Appendix A:
Methodology Descriptions

Appendix A: Methodology Descriptions

A.1 Introduction

This appendix describes the methodologies used to analyze the environmental consequences of implementing any of the alternatives presented in the environmental impact statement (EIS). The alternatives are to renew the Federal Grant of right-of-way (ROW) for the Trans-Alaska Pipeline System (TAPS) for a period of 30 years (proposed action), to renew the Federal Grant for a period of less than 30 years, or to not renew the Federal Grant (no action).

The methodologies used in the assessment of the proposed action and alternatives are presented by impact area (Sections A.2-A.15) in the order that they are discussed in the main body of this FEIS. The method used for the cumulative analysis is presented separately in Section A.16. Major assumptions specific to individual methodologies are discussed under individual impact areas; however, several assumptions apply for all methodologies and are presented below:

- Current (2001/2002) conditions of the TAPS define the base case for the analyses.
- Monitoring, maintenance, and repair of the TAPS would continue for the proposed action.
- The TAPS would operate in compliance with all applicable regulations for the proposed action.
- Operations at the Valdez Marine Terminal are treated as part of the proposed action.
- The North Slope and Prince William Sound activities are analyzed separately in the FEIS as part of the cumulative impacts (see Section A.16).
- Levels of activities that correspond to crude oil throughput of 2.1 million barrels per day (bbl/d) (design capacity), 1.1 million bbl/d (base case), and 0.3 million bbl/d (economically feasible minimum) are assumed to provide a range of reasonable operational scenarios for assessing the impact of the proposed action.
- The no-action alternative addresses removal of all aboveground components of the TAPS; belowground components would be cleaned and capped. One exception would be the removal of belowground components at river training structures.
- No new facilities would be constructed for dismantling and removing the TAPS (current pump stations, workpads, and staging areas would be used).
- Under the no-action alternative, gravel pads and disturbed surface soils would be left in place and revegetated according to accepted restoration practices.
- The impacts of such restoration activities are discussed under no action.

A.2 Physical Environment: Geology, Seismicity, Soils, Permafrost, and Hydrological Resources

From an environmental perspective, renewal of the TAPS ROW Federal Grant could produce direct, indirect, and cumulative impacts on the physical environment. Similarly, the environment could impact the TAPS.

Normal operations, routine maintenance, system upgrades, and accidents over the next 30 years are impacting factors for the physical environment under the proposed action. Under the no-action alternative, impacting factors of the TAPS on the environment include dismantling the pipeline system, removing the dismantled system, accidents, and restoration activities. The impacting factors under the proposed action, less-than-30-year renewal alternative, and no-action alternative could:

- Modify rivers and streams by erosion, deposition, migration, and flow restriction;
- Create ponding and flooding along the ROW;
- Drain and create thaw lakes;
- Degrade surface water and groundwater quality;
- Deplete surface water and groundwater resources;
- Spread contamination on land, surface water, and groundwater;
- Disturb permafrost;
- Change the number, size, and connectivity of thermokarsts along the ROW; and
- Remove geologic resources.

Conversely, the physical environment could impact the TAPS under the proposed action, less-than-30-year renewal alternative, and no-action alternative. Impacting factors on the TAPS could include:

- Earthquakes;
- Glacial movements (surges and retreats);
- Solifluction (i.e., a slow-motion debris flow created when a permafrost layer that has reduced cohesive strength because of supersaturation moves slowly downhill);
- Mud flows;
- Climate change; and
- Geologic hazards, such as debris flows, landslides, rock falls, slumps, and floods.

These impacting factors could affect the TAPS by causing physical changes and accidental releases of oil or other materials, which, in turn, could then affect the environment in the ways discussed above.

Effects of the impacting factors on the environment under the proposed action and the less-than-30-year renewal alternative were evaluated by interpolating impacts from existing conditions as a base case, historical ranges of impacts observed from more than 25 years of operation, and mitigation activities that have been implemented. If a potential impact of the proposed action would lie outside the historical range observed, the impact was evaluated by extrapolating historical impacts and their mitigation and using engineering judgment. The potential impacts of the environment on the TAPS were assessed on the basis of existing and historical information and engineering judgment. Impacts were quantified, to the extent possible, by making simplifying assumptions and using analytical expressions, energy balances, and conservation laws (e.g., the total mass in a system is constant).

Under the no-action alternative, the impact of dismantling and removing the TAPS and restoring the ROW was evaluated on the basis of historical impacts of TAPS construction, considering historical mitigation strategies. If necessary, impacts were extrapolated from historical information and engineering judgment to account for impacts outside the range of previous activities.

Data used to evaluate the impacts of geology and seismology on the TAPS were obtained from surface and bedrock maps of the underlying strata along the ROW; historical seismic monitoring information; literature on fault systems crossed by the ROW; and, where possible, aerial photographs of sensitive regions along the ROW.

Information on soil and permafrost was obtained from permafrost surveys, the scientific literature, soil classification guides, proceedings of polar conferences, maintenance databases, documented historical mitigation activities, site-characterization data for known spill sites, and throughput and accident source terms[1] developed for this analysis by Argonne National Laboratory (Argonne) staff.

Data used to evaluate the hydrological impacts included documentation on river systems crossed by the ROW, U.S. Geological Survey (USGS) databases on river flow, historical information on groundwater well completions, historical data on water uses, National Pollutant Discharge Elimination System (NPDES) permits, and the open literature. Accident source terms (such as spill volumes and release durations) and cumulative source terms (i.e., releases from activities not related to the TAPS that can impact the same resources) were developed by Argonne staff.

Source terms used in the impact analyses for geology, seismology, soils, permafrost, and hydrology were obtained from the Argonne Operations/Risk Analysis Group. Impacts evaluated by the Geology, Seismology, Soils, Permafrost, and Hydrology Group were supplied to the following disciplines for their analyses: Ecology, Human Health, Cultural Resources, Atmospheric Sciences, and Coastal Plain Management. In addition, the Geology, Seismology, Soils, Permafrost, and Hydrology Group supplied information to the Operations/Risk Analysis Group for potential accident scenarios associated with environmental impacts on the TAPS (e.g., earthquakes, glacier movement).

A.3 Paleontology

Methods used in the assessment of paleontological resources focused on evaluating the potential disturbance of plant and animal fossils under the proposed action, the less-than-30-year renewal alternative, and the no-action alternative. Paleontological remains are protected under the Antiquities Act of 1906 (and other laws as indicated in Section 3.6), pending more focused legislation currently in preparation; as a result, guidance on impact assessment is fairly general. The examination of impacts to paleontological resources ultimately relied on evidence of the existence, density, and nature of fossil deposits in areas that might be disturbed under the alternatives considered. However, the evaluation also considered the quality of available data and the likely condition of paleontological resources. The latter factor was based largely on accumulated ground disturbance from the more than three decades spent constructing and maintaining the TAPS. The region of influence for paleontological resources includes the ROW and any areas affected, or likely to be affected, by TAPS construction or maintenance.

The evaluation of impacts to paleontological resources required specific information on those resources. Critical data included deposit location, assorted information in publications on paleontological resources in the vicinity of the TAPS, data from researchers focusing on the paleontology of Alaska, and information in files maintained by the State Historic Preservation Office, the Bureau of Land Management (BLM), other federal agencies, and the Alyeska Pipeline Service Company (APSC). The analysis used this assortment of information to define where paleontological deposits occur; the age, depth, and spatial extent of each deposit; and the level of disturbance of each locality. It also used available data to understand the likelihood that other paleontological resources occur in particular locations, recognizing the special potential of sedimentary strata for such deposits. Finally, the analysis considered those portions of APSC procedures manuals dealing with paleontological resource protection and monitoring.

The assessment of potential impacts to paleontological resources involved identifying those activities that would result in surface or subsurface disturbance within the region of influence. Activities evaluated included TAPS maintenance efforts that likely would disturb areas containing known paleontological resources or areas likely to contain such resources. Impacts, in turn, were defined as the

[1] The phrase “source terms” refers to the quantities and characteristics of contaminants released to the environment from specific sources or groups of sources.

effect of anticipated activities on intact known paleontological resources. Other potential sources of impacts included the effect of increased accessibility to intact paleontological remains and any effects resulting from spills and spill response-related activities. Of particular concern were any impacts potentially affecting deposits of vertebrate fossils.

Several disciplines provided data relevant to the evaluation of impacts to paleontological resources. Geology and soils analyses provided information on the distribution of geological strata, providing insight both on likely effects of any spill in certain paleontological deposits and on areas with a high potential for undocumented paleontological resources. The hydrological evaluation, in turn, provided information on changing waterways and the potential for erosion that might threaten paleontological deposits. Personnel working on the TAPS maintenance sections of the FEIS described procedures and activities associated with TAPS operation that might disturb known fossil deposits.

A.4 Air Quality and Noise

A.4.1 Air Quality

Assessment of the potential air quality impacts for the proposed action, the less-than-30-year renewal alternative, and the no-action alternative involved a multistep process that included (1) collecting and organizing information on existing air quality and meteorological conditions in the affected environment; (2) identifying and quantifying TAPS-associated air pollutant emissions sources for a range of activities under the proposed action, no action, and the less-than-30-year renewal alternative; (3) identifying and quantifying pollutant emissions from other sources in the affected areas; (4) using computer models to estimate the dispersion of TAPS-related emissions and their contributions to ambient air quality; and (5) comparing results of the modeling to appropriate air quality standards.

Available meteorological data and ambient air quality measurements from instruments along the TAPS ROW were acquired for use in describing the existing environment and as input data in modeling potential air quality impacts resulting from the proposed action and the no-action alternative. Data for meteorological parameters, such as surface data (wind speed and direction, temperature, humidity, precipitation, etc.) and upper-air data were obtained from government agencies (e.g., National Climatic Data Center) and industry sources. Ambient monitored and modeled data for criteria and hazardous air pollutants were obtained from the U.S. Environmental Protection Agency (EPA) and industry sources.

Basic information on emission sources and emission inventory data for the TAPS stationary, mobile, and fugitive pollutant sources that is essential in assessing potential air quality impacts were obtained from such documents as TAPS facility air permit applications submitted to and air permits issued by the Alaska Department of Environmental Conservation (ADEC) and environmental impact studies conducted by industry.

Information on the extent of disturbed land areas and vehicle and heavy equipment usage associated with maintenance and system-upgrade activities was obtained from industry sources. Data on the extent of land area disturbed and vehicle and heavy equipment usage that would be associated with termination activities under the no-action alternative were developed in consultation with industry specialists. Information previously developed for other similar projects was also obtained and used to the extent applicable.

To assess the significance of TAPS emissions relative to overall air quality, information and inventory data for other emissions sources in the areas surrounding TAPS facilities were obtained from regulatory agencies.

In assessing potential air quality impacts, a number of assumptions were necessary because of the limitations of impact assessment models or uncertainties in model input data. In addition to the general assumptions outlined in

Section A.1, the following specific assumptions were made for the air quality impact analysis:

- Assessments of potential impacts were made for (1) areas up to 30 mi from sources for ambient air quality impacts of criteria pollutants, and (2) community boundaries for hazardous air pollutants.

- Assessments of potential impacts on air-quality-related values, such as visibility and acid deposition, were made for sensitive receptors located within about 60 mi of source areas.

The following procedures were used to assess potential air quality impacts resulting from the proposed action and the no-action alternative:

- Confirm or estimate emissions data for criteria and hazardous air pollutants from TAPS facilities and TAPS-related activities by reviewing available data or using available emission factors and activity levels.

- Estimate emission rates of hazardous air pollutants from accidental releases or spills of crude oil, petroleum products, and hazardous materials by using the EPA-recommended procedures for estimating evaporative emissions from mixtures containing toxic liquids and water and solutions of toxic substances (EPA 1999a; IT Alaska 2001).

- Assess the significance of TAPS-related emissions by comparing with emissions from major facilities in adjacent areas.

- Perform air dispersion modeling as needed by using EPA-recommended models, such as the Industrial Source Complex Model (ISC3) (EPA 1995) for short- and long-term continuous emissions and the ISC3 or Areal Locations of Hazardous Atmospheres (ALOHA) Model (EPA et al. 1999) for short-term emissions from accidental releases.

- Compare modeled concentration increments with prevention of significant deterioration (PSD) increments.

- Identify appropriate background concentrations used in air quality impact modeling studies conducted recently for TAPS facility emission sources.

- Add background concentrations to the modeling results and compare resultant concentrations with National or Alaska Ambient Air Quality Standards (NAAQS or AAAQS).

- Assess potential visibility and acid deposition impacts at sensitive receptors by relating recent trends in TAPS emissions to those in available visibility and sensitive lake acidity data at those sensitive receptor locations.

Factors that would determine levels of potential air quality impacts would include the intensity, duration, and frequency of TAPS activities that generate air emissions. These parameters were defined on the basis of available information or were estimated in consultation with industry specialists for normal operations, routine maintenance activities, system upgrade activities, routine security and oil spill surveillance activities, and restoration activities. These data then were used as input for impact modeling and assessments.

Certain basic information and results of impact assessments from other disciplinary areas were needed to conduct air quality impact modeling and assessments. The results from that modeling were in turn needed in conducting impact assessments for certain other disciplinary areas. Information to and from other disciplinary areas for air quality was as follows:

- *Transportation:* Received current and projected traffic volumes (ground, air, and marine);

- *Accidents:* Provided meteorological data;

- *Spills:* Received projected information on potential spills of crude oil, petroleum products, and hazardous materials; and

- *Human health:* Provided air dispersion modeling results for criteria and hazardous air pollutant emissions.

A.4.2 Noise

Intrusive noise can be continuous, intermittent, or impulsive depending on its duration. Continuous or intermittent noise is typically generated by stationary sources, such as boilers and diesel generators, and mobile sources, such as aircraft, vehicles, and construction equipment. Blasting that uses explosives to demolish concrete structures as part of termination activities under the no-action alternative would produce impulsive noise accompanied by ground vibration and airblast overpressure.

The methodology used to assess potential impacts on noise consisted of (1) collecting available information on background and ambient noise measurements and noise studies conducted in the vicinity of TAPS facilities; (2) collecting information on existing noise sources within and around the TAPS facilities as well as on TAPS-related noise sources for the proposed action and the alternatives, (3) determining the locations of potential sensitive receptors, and (4) modeling potential noise impacts for comparison with appropriate noise guidelines.

Procedures used in assessing potential impacts of continuous or intermittent noise were as follows:

- Compilation or estimation of sound-power or sound pressure level of individual noise sources along the TAPS ROW by using the data available in the literature,
- Estimation of the potential noise impacts at TAPS facility site boundaries or nearby sensitive receptors by considering geometric spreading of sound energy through the atmosphere, and
- Assessment of potential noise impacts by comparing resultant noise levels with EPA noise guidelines.

The methodology used to assess potential impacts on ground vibration and airblast overpressure consisted of (1) collecting available information on concrete structures to be demolished at TAPS facilities under the no-action alternative; (2) collecting or estimating information on the charge weight per delay,[2] charge depth, and frequency and duration of blasting; (3) determining the locations of potential sensitive receptors; and (4) modeling potential impacts on ground vibration and airblast overpressure for comparison with appropriate guidelines.

Procedures used in assessing potential impacts on ground vibration and airblast overpressure were as follows:

- Estimation of the potential impacts on ground vibration at nearby sensitive receptors by using a monograph (Rose 1981) that relates the peak particle velocity (PPV), charge weight per delay, and the distance between the blast and selected receptor. (The PPV or the velocity of ground movement is generally accepted as the best indicator of the potential for structural damage.)
- Assessment of the potential impacts on ground vibration by comparing the resultant PPV with the PPV level of 2.0 in./s, which is generally accepted as safe for poor plaster (DOE 1990).
- Estimation of the potential impacts on airblast overpressure at nearby sensitive receptors by using empirical formulas that allow computation of peak overpressure at a given receptor location for a blast of a given charge weight per delay by correcting the peak overpressure at the reference of 200 ft from 1.0 lb of charge exploded at ground level (Schomer 1973, 1981).

2 Blasting is commonly conducted in sequences using delays. Thus, for any given delay, only a portion of the total explosive charge is set off to limit the potential impact to that of the portion rather than the total.

- Assessment of the potential impacts on airblast overpressure by comparing estimated peak overpressure with a conservative upper limit value (0.01 $lb/in.^2$) below which no damage to farm or wild animal was caused (Fletcher and Busnel 1978).

Certain basic information and results of impact assessments from other disciplinary areas were needed to conduct noise impact modeling/estimation and assessments. The results of that modeling/estimation were in turn needed in conducting impact assessments for certain other disciplinary areas. Information to and from other disciplinary areas for noise was as follows:

- *Transportation:* Received current and projected traffic volumes (ground, air, and marine); and
- *Human health:* Provided impact modeling/estimation results for noise, ground vibration, and airblast overpressure.

A.5 Hazardous Materials and Waste Management

Stipulations contained in Part 2 of the Federal Grant require that all operations of the TAPS comply with relevant state and federal laws and regulations. Member agencies of the Joint Pipeline Office (JPO) have the necessary authority to interpret and apply those requirements to TAPS operations, in part through the issuance of operating permits, site licenses, or other enforceable instruments. Operating permits routinely require the collection, maintenance, and, in some cases, submission of data to demonstrate the facility's compliance with permit stipulations. These compliance-related data are valuable indicators of both the nature and dimensions of environmental impacts related to TAPS waste generation and management, and, when relevant, have been used in assessing impacts of the proposed action and the alternatives.

The APSC corporate strategy for compliance with all applicable environmental regulations, permit requirements, and Federal Grant stipulations is to establish and maintain a comprehensive environmental management system that provides explicit guidance for satisfaction of each applicable requirement. The environmental management system comprises a number of "business models," each of which establishes strategic objectives, assigns roles and responsibilities, and defines performance indicators for a specific area of interest. Models with relevance for hazardous materials and waste include water quality, waste management, environment response and remediation, hazardous materials management, field activities, and records and documentation.

In most instances, the business models direct the development of standard operating procedures to, among other objectives, ensure compliance with applicable standards. Procedures controlling the acquisition, storage, and use of hazardous materials are contained in Chapter 8 of the *TAPS Environmental Protection Manual,* EN-43-1 (ASPC 1998a). Procedures relating to the transportation of hazardous materials by APSC and its contractors are contained in APSC Manual HZ-134*, Guide for Packaging and Transporting Hazardous Materials/Dangerous Goods by Highway and by Aircraft* (APSC 2001c).

Procedures that most directly relate to waste management are incorporated into the *TAPS Environmental Protection Manual, Waste Management,* EN-43-2 (APSC 2000). Procedures specific to the Ballast Water Treatment Facility (BWTF) at Valdez Marine Terminal are contained in APSC Manual MP-69-1, *Best Management Practices Plan, Ballast Water Treatment, Alyeska Marine Terminal* (APSC 1998b).

APSC procedures also call for internal reviews of scheduled projects to define their expected environmental consequence and identify applicable external regulatory or internal APSC controls. These project reviews also are valuable sources of information indicative of affected environments from TAPS operations. Such internal reviews can also be used to qualify and in some cases, quantify, the impacts of TAPS operations on the environment.

The pertinent APSC business models and related procedures manuals, as well as data contained in required compliance submissions and environmental monitoring reports and obtained from implementation of internal standard operating procedures, were used to describe the use of hazardous materials in operation of the TAPS and to define the nature and scope of TAPS-related waste management and the associated impacts. The use of TAPS empirical operating data, especially data that have been independently validated through JPO oversight, will result in the highest possible levels of accuracy and relevance. Success of this strategy relies on the validity of the following assumptions:

- Adequate statutory authority exists for effective oversight by JPO agencies;
- Relevant and enforceable regulations are in place to control wastes resulting from TAPS activities;
- Appropriate considerations of human health and environmental risk are reflected in current grant stipulations, operating permits, and other controls;
- Appropriate commitment and resources exist within the JPO to ensure continuing effective oversight of TAPS activities;
- APSC demonstrates a continuing commitment to protect TAPS assets through appropriate preventative maintenance programs and expeditious response to system failures, including accidental or unplanned releases of contaminants to the environment; and
- No significant changes to operating conditions or reconfigurations of the TAPS are contained in the proposed action to continue the Federal Grant, notwithstanding fluctuations of oil throughput, changes made to equipment necessary to meet minimum performance standards, or changes resulting from the introduction of technology advancements, as approved by the JPO.

Identified environmental impacts associated with the generation and management of wastes are categorized as direct or indirect. Working definitions and examples for each of those categories as they pertain to hazardous materials and waste management are as follows:

- *Direct impacts:* Impacts of wastes and waste management activities resulting directly from operation and maintenance of the pipeline, pump stations, and the Valdez Marine Terminal. Examples include wastes from the corrosion digs/corrosion repairs, recovery and disposal of tank bottoms from pump stations and Valdez Marine Terminal crude oil storage tanks, and contaminated media resulting from accidental or unplanned releases of crude oil.
- *Indirect impacts:* Impacts of wastes and waste management activities related to the operation of essential ancillary systems and facilities. Examples include domestic sanitary wastewater and domestic solid waste from pump station personnel living quarters, maintenance of APSC vehicles, equipment refurbishment and repair activities conducted at maintenance yards, and ash from incineration of solid wastes at pump stations.

The JPO has stipulated that the TAPS itself ends at the product discharge points of the oil loading arms at the Valdez Marine Terminal tanker berths. Consequently, ballast water that is removed from tanker ballast tanks and delivered to the BWTF for treatment is technically outside the TAPS, and ballast water management could be addressed as a cumulative impact. However, while the primary purpose of the BWTF is the treatment of ballast water, it is also used to treat potentially contaminated storm water originating within the industrial areas of the Valdez Marine Terminal as well as condensates removed from the pipeline and from storage tanks and transfer piping within the Valdez Marine Terminal. With respect to those functions, therefore, the BWTF is an integral part of the Valdez Marine Terminal and is considered to be within the TAPS. Nevertheless, all wastewater delivered to the BWTF is commingled before treatment, and differentiating the environmental impacts of the BWTF between its treatment of various identifiable waste streams is not possible.

Consequently, it is appropriate to discuss the impacts of the entirety of BWTF operations at one location within this FEIS. However, the BWTF's operation is integral to the Valdez Marine Terminal operations and is discussed in Section 3.16 and Appendix C, and its impacts are addressed in Sections 4.3.12, 4.5.2.12, and 4.6.2.12. In addition, changes to ballast water impacts because of tanker reconfiguration are addressed in Section 4.7.6.10, Cumulative Impacts Analysis.

The following data used to support environmental impact analyses for direct and indirect activities were collected:

- Data supplied by APSC through its Anchorage administrative headquarters and its Fairbanks and Valdez Business Units, including but not limited to:
  - Copies of past and present operating permits,
  - Compliance-related data submitted to appropriate JPO agencies in satisfaction of regulatory or facility-specific permit requirements,
  - Documentation related to the disposal of APSC wastes by commercial facilities,
  - Monitoring data required to be maintained by regulation or permit,
  - Correspondence between APSC and the JPO relating to waste management issues,
  - Internal APSC monitoring data resulting from the execution of standard operating procedures, and
  - Characterization studies of sites at which accidental or unplanned releases of oil or hazardous substances had occurred,
- Compliance-related documents supplied by the JPO,
- Summary reports of unique APSC projects, and
- Personal communications with representatives of JPO regulatory agencies and APSC.

Many compliance-related documents are of a recurring nature (e.g., annual reports of discharges under a NPDES permit or a Biennial Resource Conservation and Recovery Act [RCRA] report of hazardous waste generation and management activities). For these, a number of submissions in the sequence were reviewed to detect any significant trends. Where no such trends were identified, the most recent submissions were deemed to be the most representative of APSC activities. Where substantial changes had occurred over time with respect to the volume or character of waste or their management, averages of the data contained in an appropriate number of historical submissions were used as the best representation of activity levels. Waste management activities of APSC contractors are also reflected in the APSC compliance submissions, even when those activities take place off the TAPS ROW. Consequently, neither contractor data nor personal communications with contractor personnel were deemed necessary to capture contractor waste generation and management activities.

Compliance-related documents obtained from APSC sources and the JPO were used to support environment impact assessments associated with direct or indirect activities, that is, the continuing operation of the TAPS. However, waste management documentation related to oil exploration and production at the North Slope (including both onshore and offshore activities) were collected directly from companies conducting those activities. Such documentation was used to support assessments of cumulative impacts.

For the no-action alternative, the historical record of waste generation and impact during initial TAPS construction was identified as potentially relevant, although not all wastes generated during construction would necessarily reoccur during removal and restoration, as defined by the JPO. In addition, the historical record of pipeline reroutes and replacements was reviewed for its potential relevance in describing the nature and extent of wastes that can be anticipated during removal and restoration activities.

Finally, information on volumes and types of TAPS wastes and the manner in which they are managed will be provided for incorporation into impact analyses of natural ecosystems.

A.6 Human Health and Safety

Potential health and safety impacts to workers and the general public were evaluated for normal operations and accidental releases. The following overview of the methodology addresses both the proposed action, the less-than-30-year renewal alternative, and the no-action alternative.

A.6.1 Proposed Action and Less-Than-30-Year Renewal Alternative

Two types of potential impacts are addressed: (1) the industrial (physical hazard) risk and (2) the risk from chemical exposures during both normal operations and accidental releases at the pipeline releases.

A.6.1.1 Normal Operations

A.6.1.1.1 Occupational. The numbers of worker fatalities and injuries associated with continued operation and maintenance of the pipeline were estimated by using occupational hazards statistics available from the Bureau of Labor Statistics and the National Safety Council (NSC 2000, 2001). These projections were then compared with the historical safety performance data reported for normal pipeline operations.

Fatality and injury risks for recordable injuries and those involving lost workdays were calculated as the product of the appropriate incidence rate, the number of years for operations, and the number of full-time equivalent employees for operations. These calculations of risks of fatality and injury from industrial accidents were based on historical industrywide statistics and, therefore, do not consider a threshold (i.e., any activity would result in some estimated risk of fatality and injury).

The analysis of physical hazards to workers required historical occupational hazard data from APSC and the JPO — specifically annual fatality and injury incidence rates and the number of workers by location over time.

Potential impacts of chemical exposures to workers were not quantified for normal operations and maintenance activities. It was assumed that potential worker exposures to chemicals used in TAPS operations (e.g., chemicals used at pump stations) were addressed by U.S. Occupational Safety and Health Administration (OSHA) permissible exposure limits (PELs) (OSHA 2001). To maintain compliance with OSHA standards, it is likely that chemical exposures would be minimized by various engineering mitigative controls (e.g., fume hoods and glove boxes and heating and ventilation designs for high-hazard areas) and extensive indoor air monitoring.

A.6.1.1.2 Public. The first step of the chemical exposure assessment for members of the public was to screen potential hazards of chemical exposure along the ROW on the basis of estimates of the quantities released to air, water, or soil. If the screening phase revealed that potentially significant chemical exposures could occur to the general public during normal operations, the associated risk was then quantitatively assessed. When available, chemical concentrations in air, water, and/or soil were compared with generic screening values that correspond to a fixed level of risk to human health. Chemical concentrations less than or equal to screening levels or below background concentrations were eliminated from further evaluation. The purpose of this human health screening approach was to identify any significant chemical contaminants and exposure pathways that might warrant quantitative analysis. The methodologies used in quantitatively assessing chemical risk and impacts on human health from normal operations and maintenance of the pipeline are described below.

The evaluation of chronic health hazards focused on hypothetical maximally exposed individuals (MEIs) of the general public. Because the standard methodologies for chemical health risk assessment do not usually involve assessment of collective (population) dose or risk, population risk was not evaluated for chemical exposures (EPA 1989). However, if a health risk was shown to exist for the MEI, additional assessment was conducted to estimate the number of individuals likely to be affected.

Chemical intakes and health risks from relevant exposure routes (e.g., inhalation) were assessed when estimated releases from TAPS operations exceeded screening values. For example, air dispersion modeling was conducted to estimate exposure media concentrations. Possible exposures for the MEI could include inhalation of airborne emissions, incidental ingestion of contaminants deposited on soil, and ingestion of contaminated water. Intake was summed over the appropriate potential exposure pathways. Appropriate exposure factors (e.g., data on human behaviors and characteristics that affect exposure to environmental contaminants) for the various pathways to be evaluated can generally be obtained from EPA guidance documents.

Risks from chemical releases are commonly expressed in terms of the “hazard quotient” for exposures to noncarcinogens (i.e., comparison of estimated receptor doses with reference levels or doses below which adverse effects would be very unlikely to occur). For carcinogenic chemicals, the estimated average daily intake was multiplied by carcinogenic potency factors to estimate increased lifetime cancer risks. The risks were then compared with the risk range of 10^{-4} to 10^{-6} generally used to assess the significance of exposures to carcinogens. Where possible, the reference levels used to generate hazard quotients and carcinogenic risks were obtained from the EPA's Integrated Risk Information System (IRIS) (EPA 2001). If standard reference levels were not available, the existing toxicity literature was reviewed to assess the potential hazard of estimated exposures.

Whenever possible, the assessment of chronic health hazards of chemical exposures to the general public used quantitative estimates of the chemical concentrations in air, water, or soil that were estimated in the medium-specific analyses of the FEIS. If such information was not available, the assumption was generally made that there was insufficient evidence for elevated media concentrations from normal operation releases and, therefore, the potential for public health impacts was too low to be evaluated. Another important assumption was that physical hazards to the general public are minimized through restricted access to TAPS facilities. It was also assumed that health surveillance (epidemiological) data are not available for documenting current health status of the general public.

A number of types of data from other disciplines were needed for these assessments: (1) maximum air toxics levels (e.g., at pump stations, Valdez Marine Terminal); (2) chemical concentrations in groundwater and surface water; and (3) residual chemical concentrations in soil. Demographic data on nearest residences and subsistence patterns were also needed. Data sources for evaluating chronic health hazards of chemical exposure were mostly those that the other disciplines needed to estimate releases and subsequent media concentrations (e.g., air toxics emissions data from the Valdez Marine Terminal and pump stations, BWTF effluent discharge concentrations, and demographic data).

A.6.1.2 Accidental Releases

A.6.1.2.1 Occupational. Because historical safety hazard data were not compiled and reported for specific spill events, physical hazards to workers during spill responses were included in the overall data analysis of worker fatalities and injuries associated with ongoing operations of the pipeline.

Potential impacts of chemical exposures and/or physical hazards to workers were also addressed by modeling a fire and explosion (for additional information, see the fire analysis of spill events in Section 4.4.3). The probability of fire and explosion at the Valdez Marine Terminal was estimated on the basis of historical data. Although highly speculative, estimation of the number of fatalities and injuries resulting from this scenario was also explored. However, it is assumed that potential exposures of workers to chemicals from a fire and/or explosion would be addressed both through emergency response contingency plans and by compliance with OSHA standards for minimizing chemical exposures using various engineering mitigative controls for high-hazard areas.

A.6.1.2.2 Public. This analysis primarily addressed the potential risk to the general public of chemical exposures resulting from accidental releases at the pipeline. Because it is assumed that spills onto gravel or soil surfaces would be cleaned up according to regulations, there should be no long-term impacts to soil or exposure to contaminants in soil. Therefore, the first step was to confirm that no complete exposure pathways or elevated concentrations would remain after remediation was completed at the land spill sites. Specifically, the risk-based corrective action approach that was conducted for one of the larger spill sites was reviewed to ensure that the ADEC Site Contamination Program has shown that spills to soil have not resulted in potential human health risks from direct contact or leaching to groundwater.

For spills to water, the potential for uptake of pipeline-related contaminants into the food chain, with subsequent ingestion of subsistence species by Alaskans, was evaluated. Specifically, if elevated concentrations of petroleum hydrocarbon constituents in fish tissue were found by the biological resources impact analysis or in the literature, then a screening analysis of fish ingestion was conducted. This screening analysis of potential hazards of chemical exposures to the general public was based on the comparison of incremental tissue concentrations of contaminants in fish to available screening values (e.g., Alaska and national fish advisories). Petroleum hydrocarbon-related compound concentrations less than screening levels or below background concentrations were eliminated from further evaluation. If further analysis was warranted, then available Alaskan dietary intake survey data were used to estimate potential risks from fish consumption.

It was assumed that physical hazards to the general public would be minimized through restricted access to TAPS facilities, including fire/explosion scenarios modeled at the Valdez Marine Terminal. It was also assumed that an indoor explosion event (e.g., at pump stations, North Pole metering station) is improbable because of the relatively low probability of occurrence based on historical data, as well as fire protection systems in place.

Some data needed for these evaluations had to come from impact assessments in other disciplines. For example, maximum fish tissue concentrations of chemicals resulting from spills to water bodies were necessary from the biological resources analyses. The fire and explosion modeling results were needed from the air quality accidents analysis. Demographic data on nearby residences and information on subsistence patterns were also needed. Data sources for evaluating chronic health hazards of chemical exposure include those that were needed by biological resources for estimating the incremental uptake and subsequent fish tissue concentrations. An important source was data collected after the Exxon Valdez spill relating to measured tissue levels of contaminants in fish species. Additional data needs included the level and duration of fish and wildlife advisories; Alaskan dietary intake survey data; chemical constituents in crude oil and industrial products used (including use of proprietary chemicals and pesticides along the ROW); risk characterization data for previous spill-contaminated sites; and ambient air concentration measurements collected after the Exxon Valdez spill.

A.6.2 No Action

The analysis of the no-action alternative of not renewing the Federal Grant of the TAPS ROW, including dismantling and removing TAPS assets and restoring the environment, involved some of the same methodologies as described above for the proposed action. In particular, the health and safety analysis of the no-action alternative focused mainly on deconstruction-related physical hazards to workers.

A.6.2.1 Occupational

The numbers of worker fatalities and injuries associated with pipeline termination activities were estimated by using occupational hazards statistics available from the Bureau of Labor Statistics and the National Safety Council (NSC 2000, 2001). These projections were then compared with the historical safety performance data reported for the original pipeline construction project.

Fatality and injury risks for both recordable injuries and those involving lost workdays were calculated as the product of the appropriate incidence rate, the number of years for operations, and the number of full-time equivalent employees for operations. These calculations of risks of fatality and injury from industrial accidents are based on historical industrywide statistics, for which any activity would result in some estimated risk of fatality and injury.

The analysis of physical hazards to workers used historical occupational hazard data, as available, specifically annual fatality and injury incidence rates and the number of workers by location during the original pipeline construction project. Otherwise, fatality and injury incidence rates for the construction industry were substituted.

Potential impacts of most chemical exposures to workers were not quantified for the no-action alternative. It was assumed that residual crude oil would be removed from the pipeline and that low-level emissions of potentially toxic air pollutants occurring from the use of various chemicals during removal and restoration would be minor. It was also assumed that potential exposures of workers to chemicals used would be addressed by Occupational Safety and Health (OSHA) permissible exposure limits (PELs) and engineering mitigative controls (e.g., personal protective equipment, PPE). However, levels of particulate matter generated during removal and restoration activities were evaluated through comparison with health-based standards.

A.6.2.2 Public

Potential health impacts of most chemical exposures to the general public were not quantified for the no-action alternative. It was assumed that low-level emissions of potentially toxic air pollutants occurring from the use of various chemicals during removal and restoration would be minor. It was also assumed that spills onto gravel or soil surfaces would be cleaned up according to regulations, and, consequently, there should be no long-term impacts to soil or exposure to contaminants in soil. However, levels of particulate matter generated during removal and restoration activities were evaluated through comparison with health-based standards.

It was further assumed that physical hazards to the general public would be minimized through restricted access to areas where removal and restoration activities were occurring and, therefore, potential impacts were not quantitatively estimated for the FEIS.

A.7 Biological Resources

The biological resources assessment evaluated the direct and indirect impacts of the proposed action, the less-than-30-year renewal alternative, and the no-action alternative on aquatic (freshwater, estuarine, and marine), terrestrial, and wetland (freshwater and estuarine) systems. Particular attention was given to protected species and the habitats on which they depend. For the FEIS, protected species considered included the following:

- Species and their critical habitats listed by the federal government under the Endangered Species Act,
- Species of special concern listed by the State of Alaska and the BLM,
- Marine mammals (seals, sea lions, sea otters, and whales) protected by the Marine Mammal Protection Act,
- Bald and golden eagles protected by the Bald and Golden Eagle Protection Act, and

- Essential fish habitat protected by the Magnusen-Stevens Fishery Conservation and Management Act.

The region of influence for direct and indirect effects included the footprint of the 800-mi-long TAPS ROW and associated facilities included in the Federal Grant. These associated facilities included the Valdez Marine Terminal, material sites, disposal areas, previously contaminated sites, and support facilities (e.g., airports, access roads, and work camps). The region of influence of indirect impacts also included adjacent areas that would be affected secondarily by activities within the project footprint. Examples include areas adjacent to pump stations affected by noise, the Dalton Highway (used to transport materials and people to various locations along the pipeline), areas affected by runoff from the TAPS workpad or other exposed ground surfaces, and areas affected under various spill scenarios.

A conceptual impact model was developed to structure the assessment of impacts (Table A-1). This model identified impacting factors associated with the proposed action, the less-than-30-year renewal alternative, and the no-action alternative environmental changes that impacting factors would produce, and the biological resources that would be affected by these changes. Impacting factors associated with the proposed action and the less-than-30-year renewal alternative include facility existence, normal operations, routine maintenance and system upgrades, and spills. Impacting factors associated with the no-action alternative would be the result of the termination activities needed to return the area to a stable condition and the natural succession that would proceed once termination activities were completed.

Environmental changes that would occur in response to these factors and that were evaluated in the biological resources assessment included direct habitat modification, erosion of soils and sedimentation of areas receiving runoff, changes in flow patterns, changes in water quality and temperature, impacts to permafrost areas and the development of thermokarst, contamination of areas affected by spills, barriers to animal movements, changes in air quality, disturbance associated with noise and human activities, and changes in human access. In various ways, these changes affect habitat characteristics and the species supported by these habitats. Changes in species composition, species diversity, species distributions, and population density can result from these environmental changes.

Facility existence refers to the physical presence of the TAPS and its associated facilities in the environment. The existence of the TAPS (even without operation or maintenance) affects biological resources. Existing facilities considered in the assessment included the pipeline, workpad, cleared areas of the ROW, the Valdez Marine Terminal, access roads, disposal sites, material sites, contaminated areas, pump stations, and the gas fuel line that supplies gas to PS 1 to 4. Continued facility existence would result in an extension of existing impacts of the TAPS into the future; these impacts would for the most part be limited to the ROW and vicinity. Impacts of facility existence include maintenance of habitat in an altered condition, changes in flow patterns resulting from either the impoundment of surface flows or diversion of flows, erosion of unvegetated areas (e.g., the workpad) and the subsequent sedimentation of areas receiving runoff and associated effects on water quality, modification of permafrost areas, existing contamination of areas affected by previous spills, barriers to animal movements presented by the pipeline and associated roads, and continued increase in human access and its associated impacts (e.g., noise, disturbance, and hunting).

Normal operations and routine maintenance of the TAPS include oil pumping, transportation of materials and supplies, waste management activities, workpad and access road maintenance, security operations, routine inspections, vegetation control, revegetation activities, and quarry operations at material sites. Impacts of normal operations and routine maintenance would be limited to areas already affected by facility existence. Only quarry operations would be likely to involve actions in areas not currently affected.

TABLE A-1 Conceptual Model for the Effects of the Proposed Action, the Less-Than-30-Year Renewal Alternative, and No Action on Biological Resources

Impact Sources	Environmental Changes	Affected Biological Resources
Proposed Action and Less-Than-30-Year Renewal Alternative	Habitat modification	Terrestrial and vegetation wetlands
Facility existence	Movement barriers	Fish
Normal operations	Changes in flow patterns	Birds and mammals
Routine maintenance and monitoring	Erosion and sedimentation	Threatened, endangered, and protected species
System upgrades	Noise and disturbance	
Spills	Air quality	
	Introduction of exotic organisms	
No Action	Water quality and temperature	
Termination activities	Alteration of natural permafrost patterns	
Natural succession	Contamination	
	Changes in human access to remote areas	

Environmental changes resulting from normal operations and routine maintenance include habitat modification resulting from vegetation control and revegetation activities; erosion and sedimentation from the workpad, access roads, disposal sites, and material sites; impacts to water temperature in areas where the pipeline is buried in and adjacent to streams; changes in permafrost patterns and the occurrence of thermokarst resulting from the pumping of warm oil through the pipeline; noise and disturbance resulting from human activities, especially at the pump stations, Valdez Marine Terminal, and Dalton Highway; potential introduction of exotic organisms from tanker ballast water into marine environments; and degradation of air quality by emissions at pump stations, the Valdez Marine Terminal, and transport vehicles along the Dalton Highway.

System upgrades include corrosion digs, pipeline reroutes, stream modifications, valve replacement, and vertical support member (VSM) replacement. System upgrades could result in impacts in areas outside of the current disturbed areas of the ROW. Depending on the nature of the upgrade, any of the environmental changes identified in the conceptual model (Table A-1) could result.

Spills include the accidental release of any material associated with pipeline operations; the assessment, however, focused on oil spills. Although the obvious effect of spills is related to contamination of soil and water, spills can also result in habitat modification, erosion and sedimentation, noise and disturbance associated with cleanup activities, degradation of air quality resulting from the release of oil vapors, effects on water quality, and melting of permafrost. Spills could occur along the pipeline, at pump stations, and at the Valdez Marine Terminal.

The no-action alternative would involve not renewing the TAPS ROW Federal Grant. Upon expiration of the Federal Grant, at least portions of the TAPS would be removed, and the environment would be restored to some agreed-upon condition. This process — referred to as dismantling, removal, and restoration — could affect biological resources both during and after the activities. All of the environmental changes identified in the conceptual model (Table A-1) could occur, but the direction of the impacts (beneficial or adverse) would, in some cases, be the reverse of the direction of impacts under the proposed action. Environmental changes associated with dismantling, removal, and restoration of the TAPS include erosion and sedimentation from work areas, noise and disturbance from human activities, release of air emissions (dust and vehicle exhaust) and effects on air quality, impacts to water quality from work in and adjacent to streams and other water bodies, and possible contamination resulting from spills and treatment of waste. These changes would occur during the dismantling, removal, and restoration process; eventually they would cease once restoration activities were complete. Over the long-term, the no-action alternative would eliminate impacts associated with facility existence, normal operations, routine maintenance, and system upgrades.

Existing data and research were reviewed to determine past TAPS impacts and describe the baseline conditions that are presented in the description of the affected environment, as well as to project the impacts of continued operations of the pipeline under the proposed action. This approach could be used because most characteristics of the proposed action are within the scope of past activities. Activities that went beyond the scope of past actions (e.g., some system upgrades) were evaluated on the basis of the findings of past research.

The biological resources assessment was spatially based and focused on the effects of environmental changes on habitat characteristics (structure and function), food resources, species composition, species diversity, species distributions (including movement patterns), and population characteristics (e.g., growth, reproduction, survival). Impact significance was predicted from the areal extent of change, including the project footprint and affected adjacent areas; characteristics of the area affected; the magnitude of the change (deviation from the baseline) anticipated; the time period when the impact would occur; the duration of impacts; the sensitivity of biological resources to change; and the rarity and importance of affected components.

Spill scenarios were developed that were representative of a range of spills (both in terms of consequence and frequency) that might occur during pipeline operations. These scenarios included spills in areas where the consequences to biological resources were especially significant because of the sensitivity of the resources (rare or protected species or habitats). The analysis of spill impacts focused on direct impacts to vegetation and animals (resulting in either mortality or changes in productivity), chronic toxicity effects (decreased survivorship, decreased reproduction, food chain effects), and indirect effects resulting from these changes (e.g., effects of organisms in higher trophic levels or those dependent on affected habitats). The assessment of toxicity effects was based on an extensive review of the relevant literature, particularly studies of the effects of the Exxon Valdez oil spill and experimental or actual spills that have occurred in terrestrial habitats and wetlands.

A number of data sources from federal, state, and environmental organizations were used to describe the affected environment and support the biological resources assessment. Sources included, but were not limited to, the Alaska Department of Fish and Game (ADF&G), Alaska Department of Natural Resources, Alaska Natural Heritage Program, APSC, Boreal Partners in Flight Working Group, Exxon Valdez Oil Spill Trustee Council, National Oceanic and Atmospheric Administration, Marine Mammal Commission, U.S. Army Corps of Engineers, Region 7 of the U.S. Fish and Wildlife Service (USFWS), U.S. National Marine Fisheries Service (NMFS), and University of Alaska Museum. In addition, scientific literature on biological resources of Alaska and on impacting factors associated with construction, operation, maintenance, oil exploration, and revegetation was reviewed.

Information on life histories, population estimates, species distributions, and harvest summaries were obtained from ADF&G publications, including the Wildlife Notebook Series; game management unit reports; annual performance reports; fish habitat assessment reports; finfish management reports; and the *Catalog of Waters Important for Spawning, Rearing, or Migration of Anadromous Fishes* (ADF&G 1998).

Information on fish and wildlife resources of Alaska was also obtained from reports produced by the American Cetacean Society (fact sheets), Exxon Valdez Oil Spill Trustee Council (updates on injured resources), USFWS (Cyber Salmon and other reports), NMFS (stock assessments), and USGS (Alaska Land Characteristics Data Set).

Various mapping sources were also used for distributional information on vegetation, fish, and wildlife. These sources included USFWS National Wetland Inventory maps, Environmental Sensitivity Index Files for the North Slope and Prince Williams Sound, ecoregion maps, the *Environmental Atlas of the Trans Alaska Pipeline System* (APSC 1993), and Essential Fish Habitat maps developed by the NMFS.

Consultation with the USFWS and NMFS, pursuant to Section 7(a)(2) of the Endangered Species Act [16 USC §1536(a)(2)], was conducted as part of the Federal Grant renewal process. A biological evaluation (BE) for the proposed action that addresses impacts of the proposed action on listed species and designated critical habitat was prepared (BLM 2002).

A.8 Economics

A.8.1 Introduction and Background

The analysis of the economic and demographic impacts of the proposed action, the less-than-30-year renewal alternative, and the no-action alternative used the Man in the Arctic Program (MAP) model developed at the University of Alaska-Anchorage Institute for Social and Economic Research (ISER) (Berman et al. 1986; ISER 1985). The MAP model has three essential components: an economic module, a demographic module, and a fiscal module.

The economic module is an economic base model that essentially divides the Alaska economy into two forms of economic activity — basic and nonbasic (or support) activities. Basic activities are the key economic sectors that are the source of economic growth in the economy; they bring in money from outside the state in exchange for the goods or services produced. These activities do not depend on other sectors in the economy of the state as the source of growth. All other activities in the state are characterized as nonbasic activities. They support basic activities and are dependent on them for their source of growth.

The demand for the goods or services produced by the basic sector generates money from outside the state, and the resulting multiplier effect on the economy of the state affects the nonbasic sectors in the state economy as basic activities purchase goods and services in local markets from nonbasic activities and as households with workers in these activities are hired. For example, oil produced in Alaska and transported to West Coast refineries generates wages and salaries for oil production workers, pipeline transportation workers and marine transportation workers, some of whom are based in Alaska. Oil sales also generate wages and salaries in the many industries supporting these transactions, including utilities, pipeline maintenance contractors, and accounting firms supplying the oil companies with goods and services as the oil is pumped and transported out of the state. The procurement of goods and services also generates employment and wages and salaries in oil auxiliary industries in the state, such as those producing specialized equipment and providing environmental services.

The procurement of goods and services and wages and salaries in the oil sector and in supporting activities has additional effects on the state economy. Oil production, transportation, and auxiliary industry employees spend their wages and salaries in grocery stores, banks, utilities, hospitals, and other support facilities and services. The employees of these support facilities, in turn, spend their wages and salaries in other support activities. Money brought into the state as a result of the initial purchase of oil from Alaskan oil fields continues to multiply through the economy of the state until purchases are made outside the state or money flows into savings, at which point the multiplier process stops.

The size of the multiplier effect varies among industries as a result of differences in the extent to which the various basic and nonbasic support industries purchase goods and services from within Alaska. Changes over time in the composition of the state's economy mean that the size of the aggregate multiplier for the state also changes over time.

The MAP model characterizes 12 sectors in the economy of Alaska as basic. The petroleum, seafood, mining, timber, and agriculture sectors produce commodities that are primarily for export to other parts of the United States. Tourism and air cargo are also basic industries selling services primarily to nonresidents of Alaska. Each of these industries depends on out-of-state markets as the primary sources of demand for production of goods and services that would not otherwise take place. An additional source of funds from outside the state that contributes to the economy of the state is federal government employment, including military employment. The portion of the Alaska Permanent Fund that comes from earnings on investments made outside the state and income on assets and private pensions are also classified as forms of basic activity. More information on the assumptions used to develop the MAP model and more details on the role of each of the basic sectors in the model can be found in Goldsmith (1997), Berman et al. (1986), and ISER (1985).

The demographic module contains two elements. The age and sex distributions of the population are combined with fertility and mortality rates in an age-cohort survival framework to determine the natural increase in the population. Estimates provided for the Alaska population are specified for both the Alaska Native and non-Native portions of the population to capture differences in the birth rates across the two groups. Net civilian migration to the state is estimated on the basis of Alaskan employment and income growth relative to the United States as a whole. Rapid employment growth in the state has historically attracted large numbers of in-migrants as the new jobs have tended to be relatively highly paid, particularly those in the oil sector.

The fiscal module estimates each major source of revenue at both the state and local level on the basis of the existing tax structure and measures of overall economic activity in the state. The model also incorporates revenue sharing between the state and the various local governments and assumes that total government revenues, plus any change in the balances of state financial assets, and including any allocations from the Permanent Fund, are equal to total government expenditures at both the state and local level.

A.8.2 Impacts of the Proposed Action, Less-Than-30-Year Renewal Alternative, and No-Action Alternative

After validation of the MAP model for use in this FEIS, the model was used to produce forecasts for each of the variables likely to affect the impact analysis results. These variables include employment; personal income; gross state product; oil revenues; and state, regional, and local revenues and expenditures. Sectoral employment forecasts were also prepared for the major sectors in the Alaskan economy, including petroleum, mining, seafood, tourism, international freight handling, forest products, and government.

The MAP model was then used to calculate economic and demographic impact data for the proposed action and the no-action alternative for the state and for the six census areas and boroughs in the pipeline corridor region. This region includes Anchorage, the Fairbanks North Star and North Slope Boroughs, and the Southeast Fairbanks, Valdez-Cordova, and Yukon-Koyukuk Census Areas. Impacts at the regional level were not presented at the same level of detail as those at the state level, and no data were available for gross regional product and state and local revenues and expenditures. An analysis of potential national impacts was also developed. Table A-2 lists the parameters analyzed for the proposed action and the no-action alternative, respectively.

The analysis also included an assessment of the impacts of potential accidents on the economy of the state and pipeline corridor region. For TAPS ROW renewal, the analysis considered the impact of oil spills on property values in the pipeline corridor region and on overall economic activity in the state in terms of the loss of oil revenues to the state and the consequent impact on the Permanent Fund

TABLE A-2 Economic and Demographic Impact Parameters Examined for the Proposed Action, Less-Than-30-Year Renewal Alternative, and No-Action Alternative

State of Alaska

- Population, including natural increases and migration
- Total employment, including direct TAPS employment, and overall employment levels in the state
- Sectoral employment (the impact of TAPS on employment in other sectors of the Alaska economy, such as seafood, tourism, air cargo, and government)
- Personal incomes in the state, including the role of the Permanent Fund Dividend
- Gross state product (a measure of overall economic activity)
- Fiscal impacts, including the impacts on state and local government revenues and expenditures, the Alaska Permanent Fund, and state government employment

Pipeline Corridor Region

- Population, including natural increases and migration
- Overall employment levels in the region
- Personal incomes, including the role of the Permanent Fund Dividend

National Economy

- Domestic oil production and national security (comparison of North Slope production with domestic oil production and impact of North Slope output on imports from other countries over the renewal period)
- Federal tax revenues
- Transportation, in particular shipbuilding and tanker employment
- Overall economic activity

dividend. The impact of accidents that may potentially occur in Prince William Sound as a result of tanker accidents were assessed as part of cumulative impacts.

A.8.3 Data Sources

A significant amount of data currently exists in the MAP model. Additional data were collected to update the state and regional economic and demographic baselines in the model.

Data needed to update the economic baseline were obtained from publicly available federal and state databases. Federal sources included the U.S. Bureau of the Census, U.S. Department of Commerce, U.S. Department of Agriculture, and the U.S. Department of Transportation. State data came from the Alaska Department of Labor and Workforce Development, Alaska Department of Revenue, Alaska Department of Community and Economic Development, and Alaska Permanent Fund Corporation. These data were used to validate forecasts of the key economic variables used in the model for each year in the TAPS renewal period. Additional data came from oil companies, APSC, and other industry and academic sources.

Fiscal data required for impact analysis consist of revenue and expenditure data for the State of Alaska and for local governments. Fiscal data were collected from the relevant jurisdictions and from federal government sources. Data were also collected from State of Alaska sources on oil revenues derived from TAPS operations.

Total population data and data by gender and age cohort, for the state and for the pipeline corridor region, were used in the model, both to provide estimates of the baseline population for the TAPS renewal period and to provide estimates of in-migration that would occur with changes in TAPS activities. These data came from the U.S. Bureau of the Census.

The assessment of the impacts of potential accidents used literature based on data from previous accidents, including the Exxon Valdez spill in Prince William Sound.

A.9 Subsistence

The methods used to evaluate subsistence impacts in this FEIS focused on how the proposed action, the less-than-30-year renewal alternative, and the no-action alternative may affect the customary and traditional acquisition and use of naturally occurring renewable resources for personal or family consumption.

Subsistence is an issue of considerable importance in Alaska, both to Alaska Natives and non-Natives, where many rely on hunting, fishing, trapping, and collecting to provide food, clothing, construction materials, and other items necessary for survival. Moreover, subsistence plays a particularly crucial role in Alaska Native sociocultural systems, helping to reaffirm social relations during both the acquisition and exchange of resources and to redefine sociocultural systems in times of increasing change. For years, many have believed that the TAPS has had important impacts on subsistence, primarily in disrupting migrations or otherwise affecting the availability of subsistence resources and in providing access to others seeking the same resources for other reasons (primarily recreational).

The region of influence for the subsistence analysis corresponded approximately to the aggregation of traditional harvest areas that may have been (or may be) affected by the TAPS. Communities in this region of influence consisted of 44 places anticipated to experience direct effects due to continued TAPS operation.

Residents in 11 of these places are excluded from subsistence activities by federal regulations that limit subsistence to rural places (as stipulated in the *Subsistence Management Regulations for the Harvest of Wildlife on Federal Public Lands in Alaska* [Office of Subsistence Management 2001]).

The evaluation of subsistence attempted, when possible, to examine community-specific impacts, and this formed the core of the subsistence analysis. As necessary, the subsistence analysis considered data presented by Fishery Management Area or Game Management Unit, although those units do not correspond to community subsistence areas and, strictly speaking, did not contribute to the expansion of the region of influence for subsistence.

Data for the evaluation of subsistence impacts included both quantitative and qualitative information. Quantitative data supporting the subsistence analysis included weight of subsistence resources taken, total fish and game harvested, and households participating in subsistence. The analysis for this FEIS examined these types of data, if available, for each community or management area. Qualitative data for the evaluation of impacts to subsistence similarly consisted of a range of information, including oral summaries of subsistence patterns, activities, and harvests over time; statements about game migration patterns; and summaries of seasonal subsistence activities for particular Alaska Native villages or groups.

In the absence of more complete, systematic coverage of quantitative subsistence over time, the analysis combined available quantitative and qualitative information in a complementary fashion. Nevertheless, it is important to acknowledge that incomplete data greatly compromise what one can say definitively about subsistence, the changes it has recently experienced, the causes of these changes, and their possible direct or indirect relationships to the TAPS.

The approach taken in this analysis was to examine subsistence patterns in each community or harvest area. When the data permitted, the analysis considered subsistence change over time, in part to help identify any relationship with the TAPS and also to understand how subsistence patterns have evolved in recent years. The aim of the analysis was to define changes in subsistence harvests due to a reduction in subsistence resources available, as a consequence either of decline in resource population or a change in resource migratory behavior. The analysis considered the range of resources harvested for subsistence purposes in each community, recognizing that potential impacts under any alternative might affect different resources in a dissimilar manner. The focus of the analysis was mainly geographic, depending on data availability to examine community subsistence patterns or harvests in resource management units in the proximity of the TAPS. Hypotheses on changing subsistence yields were evaluated through interviewing experts for traditional knowledge of particular areas or resources — both researchers with particular geographic or topical expertise and people engaged in subsistence activities. For the no-action alternative, the analysis explored anticipated shifts in economic activity identified in the economic evaluation, using these changes as a basis for projecting shifts in subsistence activity in the region of influence.

The factors that had an impact on subsistence were those that reduced access to subsistence resources. Main factors included changing migration patterns and declining game populations. Each of these factors has possible TAPS-related causes, and the analysis considered these as well as alternative explanations. One likely cause of subsistence declines is the Dalton/Richardson Highway, both in supporting traffic that is disrupting the migration patterns of certain species and in providing access to competitors for subsistence resources. It is important to remember in evaluating subsistence impacts that although many consider this road part of the TAPS, it is both separate from the system and considered part of existing conditions. It is likely to remain in place under any TAPS alternative considered in this FEIS.

Subsistence impacts are closely linked to certain other disciplines. Most notably, the ecology analysis provided key information on main subsistence resources and related impacts associated with the TAPS. Similarly, the recreation analysis provided insight on recreational hunting and fishing harvests, yielding an appreciation for how competition for resources contributed to subsistence changes. The hydrology analysis revealed potential impacts on fish and other water-related subsistence species, while the accident analysis presented scenarios that might affect water or terrestrial subsistence resources. The economic analysis, in turn, provided a sense of how other economic opportunities might lead to reduced subsistence activity.

A.10 Sociocultural Systems

The methods used to evaluate sociocultural impacts focused on aspects of the proposed action, the less-than-30-year renewal alternative, and the no-action alternative that particularly affect Alaska Natives and rural non-Natives.

Sociocultural system is a concept that encompasses a broad range of characteristics about a particular group, including social organization, administration, economy, ecology, demographics, and cultural values. As a result, all of the concerns explored have implications for some aspect of Alaska Native and rural non-Native sociocultural systems; a point made all the more obvious because of the large number of Alaska Natives living both in the State of Alaska and in the vicinity of the TAPS. Other disciplines worth noting include those with a particularly close relationship to Alaska Natives, such as subsistence, or those having particular importance to Alaska Natives and rural non-Natives, such as economics. They also include environmental justice, which has a special importance for Alaska Natives both because of the minority status and the frequent low-income status of indigenous groups in the state.

Issues examined specifically under sociocultural systems comprise primarily those topics related to Alaska Natives that are not covered elsewhere — location, sociopolitical characteristics, settlement patterns, and, where possible, more elusive concepts such as cultural values. The sociocultural analysis also considered certain characteristics of rural non-Natives that help distinguish them from the remainder of mainstream Alaskan and American society, such as location, adaptive patterns, and (again, as possible) cultural values.

The region of influence for the sociocultural analysis varies. This FEIS considered certain impacts at the level of the entire state — such as changes in institutional-administrative organization that have affected all Alaska Natives as a consequence of the Alaska Native Claims Settlement Act. The study also examined impacts at the level of eight Alaska Native regional sociocultural systems intersected by or close to the TAPS. Finally, the sociocultural analysis examined individual communities likely to experience direct effects under either the proposed action or the no-action alternative. On the basis of likely impacts on subsistence, employment, culture, and land selection, the BLM (2001) identified 21 communities as deserving particular attention: Alatna, Allakaket, Anaktuvuk Pass, Chenega, Chitina, Copper Center, Cordova (Eyak), Evansville, Gakona, Gulkana, Hughes, Manley Hot Springs, Minto, Nanwalek, Nuiqsut, Port Graham, Rampart, Stevens Village, Tanana, Tatitlek, and Tazlina.

Primarily because of their geographic proximity to the TAPS, this FEIS also considered possible sociocultural impacts to 23 additional communities: Big Delta, Coldfoot, College, Copperville, Deadhorse, Delta Junction, Ester, Fairbanks, Fox, Glennallen, Harding-Birch Lakes, Kenny Lake, Livengood, Moose Creek, North Pole, Paxson, Pleasant Valley, Prudhoe Bay, Salcha, Tonsina, Two Rivers, Valdez, and Wiseman.

Data requirements for the evaluation of sociocultural impacts included both quantitative and qualitative information. Quantitative data supporting the sociocultural analysis included population data, Native regional corporation characteristics, and data on social problems, such as substance abuse and suicides. Quantitative data vary widely both in their availability over space and time and in their reliability. The types of qualitative data employed in the assessment of sociocultural impacts included information on social organization, cultural values, economic activities, and administrative structure; how these components of the Alaska Native and rural non-Native world have changed over time; and Alaska Native and key informant impressions of how the TAPS has affected and would continue to affect these sociocultural systems. Much of this information came from prior anthropological and sociological research. Some of the more detailed work dates back several decades, thereby providing a valuable historical perspective but often lacking in current insight. Once again, other disciplines focused on topics that are closely related to sociocultural systems, such as economics and subsistence.

The approach used to analyze sociocultural impacts was to examine the various sociocultural systems over time in an effort to identify changes in location, demographics, sociopolitical characteristics, and settlement patterns of those systems; the degree to which the TAPS contributed to these changes; and likely future changes. Two major challenges were faced in evaluating sociocultural impacts. One was to identify the impacts to sociocultural systems as defined above. The second challenge, no less important and in many ways much more daunting, was to isolate those impacts partially or totally associated with the TAPS — recognizing that Alaska Native sociocultural systems in particular have experienced considerable change throughout much of the past century. Ultimately, impacts were associated as possible with the proposed action or the no-action alternative. Identifying effects related to the TAPS, and the probable processes underlying their emergence, makes it possible to propose likely impacts of any of the alternatives.

The factors that lead to sociocultural impacts tend to involve major components of sociocultural systems — such as the economy — as well as interaction with other, different sociocultural systems. Increased involvement in a cash economy and the growing opportunities, challenges, and frustrations of this involvement have been proposed as sources of key impacts on Alaska Natives. Growing interaction with non-Natives and the increased socioeconomic disparities between Alaska Natives and non-Natives have been seen as contributing to social pressures and resulting social ills such as substance abuse and suicides. Ultimately, impacting factors associated with the proposed action and the alternatives are determined through empirical examinations of the sociocultural systems affected by the TAPS and how these systems have changed over time, both in key characteristics (location, sociopolitical organ, and others noted above) and in the emergence or increase in social ills.

As noted above, certain other disciplines were particularly important in the examination of potential sociocultural impacts. Subsistence, of considerable importance to rural Alaskans in general and especially important to Alaska Native culture, provides not only a source of nutrition and other materials, but also plays a central role in social organization and the maintenance of social relations.

Economics, which has important implications for all Alaskans in the context of the TAPS, assumes perhaps a more important role for Alaska Natives and rural non-Natives who often fall below the poverty level and for whom sources of cash income often are fewer than for non-Natives and nonrural residents. However, virtually all other disciplines in this FEIS have implications for sociocultural systems, particularly for Alaska Natives given the relatively large number in the state and their broad geographic distribution. Nevertheless, because they were not exclusively sociocultural in nature, these other impacts are best dealt with under other disciplines, with the Alaska Native and rural non-Native components identified as possible and necessary.

A.11 Cultural Resources

The methods used to evaluate impacts to cultural resources focused on assessing the potential disturbance to archaeological sites, historic structures, and traditional cultural properties under the proposed action, the less-than-30-year renewal alternative, and the no-action alternative. As noted below, the assessment of impacts to cultural resources relied primarily on National Register of Historic Places (NRHP) eligibility status, either determined or potential. However, the evaluation also considered the quality of the available data and the condition of cultural resources (based largely on current levels of ground disturbance). The region of influence for cultural resources includes the ROW and any additional areas affected, or likely to be affected, by TAPS operation or maintenance.

The evaluation of impacts to cultural resources required specific information on those resources. Archaeological sites, traditional cultural properties, and historic structures within the region of influence were identified and assessed on the basis of site location information provided by the Alaska State Historic Preservation Office, archaeological survey reports associated with the original construction of the TAPS and all later clearance requirements, architectural survey reports identifying historic structures, and general texts on the historic and prehistoric materials and properties found along the ROW and associated activity areas.

For each cultural resource within the region of influence, the above materials also provided information on the type of site, NRHP status (if determined), level of disturbance, sacred status, age, depth, and spatial extent. The project team consulted the State Historic Preservation Officer to confirm NRHP status, discuss potential future determinations of NRHP status, and identify any particular preservation issues or problems associated with specific cultural resources. Other information used included APSC procedure manuals on cultural resource protection and background information on pipeline technology to assess the potential historical importance of the TAPS itself.

The assessment of potential impacts to cultural resources involved identifying those activities that would result in surface or subsurface disturbance within the region of influence. Activities evaluated included maintenance that would likely disturb areas containing known cultural resources. Impacts, in turn, were defined as the effect of identified activities on intact known cultural resources. The identification of impacts relied on GIS-based overlays, emphasizing either co-occurrence or geographical proximity of potential disturbance to known resources. Other potential sources of impacts included the effect of increased accessibility to intact cultural remains and any effects resulting from spills and spill response activities.

Several disciplines provided relevant data. Geology and soils studies provided information on soil types and the effect that a spill would have on soils. Erosion was a concern during the analysis, primarily because of the number of waterways that the TAPS crosses that could alter archaeological resources. Consideration of erosion was also important in assessing the effects of spill removal on cultural resources. Hydrology studies provided information on changing waterways and the resulting erosion. Personnel working on the pipeline maintenance sections of this FEIS provided information on procedures and activities in place for the pipeline that were needed to identify potential impacts.

A.12 Land Use and Coastal Zone Management

A.12.1 Land Use

The TAPS and associated facilities are located primarily on federal and state lands, with about 10% on private lands. In addition to varying land ownership of the ROW itself, land use also varies in the vicinity of the TAPS; potential uses are often related closely to ownership. The methodology used to assess impacts to land use considered anticipated changes under the proposed action, less-than-30-year renewal alternative, and no-action alternative, focusing in particular on major land use categories and how these would likely change.

This analysis assumed that the region of influence for land use consisted of the area within the ROW that varies from about 54 ft to more than 100 ft wide, and areas near the ROW that experienced past TAPS-related land use effects. It was also assumed that under the proposed action, no-action alternative, and less-than-30-year renewal alternative, the Dalton Highway would remain open to the public and the existing airports in the utility corridor would remain. The analysis assumed that recent trends in land use change would provide a reasonable basis for projected future conditions and impacts under the proposed action.

The primary data used to support the analysis of land use impacts consisted of information on existing land ownership and use patterns within the TAPS region of influence, as well as prior patterns of ownership and uses — the latter to establish trends in land use change over time. The analysis used quantified land use data when possible, consistent with the appearance of many of these data in map form. Ownership and use maps included the *State of Alaska TAPS Lease Renewal Project Map of Existing Leases and Permits* (ADNR 2001) and the *Environmental Atlas of the Trans Alaska Pipeline System* (APSC 1993). In addition, applicable land use plans were identified and reviewed, as discussed further below. Argonne staff contacted government officials and private landowners to obtain supplemental information and to collect additional information on use and ownership patterns in areas where such configurations were unclear. Applicable federal and state statutes and regulations provided information on locations and types of permitted and restricted activities in the region of influence.

The evaluation of land use impacts used a phased approach. It began with the definition of current (recent) land ownership and use patterns, as well as prior configurations, to provide the basis for any impact analysis. Special status lands, such as state parks, National Parks, National Wilderness Areas, and National Wildlife Refuges, were also identified. The analysis then determined (when possible) trends in land use change during the last 25 years and projected these into the future to support an analysis of the proposed action and less-than-30-year renewal alternative.

Impacts under the no-action alternative, in turn, were projected on the basis of results of the economic analysis, notably the negative economic impacts anticipated in the region of influence (and elsewhere in Alaska) if the ROW was not renewed. Impacts on land use from termination activities were also considered. EIS team members reviewed existing federal, state, and local land use plans to determine consistency with the continued operation of the TAPS and its (TAPS) removal and restoration. Federal plans included the river management plans for the Delta National Wild and Scenic River and Gulkana National Wild River

(BLM 1983a,b), *Utility Corridor Proposed Resource Management Plan and Final Environmental Impact Statement* (FEIS) (BLM 1989), *Dalton Highway Recreation Area Management Plan* (BLM 1991); *Management Framework Plan for the South Central Planning Area* (BLM 1980); and *Fort Greely Proposed Resource Management Plan FEIS* (BLM and U.S. Department of Defense 1994).

State plans included the *Tanana Basin Area Plan for State Lands* (ADNR 1991); *Copper River Basin Area Plan for State Lands* (ADNR and ADF&G 1986); *Prince William Sound Area Plan for State Lands* (ADNR and ADF&G 1988); and *Dalton Highway Master Plan* (Dalton Highway Advisory and Planning Board 1998). Local plans included the *Fairbanks North Star Borough Comprehensive Master Plan* (Fairbanks North Star Borough 1999), *North Slope Borough Comprehensive Plan* (North Slope Borough 1983), and *Valdez Comprehensive Plan* (City of Valdez 2000).

Private land use plans and data also were reviewed and analyzed, as available. In all cases, the evaluation of land use impacts compared anticipated changes in land use configurations with current configurations and with stipulations of current land use plans to determine levels of effect throughout the region of influence.

The analysis of land ownership and use shared key links with several other disciplines considered in this FEIS. Land use affects aesthetics, just as visual resource management objectives may dictate land use. In addition, recreation, wilderness, subsistence, and transportation corridors are all types of land use; each is addressed in a separate section. Suitable land use is determined by a combination of elements related to socioeconomics and the physical environment, including topography, geology, ecology, and water resources. Because of the potential effects of a TAPS-related accident on current and future land use under the alternatives, the examination of various spill scenarios played a key role in the analysis of potential land use impacts. Impact determinations for accident scenarios were largely based on the results of the spill analyses for hydrology and ecology.

A.12.2 Coastal Zone Management

The TAPS begins and ends in Alaskan coastal zones. One hundred ten miles of the pipeline and related structures are encompassed in the North Slope Borough coastal zone where TAPS originates, and 25 miles of the pipeline and the Valdez Marine Terminal are within the Valdez coastal zone. The federal Coastal Zone Management Act (CZMA) of 1972 (amended in 2001) and the Alaska Coastal Management Act (ACMA) of 1977 (amended in 1994) regulate activities in Alaskan coastal zones, including the TAPS. The ACMA is implemented by the Alaska Coastal Management Program (ACMP) (approved in 1979), which encourages coastal districts to develop and adopt district coastal management programs (CMPs) that become part of the ACMP once they are fully approved. All activities, including those related to the TAPS, that occur within the coastal zone or that may affect coastal resources must be consistent with the enforceable policies in an approved CMP. Both the North Slope Borough and Valdez coastal zones have approved CMPs. The methodology for evaluating coastal zone impacts for the proposed action, less-than-30-year renewal alternative, and no-action alternative focused on their potential effects on coastal resources and their consistency with applicable statewide ACMP standards and the enforceable policies in the North Slope Borough and Valdez CMPs.

The coastal zone analysis focused on data that emphasized the identification of existing permitted activities, enforceable policies, and applicable statewide standards within the North Slope Borough and Valdez coastal zones and the evaluation of all alternatives in this FEIS in terms of these criteria. The analysis used quantitative data whenever available to support the impact analyses. In addition to the information available in the North Slope Borough and Valdez CMPs, the data used for the analyses covered impacts identified by other disciplines but occurring in a coastal zone. The EIS team contacted personnel from the Alaska Division of Governmental Coordination for supplemental data on currently permitted activities. The CZMA, ACMA, and ACMP were also reviewed.

Potential impacts on both CMPs under the proposed action, less-than-30-year renewal alternative, and no-action alternative were analyzed in terms of the types of activities permitted in the two coastal zones of interest. The analysis focused on the magnitude and spatial distribution of any potential impacts and identified impacts that would result from activities under the alternatives that would not be consistent with CMP-enforceable policies or applicable statewide standards. Analysis of the no-action alternative assumes that termination activities would occur in both the North Slope Borough and Valdez coastal zones over a six-year period.

The coastal zone analysis shared links with several other disciplines in this FEIS. Permitted activities within the coastal zone affect the aesthetics of the area, and CMP-enforceable policies regarding aesthetics affect which activities are allowed, as well as associated mitigation measures. Recreation, subsistence, commercial and industrial development, and travel were important activities in coastal zones with associated CMP-enforceable policies and standards. Because a TAPS-related accident could potentially affect a variety of permitted activities in the coastal zone, spill scenarios were analyzed to determine coastal zone impacts. Impact determinations for accident scenarios were largely based on the results of the spill analyses for hydrology and ecology.

A.13 Recreation, Wilderness, and Aesthetics

A.13.1 Recreation

Recreational resources are abundant on the state and federal public lands in the vicinity of the TAPS. Some of the existing recreational opportunities include hiking, camping, boating, fishing, trophy hunting, floating, and winter sports. The methods used to assess potential impacts to recreational resources under the proposed action, the less-than-30-year renewal alternative, and the no-action alternative considered how renewing or not renewing the TAPS ROW would affect the range of recreational opportunities available near the pipeline.

For purposes of this analysis, recreational resources consisted of designated recreational areas within a few miles of the TAPS where the level of use may have been affected by the construction and operation of the TAPS and its associated Haul Road. The region of influence encompasses federal and state lands, including a federally designated Wilderness Area, a National Wild and Scenic River (the Delta River), and a National Wild River (the Gulkana River). The analysis of the alternatives assumed that the TAPS Haul Road north of Fairbanks (Dalton Highway) would remain open to the public and that the existing airports in the utility corridor would remain as well. Under the alternatives, the analysis assumed that past trends provided a reasonable basis for projecting future conditions and impacts.

Recreational resources were identified within the region of influence. Particular consideration was given to BLM recreational opportunity spectrum (ROS) classifications and management objectives for the lands near the utility corridor. The actual evaluation of impacts on recreation focused on changes in ROS classes. Levels of use were evaluated on the basis of permit data as well as other use statistics compiled by the managing government agencies. Current use statistics were extrapolated to project potential impacts to recreational resources under the proposed action. Although quantitative data were employed when possible, the analysis did not discount the value of qualitative information, particularly in the form of opinions from various experts. Appropriate government officials were also interviewed to obtain descriptions of current conditions of recreational resources and their expected future levels of use.

In addition, existing recreational management plans were reviewed to determine consistency with both TAPS renewal and the no-action alternative. These plans included the river management plans for the Delta National Wild and Scenic River and the Gulkana National Wild River (BLM 1983a,b); *Utility Corridor Proposed*

Resource Management Plan and Final Environmental Impact Statement (BLM 1989); *Dalton Highway Recreation Area Management Plan* (BLM 1991); and *Management Framework Plan for the South Central Planning Area* (BLM 1980). Finally, various scenarios were analyzed to determine the potential impacts of spills on recreational resources and the ROS in the region of influence. Impact determinations for accident scenarios were based primarily on the results of the spill analyses for hydrology and ecology.

The analysis of recreational resources was linked to several other disciplines. Visual resources affect the types of recreational opportunities available, just as the number and type of recreational activities occurring affect visual resources. Land use dictates which recreational opportunities are available, whereas the demand for a particular recreational experience or facility dictates important aspects of land use. Changes in transportation modes affect access to recreational resources, with movement by road, air, boat, or foot all providing varying levels of access. Given the nature of recreational resources in the vicinity of the TAPS, ecology was of particular concern — influencing both the availability of recreational opportunities and the quality of the recreational experience. Depending on the level of use, recreational activities in turn also affect ecological resources. Because TAPS-related accidents could potentially affect a variety of recreational opportunities, the recreation analysis was closely coordinated with the spill analysis.

A.13.2 Wilderness

No designated or proposed state or federal Wilderness Areas exist within or adjacent to the TAPS corridor. However, one federally designated Wilderness Area is located within a few miles of the TAPS. Wilderness, as defined by the Wilderness Act of 1964, is a primitive area ". . .untrammeled by man, where man himself is a visitor who does not remain" [16 USC §1131(c)]. Wilderness Areas offer outstanding opportunities for solitude and primitive recreation, are at least 5,000 acres in size, and may contain ecological or other values that contribute to the designation. The methodology for identifying potential impacts to federally designated Wilderness Areas near the TAPS focused on analyzing the effects to the qualities that qualify the area for wilderness designation. Any ecological impacts are identified as discussed in Section A.7 (Biological Resources).

The Alaska National Interest Lands Conservation Act (ANILCA) of 1980 also governs wilderness in Alaska. Specifically, ANILCA exempts Alaskan wilderness from the motorized vehicle prohibition established by the Wilderness Act of 1964. This exemption was considered in determining potential impacts to wilderness.

State-designated wilderness in Alaska is rare, and no state statute exists for such a designation. However, lands within state parks may be designated as wilderness by the Alaska Legislature. Currently, only two state parks are designated as wilderness in Alaska, and both are more than 100 mi from the TAPS. No state designations for wilderness are currently pending in legislature (Mylius 2002).

As noted above, the TAPS ROW corridor does not pass through any designated or proposed state or federal wilderness areas (BLM 1989). However, a federally designated Wilderness Area within Gates of the Arctic National Park and Preserve (NPP) is in the proximity of the TAPS. Important assumptions underlying the analysis of the proposed action, less-than-30-year renewal alternative, and no-action alternative are that the Dalton Highway would remain open to the public and that the existing airports in the utility corridor would remain. The potential environmental effects on both designated and proposed Wilderness Areas, including those related to access, were assessed, as were potential impacts from the no-action alternative, which involves six years of termination activities. Past trends provided a basis for predicting future changes in key variables.

Data were compiled and analyzed to assess the existing condition of the federally designated Wilderness Area in the vicinity of the TAPS and to analyze potential wilderness impacts from the alternatives. Maps showing Wilderness Areas provided basic information on location and configuration, both key considerations given the importance of geographic proximity to potential sources of impact. Government officials also served as key sources of information. The analysis relied on quantifiable data whenever possible.

The evaluation of impacts to Wilderness Areas analyzed potential impacts to the values that originally qualified the Wilderness Area for designation. In particular, potential impacts to its primeval character, opportunities for solitude and primitive recreation, the ecological or other values for which it was designated, and its overall size were analyzed. Because no Wilderness Areas are within or adjacent to the TAPS, no direct impacts were identified. Impacts were indirect or cumulative, as in the event of a spill. Because of the potential effects of spills on wilderness values, the spill analyses played a particularly important role in the evaluation of Wilderness Area impacts. Impact determinations for accident scenarios were largely based on the results of the spill analyses for hydrology and ecology.

A.13.3 Aesthetics

Aesthetics, also called visual resources, are related to landforms, water, vegetation, animals, and structures. The aesthetics along most of the TAPS are both outstanding and complex — a function of the 800-mi length of the TAPS in a setting known for stunning natural beauty. About half the length of the TAPS is above ground and clearly visible from the air. The majority of the above-ground components are also visible from adjacent public roads (TAPS Owners 2001c). The methodology used to identify current visual resources and potential impacts to aesthetics aimed to examine this complex visual setting in a systematic manner by characterizing aesthetic resources present and assessing impacts under the proposed action, less-than-30-year renewal alternative, and no-action alternative. All considerations of aesthetic impacts recognize that the pipeline is in place and is part of the baseline condition.

The visual resources analysis in this FEIS included considerations of land, water, animals, vegetation, and structures. One important assumption underlying the analysis of these resources under all of the alternatives was that the Dalton Highway would remain open to the public and that the existing airports in the utility corridor would remain. The region of influence for the aesthetics analysis was specified as *the viewshed*, or localities visible from the TAPS ROW (and vice versa).

Data from selected key sources were analyzed to assess the existing condition of visual resources and to assess potential aesthetic impacts under all alternatives. Visual resource management plans were reviewed for the areas where such plans exist (see below). In particular, this FEIS considered BLM visual resource management (VRM) classifications and objectives for the utility corridor. Officials from several government agencies were interviewed to complement written information. In addition to defining visual resources, VRM classifications, and management objectives, the evaluation of aesthetics impacts included a review of digital topographic data and consideration of existing visual resource mitigation measures.

Under the proposed action and the less-than-30-year renewal alternative, the evaluation of aesthetic impacts examined long-term impacts associated with the continuation of TAPS operation over 30 years or less. For the no-action alternative, the analysis evaluated both short-term (6 years of termination activities) and long-term impacts. Under the alternatives, the analysis began by defining the viewshed to focus attention on the appropriate geographic area. Within the utility corridor, the evaluation identified and plotted VRM classifications and objectives. In addition, it examined existing resource management plans that address aesthetics to determine consistency with the continued operation of the TAPS and the no-action alternative.

Pertinent plans included the river management plans for the Delta National Wild and Scenic River and the Gulkana National Wild River (BLM 1983a,b); *Utility Corridor Proposed Resource Management Plan and FEIS* (BLM 1989); *Dalton Highway Recreation Area Management Plan* (BLM 1991); *Management Framework Plan for the South Central Planning Area* (BLM 1980); and both the Federal Grant and State Lease for the TAPS ROW. These plans provided a basis for assessing likely impacts under the proposed action, less-than-30-year renewal alternative, and no-action alternative in the region of influence. A number of factors contributed to the degree to which the TAPS could affect the public viewshed, including the distance of the ROW from roadways and public areas, the topography, and vegetation.

The evaluation of aesthetics considered analyses in several other disciplines. Visual resources affect the types of recreational opportunities available in the vicinity of the TAPS, just as the number and type of recreational activities occurring affects aesthetics. Land use, wilderness, transportation corridors, vegetation, and air quality all affect aesthetics — notably landscape and viewing distance. Conversely, aesthetics affect how land is used. Lastly, the aesthetics analysis also considered the range of accident scenarios examined in this FEIS and relied heavily on the results of the spill analyses for hydrology and ecology to determine potential aesthetic impacts of a spill.

A.14 Environmental Justice

The methods used to evaluate impacts relative to environmental justice emphasize issues identified in Executive Order 12898, which defined environmental justice as a topic requiring evaluation in federal actions. This analysis is focused on the identification of any high and adverse impacts to low-income and minority populations as a consequence of the proposed action, the less-than-30-year renewal alternative, and the no-action alternative. The impacts examined include those identified in all other individual disciplines considered in this FEIS. For example, impacts identified in the economic analysis are examined to see if they have environmental justice implications. As noted below, one discipline of particular concern in this study is *subsistence*. A topic of potential concern identified in the original executive order, subsistence is of particular interest in the present study because of the high reliance of rural populations in Alaska (often low-income) and Alaska Natives (minority and also often low-income) on food acquired by fishing, hunting, and collecting.

Minority and low-income populations are defined as follows:

- *Minority* — Individuals who classify themselves as belonging to any of the following racial groups: Black (including Black or Negro, African American, Afro-American, Black Puerto Rican, Jamaican, Nigerian, West Indian, or Haitian); American Indian, Eskimo, or Aleut; Asian or Pacific Islander; or “Other Race” (CEQ 1997). In the 2000 census, many individuals categorized themselves as belonging to more than one race. This FEIS considers individuals of multiple races to be minority, regardless of the races involved. This study also includes individuals identifying themselves as Hispanic in origin, technically an ethnic category, under minority. To avoid double-counting, the analysis included only White Hispanics, the above racial groups already accounting for non-White Hispanics.
- *Low-Income* — Individuals falling below the poverty line. For the 2000 census, the poverty line was defined by a statistical threshold based on a weighted average that considered both family size and the ages of individuals in a family. For example, the poverty threshold annual income for a family of five with one child younger than 18 years was $21,024, while the poverty threshold for a family of five with three related children aged less than 18 years was $19,882 (U.S. Bureau of the Census 2000). If a family fell below the poverty line for its particular composition, the census considered all individuals in that family to be below the poverty line. Low-income figures in the 2000 census reflect incomes in 1999, the most recent year for which entire annual incomes were known at the time of the most recent census.

The region of influence for environmental justice varies by impact area, ranging from the entire state of Alaska to geographic areas near the TAPS. Because the environmental justice evaluation relied heavily on analyses in other disciplines, it also incorporated the assumptions underlying those other inquiries.

Although a certain logic suggests a greater susceptibility of environmental justice populations to many environmental impacts, perhaps because of less access to key nutrients or medical care than the population as a whole, presently there is no evidence of such differing vulnerability. As a result, the evaluation of impacts in terms of environmental justice generally assumed that minority and low-income populations respond to various impacts in the same manner as the population as a whole. Disproportionality therefore was used primarily as a geographic concept to define places with particularly high percentages of minority and low-income populations. Disproportionately high percentages are those that exceed the percentage of low-income or minority persons in the state of Alaska as a whole. The exception to the assumption that impacts affect all persons similarly are economic impacts because of per capita payments of the Permanent Fund dividend. Minority and low-income populations in Alaska, commonly with larger families than found in nonminority and non-low-income populations in the state (and thus receiving greater total payments), would experience disproportionately high impacts should the dividend be discontinued.

The data used to evaluate impacts related to environmental justice were of two types: census data used to define disproportionality and data on anticipated effects under the proposed action, the less-than-30-year renewal alternative, and the no-action alternative. Data from the most recent decennial census of population and housing, conducted in 2000, provided a recent, detailed basis for evaluating the distribution of minority and low-income populations.

This FEIS analysis examined minority and low-income populations with census data collected and presented for two different demographic units: census block groups and communities. Census block groups are clusters of census blocks (the smallest geographic unit used by the Census Bureau) generally containing 250 to 550 housing units, with the ideal size being 400 housing units. Because housing densities vary considerably, block groups cover a wide range of geographic sizes, with those in rural Alaska, which contains very few people and few houses, geographically quite broad. Individual communities include both incorporated places and *census designated places*, the latter defined by the Census Bureau for purposes of data collection and presentation. Communities were selected in part on the basis of their geographic proximity to the TAPS, which would increase the likelihood of their experiencing TAPS-related impacts under normal operations, and in part on the basis of their inclusion on a list of directly affected places defined by the BLM (2001). This FEIS considered environmental justice impacts to a total of 44 individual communities. Through the use of these two different geographic units, the environmental justice analysis was geographically commensurate with analyses in two other disciplines having important environmental justice implications — human health (which used block groups) and subsistence (which used communities). Although the economic analysis, which also has important environmental justice implications, used larger analytical units (boroughs and census areas) than the environmental justice analysis, because the block groups aggregate to these larger entities, direct comparisons can be made with the economic impacts.

Environmental justice is not, in itself, an impact area per se. Rather, it encompasses other impacts that are both high and adverse and that affect minority and low-income populations disproportionally. As such, the results of assessments in these other disciplines were crucial in the evaluation of environmental justice; they essentially preceded the environmental justice evaluation.

Because of the reliance of environmental justice assessments on analyses in other disciplines, the actual methods used to evaluate environmental justice were those used in the various other analyses. Although all other disciplines were of concern, of particular importance were those three with important implications for minority or low-income populations: human health, economics, and subsistence. Because of the relationship between environmental justice and other disciplines, impacting factors generally were those associated with the analyses in other disciplines.

A.15 Spills (Accident) Analysis Methodology

A.15.1 General Spills Analysis

A.15.1.1 Introduction and Background

The main objective of the spills[3] analysis is to estimate the frequency, quantity, and time dependence (e.g., instantaneous or prolonged) of unplanned releases of crude oil and potentially hazardous substances to the environment. Spill frequency, size, and duration are jointly considered in formulating accidental release scenarios used in estimating the environmental risk discussed in this FEIS.

The scenarios are designed to cover the risk that may be associated with a variety of spills that could affect sensitive environmental media, such as, surface and subsurface soils, groundwater and surface water resources, and the air. Included in the assessed impacts are the risk of damage or harm to plants, animals, and people that depend on and/or come in contact with resources contaminated by the postulated events. In addition to potential crude oil spills, releases involving refined petroleum products, including diesel fuel, jet turbine fuel, and gasoline, were also assessed. Where appropriate, hazardous materials used in the operation of various TAPS facilities, such as sulfuric acid and sodium hydroxide use at the Valdez Marine Terminal power plant, were considered in the postulated spill scenarios.

The scope of the spills analysis covers the entire TAPS, from production before the beginning of the pipeline (Milepost [MP] 0) to tanker loading and shipment at the end of the pipeline (MP 800). The potential impacts or risk of spills from TAPS operations from PS 1 to MP 800 at Valdez Marine Terminal and from the Valdez Marine Terminal through tanker loading were treated as part of the proposed action to renew the Federal Grant of ROW lease. Impacts associated with the North Slope oil fields and pipelines up to the boundary of PS 1 and the transport of the petroleum from loading berths at Valdez Marine Terminal to approximately 15 mi past the Hinchinbrook Entrance to Prince William Sound (about 78 nautical miles from the Valdez Marine Terminal) were treated under the cumulative impact section of this FEIS. The risk of spills connected to decommissioning, removal, and recovery activities for the TAPS were assessed under the no-action alternative. Under no action, it is assumed that all oil production at the North Slope would stop. The only crude oil that could potentially be released to the environment under such conditions would be crude left in the pipelines and storage tanks. The no-action alternative scenarios were evaluated by using data obtained from the TAPS construction period to estimate the quantities of residual products (diesel fuel, gasoline, heating oil, etc.) released to the environment.

The approach described in Section A.15.1.2 on developing the spill scenarios does not account for what would be expected in a comprehensive spill response, nor should the developed scenarios be regarded as predictions of specific spill response procedure performance. The developed scenarios were intended for use in quantifying the potential magnitude of the environmental impacts assessed and reported in this FEIS. Actual spill responses would be tailored to the existing site conditions and the requisite response requirements.

The methodology used in developing spill scenarios required careful consideration of the type of oil that could be spilled in the proposed continued operation of the TAPS or in removal and restoration activities should the TAPS ROW grant not be renewed.

Oil can be divided into five broad classes on the basis of its physical and chemical characteristics and the possible toxicity, damage, or injury to humans and natural

[3] The term spills as used in this appendix refers to unplanned or accidental releases of crude oil or other potentially hazardous materials to the environment. The spilled material can be in a liquid or vapor phase and/or occur as a secondary aerosol or gas formed in a crude oil fire or transformed to gases or aerosols in the atmosphere from the release of reactive or volatile hydrocarbons.

resources from exposure to spilled product or contaminants and/or contaminants evaporated from the original liquid state. Pertinent properties of each oil class are summarized in Table A-3. Two of the five types correspond to refined petroleum product used during pipeline operations.

Crude blends vary greatly in their chemical composition, depending on the geographical location of their origin and the particular compounds mixed with the petroleum products. Surfactants, often added to aid transport, will affect physical properties when spilled. The TAPS uses drag reducing agent as a throughput enhancing surfactant.

Hydrocarbons are by far the most abundant compounds in crude oils, accounting for 50 to 98% by volume. All crude blends contain lighter “fractions” of hydrocarbons (e.g., gasoline) as well as heavier tars and wax-like hydrocarbons.

North Slope crude blends are Type 3 oil products and are considered medium grade. The British Petroleum North Slope crude from PS 9 has a relatively high viscosity (23.9 cSt at 50°F) and an American Petroleum Institute (API) rating of 29.6 (NOAA 2001).

On the basis of their characteristics, Type 1 and Type 2 oils have differing direct effects on living organisms. Gasoline is more acutely toxic than diesel products, but evaporates faster. Diesel readily emulsifies in water, increasing its viscosity and its volume, while gasoline does not emulsify. Both types of products tend to penetrate the substrate rather than adhere to the surface.

A.15.1.2 Formulation and Development of Spill Scenarios

The first step in formulating the spill scenarios analyzed in this FEIS was to identify a representative range of accident scenarios and the associated source terms for the spills analysis by grouping or classifying potential spill events by frequency and associated magnitude. This process involved selection of four frequency classifications that would cover spills ranging from those that would be considered as high-frequency, low-consequence events, to spills considered extremely low in frequency but of potentially high consequence. The frequency classification scheme chosen is summarized in Table A-4. Spill events grouped in the high or intermediate frequency categories are anticipated or likely spills that have occurred over the operational life of the TAPS. They have a spill occurrence of one or more times per year or one or more times over the original ROW lease period. It is reasonable in considering the historical record to assume that spill events in these two categories would be anticipated at a similar frequency or would likely occur over the proposed 30-year TAPS ROW renewal. The last two categories are low or extremely low frequency events that are unlikely or very unlikely to occur during the renewal period for the TAPS.

The Exxon Valdez oil spill that occurred in Prince William Sound in 1989 would be considered a catastrophic event (a marine spill of greater than 250,000 bbl of crude). All of the other spills into Prince William Sound since 1977, in comparison, would be considered small (less than 60 bbl). Over 90% of these spills involved less than a barrel of oil, with around 60% of the total less than a gallon. Because of the scheduled phaseout of single-hulled tankers, shipments of North Slope crude by double-hulled tankers as a percentage of tanker shipment volumes will increase from 38% in 2004 to 100% in 2014. Although the Exxon Valdez spill did occur during TAPS operations, because of the resulting and anticipated changes in tanker operations and design and in consideration of the risk assessment associated with future tanker operations in Prince William Sound (PWS 1999), repetition of such an event would still be considered extremely unlikely within the proposed grant renewal period.

Data on spill frequency, quantity, and duration from the TAPS historical record and relevant engineering information on the TAPS system were collected, reviewed, and analyzed. A total of around 80 “credible” spill or accident release scenarios (with likelihoods greater than 10^{-6}) were developed and sorted into the four frequency classes identified in Table A-4.

TABLE A-3 Types and Properties of Oil

Type 1 very light grade oils (gasoline)

- Highly volatile and soluble
- Evaporates quickly, often completely within 1 to 2 days
- High acute toxicity

Type 2 light grade oils (jet fuels, diesel, No. 2 fuel oil, light crude)

- Moderately volatile
- Will leave residue (up to one-third of spill amount) after a few days
- Moderately soluble, especially distilled products
- Moderate to high acute toxicity; product-specific toxicity related to type and concentration of aromatic compounds

Type 3 medium grade oils (most crude oils)

- About one-third will evaporate within 24 hours
- Typical water-soluble fraction 10–100 ppm
- May penetrate substrate and persist
- May pose significant cleanup related impacts
- Variable acute toxicity, depending on the amount of light fraction

Type 4 heavy grade oil (heavy crudes, No. 6 fuel oil, bunker C)

- Heavy oils with little or no evaporation or dissolution
- Water-soluble fraction typically less than 10 ppm
- Heavy surface contamination likely
- Highly persistent, long-term contamination possible
- Weathers very slowly, may form tar balls
- May sink depending on product density and water density
- May pose significant cleanup related impacts
- Low acute toxicity relative to other oil types

Type 5 low API fuel grade oils (heavy industrial fuel oils)

- Neutrally buoyant or may sink, depending on water density
- Weathers slowly; sunken oil has little potential for evaporation
- May accumulate on bottom under calm conditions and smother subtidal resources
- Sunken oil may be resuspended during storms, providing a chronic source of shoreline oiling
- Highly variable and often blended with oils
- Blends may be unstable and the oil may separate when spilled
- Low acute toxicity relative to other oil types

Source: Adapted from Huguenin et al. (1996).

TABLE A-4 Event Frequency Classifications

Event Likelihood	Frequency Class	Consequence
High frequency (anticipated) Events anticipated to occur one or more times every few years	$f > 0.5$ per year	Small
Intermediate frequency (likely) Events that are likely to occur once or more during the ROW renewal period	$0.03 < f < 0.5$	Moderate
Low frequency (unlikely) Events that are unlikely to occur during the ROW renewal period	$(10^{-4} < f < 0.03)$	Large
Extremely low frequency (very unlikely) Events that are extremely unlikely to occur but, if they occurred, could have severe consequences	$(10^{-6} < f < 10^{-4})$	Very large or severe

Initiators that could generate a spill with likelihoods less than 10^{-6} were by definition deemed “incredible” events and therefore not considered for further analysis. The scenarios covered potential failures and associated frequencies in the major TAPS system components and subcomponents that could occur from a broad range of accident initiators (see Section A.15.1.5 for further discussion). Included were event causes (internal initiators) ranging from human error and failures in system subcomponents (e.g., check valves, corrosion and fatigue in the pipeline) to spills caused by external initiators such as earthquakes, landslides/avalanches, aircraft crashes, tsunamis, wildfires, flooding, and vandalism or sabotage.

The major TAPS components covered in the analysis included the main-line pipe, pump stations, crude oil tanks and tank farms, and loading berths. Subcomponents considered included pipeline gate and check valves, pipeline controls (e.g., leak detection, telecommunication, remote gate valve system), and the metering stations. In addition to potential crude oil releases to the environment, other material releases considered included refined petroleum products (e.g., gasoline, diesel fuel, turbine fuel, oils, and jet fuel), drag reducing agent, and other system-related chemicals (e.g., sulfuric acid).

A.15.1.3 Spill Analysis Output

For each of the scenarios, the quantity and rate of material released (the source term) were established as functions of pipeline operating assumptions or crude oil throughput (see discussion in Section A.15.1.4). Source terms were established for affected TAPS system components or subcomponents. A variety of system parameters and assumptions were required, including failure modes (e.g., pipe corrosion hole size, location on pipeline of guillotine break initiated by an external event), pipeline static and dynamic pressure and temperature, and other design and/or operating parameters (e.g., tank capacity). In some cases, the source term may be given as a range of values or as different amounts released for different locations along the pipeline. The time dependence and mode of release were also factored into the established spill scenarios. Although the most common or likely mode of release considered was a liquid crude oil spill along the pipeline, other release modes, such as an explosion, fire, and evaporation from a liquid spill, were also considered. Most of the scenarios were characterized as continuous releases over a finite duration or instantaneous, such as a vapor cloud explosion.

A.15.1.4 Major Assumptions

One of the key assumptions necessary for estimating potential future crude oil spill rates and spill volumes is a reasonably reliable forecast of pipeline throughput, typically expressed in millions of barrels of crude oil per day (bbl/d). The TAPS Emergency Preparedness and Contingency Plan is based on a throughput of 1.5 million bbl/d (APSC 2001a). The plan used estimates of spill volumes in accordance with the State of Alaska Planning Standard and used APSC's TAPS Spill Program to estimate spill volumes assuming this throughput. Historical throughputs over the past 10 to 15 years have ranged from around 1.0 million to 2.1 million bbl/d, the maximum design capacity throughput for TAPS. Since 1988 the average annual throughput has declined steadily, as shown in Figure A-1. The Environmental Report (TAPS Owners 2001a) referenced the U.S. Department of Energy (DOE) forecast of throughput that indicated a steady decline at around 4.2% per year for the next 18 years and then assumed a leveling off at around 0.49 million bbl/d through the end of the pipeline proposed action for ROW renewal through 2034. A daily throughput of around 0.7 million bbl/d was observed in October 2001, but projections of the annual average for 2001 are expected to be around 1 million bbl/d.

The DOE Energy Information Administration's (EIA's) Office of Oil and Gas, Reserves and Production Division, publishes annual updated data and forecasts of future oil production for the North Slope. The last report included a range of plausible production scenarios for the North Slope area of Alaska (DOE 2001). These scenarios were based on the decline of existing production, the anticipated start-up of identified field development projects, and future discovery and development of the remaining undiscovered oil resources estimated for the area by the USGS, the BLM, and the Minerals Management Service (MMS). The EIA's 30-year projections (2004 through 2034) show that crude oil production from existing producing and developing oil fields of the North Slope plus future production potential from three other areas (two in the National Petroleum Reserve and the Central North Slope) show a decline from around 1 million bbl/d in 2004 to around 200,000 bbl/d by 2034. The average over this 30-year projection period is 703,000 bbl/d. Figure A-2 shows the trend in total North Slope oil production projections along with the contributing projections from each four producing or potentially producing areas. Included in the figure is the 300,000 bbl/d number identified in the EIA report as the minimum operating volume or throughput lower limit. The TAPS maximum design capacity is 2.1 million bbl/d.

To limit the spill scenarios to a reasonable number, three throughput assumptions were used: the TAPS maximum design capacity of 2.1 million bbl/d, the minimum economically based operating value of 300,000 million bbl/d, and a base-case value of 1.1 million bbl/d that would represent a more likely throughput for continued operation of the TAPS. These throughputs provide upper and lower bounds to the spill scenarios analyzed in this FEIS, along with a value that would be considered representative of future operations.

In addition to throughput, the spills analysis assumed that all tankers loading crude at the Valdez Marine Terminal and shipping crude though the Prince William Sound would be double-hulled after May 2013. A recent review by the National Research Council (1998) concluded that double-hulled tankers are four to six times less likely than single-hulled tankers to spill oil in a vessel collision or grounding that penetrates the outer hull. The National Research Council estimated that the expected or average outflow is three to four times less with a double-hulled vessel compared with a single-hulled tank vessel and that the probability of a spill would be reduced by a factor of 4 to 6. Expected spill volume would be reduced by factor of 3 to 4.

Scenarios involving leaks from the pipeline under current operating controls and with leak detection systems in operation would allow small leaks to go undetected at a rate of 3,000 to 6,000 bbl/d (under slack line conditions) for around 4 to 7 days. Where practical, the spill scenarios and the assessed impacts gave credit for spill containment and cleanup actions consistent with records of TAPS historical spill response and cleanup, as coordinated from the APSC Fairbanks office and their SERVS unit at the Valdez Marine Terminal.

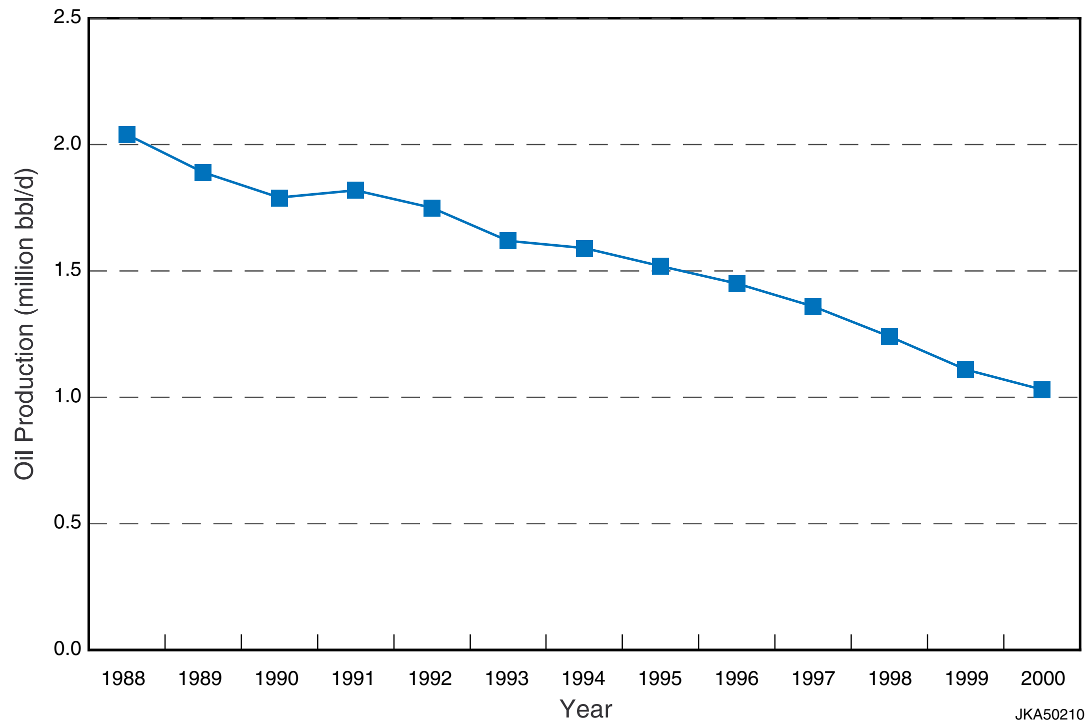

FIGURE A-1 North Slope Crude Oil Production from 1988 to 2000

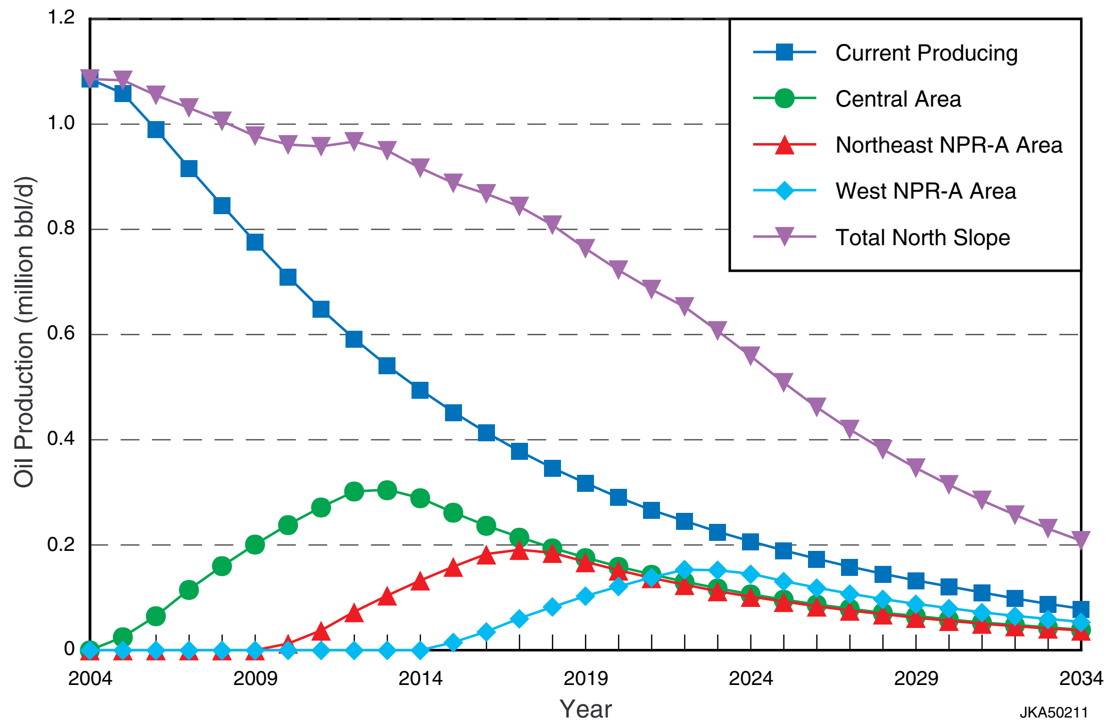

FIGURE A-2 Projections of North Slope Crude Oil Production

A.15.1.5 Data Used in the Spills Analysis

As mentioned above, the high and intermediate frequency spill events were identified from the historical TAPS spill record. Several available existing databases were reviewed, including the ADEC and APSC data referenced in the Environmental Report (TAPS Owners 2001a). The database, known as the Operations Oil Spill database, was the primary source of data used in developing spill scenarios with high and intermediate recurrence frequencies. The database, originally compiled by the TAPS Spills Database (TAPS Owners 2001b) with amendments and verification by Argonne, was updated with spill data for the period August 1999 through October 2001. Refinements to these spill scenarios and development of the low and extremely low frequency scenarios were made with the aid of several TAPS-related system and system component risk assessments. A snapshot from the spills database is given in Figures A-3 and A-4, which show the crude oil spill frequency by the major TAPS segments and by spill size groupings. The data reveal that the majority of the spills over the TAPS lifetime have occurred in the North Slope, with around 20% equally split between the pipeline and Valdez Marine Terminal spills. Almost 80% of the spills were in quantities of less than a barrel.

Where necessary, additional sources of data were collected to help identify creditable extremely low frequency events. The *Trans-Alaska Pipeline System Risk Assessment* (Technica, Inc. 1991) was one of the more quantitative of the risk assessments reviewed. An update to that assessment was in preparation, but the final report was not available in time for full consideration in developing the spill scenarios. Other risk assessment studies considered in formulating scenarios were those conducted for the major pipeline components, including the North Slope, Valdez Marine Terminal, and Prince William Sound, and for some of the systems subcomponents. Some of these studies are listed below:

- *Risk Analysis Screening Study for the Trans-Alaska Pipeline System* (Taylor and Associates 1995);
- *Prince William Sound, Alaska Risk Assessment Study, Final Report* (Det Norske Veritas et al. 1996);
- *Trans-Alaska Pipeline System Primary Block Valve Risk Assessment* (Malvic and Weber 1997);
- *Estimation of Oil Spill Risk from Alaska North Slope, Trans-Alaska Pipeline, and Arctic Canada Oil Spill Data Sets* (Mach et al. 2000);
- *Valdez Marine Terminal Oil Spill Risk Assessment* (Emerald Consulting Group 2001);
- *10 Pipeline Valves with Leak-Through Risk Assessment* (Aus et al. 2001); and
- *Risk Assessment, Trans Alaska Pipeline System, Final Report* (Capstone 2001).

Information sources for development of the spill scenarios included the risk assessments, systemwide and component emergency preparedness and response plans, the TAPS ROW Environmental Report, and other related data. The data and assumptions used for spill analysis in this EIS were coordinated through interactions with the JPO and APSC engineers. Discussions covered reliability of system components, corrosion and metal fatigue data, historical incident databases, plans for drag reducing agent use, and transportation data along the pipeline.

A.15.1.6 Impacting Factors or Event Initiators

The accident scenarios covered both internal and external initiating events. The internal initiators considered included spills caused by equipment failure in valves, pumps, turbines, or tanks; human error; and aging effects, including corrosion and metal fatigue. Traffic accidents were covered under human error. External initiators covered natural phenomena, such as earthquakes, lightning strikes, floods, and climate change. Events caused by an aircraft crash into the pipeline or into a storage tank were also assessed as

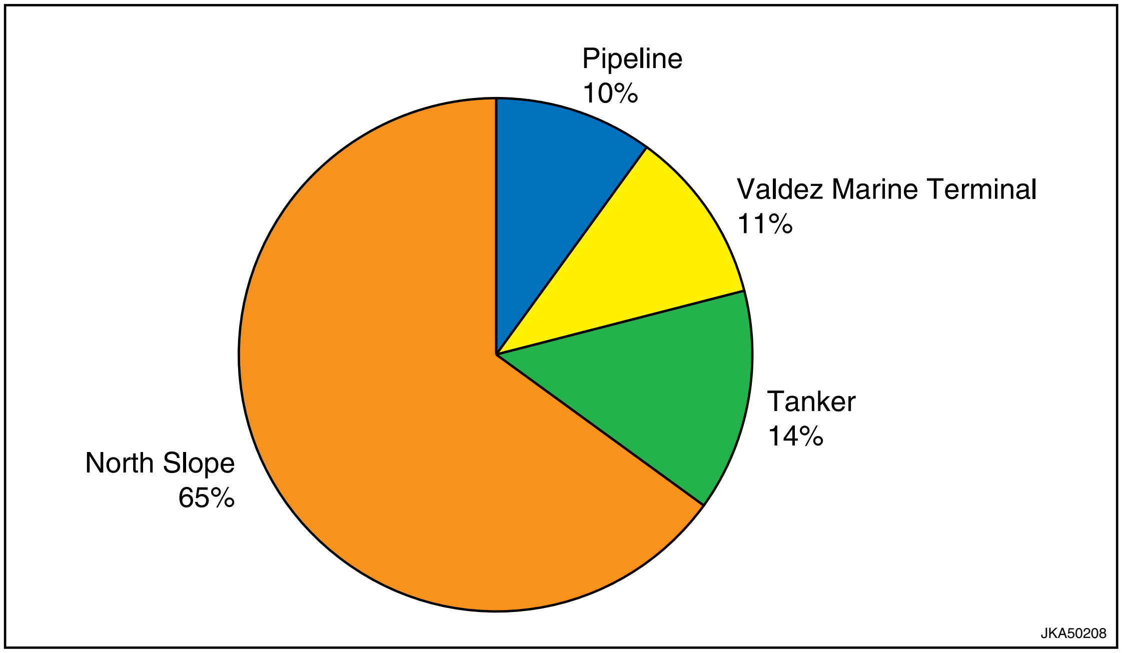

FIGURE A-3 Spill Frequency by TAPS Segment

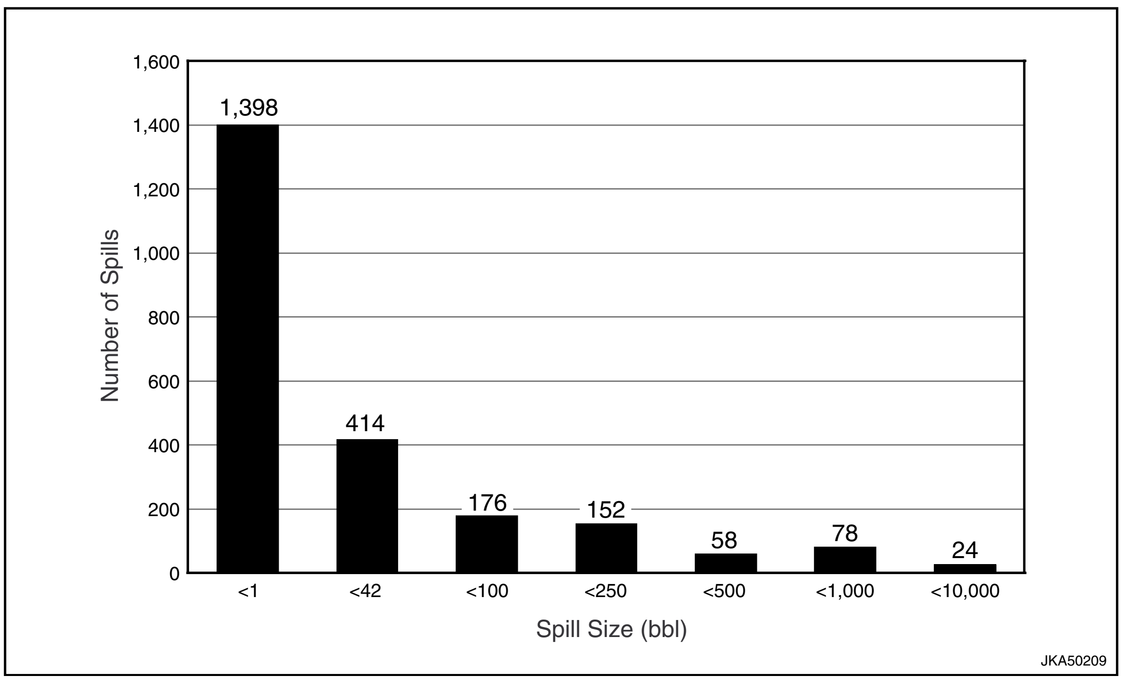

FIGURE A-4 Number of Spills by Size over TAPS Lifetime

external initiators or impacting factors. Finally, acts of vandalism, sabotage, or terrorism were also considered as initiators.

A.15.1.7 Links to Environmental Resource Impact Disciplines

The output of the spills analysis consists of source terms or accidental environmental releases used in support of risk assessments conducted for other disciplines or environmental impact areas covered in this FEIS. Spill quantities, duration, and recovery or cleanup assumptions were provided to support the hydrological (surface and subsurface), ecological (land and marine based), human health and safety (immediate and long-term), and air resource (concentrations and deposition) risk assessments. The risk of spills to these resources was factored into associated social and economic impacts. Potential iteration and refinements were made to the spill scenarios from consultation with each of the disciplinary teams and from the review and discussion of results.

A.15.2 Calculations Relative to Oil Spills to Surface Water and Groundwater

A.15.2.1 Calculations for the Potential Capture of Crude Oil

In the event of a pipeline break that releases crude oil to flowing water, estimates are needed for several parameters in order to calculate the potential for recovery of the oil. Parameters involved include the location of the leading edge of the oil in the water at the response time of the containment crew (based on time needed for the response team to arrive at the containment site and begin containment activities); the length of the oil plume; the percent of oil subject to capture at the containment location; and the width of a spill downstream of the break.

The location of the leading edge of the oil in the stream or river at the response time was estimated by multiplying the velocity of the water times the response time. The oil is assumed to travel at the water velocity; the water velocity is assumed to be equal to values presented in the contingency plans for the TAPS ROW. Response times were provided by Folga et al. (2002).

The length of the oil smear in the moving water was estimated as the product of the water velocity and the time needed to discharge the designated volume of oil from the break. Release volumes and emptying times were obtained from Folga et al. (2002). For this calculation, the oil slick is assumed to move downstream as a plug, with distinct leading and trailing edges. The first drop of oil into the water defines the leading edge, and the last drop of oil defines its trailing edge. Under actual conditions, the length of the oil slick would extend from the leading edge of the plume to the location of the break because of hangup along the route, regions of slower moving water, bends in the river, turbulent mixing and dispersion, and remobilization of oil from banks and stream beds.

If the flow of oil in the water is conservatively treated as plug flow (i.e., flow in which the leading and trailing edge of the flow are abrupt), the following equation can be used to estimate the percent of oil subject to capture at the containment site:

$$PC = 100 \times \frac{T_{empty} - T_{response} + T_{cs}}{T_{empty}}, \quad \text{(E-1)}$$

where

PC = percent of crude oil subject to capture at the location of the containment site,

T_{cs} = time for the oil to reach the containment site,

T_{empty} = time to discharge the oil from the pipeline break, and

$T_{response}$ = time for the response team to reach the containment site and begin containment activities.

The time for the oil to reach the containment site is calculated as the distance from the break to the containment site divided by the velocity of the water in the river or stream. Two methods were used to estimate the time to discharge the oil from the break (T_{empty}). For a guillotine break (instantaneous release), the time was estimated as the volume of oil that would be released divided by the throughput value (Folga et al. 2002). For prolonged discharges, the emptying time was estimated as the volume of oil released divided by the duration time (e.g., 48 hours). Response times were obtained from values provided by Folga et al. (2002).

Because the above equation assumes plug-flow conditions, the result is likely to underpredict the amount of oil that could be captured at the containment site. However, more detailed calculations would require extensive site-specific hydrological information (e.g., flow rates, stream widths, bed and bank conditions, wind speed and direction, temperature, and ice cover) that would only be available at the time of an actual release.

The final parameter for estimation is the width of the slick downstream of the break. In many applications, crude oil spills are assumed to spread circularly (Shen et al. 1988). This spreading is often represented by the following equation:

$$A_s = 10^5 vol^{3/4}. \quad \text{(E-2)}$$

where

A_s = area of the spill (m^2), and

vol = volume of the spill (m^3).

The width of the slick, w_{slick}, is then obtained from the relationship:

$$w_{slick} = 2 \times \sqrt{\pi A_s}. \quad \text{(E-3)}$$

A.15.2.2 Groundwater Calculations for a Subsurface Guillotine Break

In an underground guillotine break, crude oil would be released to the area adjacent to the buried pipe. In regions of stable permafrost, the pipe would release its contents to thaw bulbs formed under normal operations by heat transfer from warm oil flowing in the pipeline. In areas in which permafrost is absent, the release would be to the surrounding soil. As discussed in Section 4.4.4.4.2, a guillotine break in the Brooks or Alaska Ranges would release a maximum of 46,994 bbl of oil to stable permafrost and thaw bulbs. In the Chugach Range, a maximum release of 38,773 bbl would occur to the backfilled trench. If the trench was not sufficiently buried, the pressure from the oil could force the fluid to the surface of the ground. The presence of ice above the pipeline could reduce the possibility of this type of event; however, the warm oil could melt the ice and force its way up to the surface anyway. Impacts from this type of spill are addressed in Section 4.4.4.1 for an aboveground guillotine break. For an underground guillotine break of the pipeline, the oil is assumed to remain belowground in either thaw bulbs in permafrost areas or along the pipeline trench in areas where permafrost is not present.

In the Brooks and Alaska Ranges, thaw bulbs have developed along sections of the buried pipeline. Precise information is not available on their size; however, in the vicinity of PS 3, the thaw bulb is estimated to have a diameter of 60 ft (Keyes 2002). For this analysis, the thaw bulbs are assumed to be circular, with a width equal to 60 ft. The cross-sectional area, A_t, of the thaw bulb is then calculated as:

$$A_t = \pi R^2, \quad \text{(E-4)}$$

where R is the radius of the thaw bulb. The total area is thus about 2,800 ft^2.

This entire area is not available for transporting fluids because of the presence of solid material such as sands, gravel, and the pipeline, which has an effective area of about 12.6 ft^2. For the backfilled trench, the ratio of the volume of void space present to the total volume (i.e., porosity) is assumed to be 0.3 (Freeze and

Cherry 1979). The area of the thaw bulb that can transmit a fluid is called the effective area and is designated as A_e. This area can be calculated from the total area by multiplying the total area, less the area of the pipeline, by the porosity of the fill material, ϕ. That is:

$$A_e = (A_t - A_{pipe})\phi \,. \qquad \text{(E-5)}$$

For a porosity of 0.3, the effective area of the thaw bulb zone is about 850 ft^2.

The maximum volume of oil released for an underground guillotine break in the Brooks or Alaska Ranges would be 46,994 bbl (about 2 million gal). Converting this volume to cubic feet gives a spill volume of about 263,900 ft^3. Dividing the volume of the spill by the effective area gives an estimate of the length of oil-filled space along the pipe. For an effective flow area of 850 ft^2, the oil could occupy a length of about 300 ft.

Once in the thaw bulb, the oil would flow downhill. Because it would be in a porous material, it would have an apparent velocity given by the expression:

$$Vel = \frac{K\nabla h}{\Phi}, \qquad \text{(E-6)}$$

where

K = the hydraulic conductivity (measure of the ability of a material to transport a fluid) of the fill material in the trench and

∇h = the hydraulic gradient (change in elevation with respect to distance).

For a gravel-like fill, the hydraulic conductivity is about 280 ft/d (Freeze and Cherry 1979). Neglecting the initial pressure of the oil in the pipe, the hydraulic gradient for a mountainous region is assumed to be 0.2 (TAPS Owners 2001c). The velocity of the oil in the thaw bulb would, therefore, be about 200 ft/d. It would thus take about 1.6 days for the oil to travel 300 ft. Because the pipeline operates at a pressure of about 1,180 psi (APSC 2001b), the initial velocity of the emergent oil will be higher than that calculated, assuming that the oil would flow under the conditions of the natural hydraulic gradient present. For a pressure of 1,180 psi, the equivalent pressure head (elevation) of the oil can be found from the expression:

$$h_{oil} = \frac{P}{\rho_{oil}\, g} \,. \qquad \text{(E-7)}$$

The pressure head of the oil is thus about 3,130 ft for a crude oil density of 0.8699 g/cm^3 (Folga et al. 2002). This pressure head would increase the velocity by about 50 to 10,430 ft/d if a separation distance of 300 ft is used to define the gradient. The travel time would, therefore, be reduced to about 1 hour. Because the pressure head of the oil is so high, the spilled oil would probably escape the thaw bulb and discharge at the ground surface. Once all of the oil in the broken pipeline segment was released to the thaw bulb, it would continue to move downgradient until there was a sufficient topographic change to reduce the hydraulic gradient to zero, or until the oil found a path to the surface of the ground.

Depending on the time needed to respond to the spill, more than 300 ft of thaw bulb would be contaminated by the spilled oil. Because the spilled oil in the thaw bulb would still be under pressure, care would have to taken in excavating down to the pipeline.

In addition to contaminating the water in thaw bulbs along the TAPS, oil released from an underground guillotine break could melt the surrounding permafrost. The melting would occur because the crude oil from the pipeline would be warmer than the ice.

It is assumed that initially, the oil in the pipeline in the vicinity of the spill would be 110°F (43°C) and the temperature of the permafrost would be 23°F (-5°C). It is assumed that at equilibrium, the oil would cool to 32°F (0°C), and the permafrost would convert to water at 32°F (0°C). The change in energy in the oil would warm the permafrost to its melting point and then melt it. Sufficient ice is assumed to be present to prevent the melt water from increasing in temperature to a value greater than 32°F (0°C). This thermodynamic process can be represented by the following equation derived from phase change information presented in Sears (1964):

$$Cp_{oil}\Delta T_{oil}M_{oil} = M_{ice}h_f + Cp_{ice}\Delta T_{ice}M_{ice}\,, \qquad \text{(E-8)}$$

where

Cp_{oil} = specific heat capacity of oil (j/kg/K),

Cp_{ice} = specific heat capacity of ice (j/kg/K),

h_f = latent heat of fusion (ice to water) (j/kg),

M_{oil} = mass of oil spilled (kg),

M_{ice} = mass of ice melted (kg),

ΔT_{oil} = temperature change of the oil (K), and

ΔT_{ice} = temperature change for the ice (K).

Equation 5 can be solved for the mass of ice that could be melted by the warm oil:

$$M_{ice} = \frac{Cp_{oil}\Delta T_{oil}M_{oil}}{h_f + Cp_{ice}\Delta T_{ice}}\,. \qquad \text{(E-9)}$$

The mass of oil spilled is calculated as its density (0.8699 g/cm^3 times the spill volume (46,994 bbl). The specific heat capacity of the crude oil was assumed to be constant and equal to about 2,100 j/kg/K (mid-continent crude with an API gravity of 30° [Bradley 1992]). This value is consistent with the finding that the specific heat capacity of crude oil is about one-half that of water (Davies et al. 1999), which is about 4,190 j/kg/K (Weast 1968). Other values needed to evaluate Equation E-9 are listed in Table A-5.

TABLE A-5 Physical Constants for Ice-Melt Calculation

Parameter	Value
H_f	335,000 j/kg (Weast 1968)
ΔT_{ice}	5°C
ΔT_{oil}	43°C
Cp_{water}	4,184 j/kg/K (Weast 1968)

The maximum volume of ice that could be melted according to Equation E-9 for the given input parameters is about 1.7 × 10^6 kg. For an ice density of 917 kg/m^3 (Davis 2001), about 65,300 ft^3 (1,850 m^3) of ice could melt. If ice melted from around the thaw bulb in a concentric circle, the radius of the melted zone can be found from the following relation:

$$\pi(r^2 - r_0^2)L = Vol_{ice}\,, \qquad \text{(E-10)}$$

where

L = the length of the region that would fill with oil,

r_0 = the radius of thaw bulb (30 ft), and

Vol_{ice} = the volume of ice melted.

Solving for the radius of the melt zone gives:

$$r = \sqrt{\frac{Vol_{ice}}{\pi L} + r_0^2}\,. \qquad \text{(E-11)}$$

For a volume of ice of 65,000 ft^3, the radius of the circle melted by the warm oil would be about 31 ft. The new diameter of the thaw bulb would be about 62 ft.

In the Chugach Range, an underground guillotine break would release crude oil to the soil. In that region, the pipeline trench is assumed to have a width of 8 ft and a depth of 12 ft, with about 4 ft of fill material on top of the gravel pack. The total cross-sectional area of the gravel pack and pipe is assumed to be 64 ft^2. Subtracting the area of the pipe and multiplying by an assumed porosity of 0.3 gives an effective area of about 15 ft^2. For a release of 38,773 bbl (about 220,000 ft^3), the oil could fill an annulus of about 2.7 mi.

A.15.3 Fire Analysis of Spill Events

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 and 3, (2) Williams North Pole Refinery to PS 9, and (3) PetroStar 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. 2000a).

To estimate fire impacts, simulations were performed with two models: the Fire Dynamics Simulator (FDS) and FIREPLUME. 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.

Earlier versions of FDS have been applied in estimating particulate concentrations from in-situ burning of crude oil in Alaska as far out as 4 to 6 km (McGrattan et al. 1995). The strongest limitation of the FIREPLUME analysis for the Valdez cases is the neglect of terrain considerations since FIREPLUME is based on a flat terrain representation of the atmospheric boundary layer. The mountains surrounding Valdez may lead to higher ground-level impacts than predicted by the model because of the large amount of vertical mixing that can occur on the lee sides of mountain ranges.

The FDS (version 2.2) model was used to estimate key fire buoyancy parameters (temperature, vertical velocity, and plume density) and near-field soot and other combustion product impacts. The model is capable of simulating fire-induced flows or wind fields that influence smoke ground concentrations close to or within a few kilometers of the fire. A detailed description of the model can be found in McGrattan et. al. (2001). The fire combustion product air emissions were estimated using emission factors derived from the Newfoundland offshore burn experiment as reported in McGrattan et. al. (1997) and with an average constant burn rate of 0.051 kg/m^2-s for North Slope crude oil (McGrattan et. al. 1997).[4] Emission factors, which express pollutant mass release per unit mass of fuel consumed, were available for smoke/soot particles in various size fractions and for six gaseous fire combustion products (CO, SO_2, NO_x, VOCs, PAH, and CO_2). Laboratory and field experiments involving various crude oil pool fire sizes show that larger fires tend to produce larger soot yields (ranging from around 5 to 15%). The quantity of soot generated in pool fires is by far the largest quantity on a mass basis of any of the major pollutants emitted from such fires. On the basis of smoke production data collected in large crude oil mesoscale burn experiments, a soot yield of 13.7% was assumed for the Valdez Marine Terminal and pipeline scenarios (Notarianni et al. 1993). A soot emission factor can be computed by taking the ratio of the mass

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4 As multicomponent mixtures do not evaporate at uniform rates, fires involving fuel blends, such as crude oil, do not burn at uniform rates. At the beginning of the fire the burning rate is characteristic of the more volatile lower boiling point components (e.g., butane burns at around 0.8 kg/m2-s), while near the end of the fire the higher boiling point components burn at a slower rate, typically around 0.04 kg/m2-s (Mudan 1994). Because the light-ends burn off so rapidly, the average burn rate is closer to slower and, therefore, longer burning heavy-ends (higher molecular weight and higher boiling point components, such as acetone).

of soot released in the fire (soot yield × mass of oil burned) to the mass of oil burned. The soot emission factor with a 13.7% yield is calculated to be 137 g/kg (estimated soot generation mass/mass of crude oil burned). Data on smoke particle size distributions reported by McGrattan et al. (1997) show that 87% of the particulate mass from burns of several crude oil types, including North Slope and Cook Inlet crudes, was represented by particles less than or equal to 10 μg in diameter. These data assume a 13% soot emission factor.

The buoyancy parameters generated with the FDS model were used as input to the FIREPLUME model (Brown et. al. 2000b). The FIREPLUME model predicts the ground-level concentration field resulting from chemicals or combustion products emitted from or within (1) fires that generate hot continuous plumes such as the oil fires considered in this analysis; (2) instantaneously discharged thermal or explosive discharges; or (3) smoldering or decaying fires, including the nominal case of passive or neutrally buoyant releases, which serve as a limiting case for a smoldering fire. There are four classes of fires, categorized according to the kind of material that is burning. Both of the TAPS pool fire scenarios would generate very hot plumes typical of Class B fires, which involve flammable and combustible liquids that are best extinguished by foam, CO_2, or dry chemicals. All petroleum fires, including fires involving crude oil, are considered Class B fires, which can be very hot and do not exhibit a smoldering combustion phase.

The FIREPLUME model consists of two components. The first is a single particle Lagrangian dispersion model that estimates vertical dispersion of both buoyant and nonbuoyant releases in the atmospheric boundary layer. The second component is a puff dispersion model that translates the vertical dispersion estimates to ground-level concentrations taking into account horizontal dispersion and transient source emission characteristics. The calculation is broken up in this manner to reduce computational time. Taken together, these components provide time varying concentration fields resulting from releases in which both the buoyancy and chemical release rate vary with time. The framework for treating source buoyancy closely follows from the so-called Brigg's two-thirds law (see Briggs 1984), which is applicable in cases in which the buoyant source has low initial momentum. Fires clearly fall into this category (Weil 1982). The plume rise relationships incorporated into FIREPLUME provide a mean vertical velocity for the individual particles. The final or limiting rise of the particles is established using published relationships for a variety of atmospheric conditions that incorporate natural statistical variability in plume rise observed in experimental studies. Using this framework, the vertical dispersion from a variety of buoyant release scenarios can be evaluated; from intensely buoyant sources typical for large oil fires to very low buoyancy sources, such as in the residual stages of smoldering biomass. Additional details on the underlying basis of FIREPLUME are contained in Brown et al. (1997).

Ground-level concentration-emission ratios (χ/Q, commonly referred to as *Chi* over *Qs*) were computed with FIREPLUME at 500-m intervals with downwind distances ranging from 3 to 50 km. Air pollutant concentrations at these distances were derived by multiplying these ratios by the computed fire combustion product pollutant emission rates. The fire emission rates were calculated by multiplying the North Slope crude oil fire emission factors by the assumed burn rate flux (i.e., rate of crude oil burn per unit area) and the estimated fire pool area.

A variety of meteorological conditions were considered in the analysis of fires at Valdez and Fairbanks. However, because of the large size of the hot fires in each of these locations, very buoyant high-rising plumes would be expected either to fully penetrate or become partially trapped below the mixing layer. The largest downwind concentrations of soot and smoke would be expected to occur under unstable atmospheric conditions. However, those conditions would also need to be accompanied by sufficiently inversion layer heights to prevent penetration of the plume and loss of soot particles above the boundary layer. Complete penetration of this layer would result in pollutant transport above the boundary layer over large downwind distances. In considering daytime unstable conditions (as represented with Pasquill Gifford stability Classes A, B, or C), the plume fully penetrates the temperature inversion, marking the top of the atmospheric boundary layer, and becomes confined above that level. The conditions necessary for a portion of the plume to become trapped within the boundary layer include both a wind speed in excess of 7 m/s at 10 m and a strong elevated inversion layer. If these conditions are met, it is estimated that significant ground-level impacts would be possible. Even for these cases, though, most of the plume rises above the inversion and is, therefore, prevented from reentering the mixing layer and thereby through vertical advection and dispersion make it possible for soot impacts at ground level. During the daytime cases studied for Valdez and Fairbanks, it is estimated that 90 and 80%, respectively, of the material penetrates the inversion and is therefore trapped above. The remaining quantity cools within the region of the inversion and then disperses back down to ground level after a few hours. The occurrence of plume penetration and the percentages of the plume trapped above the boundary layer are conservatively estimated based on formulation presented in Weil (1988).

The same general considerations apply for stable conditions; namely, ground-level impacts do not occur when wind speed is less than about 7 m/s. The mechanism here is a little different, however, in that the plume rises to a height at which the atmosphere is very stably stratified, thus preventing the plume from dispersing back down to ground level. Depending on the low-level stability of the atmosphere and the lapse rate, this final plume height can be as low as 300 m or as high as 3,000 m. Cases in which the plume rises to a height exceeding the boundary layer height (which for stable conditions is the height at which sheer-induced turbulence falls to negligible value) led to no ground-level impacts in our analysis. In practice, however, these cases may result in some ground-level impacts when strongly stable conditions (say F stability) are followed by fairly rapid warming, thus creating a classic fumigation condition. This is a fairly unlikely scenario in Alaska, although, because of the slower warming caused by the generally low solar elevation angles coupled with the very gradual increase of solar elevation angle with time. Nighttime cases that lead to ground-level impacts are characteristic of D stability as is the case for the daytime cases, due to the need for high wind speeds. Boundary layer heights chosen for these cases (between 700 and 1,500 m) are at the upper range of possible values and were selected to capture as much of the plume within the boundary as reasonably possible given the wind speed.

A.16 Cumulative Assessment

A.16.1 Introduction

Cumulative effects would result from the incremental impact of the proposed action when added to other past, present, and reasonably foreseeable future actions, regardless of what government agency or private entity undertakes such actions. Cumulative effects can result from individually minor impacts that when viewed collectively over space and time can produce significant impacts (40 CFR 1508.7).

The analysis of cumulative impacts presented in Section 4.7 focuses on human and natural resources or environmental receptors that can be affected by the incremental impacts of the proposed action and alternatives. Generally, the geographic area for a cumulative impact analysis is defined by the specific resource or receptor of concern and the spatial extent of the interacting (cumulative) impact generators. The temporal extent of the cumulative analysis extends from the past history of impacts to each receptor through the anticipated life of the project, including additional time necessary for decommissioning and restoration, if appropriate.

Cumulative analyses, by definition, incorporate an extensive range of potential stressors and thus provide decision makers and the public with an overview of the condition (past, present, future) of a receptor or resource within the region of interest. This broader overview of the set of potential impacts to a resource allows decision makers to place the direct and indirect impacts of the proposed action within the context of other potential stressors.

As a starting point, the cumulative analysis uses the direct and indirect effects of the proposed action and alternatives developed during the scoping phase of this EIS. For the proposed action (renew the Federal Grant for the TAPS ROW) and the less-than-30-year renewal alternative, a number of impacting factors would result from the continued operation and maintenance of TAPS facilities. The impacting factors and the resultant direct and indirect impacts of the proposed action on receptors and resources are developed in Chapter 4 of this FEIS. The no-action alternative also has a set of impacting factors with another set of direct and indirect impacts. Examples of impacting factors include accidental spills of oil, operation of material and disposal sites, operation of support facilities (e.g., airports, access roads, work camps), repair and maintenance activities, pipeline surveillance activities, and the transportation of goods and services for pipeline operation or pipeline disassembly, removal, and ROW restoration.

Direct effects would be the initial impacts caused by the proposed action, less-than-30-year renewal alternative, and no-action alternative and would occur at the same time and place as those actions. Indirect effects would also be caused by the proposed action and the alternatives, but generally would be subsequent to or caused by the initial direct impacts. Indirect effects may occur at a later time or in another location than direct effects. For example, changes in land use, population density, or economic conditions that are a direct result of the proposed action or no-action alternative could then impact air or water quality, ecosystem function, or the introduction of invasive species. In addition, indirect effects can result in positive or negative feedback systems that further exacerbate positive or negative changes in environmental quality.

The cumulative analysis for the proposed renewal of the TAPS ROW encompasses energy development and transportation activities that begin on the North Slope and end with transport of oil in tankers departing from the Valdez Marine Terminal at Prince William Sound. The primary energy activities include oil exploration, oil field development, the transportation of oil in pipeline systems located within developed oil fields (including oil fields located in offshore areas), the transportation of oil in the TAPS, operations at the Valdez Marine Terminal, and the transport of oil in tankers. Energy activities (development, extraction, and transportation) constitute a primary set of potential impacting factors for the cumulative analysis of the proposed action and alternatives. Additional activities include oil refining, potential natural gas development and transportation, human habitation and development, other transportation (roads, rails), legislative actions related to land use, land management, natural resource use, and petroleum spills.

A.16.2 General Approach

The general approach for the cumulative assessment follows the principles outlined by the CEQ (1997) and the guidance developed by the EPA (1999b) for independent reviewers of environmental impact statements. The cumulative assessment conducted for the renewal of the Federal Grant of ROW for the TAPS incorporates the following basic specifications:

- Individual receptors described in Chapter 4 become the end points or units of analysis for the cumulative assessment;
- Direct and indirect effects described in Chapter 4 form the basis for the impacting factors used in the cumulative analysis;
- Impacting factors are derived from a set of past, present and reasonably foreseeable future actions or activities; and
- Each individual receptor and the set of past, present, and reasonably foreseeable future actions or activities that could impact the receptor define the temporal and spatial boundaries of the cumulative analysis.

The evaluation of significance incorporates data, analysis, and results on probability of impact, consequences of impact, spatial and temporal extent of the impacting factor and receptor, recovery potential, and mitigation actions. Some of the information can be quantified, such as the spatial extent of the impacting factors, while other analyses and results could require estimates based on summaries of published literature or scientifically based first principles developed within each discipline. First principle can also be defined as professional judgment; the judgment, however, is based on accepted theories, experiments, and analytical constructs developed under standard scientific methods for each scientific discipline.

A.16.3 Methodological Steps

The methodology of cumulative impact assessment follows the steps presented below. The cumulative analysis uses results produced in Chapter 4 of the EIS and the set of past, present, and reasonably foreseeable activities developed specifically for the cumulative analysis. The methodology is consistent with guidance developed by the CEQ and the EPA. The procedure used is outlined below:

- ***Step 1, Define Alternatives for the EIS:*** The alternatives considered in the TAPS EIS include (1) proposed action (renew the grant of ROW for up to 30 years) (2) less-than-30-year renewal (renew the grant of ROW for a period less than 30 years), and (3) no action (do not renew the grant of ROW). Each alternative is described in Chapter 2. On the basis of the impacting factors associated with each alternative, the direct and indirect effects of the alternatives are developed in Chapter 4.

- ***Step 2, Define the Region of Influence:*** The cumulative analysis delineates TAPS oil production and delivery components into three major geographic categories: (1) North Slope (including off-shore) exploration, development, and production activities; (2) the TAPS ROW and associated facilities; and (3) the transportation of oil in tankers from the Valdez Marine Terminal, especially transportation activities in Prince William Sound. While these geographic areas for the cumulative analysis are not used to constrain individual analyses, the spatial delineation along three major components of oil production and distribution activities provides a useful format for organizing the document and presenting results.

- ***Step 3, Define Past, Present, and Reasonably Foreseeable Actions:*** The set of past, present, and reasonably foreseeable actions is developed from consultations with other government agencies, elected officials, Alaska Native organizations and nongovernmental organizations; through public scoping; and in consultation with knowledgeable private entities, such as the TAPS owner companies. The past, present, and reasonably foreseeable actions include actions directly related to the proposed action. These actions are dependent on renewal of the grant of ROW and are strongly tied to future pipeline operations. In addition, the past, present, and reasonably foreseeable actions include indirect activities that were dependent on past TAPS actions, such as construction or past pipeline operations. Finally, past, present, and reasonably foreseeable actions include activities that are unrelated to the renewal of the ROW or TAPS present and future operations, but which could have impacts on receptors identified in Chapter 4 and that are located in the TAPS region of influence.

- ***Step 4, Develop the List of Receptors:*** The list of receptors (end points) for the cumulative assessment was derived from the receptors developed in Chapter 4. If possible, the receptors are placed or binned into a smaller number of categories. For example, habitat condition could be described in a way that a number of ground nesting birds can be examined together, rather than a species by species analysis.

- ***Step 5, Incorporate the Direct and Indirect Effects Developed in Chapter 4:*** The direct and indirect effects are taken from the direct and indirect effects developed in Chapter 4. Direct effects are caused by implementing each alternative and occur at the same time and place. Indirect effects are caused by the alternative, but are later in time or farther removed in distance. Indirect effects may include growth-inducing effects and other effects related to induced changes in the pattern of land use, population density or growth rate, and related effects on air and water and natural system function (e.g., ecosystem function).

- ***Step 6, Determine the Impacting Factors of Each Cumulative Action or Activity:*** For each action developed under Step 3, a description (qualitative or quantitative) of the impacting factors is developed. The impacting factors are categorized so that similar impacting factors from different activities are considered as a single cumulative impacting factor. However, the spatial extent of the single impacting factor incorporates all the cumulative actions that contribute to the impacting factor. Intensity is defined in terms of some aspect of quantity (e.g., volume, land or water area affected, toxicity level, persistence) for the impacting factor.

- ***Step 7, Evaluate Cumulative Impacts on the Receptors:*** For each receptor or category of receptors, an evaluation of the cumulative impacts addresses the following:

  – The collective magnitude, importance, and significance of all actions;

  – The incremental contribution of the proposed action to the magnitude, importance, and significance of the cumulative impact; and

  – The magnitude, importance, and significance of the impact that could occur under the alternatives, including no action.

The cumulative assessment uses the following set of criteria to judge the magnitude, importance, and significance of an impact on a receptor:

– Likelihood of the impact,

– Consequences of the impact,

– Geographic or spatial extent of the potential impacting factor,

– Geographic or spatial extent of the receptor,

– Temporal extent of the impacting factor,

– Regulatory considerations (e.g., threatened and endangered species, marine mammals, cultural resources),

– Potential for recovery of the receptor after removal of the impacting factor, and

– Potential for effective mitigation.

- ***Step 8, Presentation of the Cumulative Impacts in the EIS***: The cumulative impacts are presented in text form incorporating the information developed in Step 7. A summarization of impacts is presented in Table 2.1.

A.17 References for Appendix A

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