zone management.[10] The severity of the impact would be largely determined by the volume, location, duration, and time of year of the spill. Twenty-one spill scenarios have been developed for the proposed action and are presented in Table 4.4-1. The scenarios are categorized by frequency range, which include anticipated, likely, unlikely, and very unlikely. Frequencies are calculated for the pipeline as a whole; therefore, the probability of a spill occurring at a specific point along the pipeline or within a specific area crossed by the pipeline is substantially less. The scenarios discussed below represent the greatest potential release of oil for each frequency range.

An anticipated scenario, expected to occur at some point along the pipeline one or more times every two years, is an instantaneous release of 50 bbl of crude oil caused by a pipeline leak (Scenario 1). For a land-based spill, about seven-hundredths of an acre would be covered one inch deep, which would equal a circle roughly 60 ft in diameter. For a water-based spill, this volume of oil would produce contamination problems downstream.

Spill scenarios likely to occur (Scenarios 12 and 14) would involve a prolonged pipeline leak (potentially lasting for days) due to sabotage, vandalism, or corrosion-related damage. The maximum amount of crude oil spilled would be 10,000 bbl and for a land-based spill would cover about 15 acres at a depth of 1 in. For a water-based spill, this volume would produce a lengthy slick. A likely scenario is one estimated to occur somewhere along the pipeline once every 2 to 30 years.

The greatest impact on land use would be from a spill caused by a fixed aircraft crash (Scenarios 19a and 19b, without and with a fire, respectively) or helicopter crash (Scenario 21) into the pipeline that resulted in a guillotine break. For one of these events, a maximum of

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10 Separate spill scenarios have been developed for the Valdez Marine Terminal and are discussed below.

54,000 bbl of crude oil would be released over a period of hours. For a land-based spill, this volume of oil would cover about 84 acres at a depth of 1 in. The aircraft crash could also result in a fire (Scenario 19b). For a water-based spill, this volume of oil could result in an oil slick almost 13 mi long and could affect shoreline areas where oil washed ashore. A guillotine break from an aircraft crash, with or without fire, is unlikely and is estimated to occur once in 30 years to once in 1,000 years somewhere along the pipeline. A guillotine break from a helicopter crash is very unlikely, with an estimated probability of occurring at some point along the pipeline between once in 1,000 years and once in 1,000,000 years.

Impacts of Oil Spills on Land Use

All of the spill scenarios evaluated in this section would result in immediate and potentially long-term land use impacts, with the severity largely determined by the volume, duration, location, and time of year of the spill. Both the spill and cleanup activities could potentially interfere with existing land uses in the area. These uses include recreation, wildlife habitat and other natural resource conservation, commercial, municipal, residential, agricultural, Native corporations, and military reservations.

4.4.4.17.1 Land Uses. A variety of land uses occur in the vicinity of the TAPS that could be affected by a spill, including recreation, wildlife habitat and other natural resource conservation, commercial, municipal, residential, agricultural, Native corporations, subsistence activities, and military reservations.

Land-Based Spills. In all of the scenarios, the number of acres actually impacted by a land-based spill would depend on the type of geology, soils, topography, and vegetation present in the spill area. If a fire occurred as a result of an aircraft crash into the pipeline, additional acres beyond the spill area could be directly affected. Air quality would also be temporarily affected in the spill area, as well as downwind, because of smoke and airborne ash. Areas in the vicinity of the spill would likely be evacuated, thereby disrupting normal activities. If any of the above-listed scenarios occurred in proximity to surface water, impacts to that resource would be likely because of overland flow of the oil into the water, resulting in lengthy cleanup activities (see Section 4.4.4.3).

All of the spill scenarios evaluated here would result in immediate and potentially long-term land use impacts, with the severity largely determined by the volume, duration, location, and seasonal occurrence of the spill. The aesthetic quality of the area would be diminished because of visible oil, damaged vegetation, and the presence of personnel and machinery during cleanup. Visual effects would be evident until revegetation occurred. Cleanup activities would be noisy and likely dusty and could last weeks, months, or years, depending on spill volume. Both the spill and cleanup activities could potentially interfere with existing land uses.

A spill could have a long-term impact on recreational resources and opportunities, particularly if it were within or near a park or recreation area or site. Several recreational parks, areas, or sites are within 1 mi of the TAPS and could be directly or indirectly affected by a spill. Potential recreational impacts are discussed in Section 4.4.4.18.1.

Some lands set aside for wildlife habitat conservation (as well as other purposes) could be either directly or indirectly affected by a spill, including ACECs, national wildlife refuges, and national parks. Four ACECs within 2 mi of the pipeline are protected for critical wildlife habitat: Galbraith Lake, Snowden Mountain, Nugget Creek, and Jim River. In the event of a spill, these ACECs could be indirectly affected by noise from cleanup activities. A small portion of the western boundary of the ANWR comes within 0.25 mi of the pipeline and part of the western boundary of Yukon Flats NWR comes within 2 mi of the pipeline. Neither refuge would be directly affected by a spill, including a guillotine break, because of their relatively long distance from the pipeline. Even the portion of the ANWR that is closest to the TAPS would likely not be affected by a major spill because of the topography of the area, which slopes away from the refuge. A guillotine break caused by an aircraft crash into the pipeline that resulted in a fire could potentially affect both refuges, depending upon the extent of the fire, but this is unlikely (see above). Both could be indirectly affected by noise from cleanup activities. The Kanuti NWR, which is 8 mi west of the TAPS at its closest point, would not be directly or indirectly affected by a land-based pipeline spill. Noise from cleanup activities might be audible within Gates of the Arctic NPP, which is 2 to 3 mi from the pipeline at its closest point, and from the small portion of Wrangell-St. Elias NPP that comes within 2 mi of the pipeline.

A guillotine break spill that occurred near a municipal, residential, commercial, or agricultural area would temporarily interfere with those land uses. An aircraft crash into the pipeline resulting in a fire would cause the greatest impact, potentially resulting in temporary evacuation of the area, destruction of private property, and interference with activities. Cleanup activities would also be disruptive. However, occurrence of such an event is unlikely. A likely spill of 10,000 bbl could result in some temporary disruption of land use, but an anticipated scenario involving a release of 50 bbl of oil would have a minimal effect on commercial, municipal, or residential land use, but a somewhat greater effect on agriculture. However, these land uses rarely occur near the pipeline along its 800-mi length. In addition, the pipeline is often below ground in commercial, municipal, residential, and agricultural areas.

Land owned by Native corporations is used primarily for subsistence hunting. A discussion of the effects of spills on subsistence is provided in Section 4.4.4.14.

A guillotine break spill that occurred on or near a military reservation would temporarily interfere with land use. An aircraft crash into the pipeline resulting in a fire would cause the greatest impact, resulting in temporary evacuation of the area, potential destruction of military property, and interference with military activities. Cleanup would also be disruptive and could interfere with military activities on a long-term basis. However, occurrence of such an event is unlikely. A likely spill scenario involving release of 10,000 bbl of oil could result in temporary disruption of military activities, but an anticipated scenario involving a release of 50 bbl of oil would be much less likely to result in disruption. Eielson AFB, Fort Greely, and Fort Wainwright are all crossed by the pipeline and would be directly affected by any spill along portions of the pipeline crossing those reservations.

A major spill at the Valdez Marine Terminal would disrupt other land uses within the Valdez coastal zone. These scenarios are discussed below in Section 4.4.4.17.2.

In spite of the realm of potential spills and associated environmental impacts that could occur, historical data indicate that most land-based oil spills in the vicinity of the TAPS have been relatively small. Temporary impacts to land use have occurred from past spills.

Water-Based Spills. Any of the scenarios described above for water-based spills could result in immediate and long-term land use impacts. Initially, an oil slick would form on the river, oil would be visible on the shoreline, and shoreline vegetation would be damaged and/or killed. Cleanup activities, which could be long term, would be noisy and disruptive, and could temporarily prohibit other activities in the vicinity of the spill. A water-based spill, particularly a guillotine break directly into a river, would likely have a long-term impact on water-related recreational activities, including floating, boating, sport fishing, and shoreline camping. Potential impacts are discussed in Section 4.4.4.18.1.

The Kanuti NWR could be affected by a water-based spill. A guillotine break along the Koyukuk River near MP 245 would cause oil to flow almost directly into the river and potentially reach the refuge. An oil slick would form on the river, fisheries would be affected, and shoreline vegetation would be damaged and/or killed. Cleanup activities would disturb and possibly temporarily displace wildlife. Subsistence activities within the refuge would likely be affected, at least temporarily. See Section 4.4.4.3 for a discussion of spill impacts to surface water, Sections 4.4.4.8 through 4.4.4.12 for impacts to biological resources, and Section 4.4.4.14 for impacts to subsistence.

Native corporation land is used primarily for subsistence hunting. See Section 4.4.4.14 for a discussion of the effects of a water-based spill on subsistence activities.

Activities on military reservations could be disrupted by a water-based spill, with Eielson AFB most likely to be affected if a water-based spill occurred in a portion of the pipeline crossing the base. The TAPS crosses a number of creeks as well as Little Salcha River as it passes through a large portion of Eielson AFB, and the pipeline is aboveground for the majority of its length through the base. The pipeline is belowground as it crosses a small portion of Fort Greely and Fort Wainwright, reducing the likelihood that military activities on either of those reservations would be disrupted by a water-based pipeline spill. However, a large volume pipeline spill nearby could potentially reach any of these military reservations because of the number of creeks, rivers, and tributaries in the vicinity.

For any water-based spill, the length of the oil slick would depend on the velocity of the river, duration of the spill, location of the spill in relation to the nearest containment site, and the rapidity of the spill response. Historical data indicate that few spills into rivers have occurred since TAPS construction.

4.4.4.17.2 Coastal Zone Management. A land- or water-based pipeline spill could potentially affect either the North Slope Borough or Valdez coastal zones. Both the North Slope Borough and Valdez CMPs recognize this risk and require oil spill prevention and response plans (see Section 4.1.4), which are also subject to statewide ACMP standards. The North Slope Borough CMP also requires risk analyses for various spill scenarios. The TAPS is in compliance with these requirements.

The pipeline spill scenarios evaluated were chosen from the 21 scenarios presented in Table 4.4-1 and outlined above. The Valdez Marine Terminal scenarios discussed below were chosen from the 12 scenarios summarized in Table 4.4-2. The scenarios in both tables are categorized by frequency ranges, which include anticipated, likely, unlikely, and very unlikely. Frequencies are calculated for the pipeline as a whole and the probability of a spill occurring at a specific point along the pipeline is substantially less. Each scenario discussed below represents the greatest potential release of oil for that frequency range. The severity of the impact would be largely determined by the volume, location, duration, and season of occurrence of the spill.

Impacts of Oil Spills on Coastal Zone Management

All of the spill scenarios evaluated in this section could result in immediate and potentially long-term coastal zone impacts, with the severity largely determined by the volume, duration, location, and time of year of the spill. The spills would not be likely to substantially interfere with terrestrial subsistence activities or resources within the North Slope Borough coastal zone, although a water-based spill could at least temporarily impact those activities and/or resources. Spills within the Valdez coastal zone could disrupt other land use activities in the area or impact Prince William Sound.

Most of the pipeline is below ground within the North Slope Borough coastal zone. All but a small segment near the Valdez Marine Terminal is below ground within the Valdez coastal zone.

North Slope Borough Coastal Zone. The *anticipated*, *likely*, *unlikely*, and *very unlikely* scenarios discussed above would also apply to the North Slope Borough coastal zone along the aboveground portion of the pipeline. Because the pipeline runs below the ground through most of the North Slope Borough coastal zone, most other potential land-based spills would involve a belowground release of oil. The anticipated scenario (Scenario 1) and likely scenario (Scenario 14) described above could also occur as belowground releases along the buried portion of the pipeline. An unlikely scenario (Scenario 16), which could occur along the buried portion of the pipeline and result in an underground release, is described below under the Valdez CMP. Any of these belowground spills could result in surface water or groundwater contamination (see Sections 4.4.4.3 and 4.4.4.4), but direct spills to surface water would be improbable.

All of the above- or belowground land-based spill events could result in immediate and potentially long-term impacts to coastal resources and disrupt other activities within the coastal zone. The severity of the impacts would depend largely on the volume, duration, location, and season of occurrence of the spill. The spills would not be likely to substantially interfere with terrestrial subsistence activities within the North Slope Borough coastal zone or jeopardize the continued availability of terrestrial subsistence resources. See Sections 4.4.4.8 through 4.4.4.12 for discussions of spill impacts on biological resources and Section 4.4.4.14 for a discussion of impacts on subsistence.

The number of acres actually impacted by each type of spill would depend on the type of geology, soils, topography, and vegetation present in the spill area. If a fire occurred as a result of an aircraft crash into the pipeline, additional acres beyond the spill area could be directly affected, dependent upon the extent of the fire. Cleanup activities could last weeks, months, or years. Overland flow of oil could also result in impacts to surface water and necessitate additional cleanup activities (see below).

Direct spills to surface water would also cause immediate and potentially long-term impacts to the North Slope Borough coastal zone. The length of the resulting oil slick would depend on the velocity of the river, duration of the spill, location of the spill in relation to the nearest containment site, and season of occurrence. A complete discussion of spills to surface water is presented in Section 4.4.4.3.

Even a relatively small spill, such as the 50 bbl release under the “anticipated” release scenario, would likely affect aquatic resources and activities, at least temporarily. The severity of the impacts would depend on the spill volume, duration, location, and season of occurrence.

Under the *unlikely* and *very unlikely* scenarios, a guillotine break in the pipeline along the Sagavanirktok River (within the North Slope Borough coastal zone) resulting in release of up to 54,000 bbl of oil would result in oil flowing almost directly into the river. Effects to fisheries could result in impacts to subsistence resources and/or activities, at least temporarily. However, the probability of such an event occurring on the Sagavanirktok River within the North Slope Borough coastal zone is substantially less than the overall probability of occurrence along the entire pipeline.

Valdez Coastal Zone. The *anticipated* and *likely* scenarios evaluated for the Valdez coastal zone were generally the same as those evaluated for the North Slope Borough coastal zone and land use in general. They would result in an above- or belowground release of 50 bbl and 10,000 bbl of oil, respectively.

An *unlikely spill* (Scenario 16) would be a crack caused by seismic activity resulting in a short-term (hours), belowground release of 16,000 bbl of oil. The probability of this type of spill occurring is once in 30 years to once in 1,000 years anywhere along the pipeline, with substantially less likelihood of occurring specifically with the Valdez coastal zone.

The greatest impact to the Valdez coastal zone from a land-based spill would occur from an aircraft crash into the crude oil tank at the East Tank Farm of the Valdez Marine Terminal, resulting in a fire and the prolonged (over a number of days) release of 382,500 bbl of oil (Scenario 10 from Table 4.4-2). This spill scenario is *very unlikely*, but if it did occur, this spill would disrupt other activities within the Valdez coastal zone, at least temporarily. Air quality would be temporarily affected in the spill area and downwind because of smoke and airborne ash. Surrounding areas would likely be evacuated until the fire was extinguished. Cleanup activities would be noisy and could last weeks, months, or years. However, because of containment measures, this type of spill would not be expected to reach Prince William Sound (Table 4.4-2).

Because the pipeline runs below ground throughout the Valdez coastal zone except for a small segment at the Valdez Marine Terminal, most other potential land-based spills would involve a belowground release of oil. This type of spill could result in surface water or groundwater contamination (see Sections 4.4.4.3 and 4.4.4.4), but direct spills to surface water other than Prince William Sound would be improbable (see below). Cleanup activities for any of the underground releases discussed could be extensive and long-term, resulting in at least temporary disruption of other activities in the Valdez coastal zone.

A direct spill to Prince William Sound could result from the catastrophic rupture of a crude oil storage tank at the Valdez Marine Terminal (Scenario 11 from Table 4.4-2). In this scenario, a total of 193,800 bbl of oil could be released instantaneously and 143,450 bbl could reach Prince William Sound. Up to 2 mi of shoreline within the Port of Valdez could be impacted, depending upon spill response time and current and wind speeds at the time of the spill. Other activities within the coastal zone could be disrupted by shoreline cleanup activities at least temporarily. However, this type of catastrophic spill is very unlikely to occur.

As discussed above, all but a small portion of the pipeline is below ground within the Valdez coastal zone. Therefore, other than the remote possibility of a catastrophic spill at the Valdez Marine Terminal that releases oil to Prince William Sound, there is very little probability that a direct spill to surface water from the pipeline would occur within the Valdez coastal zone.

4.4.4.18 Recreation, Wilderness, and Aesthetics

Continued operation of the pipeline would entail the risk of a land- or water-based oil spill that could potentially affect recreation or wilderness resources, or aesthetics. The severity of the impact would be determined largely by the volume, duration, location, and season of occurrence of the spill. Twenty-one spill scenarios have been developed for the proposed action and are presented in Table 4.4-1. The scenarios are categorized by frequency range as follows: anticipated, likely, unlikely, and very unlikely. The scenarios discussed below represent the greatest potential release of oil for each frequency range. Frequencies are calculated for the pipeline as a whole; therefore, the probability of a spill occurring at a specific point along the pipeline is substantially less. Spills occurring near, in, or visible from, a public road (e.g., Dalton Highway); river (particularly a Wild and Scenic River); ACEC; Wilderness Area; or national or state park, recreation area, or site would have the most substantial impact on recreation resources, wilderness, and aesthetics. Because sight-seeing is such a popular recreational activity in Alaska, any impact to aesthetics also represents an impact to recreation.

For this analysis, an anticipated scenario, which is an event expected to occur one or more times every 2 years, is an instantaneous release of 50 bbl of crude oil caused by a pipeline leak (spill Scenario 1). In case of land-based spill, about seven-hundredths of an acre would be covered 1 in. deep, which would equal a circle about 60 ft in diameter. For a water-based spill, this volume could produce contamination problems downstream.

Spill events likely to occur (Scenarios 12 and 14) would involve a prolonged pipeline leak (lasting for days) caused by sabotage, vandalism, or corrosion-related damage. The maximum amount of crude oil spilled would be 10,000 bbl and for a land-based spill would cover about 15 acres at a depth of 1 in. For a water-based spill, this volume could result in a lengthy downstream oil slick. A likely scenario is one estimated to occur between once in 2 years and once in 30 years.

The greatest impacts would occur from a helicopter crash (Scenario 21) or fixed-wing aircraft crash (Scenarios 19a or 19b, with and without fire, respectively) into the pipeline that resulted in a guillotine break and that occurred near or at a designated recreation or wilderness area or other area of aesthetic value (see Table 3.27-1). For both an aircraft crash and a helicopter crash, a maximum of 54,000 bbl of crude oil would be released over a period of hours and for a land-based crash would cover about 84 acres at a depth of 1 in. If it occurred on land, the aircraft crash could also result in a fire (Scenario 19b).

If the guillotine break occurred directly into a river, a release of 54,000 bbl of oil could produce an oil slick almost 13 mi long and cause recreational and aesthetic impacts. A guillotine break from an aircraft crash, with or without fire, is unlikely and is estimated to occur once in 30 years to once in 1,000 years. A guillotine break from a helicopter crash is very unlikely, with an estimated frequency of between once in 1,000 years and once in 1,000,000 years.

4.4.4.18.1 Recreation. All the spill scenarios described above would result in immediate and potentially long-term recreational impacts if they occurred at or near a designated recreation area. The aesthetic quality of the area would be degraded because of visible oil, damaged vegetation, and the presence of personnel and machinery during cleanup. Cleanup activities would be noisy and likely dusty, and could last weeks, months, or years, depending on spill volume. The quality of the recreational experience in the vicinity of the spill would be substantially reduced until remediation efforts were completed, and visual effects would be evident until revegetation occurred. Use of the recreation resources in the vicinity of the spill could be temporarily lost if the spill resulted in closure of an area. Consequently, even a low-volume spill within the likely or anticipated frequency range could have a substantial effect on recreation resources, particularly if it were within or near a park or a designated recreational area or site. Several recreational parks, areas, or sites are within 1 mi of the TAPS and could be directly or indirectly affected by a spill.

A guillotine break spill, with or without fire, would be particularly damaging to recreation if it occurred at a popular tourist attraction such as Worthington Glacier State Recreation Site (SRS), which is crossed by the pipeline. A high-volume spill would be particularly visible at this SRS and would likely reach the surface water at the base of the glacier because of the topography of the area. Cleanup activities would be extensive and long-term and would likely require temporary, but potentially long-term, closure of the SRS, resulting in loss of use of the recreational resources at the site for the duration of the closure.

Impacts of Oil Spills on Recreation

All of the spill scenarios described above would result in immediate and potentially long-term recreational impacts if they occurred near or at a designated recreation area. The quality of the recreational experience in the vicinity of a land- or water-based spill would be substantially reduced by the visual effects of the spill and the noise from cleanup activities. This situation would continue until remediation efforts were completed. Use of the recreation resources in the vicinity of the spill could be temporarily lost if the spill resulted in closure of an area. Several recreational parks, areas, or sites are within 1 mi of TAPS and would be directly or indirectly affected by a spill. A spill into a river would prohibit water-based activities, at least temporarily, until initial containment and cleanup activities were complete.

Land-Based Spills. For all the scenarios, the number of acres actually impacted by a land-based spill would depend on the type of geology, soils, topography, and vegetation present in the spill area. If a fire occurred as a result of an aircraft crash into the pipeline, additional acres beyond the spill area could be directly affected, depending on the extent of the fire. Air quality would also be temporarily affected in the spill area, as well as downwind, because of smoke and airborne ash. Recreational areas in the vicinity of the spill would be evacuated, thereby disrupting activities. If any of the spill events occurred near surface water, impacts to that resource would be likely because of overland flow of the oil, which would result in additional visual and recreational impacts and lengthy cleanup activities (see Section 4.4.4.3).

In spite of the realm of potential spills and associated environmental impacts that could occur, historical data indicate that most land-based oil spills in the vicinity of the TAPS have been relatively small. Environmental effects have been localized and temporary and have not resulted in long-term impacts to recreation resources. In addition, most spills have not been visible to visitors except by air.

Water-Based Spills. All the spill scenarios described above could result in immediate and long-term impacts on water-based recreation if the spills occurred directly into water. The severity of the impacts would be largely determined by the volume and location of the spill. Initially, an oil slick would form on the river, oil would be visible on the shoreline, and shoreline vegetation would be damaged and/or killed. Recreational activities on or along the river, such as floating, boating, sport fishing, or shoreline camping, would be prohibited at least temporarily until initial containment and cleanup activities were complete. Cleanup could be long-term, as could the aesthetic effects on the shoreline and impacts to sport fishing. See Sections 4.4.4.3 and 4.4.4.10 for discussions of spill impacts to water resources and fish, respectively.

In particular, an oil spill in a popular recreational river such as the Gulkana or Tanana could have substantial impacts. The pipeline crosses both rivers on elevated bridges, and both rivers are adjacent to the Richardson Highway and, thus, are highly visible. Both rivers are very popular with boaters, and floating is particularly popular on the Gulkana. The pipeline crosses the Tanana River at a popular put-in point, and crosses the Gulkana downstream of Sourdough Campground, which is a popular take-out point for floaters and a put-in point for powerboaters.

The Gulkana River is also a federally designated Wild River, protected for its beauty and pristine condition. A guillotine break in the pipeline where it crosses the Gulkana would be particularly damaging to its aesthetic qualities and would destroy its pristine quality — at least temporarily. Long-term ecological impacts such as damage to sport fisheries or destruction of shoreline vegetation would result in long-term recreational impacts.

For all the scenarios, the length of the oil slick would depend on the velocity of the river, duration of the spill, and location of the spill in relation to the nearest containment site. Historical data indicate that few spills into rivers have occurred since construction of the TAPS, and recreational effects have been short-term. A complete discussion of spills to surface water is presented in Section 4.4.4.3.

4.4.4.18.2 Wilderness. The only federally designated Wilderness in the vicinity of the TAPS is within the Gates of the Arctic NPP. No state-designated Wilderness exists near the pipeline. Historical data indicate that no land- or water-based spills have affected the Gates of the Arctic NPP Wilderness Area since construction of the TAPS.

Impact of Oil Spills on Wilderness

It is very unlikely that a land-based TAPS spill would directly affect the federally designated Wilderness Area within the Gates of the Arctic NPP because the easternmost boundary of the area is 2 to 3 mi from TAPS at its closest point. Impacts on the Wilderness Area from a water-based spill are also very unlikely because of the way surface waters flow near the area. Only a large-volume spill into the Koyukuk River near MP 245 would be likely to reach the Wilderness Area, where the Koyukuk flows west along its southeastern boundary. Wilderness values would be affected if such a spill occurred.

It is very unlikely that a land-based TAPS spill would directly affect the Wilderness Area within Gates of the Arctic NPP (between MP 139 and 266) because the easternmost boundary of the area is 2 to 3 mi from the TAPS at its closest point. Impacts on the Wilderness Area from a water-based spill are also very unlikely because of the way surface waters flow near the area.

Land-Based Spills. For a small spill such as covered by the *anticipated* spill scenario, the area affected would be small and the potential for cleanup activities to be heard from the wilderness area would be very low. For a *likely* spill event releasing 10,000 bbl, cleanup activities might be audible from eastern ridgelines within the Wilderness Area.

For land-based guillotine breaks in the pipeline caused by the crash of a helicopter or aircraft between MP 139 and 266, cleanup activities would be extensive and could require months or years to complete. Noise from the actual crash and cleanup activities might be heard from eastern ridgelines within the Gates of the Arctic Wilderness Area. If the aircraft crash resulted in a fire, smoke would likely be visible from the wilderness. An extensive fire could result in evacuation of the area. It is very doubtful that the spill or any related visual effects, including cleanup activities, could be seen from the Gates of the Arctic Wilderness Area.

Water-Based Spills. A water-based spill along the pipeline would be very unlikely to affect the Gates of the Arctic Wilderness Area unless the spill occurred at MP 245 near the Koyukuk River. Only a large-volume spill could potentially reach the Wilderness Area via water. A guillotine break (caused by a aircraft or helicopter crash into the pipeline) along the Koyukuk River near MP 245 would result in oil flowing almost directly into the river. The oil slick would likely reach the Wilderness Area, where the Koyukuk flows west along its southeastern boundary.

If spilled oil did reach the Gates of the Arctic Wilderness Area via the Koyukuk River, the wilderness values within a localized portion of the Wilderness Area could be affected. The severity of the impacts would depend on the amount of oil that actually reached the area via the river. An oil slick would be visible on the river, and oil would likely be visible on the shoreline. Shoreline vegetation would likely be damaged and/or killed. Cleanup activities would involve machinery and personnel and would be noisy and potentially long term. Visual effects would be evident until remediation efforts were completed and shoreline revegetation occurred. Recreational activities on or adjacent to the river would likely be prohibited at least temporarily. In short, the wilderness qualities along this portion of the Koyukuk River would be substantially affected. The area would no longer be untrammeled by man, and opportunities for solitude and unconfined recreation in this portion of the Gates of the Arctic Wilderness Area would be unavailable at least temporarily.

4.4.4.18.3 Aesthetics. A land- or water-based pipeline spill could potentially affect visual resources in the vicinity of the pipeline, with the severity of the aesthetic impact largely determined by the volume, duration, location, and season of occurrence of the spill. Spills occurring near, in, or visible from a public road; pipeline viewing station; river (particularly a Wild and Scenic River); ACEC; Wilderness Area; or national or state park, recreation area, or site would have the most substantial impact on aesthetics.

Impact of Oil Spills on Aesthetics

A land- or water-based pipeline spill would have the potential to affect visual resources in the vicinity of the pipeline, with the severity of the impact largely determined by the volume, duration, location, and season of occurrence of the spill. Spills occurring near, in, or visible from a public road; pipeline viewing station; river (particularly a Wild and Scenic river); area of critical environmental concern; Wilderness Area; or national or state park, recreation area, or site would have the greatest impact on aesthetics.

Land-Based Spills. All of the spill scenarios described above could result in immediate and long-term aesthetic impacts, with the severity largely determined by the volume and location of the spill. Initially, oil would be visible, and dead or damaged vegetation would be apparent. During cleanup, which could last weeks, months, or years, depending on spill volume, vegetation would be denuded, soil would be removed, and personnel and machinery would be on-site. Effects from the spill would be visible until remediation efforts were completed and revegetation occurred.

A guillotine break spill, with or without fire, would be particularly damaging to aesthetics if it occurred at a popular tourist attraction such as Worthington Glacier SRS, which the pipeline crosses. A high-volume spill would be particularly visible at this SRS and would likely reach the surface water at the base of the glacier because of the topography of the area. Cleanup activities would be extensive and long-term and could result in long term visual degradation of the site.

For all the scenarios, the number of acres actually affected would depend on the type of geology, soils, topography, and vegetation present in the spill area. If a fire occurred as a result of the aircraft crash, additional acres would likely be directly affected, depending on the extent of the fire. Air quality would also be temporarily affected in the spill area as well as downwind because of smoke and airborne ash. If any of these spill events occurred near surface water, impacts to that resource would be likely because of overland flow of the oil, resulting in an additional aesthetic impact. Cleanup efforts for surface water could also entail months or years of effort (see Section 4.4.4.3).

In spite of the realm of potential spills and associated environmental impacts that could occur, historical data indicate that most land-based oil spills in the vicinity of the TAPS have been relatively small. Environmental effects have been minor, localized, and temporary. In addition, most spills have not been visible to visitors except by air.

Water-Based Spills. If they released oil into water, all the spill events discussed above could result in immediate and long-term aesthetic impacts, with the severity largely determined by the volume, duration, and location of the spill . Initially, an oil slick would be visible on the river, and oil would be visible on the shoreline. Shoreline vegetation would be damaged and/or killed. During cleanup, which could last weeks, months, or years depending on spill volume, personnel and machinery would be on-site, and shoreline vegetation would be trampled and likely denuded. Effects from the spill would be visible until remediation efforts were completed and the shoreline was revegetated.

Oil spills to rivers such as the Gulkana, Tanana, or Yukon would be particularly noticeable to the public because they are crossed by, or adjacent to, public highways. In addition, these rivers, as well as several others in the vicinity of the TAPS, are used for a variety of recreational activities and are very visible to large numbers of people. In particular, any spill to the Gulkana River would have particularly noticeable aesthetic impacts because it is a federally designated Wild River, protected for its beauty and pristine condition. A guillotine break in the pipeline where it crosses the Gulkana would be particularly damaging to the river's aesthetic qualities.

For all the spill scenarios, the length of the oil slick would depend on the velocity of the river, duration of the spill, and location of the spill in relation to the nearest containment site. Historical data indicate that few water-based spills have occurred since construction of the TAPS, and aesthetic effects have been minor. A complete discussion of spills to surface water is presented in Section 4.4.4.3.

4.4.4.19 Environmental Justice

In a manner identical to the assessment of impacts on minority and low-income populations under the proposed action and alternatives, the assessment of environmental justice impacts on these populations from accidents requires an assessment of effects in other impact areas to identify any that are high and adverse (see Section A.14). Those areas expected to experience high and adverse impacts, in turn, are examined to determine how they disproportionately affect minority and low-income populations.

In general, this EIS considers the consequences of spills for all impact areas under four probability categories: *anticipated* (>0.5/yr), *likely* (0.03 to 0.5/yr), *unlikely* (10^{-3} to 0.03/yr), and *very unlikely* (10^{-6} to 10^{-3}/yr) — with accompanying estimates of spill volumes. As discussed in Section 4.4.1, spill volumes (and hence impacts) tend to increase as probability decreases — such that *unlikely* and *very unlikely* spill scenarios tend to have the greatest potential to do the most damage. For purposes of assessing the impacts of spills on environmental justice, this evaluation considered the entire range of impacts that were examined for each impact area — because smaller, more frequent spills occasionally lead to high and adverse impacts (e.g., for groundwater, see Section 4.4.4.4). Although spills of oil, diesel fuel, and other materials associated with the movement of oil through the TAPS by definition yield adverse impacts, the majority of consequences from spills are anticipated to be small and short term. On the basis of an evaluation of the anticipated consequences of spills that might occur at specific locations and under particular conditions during the continued operation of the TAPS, described throughout Section 4.4.4, eight impact areas would experience impacts that can be interpreted as high and adverse:

- Surface water;
- Groundwater;
- Human health and safety;
- Fish;

Environmental Justice Impacts Related to Oil Spills

Depending on the exact circumstances, TAPS-related spills could result in the following impacts that could affect environmental justice populations:

- Surface Water: Possible constraints on transportation along navigable waterways and impacts to subsistence fisheries (see below)
- Groundwater: Possible need for alternatives to wells as sources of water
- Human Health and Safety: Possible impacts from inhalation of contaminants emitted from spills or fires in communities closer than 4 km to the TAPS
- Fish: Possible severe negative impacts from large *unlikely* and *very unlikely* spills into a river
- Birds and Terrestrial Mammals: Possible high negative impacts from a large spill that affects a large concentration of birds or mammals
- Subsistence: Possible short- or long-term destruction (or substantial reduction) of riverine subsistence fisheries
- Sociocultural: Possible short- or long-term modification of economic bases, because of impacts on riverine subsistence fisheries
- Recreation and Aesthetics: Possible impacts to the Gulkana National Wild River

- Birds and terrestrial mammals;
- Subsistence;
- Sociocultural systems; and
- Recreation, wilderness, and aesthetics.

Table 4.4-39 provides a summary of impacts in these and other impact areas due to spills. The following paragraphs discuss anticipated high and adverse impacts in greater detail, particularly in the context of environmental justice.

Impacts to surface water depend on the size of spill and characteristics of the body of water affected. As discussed in Section 4.4.4.3, the TAPS crosses about 800 streams and rivers over the length of the pipeline. For a spill of a given volume, shallower, slower-moving streams and rivers generally would experience larger impacts. Impacts to humans could include constrained transportation (on navigable streams and rivers), human health and safety, subsistence (emphasizing riverine resources), and recreation and aesthetics. Possible consequences for the last three impact areas are examined in the paragraphs below.

Impacts to movement along rivers and streams would be limited to those water bodies experiencing a spill of sufficient volume to hinder travel by boat. As shown in Maps 3.29-1 and 3.29-2, and in Table 3.29-1, disproportionately high percentages of minority and low-income populations occur throughout much of the area where the TAPS passes and in many of the nearby communities. These areas of disproportionately high minority and low-income populations also include several navigable rivers. The oil slicks described in Table 4.4-15 on only two of the six example rivers and streams considered would approach populated places — spills on the Tanana River (reaching river locations near Fox, Fairbanks, College, and Ester) and on the Tazlina River (reaching river locations near Copper Center, Copperville, Kenny Lake, and Tazlina). However, in certain times of the year, virtually any of the navigable waterways crossed by the TAPS might be supporting human movement, and because of the demographic characteristics of the area described in Section 3.29, a spill might affect travel by members of minority or low-income populations more than members of the population as a whole. All this stated, the probability of a large spill in any particular waterway is remote — for example, on the order of 1 chance in 255 million for a 300-ft river crossing (see Section 4.4.4.3) — greatly reducing the overall risk of spill impacts to surface water. Moreover, quick, targeted spill response could limit the impacts of such a spill

TABLE 4.4-39 Summary of Anticipated Impacts under Spill Scenarios

Issue Area	DEIS Section	Summary of Impacts[a]
Soils and permafrost	4.4.4.1	Anticipated impacts would be localized, affecting 84 acres or less (depending on size and location of spill); prompt cleanup would limit dispersal of contaminants, but resulting disturbance of surface vegetation would affect local permafrost.
Paleontology	4.4.4.2	No anticipated impacts.
Surface water resources	4.4.4.3	Impacts of guillotine break at a river crossing would be large, adversely affecting many miles of river and riverbank and requiring long-term cleanup; frequency (or likelihood) of such a spill in any given river is very low, about 1 in 255 million.
Groundwater resources	4.4.4.4	Impacts of *likely* spills could be high if occurring in the Chugach Mountains; impacts of *unlikely* and *very unlikely* (i.e., larger volume) spills could also be high, with less locational restriction than for the *likely* spill.
Physical marine environment	4.4.4.5	Impacts could accompany a *very unlikely* spill at Valdez Marine Terminal, although release of a large amount of oil would in part be countered by confinement to an area about 2 mi from the terminal; impacts would be high, but relatively localized.
Air quality	4.4.4.6	Impacts would vary with the size of spill, horizontal dispersal, and time until cleanup; impacts appear under human health and safety.
Human health and safety	4.4.4.7	Impacts could accompany spill scenarios in all four probability categories, with smaller (more probable) spills requiring close proximity to receptors for high impacts; human health effects also could result from eating fish and marine invertebrates exposed to oil, although the level of exposure necessary to yield noteworthy human health impacts would be noticeable on the food affected (thereby likely leading to avoidance).
Biological resources	4.4.4.8 (Biological Resources Overview), 4.4.4.9 (Terrestrial Vegetation and Wetlands), 4.4.4.10 (Fish), 4.4.4.11 (Birds and Terrestrial Mammals), and 4.4.4.12 (Threatened, Endangered, and Protected Species)	Impacts to vegetation would affect 84 acres or less and, although possibly long term, would involve a relatively very small land area. Impacts on fish could be severe and possibly long term for large spills under *unlikely* and *very unlikely* scenarios, depending on location and timing, although a large spill into a river is highly improbable. Impacts on terrestrial mammals and birds could be high (i.e., yield effects at a population level) if the spill was large or affected a concentration of animals (both highly improbable). Impacts of either terrestrial or waterborne spills on threatened, endangered, and protected species likely would be negligible to moderate, the latter resulting from a worst-case (low-probability) high-volume spill reaching Prince William Sound.

TABLE 4.4-39 (Cont.)

Issue Area	DEIS Section	Summary of Impacts[a]
Economics	4.4.4.13	Impacts on state revenues would potentially be large, a function of how long normal TAPS operations were interrupted by the spill; negative impacts on tourism and recreation probably would be small; impacts on property values would be limited to areas where alternative uses to the TAPS are possible (e.g., Fairbanks area); impacts might occur in the form of hiring additional staff for cleanup operations.
Subsistence	4.4.4.14	Large impacts on subsistence fisheries could occur locally from high-volume spills in rivers under certain conditions (shallow river, low flow, key period of fish reproduction), although the frequency (likelihood) of such an event in a river is very low (1 in 255 million); large impacts on terrestrial subsistence resources could occur locally if a large number of animals are concentrated and hence affected, although the frequency (likelihood) of this occurring is very remote.
Sociocultural systems	4.4.4.15	Impacts could occur due to large spills that undermine subsistence fisheries or terrestrial game, thereby disrupting local rural economies that rely largely on subsistence; impacts would occur in the form of employment opportunities for rural residents, both Alaska Native and non-Native.
Cultural resources	4.4.4.16	Impacts could accompany spills of sufficient volume to affect important cultural resources near the TAPS.
Land use and coastal zone management	4.4.4.17	Land use impacts would be possible, depending on the size, location, and timing of a spill, although impacts would be limited in geographic extent; impacts to coastal zone management also would be possible, depending on the size, location, and timing of a spill, with terrestrial impacts limited in geographic extent and water-borne spills potentially affecting a larger area, both having possible (though highly unlikely) subsistence impacts.
Recreation, wilderness, and aesthetics	4.4.4.18	Recreation impacts could be long-term and severe, depending on the location and extent of a spill, until cleanup is complete; negative impacts on Wilderness Area in Gates of the Arctic NPP would be possible only via a large-volume spill into the Koyukuk River, both of which are highly improbable; impacts could affect aesthetics, depending on the location, duration, and timing of the spill, with the greatest impacts associated with parks, wilderness areas, recreation areas, and localities visible from a public road.

a Impacts are summarized here for the convenience of the reader. Details of the impact evaluations could not be included because of space limitations; additional information for each issue area may be found in the referenced EIS section.

considerably, thereby reducing effects to environmental justice populations.

The effects of a spill on groundwater also could be high and adverse, even for a comparatively smaller routine spill under the *likely* probability category (see Section 4.4.4.4). In cases where people draw water from wells, spills that affect groundwater could restrict well use or adversely affect human health if contaminated water continued to be used. Well use is greater outside of urban areas, where municipal water systems are unavailable; the vast majority of the area crossed by the TAPS consists of these rural areas.

Because much of the area in geographic proximity to the TAPS and many of the communities examined here occur in areas lacking municipal water and contain disproportionately high percentages of minority and low-income persons (see Maps 3.29-1 and 3.29-2 and Table 3.29-1), it is likely that groundwater impacts from a spill could have disproportionately high and adverse effects on one or both environmental justice populations. Regulatory guidelines guard against human use of contaminated water, thereby providing a type of protection from negative effects of groundwater impacts on human health (see Section 4.4.4.7). However, the need to obtain an alternative source of water should groundwater become contaminated would persist for those localities affected. Sufficiently detailed, site-specific information on local groundwater is not available to enable a listing of communities that likely would have their water supplies affected by a spill. However, as shown in Map 3.25-1 several communities with disproportionately high percentages of minority and low-income populations are located near the TAPS and presumably their groundwater resources could become contaminated by a spill. Rapid response once again could help limit the magnitude of impacts to groundwater in general and environmental justice impacts in particular.

Most impacts to human health and safety from spills are not anticipated to generate high and adverse impacts, regardless of the amount of contaminant released or the probability of release (see Section 4.4.4.7). Regulatory limits provide protection in some cases, such as exposure to contaminated water and soil. In other cases, estimates of likely negative health impacts are not anticipated to be high enough to warrant concern — such as the ingestion of fish and marine invertebrates exposed to a spill. The exception to these tendencies is a large spill, with or without fire, where inhalation of contaminants could introduce unacceptably high human health impacts. The location of such a spill-fire event would be critical. The analysis in Section 4.4.4.7 indicates that human health impacts could accompany *anticipated* (i.e., small volume) spills within 0.02 km of receptors, *likely* spills within 0.4 km of receptors, and *unlikely* or *very unlikely* (i.e., large volume) spills within 13.0 km of receptors. Available data indicate that 24 communities lie within 13.0 km of the TAPS (none closer than 0.4 km, however) (Table 4.4-40). Four of these 12 communities contain a disproportionately high percentage of minority residents, while 9 contain disproportionately high percentages of low-income residents, indicating the possibility of environmental justice impacts under certain *unlikely* and *very unlikely* spill scenarios. However, the likelihood of one of these improbable accidents occurring near any community, much less one with disproportionately high environmental justice populations, is extremely low. Rapid spill response, coupled with evacuation of any human population in danger of excessive exposure to fumes or smoke, would help to minimize possible impacts if such a spill did occur.

As discussed in Section 4.4.4.10, an oil spill in a river or stream crossed by the TAPS may cause high negative impacts to fish. The highest impacts would occur under a combination of particular circumstances — large volume spill, shallow stream or river, low-flow conditions, and a key period in anadromous or resident fish life cycle. Removing any of these circumstances would reduce the magnitude of the impact, whereas having them all occur at once in addition to the likelihood of a spill in a river would reduce the likelihood of occurrence considerably (although it would increase the impacts should it occur). The main environmental justice impacts of a spill affecting fish would be related largely to subsistence and sociocultural systems, both discussed below.

TABLE 4.4-40 Communities within 13.0 km of the TAPS Possibly Experiencing High Human Health Impacts due to *Unlikely* or *Very Unlikely* Spills[a]

Community	Disproportionately High Minority Population	Disproportionately High Low-Income Population
Big Delta		X
Coldfoot		
College		
Copper Center	X	X
Copperville		
Deadhorse		
Delta Junction		X
Fairbanks	X	X
Fox		
Gakona		X
Glenallen		
Gulkana	X	X
Harding Lake		
Kenny Lake		X
Livengood		X
Moose Creek		
North Pole		
Paxson		
Prudhoe Bay	X	
Salcha		
Tazlina		
Tonsina		
Valdez		
Wiseman		X

[a] X = minority population in 2000 in excess of 32.4% or low-income population in excess of 9.4%.

Source: Summary of selected data from Table 3.29-1.

Under certain conditions, oil spills also could have high negative impacts (impacts at a population level) on birds and terrestrial mammals, as described in Section 4.4.4.11. Large-volume spills, under *unlikely* or *very unlikely* scenarios, affecting concentrations of birds or mammals are of particular concern. As noted in the original discussion of these impacts, large spills and concentrations of birds or terrestrial mammals are individually improbable, and the combination of these conditions is even less likely. The main environmental justice impacts of such a spill affecting birds or terrestrial mammals would largely concern subsistence and sociocultural systems, both discussed below.

Section 4.4.4.14 discusses impacts to subsistence from various spill scenarios. The largest negative impacts identified were those from *unlikely* and *very unlikely* large-volume spills in streams and rivers — the same high-impact scenarios just described for fish. As noted, under certain conditions the impact of a high-volume spill on fish would be large, taking the form primarily of high fish mortality. Under worst-case conditions, recovery of a subsistence fishery could take years. Although the amount of river or stream affected is anticipated to vary with spill volume, waterway configuration, and water flow, the larger areas affected would be sufficiently broad to preclude easy relocation of subsistence activities.

Consistent with federal guidelines in Alaska, this FEIS treats subsistence as an activity of rural Alaskans. Section 3.24 notes that 11 of the 45 communities considered in this study do not meet the rural requirements for subsistence. Many of the remaining communities (for which data are available) conduct subsistence fishing downstream from the TAPS (see Map 3.24-1). The following locations could have their subsistence base affected by a large spill in the Gulkana River, given the estimated leading edge of an oil slick (see Table 4.4-14; see also Appendix D): Copper Center, Gakona, Glennallen, Gulkana, Kenny Lake, Paxson, and Tonsina. As noted in Section 4.4.4.10, because it is shallow, a large spill in the Gulkana River could be particularly harmful to fish. A large spill in the Tazlina River, in turn, could damage the subsistence fishery of Chitina, Copper Center, Gakona, Glennallen, Gulkana, Kenny Lake, and Tonsina. Several of both groups of communities contain disproportionately high percentages of minority or low-income populations (Table 4.4-41). In combination with possibly high and adverse subsistence impacts, this situation introduces the possibility of negative environmental justice impacts. Despite the impacts that would be possible given the specified conditions, as noted above the chance of large spills in a particular river would be quite improbable — on the order of 1 in 255 million for a guillotine break caused by a helicopter crash affecting a 300-ft length of pipeline crossing a specific waterway (see Section 4.4.4.3.1).

TABLE 4.4-41 Selected Communities Possibly Affected by Worst-Case *Very Unlikely* Guillotine Break during Low-Flow Conditions, Gulkana and Copper Rivers

River/Community Affected	Disproportionately High Minority Population	Disproportionately High Low-Income Population
Gulkana River		
Copper Center	X[a]	X
Gakona		X
Glennallen		
Gulkana	X	X
Kenny Lake		X
Paxson		
Tonsina		
Tazlina/Copper Rivers		
Chitina	X	X
Copper Center	X	X
Gakona		X
Glennallen		
Gulkana	X	X
Kenny Lake		
Tonsina		

[a] X = minority population in 2000 in excess of 32.4% or low-income population in excess of 9.4%.

Source: Summary of selected data from Table 3.29-1.

As discussed above, large spills under certain conditions also could have high impacts on birds and terrestrial mammals, both potential subsistence resources (depending on the location and species — see Section 3.24). However, as discussed in Section 4.4.4.14, subsistence impacts probably would not be extremely high from such a spill, primarily because terrestrial resources tend to be dispersed over broad geographic expanses and harvest areas typically involve large areas well removed from the TAPS (see Appendix D). Environmental justice impacts thus would not likely be a concern in terms of subsistence due to a spill with localized impacts on birds or terrestrial mammals.

As noted in the evaluation of impacts to sociocultural systems from spills (see Section 4.4.4.15), large spills in rivers or streams could disrupt subsistence in a way that also would affect sociocultural systems. For sociocultural systems with a heavy reliance on subsistence, such disruption could undermine a major portion of the economic or adaptive base of the society. As discussed above, the greatest impacts would occur through the combination of several conditions whose co-occurrence would be highly improbable. The area most likely to experience high and adverse subsistence impacts, and hence high and adverse socioeconomic impacts, would be that including the communities listed in Table 4.4-41 for spills in the Gulkana and Tazlina Rivers. The socioeconomic systems most likely affected adversely would be the Ahtna Athabascans and the general, rural non-Native socioeconomic system considered in several parts of this FEIS (see Section 3.25). As discussed above, high impacts on birds and terrestrial mammals are not anticipated to generate large subsistence impacts and, therefore, should not disrupt sociocultural systems to any great extent.

High and adverse impacts to recreation and aesthetics are anticipated under certain spill scenarios — for recreation areas or parks near the TAPS, and for Wild and Scenic Rivers that might be affected (see Section 4.4.4.18). Although several recreation areas and parks (or portions thereof) occur in the vicinity of the TAPS, only three lie within one-quarter mile of the pipeline and related facilities (see Table 3.27-1), reducing the likelihood of noteworthy spill impacts and hence environmental justice concerns. However, the Gulkana River is federally designated as a Wild River and intersects the TAPS. Although a large spill into a particular river or stream is highly unlikely, such an event would have high and adverse impacts. Communities downstream of the TAPS on the Gulkana and Tazlina/Copper Rivers include Copper Center, Gulkana, Kenny Lake, and Tazlina (see Map 1-2). Each of these communities contained disproportionately high percentages of minority or low-income persons in 2000 (see Table 3.29-1). Data on the use of the Gulkana River for recreational purposes by either minority or low-income populations do not exist, although either may use it for recreation. Aesthetic impacts, in turn, could occur for any of the five communities listed in Table 4.4-41. As a result, environmental justice impacts in recreation and aesthetics may accompany large spills into the Gulkana River.

The examination of environmental justice tends to focus on negative impacts, in a manner consistent with the definition of the concept in Executive Order 12898. However, short-term positive impacts likely would also accompany spills in the form of employment of local people on cleanup crews, providing wage employment to areas where jobs paying cash often are hard to find (see Section 4.4.4.15). If individuals living close to the spill are hired, the relatively large percentage of low-income and minority residents near the TAPS, coupled with agreements for employment between APSC and selected Alaska Native villages, suggests that environmental justice populations would be among the beneficiaries of spill-related employment.

In summary, it is important to reiterate that the high and adverse impacts discussed would be the result of generally highly improbable accidents, not normal operation of the TAPS.

This statement is not meant to downplay the possible consequences of such accidents, which, in many cases, could be severe and last several years. Rather, it is meant to help keep in perspective that the spills necessary to generate the impacts mentioned above probably would not occur during the renewal period. Should such an accident occur, explicit steps would be taken to limit impacts and mitigate consequences, for both environmental justice populations and affected people in general.