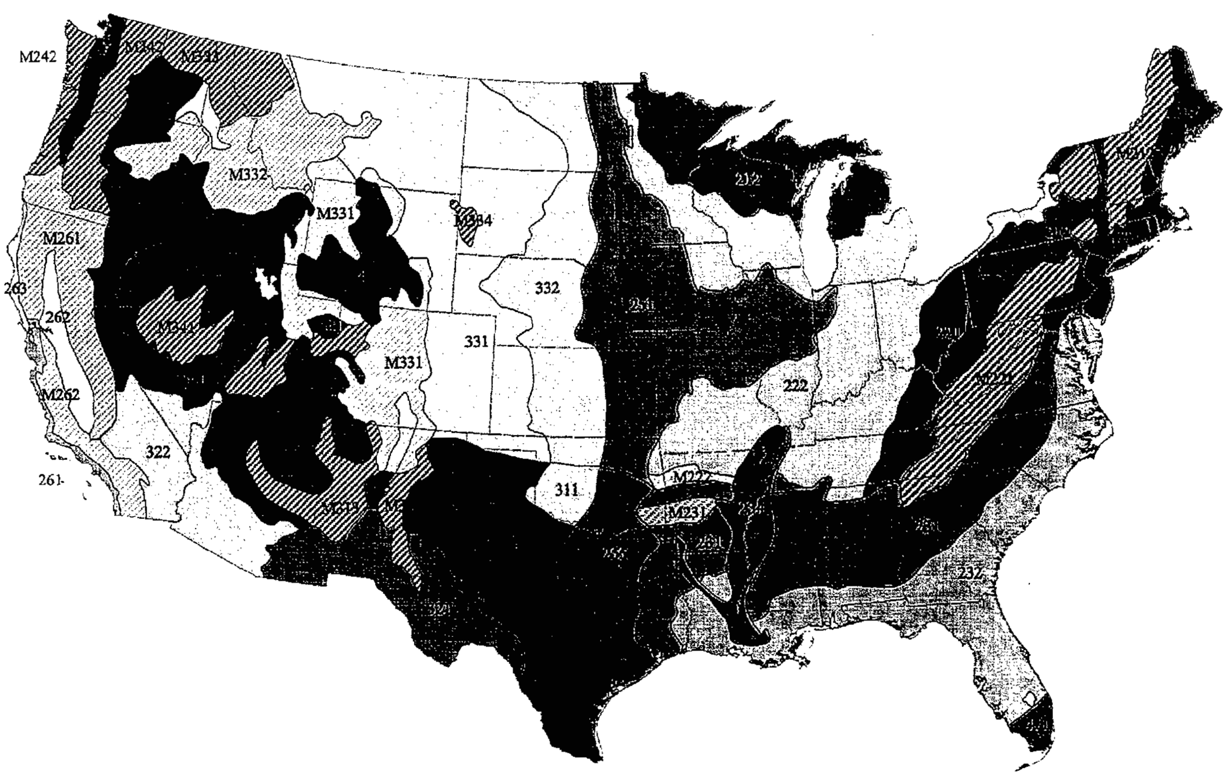
STD.API/PETRO PUBL 4684-ENGL 1999 ■ 0732290 0614024 413 ■

American Petroleum Institute

STEP Strategies for Today's Environmental Partnership

COMPILATION AND REVIEW OF DATA ON THE ENVIRONMENTAL EFFECTS OF *IN SITU* BURNING OF INLAND AND UPLAND OIL SPILLS

Health and Environmental Sciences Department
Publication Number 4684
March 1999



American Petroleum Institute

American Petroleum Institute Environmental, Health, and Safety Mission and Guiding Principles

MISSION

The members of the American Petroleum Institute are dedicated to continuous efforts to improve the compatibility of our operations with the environment while economically developing energy resources and supplying high quality products and services to consumers. We recognize our responsibility to work with the public, the government, and others to develop and to use natural resources in an environmentally sound manner while protecting the health and safety of our employees and the public. To meet these responsibilities, API members pledge to manage our businesses according to the following principles using sound science to prioritize risks and to implement cost-effective management practices:

PRINCIPLES

- To recognize and to respond to community concerns about our raw materials, products and operations.
- To operate our plants and facilities, and to handle our raw materials and products in a manner that protects the environment, and the safety and health of our employees and the public.
- To make safety, health and environmental considerations a priority in our planning, and our development of new products and processes.
- To advise promptly, appropriate officials, employees, customers and the public of information on significant industry-related safety, health and environmental hazards, and to recommend protective measures.
- To counsel customers, transporters and others in the safe use, transportation and disposal of our raw materials, products and waste materials.
- To economically develop and produce natural resources and to conserve those resources by using energy efficiently.
- To extend knowledge by conducting or supporting research on the safety, health and environmental effects of our raw materials, products, processes and waste materials.
- To commit to reduce overall emission and waste generation.
- To work with others to resolve problems created by handling and disposal of hazardous substances from our operations.
- To participate with government and others in creating responsible laws, regulations and standards to safeguard the community, workplace and environment.
- To promote these principles and practices by sharing experiences and offering assistance to others who produce, handle, use, transport or dispose of similar raw materials, petroleum products and wastes.

Compilation and Review of Data on the Environmental Effects of *In Situ* Burning of Inland and Upland Oil Spills

Health and Environmental Sciences Department

API PUBLICATION NUMBER 4684

PREPARED UNDER CONTRACT BY:

JEFFREY A. DAHLIN
SCOTT ZENGEL
CARRIE HEADLEY
JACQUELINE MICHEL
RESEARCH PLANNING, INC.
1121 PARK STREET
COLUMBIA, SOUTH CAROLINA 29201

MARCH 1999

American Petroleum Institute

FOREWORD

API PUBLICATIONS NECESSARILY ADDRESS PROBLEMS OF A GENERAL NATURE. WITH RESPECT TO PARTICULAR CIRCUMSTANCES, LOCAL, STATE, AND FEDERAL LAWS AND REGULATIONS SHOULD BE REVIEWED.

API IS NOT UNDERTAKING TO MEET THE DUTIES OF EMPLOYERS, MANUFACTURERS, OR SUPPLIERS TO WARN AND PROPERLY TRAIN AND EQUIP THEIR EMPLOYEES, AND OTHERS EXPOSED, CONCERNING HEALTH AND SAFETY RISKS AND PRECAUTIONS, NOR UNDERTAKING THEIR OBLIGATIONS UNDER LOCAL, STATE, OR FEDERAL LAWS.

NOTHING CONTAINED IN ANY API PUBLICATION IS TO BE CONSTRUED AS GRANTING ANY RIGHT, BY IMPLICATION OR OTHERWISE, FOR THE MANUFACTURE, SALE, OR USE OF ANY METHOD, APPARATUS, OR PRODUCT COVERED BY LETTERS PATENT. NEITHER SHOULD ANYTHING CONTAINED IN THE PUBLICATION BE CONSTRUED AS INSURING ANYONE AGAINST LIABILITY FOR INFRINGEMENT OF LETTERS PATENT.

Previous page is blank

ACKNOWLEDGMENTS

THE FOLLOWING PEOPLE ARE RECOGNIZED FOR THEIR CONTRIBUTIONS OF TIME AND EXPERTISE DURING THIS STUDY AND IN THE PREPARATION OF THIS REPORT:

API STAFF CONTACT

Alexis E. Steen, Health and Environmental Sciences Department

MEMBERS OF THE INLAND SPILLS WORKGROUP

David E. Fritz, Work Group Chair, Amoco Corporation

Andrie C.T. Chen, Exxon Production Research Company

Donald K. Erickson, Bay West, Inc.

Jack Farlow, U.S. EPA

Robert J. Fiocco, Exxon Research and Engineering Company

Richard M. Gaudiosi, U.S. Coast Guard

Ronald H. Goodman, Imperial Oil Ltd.

John Kimball, TriData, Inc.

Jerry Langley, Williams Pipeline Company

Zelvin Levine, U.S. Department of Transportation

Ken D. Ratliff, Phillips Petroleum Company

Gail Thomas, U.S. EPA

James Sanders, CITGO Pipeline

Dana Slade, Lakehead Pipeline Company

Dot Zaino (RPI) is recognized for her contributions to the final preparation of this work.

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

API	-	American Petroleum Institute
bbl	-	barrel(s)
BTEX	-	Benzene, Toluene, Ethyl benzene, and Xylene; Volatile Hydrocarbons
cm	-	centimeter
dbh	-	diameter at breast height
ERNS	-	Emergency Response Notification System
FEIS	-	Fire Effects Information System
km	-	kilometer
L	-	Liters
m	-	meter
mg	-	milligram
mg/m^3	-	milligram per cubic meter
mph	-	miles per hour
m/s	-	meters per second
NIST	-	National Institute of Standards and Testing
NOAA	-	National Oceanic and Atmospheric Administration
PAH	-	Polynuclear aromatic hydrocarbons
ppm	-	parts per million
RRT	-	Regional Response Team
TPH	-	Total petroleum hydrocarbons
USDA	-	U.S. Department of Agriculture
USEPA	-	U.S. Environmental Protection Agency
USFWS	-	U.S. Fish and Wildlife Service

EXECUTIVE SUMMARY

The primary objective of this study was to identify those environmental conditions under which burning should be considered as a response option for oil spilled in inland and upland habitats. Two very different approaches were used: 1) documenting the "state of the practice" for spills where burning was used; and 2) extracting guidelines from the extensive literature on fire ecology and prescribed burning of vegetation. Combined, these two approaches provide the best available guidance on when burning should and should not be considered for a specific spill in inland and upland areas.

Previous literature searches, recent publications, and personal contacts were used to identify 31 case histories of spills or experiments where oil was burned in inland and upland habitats. These case histories were reviewed in Section 2 to identify the conditions under which oil has been burned in the past. Generally, burns were conducted mostly in marshes and open fields. Nearly half of the burns of a known volume of spilled oil were for quantities of less than 1,500 liters. The most common type of oil burned was crude oil; there was only one case where a heavy crude oil was burned. Short summaries were prepared (Appendix B) to document the spill conditions, an evaluation of the burn, and any follow-up monitoring results. Unfortunately, there have been very few spills where post-burn monitoring was conducted for any period of time. Burning, especially of small spills, is routinely conducted in some states, but there is little documentation available other than the fact that the oil was burned. Because of the focus on environmental issues, those relating to human health and air quality were not extensively addressed in this study. It should also be noted that there are few data on health concerns since most burns are conducted in remote areas.

However, the case histories do provide information on the state of the practice in terms of how *in situ* burning is used in inland and upland areas, which is presented in Section 3. In the past, spilled oil has been burned for the following reasons:

- To quickly remove oil to prevent its spread to sensitive sites or over larger areas

- To reduce the generation of oily wastes, especially where transportation or disposal options were limited
- Where access to the site was limited, by shallow water, soft substrates, or the remoteness of the location
- As a final removal technique, when other methods began to lose effectiveness or become too intrusive

The following favorable conditions for burning were identified from the case histories:

- Remote or sparsely populated sites
- Mostly herbaceous vegetation (with few trees or shrubs)
- Plants are dormant
- Unvegetated areas, such as ditches, dry streambeds, etc.
- In wetlands, presence of a water layer covering the substrate
- In cold areas, presence of snow and ice which provides natural containment and substrate protection
- Calm winds
- Spills of fresh crudes or light refined products

Sections 4 and 5 present applicable information gleaned from the field of fire ecology and prescription burning. Prescribed fires are often used as a forest and range management tool, and are often conducted for the same reasons as *in situ* burning: fire can be less damaging, more effective, and less costly than chemical and intrusive mechanical methods. The fire ecology literature was searched for both general guidelines as well as species-specific profiles on fire ecology and effects, providing excellent guidelines on the effects of burning (in the absence of oil) on plant communities. There are many lessons already learned by fire practitioners and ecologists which are directly applicable to the use of *in situ* burning of spilled oil. These lessons apply to conditions when a burn should/should not be considered (e.g., soil type and moisture, droughts), the conducting of actual burn events (e.g., the direction of the burn and how to control the burn intensity), as well as post-burn considerations (e.g., the potential for erosion and over-grazing).

The U.S. Department of Agriculture maintains a Fire Effects Information System which includes data on the fire ecology and adaptations of numerous plant species, including post-fire regeneration strategy, immediate fire effect, plant response to fire, fire management considerations, and fire case studies. Information on fire effects and ecology of more than 200 dominant plant species of the United States were summarized from this database in Section 5. These summaries should provide spill responders with better information on the potential response of different habitat types and plant species to *in situ* burning.

The conclusions of the study on the environmental effects of *in situ* burning in inland and uplands areas are presented in Section 6. Burning is a valuable tool under many conditions, such as: in locations at a distance from populated areas; for spills of light to medium oils; when the oil is likely to spread to more sensitive or larger areas; at sites with restricted access; and where other options are likely to be very intrusive and cause more harm. However, there is still insufficient documentation to answer some of the key questions likely to be asked by resource managers and agency representatives. Only through better documentation and monitoring will the response community be able to confidently state the conditions under which burning is an appropriate response tool.

Section 1
PURPOSE OF THE STUDY

Burning of spilled oil provides a relatively easy, low cost cleanup method by eliminating removal, transportation, and disposal costs, as well as reducing the time required for cleanup. There is a strong opinion among oil spill professionals that *in situ* burning of oiled habitats is a viable alternative which can, when used properly, minimize the kinds of environmental impacts associated with mechanical and manual removal efforts. In a guide rating the environmental effects of response options (American Petroleum Institute and National Oceanic and Atmospheric Administration, 1994), *in situ* burning was favorably ranked as a response option for many of the more sensitive inland and upland habitats. However, such "alternative" response options are generally considered on a case-by-case basis until there is sufficient field experience for the response community to confidently make routine decisions on when to use them.

Although published information on burning of spilled oil in inland and upland sites is very limited, there was a general sense in the response community that, perhaps, unpublished experiences of the use of burning existed in the files and records of government response agencies and oil production and transportation companies. This study was commissioned by the American Petroleum Institute (API) to locate and obtain this potentially valuable resource of unpublished information on use of burning as a spill response tool in inland and upland areas. A parallel effort was made to review and summarize information on the effects of fire and prescribed burning on different upland and wetland vegetation types in the absence of oil. General fire ecology and prescribed burning documents were reviewed, and a national database on fire effects was consulted. This report presents a summary of the case histories and lessons learned from previous uses of burning in inland environments, with and without oil. While some information on human health and safety is included, the focus of this report is on the environmental fate and effects of *in situ* burning. For more information on inhalation hazards from smoke particles and other emissions from burning oil, refer to Fingas *et al.* (1993, 1994) and Benner *et al.* (1990).

Section 2
IN SITU BURN CASE HISTORIES

INTRODUCTION

The initial focus of this study was to compile and summarize case histories of *in situ* burning of oil in inland and upland environments. By integrating case history information for various spill scenarios and habitat types, it was thought that meaningful *in situ* burn guidelines could be developed for inland and upland areas. *In situ* burning case summaries and lessons learned are provided below. Because of the general lack of good documentation for most spills where burning was used during the response, it is suggested that better documentation of inland and upland *in situ* burns in the future could greatly increase the knowledge base.

METHODS

Identification and Collection of Data

The data collection effort focused on information on *in situ* burning in inland and upland environments, including brackish and freshwater wetlands. The primary contacts for identifying or collecting data were federal agencies, state agencies, and petroleum corporations. A list of the people and organizations contacted during this study is provided in Appendix A. The federal agencies contacted were:

- National Institute for Standards and Testing (NIST)
- National Oceanic and Atmospheric Administration (NOAA)
- Transportation Safety Institute
- U.S. Coast Guard
- U.S. Environmental Protection Agency (USEPA)
- U.S. Fish and Wildlife Service (USFWS)

The states contacted were:

- Alaska
- Illinois
- Indiana
- Iowa
- Kansas
- Kentucky
- Louisiana
- Maine
- Minnesota
- Missouri
- Ohio

- Oklahoma
- North Dakota
- Pennsylvania
- Texas
- Wisconsin
- Wyoming

The oil and pipeline companies contacted were:

- Amoco
- Imperial Oil
- Lakehead Pipeline
- Marathon Oil
- Williams Pipeline

The following universities and land managers were contacted:

- Louisiana State University
- Rockefeller Wildlife Refuge (Louisiana state refuge)
- Texas A&M University

Two recent computerized literature searches on *in situ* burning of oil spills (Mendelssohn *et al.*, 1995; S.L. Ross, 1996) were utilized to identify case studies where *in situ* burning of oil spills had been conducted. This information was also updated with papers from the 1997 Oil Spill Conference session on *in situ* burning. Information from other sources and contacts included monitoring, survey, and research reports, USEPA spill reports [downloaded from the Emergency Response Notification System (ERNS) database], state spill reports, and anecdotal information from telephone interviews.

A brief summary of each case history for *in situ* burning in inland and upland areas was prepared, including as much information as available on the amount of oil burned, the habitats burned, and observations on the effectiveness and effects of the burn (Appendix B). The case studies are listed in Table 2-1 in alphabetical order using the spill name. References for each case study are listed in each summary. Based on these case studies, the "state of the practice" in terms of the key considerations for burning oil was summarized. A checklist for observing burns was also developed (Appendix C). The checklist should provide a quick and easy method of documenting

Table 2-1. Summary list of *in situ* burn cases included in this report.

Spill	Location	Spill Volume (Liters)	Oil Type	Environment	Volume Burned (Liters)*	Time till Burn (Days)*	Substrate*	Vegetation
Black Lake	West Hackberry, LA	11,447,086	Light Arabian Crude	Lacustrine and Fringing Marsh	?	?	?	Herbaceous
Brunswick Naval Air Station	Brunswick, ME	240,389	JP-5	Freshwater Marsh	79,494	8	?	Herbaceous
California Crude Spill	California	794,937	Heavy Crude Oil	Dry Creek Bed, Unvegetated	954	?	?	None
Chiltipin Creek	Copano Bay, TX	469,013	South Texas Light Crude	Brackish to Salt-water Marsh	182,835	?	?	Herbaceous
ESSO Bayway	Port Neches, TX	1,040,572	Light Arabian Crude	Saltwater Marsh	?	?	Water	No
Friendship II Pipeline	Kékcse, Hungary	422,470	Russian Crude Oil	Peat Bog	4,823	?	Peat	Herbaceous
Imperial Oil Calgary	British Columbia	133,549	South Louisiana Crude	Freshwater Bog	?	?	Peat	Woody/ Herbaceous
Kolva River Basin Pipeline Site 5	Komi Republic, Russia	Large Volume	Crude Oil and Formation Water	Muskeg	?	?	Peat	
Lafitte Site 1	Lafitte, LA	159	South Louisiana Crude	Brackishwater Marsh	?	?	?	Herbaceous
Lafitte Site 2	Lafitte, LA	44,834	South Louisiana Crude	Brackishwater Marsh	?	?	?	Herbaceous
Lafitte Site 3	Lafitte, LA	636	South Louisiana Crude	Brackishwater Marsh	?	?	?	Herbaceous
Marathon Pipeline, Gillespie Facility	Bridgeton, IL	795	Crude Oil	Cultivated Field, Unvegetated	159	0.5	?	None
Marathon Pipeline, Noble Gathering	Noble, IL	795	Crude Oil	Cultivated Field, Unvegetated	477	0.5	Mud	None

Table 2-1. Continued.

Spill	Location	Spill Volume (Liters)	Oil Type	Environment	Volume Burned (Liters)	Time till Burn (Days)	Substrate	Vegetation
Marathon Pipeline, Noble S. Gathering	Cisne, IL	477	Crude Oil	Cultivated Field, Unvegetated	318	0.5	Mud	None
Marathon Pipeline, Patterson	Clay City, IL	795	Crude Oil	Cultivated Field, Unvegetated	525	1	Water	None
Marathon Pipeline, Roy Gill Site	Clay City, IL	79	Crude Oil	Cultivated Field, Corn Stalks	79	0.5	?	Corn Stalks
Marathon Pipeline, Sanders Lease	Allendale, IL	1,590	Crude Oil	Cultivated Field, Corn Stalks	79	0.5	?	Corn
Meire Grove	Meire Grove, MN	397,468	Fuel Oil and Gasoline	Freshwater Wetland and Pond	?	11	No	Herbaceous
Nipisi Bog Pipeline Spill	Alberta, Canada	9,539,238	Nipisi Crude Oil	Ombrotrophic Bog	?/158,987	1,551/?	Peat	?
Norsk Hydro Experiment	Spitsbergen, Iceland	954	Marine Diesel/ Oseberg Crude Oil	Snow Covered Moraine	954	4-13	?	None
Old Peace River Fen Pipeline	Alberta, Canada	1,589,873	Nipisi Crude Oil	Wet Meadow/Thin Peat	?	365	Peat	Herbaceous
Pass-a-Loutre	Southeast Pass, LA	10000s	South Louisiana Crude	Brackishwater Marsh	?	?	?	Herbaceous
Rainbow Fen Pipeline	Alberta, Canada	3,179,746	Nipisi Crude Oil	Poor Fen	?	365	Peat	Herbaceous
Rockefeller Wildlife Refuge	Cameron Parish, LA	6,359	Condensate Oil	Brackishwater Marsh	4,770	5	?	Herbaceous
Siroco Pipeline	DeBerry, TX	7,949	Texas Sweet Crude Oil	Forested Upland/ Intermittent Creek	7,949	4	?	Woody/ Herbaceous

Table 2-1. Continued.

Spill	Location	Spill Volume (Liters)	Oil Type	Environment	Volume Burned (Liters)	Time till Burn (Days)	Substrate	Vegetation
Trans-Alaska Pipe-line, Fairbanks	Fairbanks, AK	2,543,797	Prudhoe Bay Crude	Ponded Tundra	79,494	63	Tundra/Ice	Herbaceous
Vermilion 16	Freshwater City, LA	79,494	API 50 Condensate	Brackishwater Marsh	79,494	120?	?	Herbaceous
Warwick Lake	Ontario, Canada	58,825	Diesel Fuel	Wooded Upland/ Frozen Lake	58,825	>4	?	Woody/None
Williams Pipeline Co. Surface Spill Barnsdall	Barnsdall, OK	11,924	Jet Fuel	Open Field/Ditch/ Stream, Partially Vegetated	2,862	?	?	Herbaceous/ None
Williams Pipeline Co. Subsurface Gasoline	Mexico, MO	14,309	Gasoline	Open Field, Unvegetated	?	?	?	None

* ? indicates that the information was not provided in the references or by the interviewees.

the spill and burn, so that in the future, guidelines can be refined based on a larger, more substantial data set.

SUMMARY OF CASE STUDIES

Table 2-1 lists the 31 case histories of inland and upland *in situ* burns included in this report. There have been many more spills in which *in situ* burning was used as a cleanup method, but they were not included in this report because of the lack of documentation. Some states have allowed burning on a regular basis (Illinois, Kansas, Wyoming); however, the only documentation is the fact that product was spilled and then burned. The general guidelines for burning followed by these states have been: (1) the smoke plume should not impact any populated areas; and (2) oil recovery by other methods is not feasible, based on information provided by the Responsible Party. Typically if a burn site is at least 0.8 to 1.6 kilometers (km) from a populated area, burning has been allowed. These burns have usually been for spills of less than 800 liters (L) or about 5 barrels (bbl) of oil.

Most of the 31 spills included in this report are located in the U.S., but spills in Canada, Hungary, Norway, and Russia are also included. They cover geographic regions ranging from southern Texas to the Arctic Circle. Environmental regimes ranged from brackish and freshwater marshes to cultivated fields and dirt roads (Fig. 2-1). Volumes burned ranged from as little as 80 L to as much as several million liters (Fig. 2-2). The products burned were primarily light to medium crude oils or light refined products (Fig. 2-3).

Burns were conducted most frequently in marshes and open fields (Fig. 2-1). In most cases, the oil was burned because it was not possible or was extremely difficult to remove the oil by mechanical methods. In many cases, burning was a secondary treatment method once mechanical removal efforts were terminated, for whatever reason. In other cases, burning was used because it was the most expedient method for oil removal when time was short.

Nearly half of the burns of a known volume of spilled oil were for quantities less than 1,500 L (Fig. 2-2). Often, other techniques were used to remove the bulk of the spilled oil, and burning was used as a final removal method. Burning was used in areas where physical disruption of the substrate by mechanical or manual removal efforts was of concern, and burning was selected as an option to reduce the probability of the

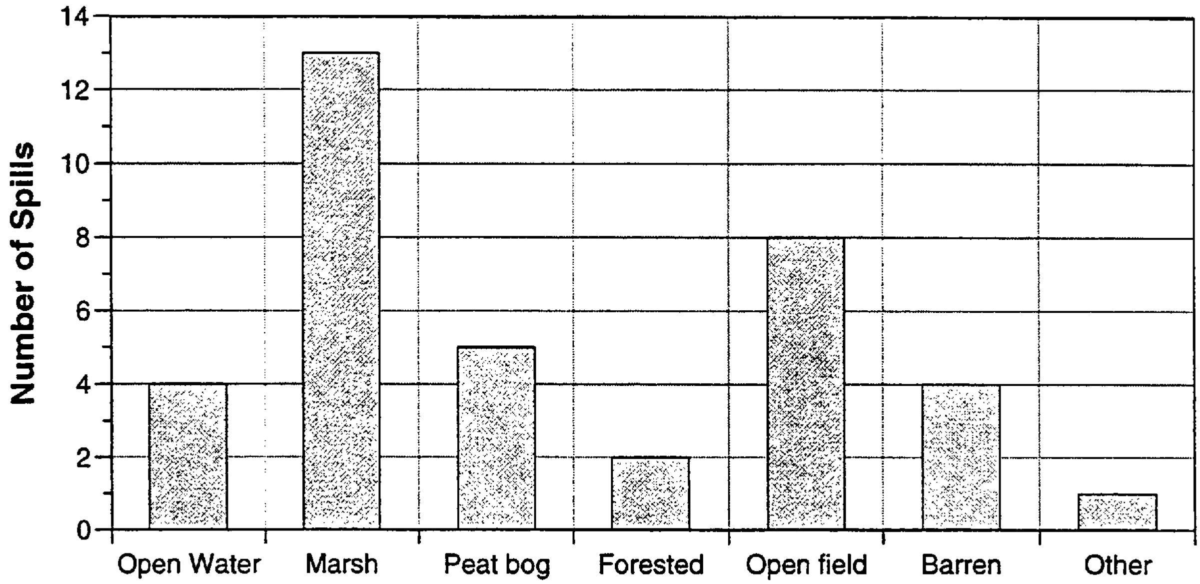


Figure 2-1. Types of Environments Where *In Situ* Burning of Spilled Oil Was Conducted; Includes Spills Where Multiple Environments Were Burned

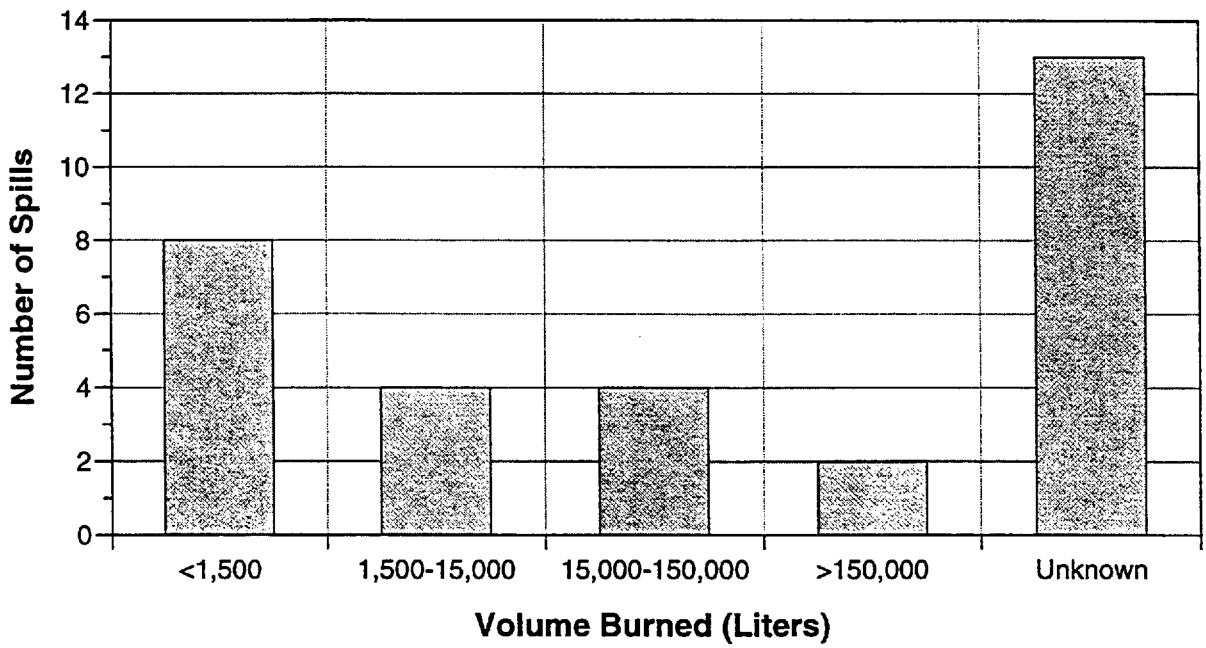


Figure 2-2. Range of Volume of Oil Burned, for the 18 Cases Where the Volume Burned Was Known

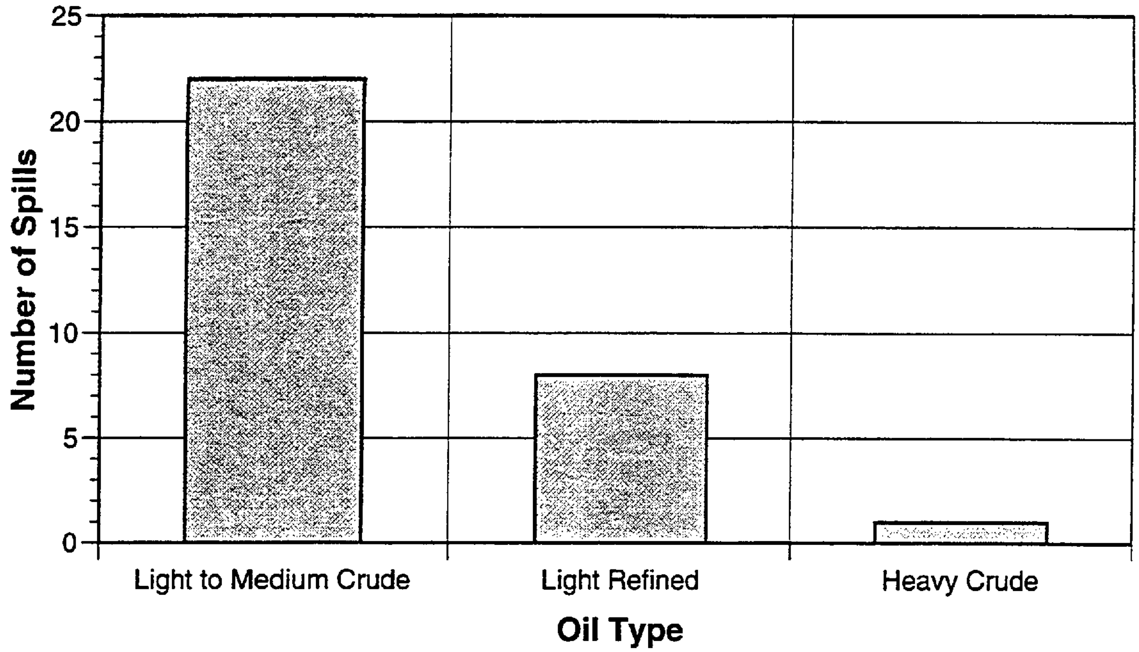


Figure 2-3. Types of Oil Burned for the 31 Cases Included in This Analysis

oil being forced further into the sediments as a result of cleanup efforts. For many of the spills where the volume burned was unknown, the original amount of oil spilled was very large. Based on the available information, it was not possible to estimate the amount burned.

The most common types of oil burned were medium or light crude oils. The remainder of the burns were of light refined products such as gasoline, diesel, or jet fuel. There were no reported cases where heavy refined products like Bunker C were burned. There was only one report where a heavy crude oil was burned, and the observation was that the heavy crude oil did not burn well. Heavy refined oil products are not often burned because of the difficulty of ignition and low removal efficiencies (Tom Lael, personal communication).

Section 3
IN SITU BURNING OBSERVATIONS AND LESSONS LEARNED

In this section, experiences gleaned from the reports on previous uses of *in situ* burning of inland and upland areas are summarized for the following topics:

- Reasons for burning
- Conditions for burning
- Public health and safety issues
- Pre-burn considerations
- Post-burn considerations

REASONS FOR BURNING

Selecting a response option during oil spill response requires evaluating spill-specific conditions and analyzing the pros and cons of various methods. In many places, open burning of oil is regulated by the state air quality agency and USEPA air quality guidelines. Before obtaining approval from these agencies, there needs to be strong justification for burning the oil, as opposed to other cleanup methods. The following discussion summarizes reasons that supported burning of spilled oil in the past.

Burning Removes the Oil Quickly, Preventing the Spread of Oil Into More Sensitive Environments or Over Large Areas

Burns typically last for only a few hours but are effective in removing large amounts of oil. If there is only a short window of opportunity (typically 1-2 days) to remove the oil from the environment before it causes significantly more damage, then burning becomes a viable possibility. With several of the cases (Gonzalez and Lugo, 1995; Hess *et al.*, 1997; May and Wolfe, 1997), rain was forecast for the near future and there was concern that the rain would flush the oil into more sensitive environments, or prevent removal of the oil. With the Williams Pipeline subsurface gasoline spill, the site geology/hydrology was not well understood (Williams Pipeline Company, undated report). There was concern that the product would migrate down gradient toward a nearby creek and impact surface water. Based on this information, the decision was made to burn the product to quickly remove it from trenches dug to intercept the oil on top of the ground water.

Burning Reduces the Amount of Oily Waste for Collection and Disposal

For the Warwick Lake spill in Ontario, Canada, the only way to and from the site was by small plane (Burns, 1988). Transporting large amounts of oil or oiled debris was not feasible, therefore the decision to burn on-site was made. For the Trans-Alaska Pipeline spill, there was easy access via a road; however, with spring thaw, weight restrictions were placed on the road, preventing the transport of large amounts of oil (Buhite, 1979). As a result, approval was granted to burn the remaining oil at the site. With burning, there is often a residue, but this is usually only a fraction of the original volume.

<u>There is Limited Access to the Spill Site, Reducing the Feasibility of Mechanical or Manual Recovery</u>
The equipment required for burning is minimal compared to the equipment and personnel needed for mechanical or manual recovery, handling, and storage. Access may be limited by the surrounding terrain. In the case of the Brunswick spill, the oil was in a marsh where sediments would not support vehicular traffic (Eufemia, 1993). An existing dirt road was upgraded to allow access to one portion of the marsh, but the remaining wetlands were inaccessible. The site may also be in a very remote location, where the only access may be by small plane, as with the Warwick Lake spill in Canada (Burns, 1988). In this case, it was not possible to bring in any type of equipment, other than manpower.

<u>Burning is a Final Measure or Last Resort, When Mechanical Cleanup Methods Lose Their Effectiveness or Pose a Greater Threat to the Environment</u>
Imperial Oil in Canada (Moir and Erskin, 1994) used burning to remove oil from a peat bog because the pumping operation was drawing down the water level, and there was concern that the oil would penetrate the peat substrate. At the Rockefeller Refuge spill, conventional methods removed only 15,900 L (100 bbl), of an estimated 63,600 L (400 bbl) after seven days of effort. Burning of the residue was selected as the preferred alternative over more intrusive mechanical removal (Hess *et al.*, 1997). Many of the Marathon pipeline spills were land-based and relatively small [160-795 L (1-5 bbl)], where it was difficult to remove the oil by any other means. In some cases, vacuum trucks were used to recover the pooled oil, and the remainder was burned.

CONDITIONS FOR BURNING

There are numerous environmental conditions that influence effectiveness, safety, and the recovery of the habitat following *in situ* burning. Conditions that were reported as both favorable and unfavorable to burning are discussed below. In addition to the considerations listed below, it is also highly recommended that experienced wildfire experts and prescribed fire practitioners be consulted for guidance concerning burning conditions, fire behavior, and fire control. There are also several modeling systems developed by the U.S. Forest Service and others that can be used to predict fire behavior and control, smoke production, fire effects, etc. For more information on fire management models and tools, consult "Fire Management Tools *Online*" at "*http://www.fire.org/perl/tools.cgi.*" Models that could be adapted for *in situ* burn planning include: the BEHAVE Fire Behavior Prediction and Fuel Modeling System, the First Order Fire Effects Model (FOFEM), and others.

The Burn Site is Remote or Sparsely Populated

One of the major issues with burning is the human health risk associated with the smoke plume generated by the burning oil. Except for the Brunswick spill, all of the burns were in relatively remote locations. In contrast to the stated concern about the smoke plume, air monitoring was conducted at only two of the sites (Rockefeller Refuge and Brunswick Naval Air Station) that were reviewed in this study. Most of the available air quality data are from experimental spills where there are sufficient time and resources for implementing air monitoring programs by trained teams.

Woody Vegetation (Trees and Shrubs) is Absent

The advantages of non-wooded areas was not directly addressed in any of the reports, but can be inferred based on the actions at both wooded and non-wooded sites. Open areas allow easy monitoring of burning and reduce the chance of losing control of the burn. Fire breaks are more easily constructed in unwooded areas, thus reducing the risk of the fire spreading beyond the intended burn site. For example, the fire break at the Vermilion 16 spill (Henry, 1997) was constructed by flattening the marsh grass around the burn site with an airboat. Mendelssohn *et al.* (1995) also concluded that most wetlands with woody vegetation should not be burned, primarily because these areas take much longer to recover, compared to herbaceous wetlands. In wooded areas, intense fire may scorch or ignite trees, possibly damaging or killing them, and may also start secondary, uncontrolled burns. There were two cases where burning was conducted in wooded areas (Moir and Erskin, 1994; Labay, 1997). In the Imperial Oil and SIROCO Pipeline cases, the condition that made the burns possible was heavy rains in the areas just prior to the burn. The ground and vegetation were very wet and not likely to burn; therefore, a controlled burn was more feasible. In wooded areas, a large firebreak needs to be constructed to contain the fire to prevent unintentional burning of the trees. In the Imperial Oil case study, the firebreak was

3-6 m wide. Even then, there was mortality to trees near the burn site as a result of heat stress (Moir and Erskin, 1994).

The Spill Site Consists of Open Fields

Protective equipment can be easily staged around a burn site in open fields, and the area is typically free of physical obstructions for isolating the burn area. At the Williams Pipeline spill in Barnsdall, Oklahoma (Williams Pipeline Company, undated report), the fire department was present during the spill and controlled the heat of the burn under some power lines. In addition, burning is a common management technique for open fields, and they usually recover quickly. The area can be tilled, fertilized, and re-seeded to enhance degradation of any oil residues and prepare the site for re-vegetation.

The Spill Site Consists of Crop Lands

Most crop lands have annual vegetation, so impacts to these environments as a result of burning usually last less than one year. Normal cleanup methods are complicated by the terrain in plowed fields. Based on the Marathon Pipeline Company burns, it is difficult to recover the last remaining oil from spills in fields. The fields are typically far enough from human habitation so as not to present a health risk, and it is easy to control the burn area. For the case histories studied, the burns were conducted in winter or early spring when the fields were either bare or had stubble from the previous crop; thus, no live vegetation was impacted. Following the burns, the area was tilled, limed, fertilized, and then farmed normally the next season.

The Spill is in an Area Devoid of Vegetation, e.g., Roads, Ditches, and Dry Stream Beds

There is no vegetation to be impacted in these areas, although wildlife in the area would have to be considered. Additional fuel may be needed to promote the burn in the absence of vegetation. Oil may remain in the sediment after the burn, but most of the free surface oil is usually removed. Depending on the substrate, it is expected that the oil will only penetrate a few centimeters (Burns, 1988), and have moderate concentrations (1,000 ppm) (May and Wolfe, 1997).

The Plants Are Dormant Which May Minimize Vegetation Impacts and Accelerate Recovery

Mendelssohn *et al.* (1995) concluded that *in situ* burns in marshes are less damaging when the vegetation is dormant. During dormancy, energy reserves are stored in plant roots and rhizomes. After burning, plants can sprout using these stored reserves. During the growing season, energy reserves have been directed toward shoot growth and may not be available for re-growth after fire. Thus, plant recovery may be slowed or reduced. In the case histories, marshes burned during the dormant season showed rapid regrowth during the subsequent growing season (Pahl *et al.,* 1997; Buhite, 1979).

For Marsh Areas, the Substrate is Submerged Beneath a Water Layer

A water layer serves several purposes. It insulates the substrate from the heat of the burn to prevent destruction of plant roots and ignition of organic soils. It also serves as a barrier preventing oil from being driven into the substrate during the burn. The Kolva River Basin muskeg swamp had little water on it and the heat from the burn drove the oil into the peat mat (Hartley, 1996). There has been relatively good success with having as little as 5 to 10 centimeters (cm) of water over the substrate (Hess *et al.*, 1997). In all of the sites that had a water layer at the beginning of the burn, a water layer remained following the burn. Few reports documented the water depth, and no requirements for a prescribed minimum water depth for conducting a burn were found.

Snow and Ice Cover Provides Natural Containment and Protects the Substrate

Snow acts as a natural sorbent (Burns, 1988). When ignited, snow melts, releasing oil which then burns (Sveum *et al.*, 1991). Usually there is sufficient heat generated by burning oil to continue melting the snow and releasing oil. Unoiled snow also serves to contain the fire (Eufemia, 1993). Ice is considered an impermeable barrier, and as such can be used to concentrate oil for burning in open water conditions (Buhite, 1979; Eufemia, 1993). Burning can also create a wicking effect and remove large amounts of oil from under ice. Ice can protect the substrate during burning (Buhite, 1979) and may also reduce vegetation impacts.

The Winds Are Calm

Burns should be conducted with current and forecasted winds less than 5 m/s [11 miles per hour (mph)] and preferably less than 2.5 m/s (5.5 mph). In the reviewed reports, the winds were almost always below 5 m/s. Under calm conditions, smoke has a high vertical rise (assuming no inversions), dispersing them to safe concentrations. Where human populations may be at risk, the wind direction and speed must be considered, so that it will carry the smoke away from the populated areas (Eufemia, 1993). Low wind speed makes it easier to control the actual burn as well.

The Spilled Materials Are Unweathered Oils or Light Products Which Are Most Effectively Burned

Light fuel oils such as diesel, jet fuel, and gasoline are relatively easy to ignite and can be burned days or weeks after a release (Eufemia, 1993; Burns, 1988). Light or medium crude oils burn well if ignited within days after release. Extreme cold or snow cover can extend this time frame to weeks or months [Buhite, 1979; Blenkinsopp *et al.*, 1996 ([Nipisi Bog Pipeline spill)]. Heavy refined oils and crude oils need to be ignited within days of being released to burn efficiently (May and Wolfe, 1997), otherwise they are extremely difficult to ignite. Typically, a large amount of accelerant needs to be added to begin the burn. A heavy viscous burn residue is produced (Hartley, 1996; Lael, 1997), which may be more difficult to remove than the original oil. Surviving vegetation may not be able to grow up through heavy residual crusts, and seeds and propagules may be prevented from contacting the soil and germinating. Even with lighter oils, as they weather, more residue is left following the burn.

Marshes Should Not be Burned if a Sustained Increase in Water Level is Anticipated Following Burning

Mendelssohn *et al.* (1995) concluded that post-burn water level increases could drastically impact burned marshes if the vegetation were completely submerged for several weeks. This may have been a factor in the poor recovery of burned marsh at the Port Neches, Texas spill (McCauley and Harrel, 1981).

PUBLIC HEALTH AND SAFETY ISSUES

The protection of public health and safety is of utmost importance during an *in situ* burn. Human health is not the focus of this report; however, public health and safety issues are discussed here as part of the overall response strategy. Lessons learned from the case histories are listed below.

Request and Obtain the Necessary Permission to Proceed With the *In Situ* Burn

Burning is a permitted means of mitigation in most states. It is necessary to carefully coordinate the burn with the governing agencies in the spill area, which may include the USEPA, state air quality control board, state environmental protection agencies, state natural resource agencies, and state and local health officials. It is important to follow the local guidelines, if any are in place, and any additional requirements set forth by any agency as deemed necessary for that particular spill location. These might include additional monitoring during and after the spill in heavily populated areas, as well as extensive restoration in highly sensitive areas. Pre-approval areas or predefined decision-making procedures can expedite the entire approval process.

Develop a Burn Plan and Present It to the Regulatory Authorities so They Can Review and Modify It Before the Burn Event

The plan should take into consideration the environment in which the burn will be conducted, health and safety issues, details concerning the methodology to be followed, monitoring plans, and post-burn cleanup and monitoring. See the introductory paragraph under "Conditions for Burning" (page 3-2) for sources of information and tools to assist with burn planning.

Notify Local Emergency Authorities (Fire, Police, and Ambulance) Prior to the Burn

These authorities should be provided with the exact location and expected duration of the burn. The reason for this is twofold: (1) to dispel confusion; this will prevent the local authorities from thinking that the burn is an emergency situation; and (2) if any problems arise during the burn, the authorities will be able to respond more effectively. Local authorities can be requested to provide standby fire control at the burn site, but this should only be requested if responders deem it necessary. Many emergency response departments, especially in rural areas, do not have sufficient resources to provide extensive standby fire control. The Williams Pipeline Company alerted the local fire department of the burn conducted at the Barjenbruch property in Mexico, Missouri and the fire department was on-scene at their burn at the Barnsdall Station Property. Moir and Erskin (1994) report that fire fighting equipment was staged around the site to combat secondary fires. May and Wolf (1997) discuss the use of hand-held spray bottles to extinguish embers or any vegetation that catches fire outside of the burn area.

Provide Appropriate Site Security and Prevent Public Access to the Burn Site

Large burn events will likely draw spectators, thus all possible access points at the site must be controlled to assure public safety. The blockage of any public roads must be coordinated with local law enforcement officials prior to the burn. The Williams Pipeline Company blocked off several nearby roads and re-routed traffic away from the burn site during response efforts at the Barnsdall Station Property in Oklahoma (Williams Pipeline Company, undated report).

PRE-BURN CONSIDERATIONS

Once permission to conduct the burn is obtained, the following considerations are recommended prior to initiating the burn.

Immediately Prior to Burning, Survey the Entire Area to be Burned and Implement Necessary Precautions

For most spills, once the oil is ignited, it usually is not possible to extinguish the fire. All of the burns were allowed to go until they burned out. Any areas outside the proposed burn area that may be impacted by the burn should be wetted down or protected with a fire break. Fire breaks help control the spread of the fire and provide a buffer from the flames and excessive heat. Fire breaks have been used to protect surrounding woodland areas (Moir and Erskin, 1994), power lines (Eufemia, 1993), and pipelines (Buhite, 1979). They can be in the form of a trench, earthen berms (Moir and Erskin, 1994; Eufemia, 1993; Buhite, 1979), or by flattening marsh grasses (Henry, 1997). Eufemia (1993) pointed out that snow acts as an effective natural fire break and containment barrier. The herding of oil into certain areas within the proposed burn site is also a good idea to prevent adjacent trees, shrubs, utility wires, structures, etc. from being burned or scorched (Williams Pipeline Company, undated report [Barnsdall, Oklahoma]).

Avoid Physical Disturbance of Vegetation or Substrate

One of the objectives of a burn is to remove oil while minimizing physical destruction of the environment. In some cases, mechanical cleanup activities prior to the burn, or in preparation for the burn, have resulted in impacts to wetlands (Mendelssohn *et al.*, 1995). When it is evident that physical disruption of the vegetation or the substrate is occurring, activities should cease (Moir and Erskin, 1994; Eufemia, 1993).

If Spilled Oil Will Not Ignite Readily, It May be Necessary to Use Ignitors or Accelerants

The type of oil and degree of weathering affect the ignition process. If the spilled product cannot be readily ignited, a more flammable substance may be added to the spilled product. Accelerants may be added during the burn to maintain the fire. Various types of ignitors and accelerants have been used. Gasoline proved to be hazardous during the Imperial Pipeline spill (Moir and Erskine, 1994), so a mixture of gasoline and diesel was used. In the experiments conducted by Norsk Hydro, a petrol (gas) soaked rag was used successfully (Sveum *et al.*, 1991). Other ignitors include: varsol (Chiltipin Creek, Texas); diesel (Lafitte Oil Field incidents); flares (Pass-a-Loutre, Louisiana; Trans-Alaska Pipeline incident, Alaska); blow torch (Barnsdall

Station Property Spill); burning hay (Rockefeller Refuge, Louisiana; Vermilion 16, Louisiana); and flame or drip torches. A common accelerant during prescribed burning includes 70:30 mixes of diesel and gasoline.

Ignite the Downwind Side of the Burn Area First, Allowing the Fire to Spread Upwind (Under Most Conditions)

Burning upwind produces a slower and more complete burn that is more easily controlled. However, a slower burn may cause greater damage to the vegetation and increase the risk of igniting organic soils, as a result of increased burn duration. Downwind ignition will also place the personnel lighting the fire downwind of the smoke and flames, so they should ensure that there is light wind during ignition. Lighting the fire on the upwind side can be hazardous, as it will likely produce a rapidly spreading and perhaps uncontrollable fire (May and Wolfe, 1997).

POST-BURN CONSIDERATIONS

Following the Burn, Patrol the Entire Area Carefully to Identify Remaining Oil, Residue, and "Hot Spots" That Could Flare Up Again

The area should be checked for residual oil or burn residue. Any remaining oil can either be re-ignited (Eufemia, 1993; Moir and Erskin, 1994; Pahl *et al.*, 1997) or removed with skimmers, sorbents, flushing, mechanical or manual efforts (Moir and Erskin, 1994; Williams Pipeline Company, undated reports). Removing oily residues is difficult or impossible in remote areas or soft substrates (Hartley, 1996). Once the burn is terminated, hot spots should be extinguished (wetted down or covered with earth).

A Crust (Residue) is Typically Formed on Burned Soil That Retards Re-vegetation, and Thus May Need to be Broken Up or Removed

There is usually some post-burn residue, particularly for black oils. The burn residue composition is similar to heavily weathered oil which is slightly enriched in high molecular weight aromatic hydrocarbons (Henry, 1993). All sediment samples collected in the case histories revealed the presence of residual contamination post-burn. On land, this crust (and underlying substrate) should be tilled or removed and fertilized soon after the burn (Buhite, 1979; May and Wolfe, 1997; Moir and Erskin, 1994; Williams Pipeline Company, undated report for the Barnsdall Station Property, Oklahoma) to promote the re-colonization of plants. In wetland environments, it may be necessary for cleanup crews to re-enter the burn area and remove the burn residue

(Gonzalez and Lugo, 1995). Another form of burn residue is soot (Henry, 1993; 1997), though it is not likely to be a source of long-term sediment contamination.

<u>Erosion May be a Problem in Burn Areas Where Plants Were Damaged or Killed</u>
Erosion control measures may be necessary, temporarily, until new vegetation is established at the burn site. Increased erosion may affect nearby water quality. Inspect the burn area for potential erosion areas and take preventative actions. Both wind and water erosion should be considered. A variety of erosion control methods or devices are available, including mulching, biodegradable textiles, seeding with annual grasses such as rye, sediment fencing, etc. Erosion control measures often need to be tailored to the specific site location and conditions. Local soil conservation, forestry, or range management officials can often provide guidance on appropriate and effective erosion control measures.

<u>Vegetation in and Adjacent to the Burn Site Can be Affected</u>
Obviously, the vegetation within the burn site is engulfed by flames and damaged to a certain degree. Vegetation adjacent to burn sites is often scorched by flames or stressed from the heat produced by the fire (Moir and Erskin, 1994; Labay, 1997). Therefore, some off-site re-vegetation efforts or monitoring may be required.

<u>Burning Can Alter Vegetation Community Types</u>
In some instances, burned areas will shift to a less diverse plant community, such as at the Chiltipin Creek, Texas site (Tunnell *et al.*, 1995; 1997). For intense, long duration-burns, pioneering species return first, with the climax species starting to take over in a few years. For areas with sensitive species, or where organic soils burn, long-term or permanent changes in plant communities could occur. Tunnell *et al.* (1997) predicted that it would take 7-8 years before the climax community structure returns at a high marsh burn site in Texas.

<u>Burning Can Severely Impact Organic Soils Such as Those Found in Peat Bogs (Moir and Erskin, 1994), Muskeg Swamps (Hartley, 1996), or Fens</u>
Fire can ignite organic sediments and consume them to the point of altering local topography. This can change hydrological conditions at a site, as well as alter the plant community. In addition, when organic soils burn, plant roots and rhizomes are usually destroyed, killing the vegetation. In some cases, fire may liquify the oil, allowing it to penetrate deeper into the sediments (Hartley, 1996).

In summary, there are four reasons for burning:

- Rapid oil removal,
- Reduction of oily wastes that require disposal,
- Site access is limited, and
- As a last resort response option.

Unweathered crude and light petroleum products are most effectively burned.

Favorable site conditions for burns include:

- Remote or sparsely populated,
- No woody vegetation,
- Open fields or crop lands,
- Devoid of vegetation,
- Plants are in a dormant state or submerged, and
- A layer of snow or ice protects substrates.

Weather also can influence burn results and consequences:

- Calm winds provide better conditions for plume rise, and
- Higher water levels, post-burn, may adversely affect vegetation recovery.

While this document primarily addresses environmental conditions, there are public health and safety concerns that should be considered. These can be addressed via:

- Preparing a burn plan for regulatory review,
- Obtaining appropriate permits,
- Notifying local emergency response authorities prior to a burn, and
- Providing site security and restricting public access.

Considerations for conducting an inland or upland burn include:

Pre-burn	Post-burn
Survey the area to be burned	Patrol the burn site
Implement precautions	Identify hot spots that may re-ignite
Avoid physical disturbance	Break or remove any crusting
May need ignitors or accelerators	Take erosion control measures
Ignite downwind	Potential re-vegetation efforts needed

While burning can provide environmental benefits, it can also modify soils and vegetation.

Section 4
SUMMARIES OF FIRE ECOLOGY AND PRESCRIBED BURNING

INTRODUCTION

In addition to the case histories of *in situ* burning in oiled environments, information on the effects of fire in the absence of oil, both wildfire and prescribed burning, was reviewed and summarized. There is unquestionably a much greater body of knowledge concerning general fire ecology and prescribed fire as a management tool, as compared to *in situ* burning as an oil spill cleanup technique. It is thought that this knowledge base could provide important lessons and guidelines that could be applied to the special case of *in situ* burning of oil. Interestingly, some of the reasons which support the use of prescribed fire as a forest and range management tool are similar to those which support *in situ* burning: fire may be more environmentally acceptable than other methods (namely chemical and intrusive mechanical treatments); burning may be more effective than other methods; and use of fire may be easier to implement and less costly than other methods, particularly for large areas, remote locations, and sites with limited access (Wright and Bailey, 1982). In addition, fire is a natural feature in many ecosystems. There is quite a range of fire tolerance and fire "adaptation" among different plant community types, depending to a large extent on past fire frequency and intensity. Some plant communities are eliminated or excluded from areas by fire, while others may even be referred to as "fire dependent", requiring fire for their continued existence and/or maintenance. Information concerning the ecology and effects of fire on different plant community types should be a valuable tool for spill responders considering *in situ* burning.

METHODS

Two major references were consulted for general information on fire ecology, fire effects, and prescribed burning (Wright and Bailey, 1982; Whelan, 1995). Major points from these sources are listed so that they can be quickly consulted when *in situ* burning is considered as a response option.

For individual plant species, the U.S. Department of Agriculture (USDA) Forest Service maintains a Fire Effects Information System (FEIS) which was used as the major source for reviewing and summarizing information on the ecology and effects of fire (Fischer, 1992). This database can be accessed over the world wide web (www) at the following address, "www.fs.fed.us/ database/feis/welcome.htm". The FEIS contains literature summaries and case histories from a wide body of sources. The FEIS database provides information on the effects of fire on plant species, wildlife species, and plant cover and community types. Currently, information on fire effects by plant community and cover type is limited, with much more information available for individual species of plants and animals. For plants, species lists can be viewed by plant growth form (tree, shrub, graminoid, forb, cactus, etc.) or in total. Major data categories for each plant species cover the following topics: plant distribution and occurrence; value and use; botanical and ecological characteristics; fire ecology; fire effects; and references. For fire ecology and effects, database fields include the following:

- fire ecology and adaptations
- post-fire regeneration strategy
- immediate fire effect
- plant response to fire
- fire management considerations
- fire case studies

Wright and Bailey (1982), McCune (1988), Cerulean and Engstrom (1995), and Whelan (1995) were consulted for additional information on the effects of fire on particular plant species and communities.

To determine which species of plants to examine in the FEIS database, an ecoregion approach (Bailey, 1983; 1995) was used to identify the major vegetation types and plant species for different ecological regions of the coterminous United States. Ecoregion provinces defined and mapped by the USDA Forest Service (Fig. 4-1) were examined, and the major plant species associated with each province were identified (McNab and Avers, 1994; Bailey, 1995).

Plant species included in the fire effects summaries are listed by ecoregion in Table 4-1, cross-referenced by community type. Cross-referenced community types correspond closely with vegetation classes defined by Kuchler (1964). Figure 4-1 (map) and Table 4-1 (species list) can be used in conjunction to initially determine general vegetation types and fire effects that might need to be considered when planning or initiating *in situ* burning. All plant communities and species that may be prominent in particular areas are not represented, just the major groups listed by McNab and Avers (1994) or Bailey (1995). Species listed for some regions may also be abundant in adjacent regions, or in other regions with similar vegetation communities. Note also that vegetation groups can occur in combination in some locations (e.g., oak-hickory-pine forest and bluestem prairie occur together as a mosaic in parts of ecoregion #222).

In addition to major vegetation types by ecoregion, fire effects summaries for wetland grasses and sedges were also prepared, since the feasibility of burning oil in marshes and similar habitats is high. Species from across North America (including Alaska) were chosen from wetland species listed in the FEIS database.

GENERAL POINTS ON FIRE ECOLOGY AND PRESCRIBED BURNING

Major points from Wright and Bailey (1982) and Whelan (1995) are listed below, concerning general fire ecology, fire effects, and prescribed burning.

General Prescribed Fire Guidelines from Wright and Bailey (1982)

It is important to have personnel trained and experienced in prescribed burning on-site if ecological, environmental, and safety considerations are to be adequately treated. The use of prescribed burning practitioners was not identified in any of the *in situ* burn case histories (Sections 2 and 3); however, they could provide highly valuable knowledge, skills, and experience that spill responders may not possess.

To minimize harmful ecological effects, prescribed fire should rarely be used during extended droughts or dry periods.

Ground temperature (in the root zone) influences plant impact and survival more so than surface temperatures or aboveground temperatures.

Temperature and duration of exposure influence plant impact and survival more so than maximum temperature or temperature level alone (similar to the dose concept in toxicology, where the concentration and duration of exposure are considered, e.g., 24-hr LC_{50}).

Soil moisture is an important factor during prescribed burns; higher soil moisture protects the vegetation from root damage and also protects organic soils.

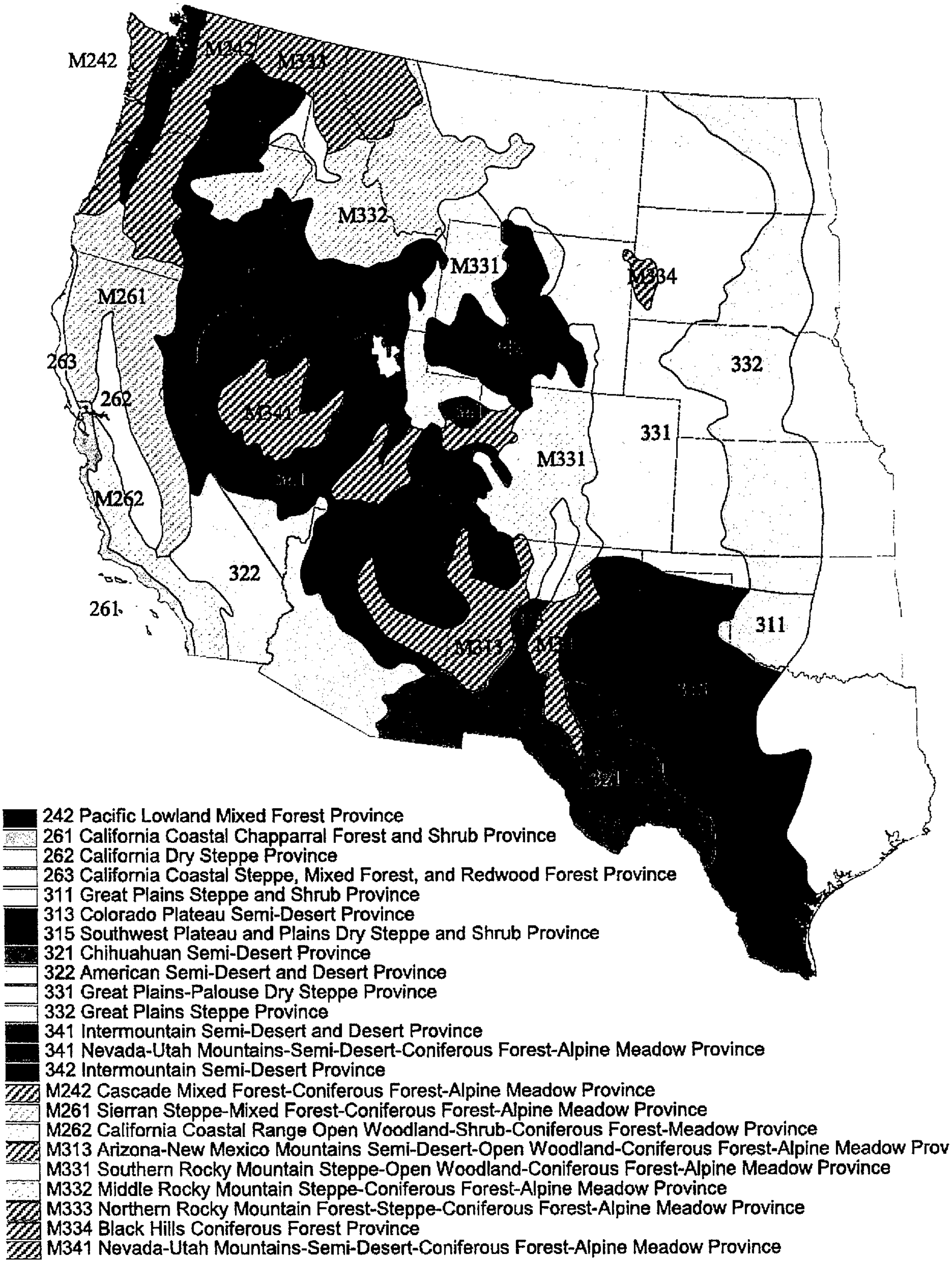
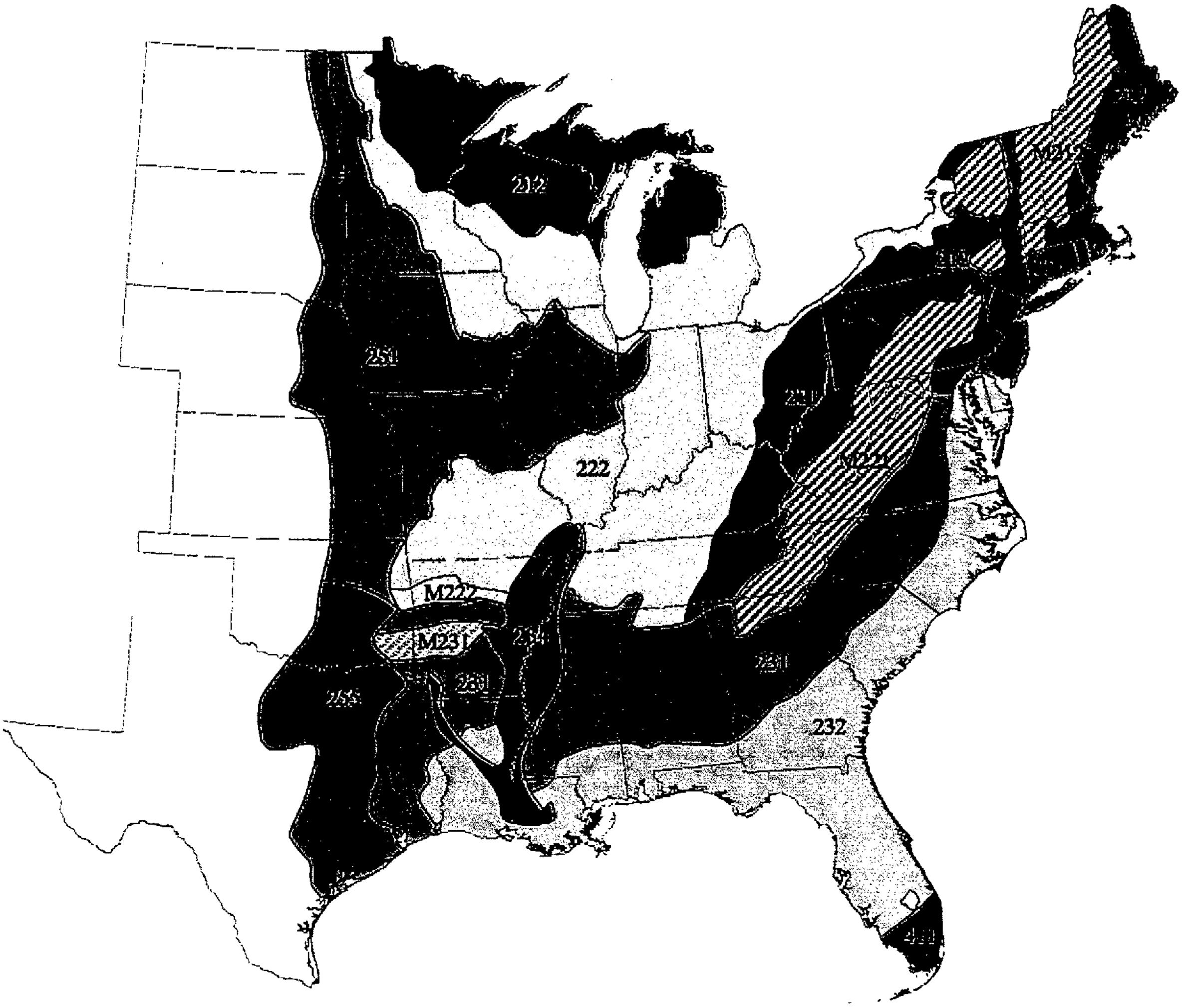


Figure 4-1. Ecoregion Provinces for the Coterminous United States (Bailey, 1995)



212 Laurentian Mixed Forest Province
221 Eastern Broadleaf Forest (Oceanic) Province
222 Eastern Broadleaf Forest (Continental) Province
231 Southeastern Mixed Forest Province
232 Outer Coastal Plain Mixed Forest Province
234 Lower Mississippi Riverine Forest Province
251 Prairie Parkland (Temperate) Province
255 Prairie Parkland (Subtropical) Province
411 Everglades Province
M212 Adirondack-New England Mixed Forest-Coniferous Forest-Alpine Meadow Province
M221 Central Appalachian Broadleaf Forest-Coniferous Forest-Meadow Province
M222 Ozark Broadleaf Forest - Meadow Province
M231 Ouachita Mixed Forest - Meadow Province

Figure 4-1. Continued

Soil organic content is an important factor during burning; inorganic soils are good insulators; organic soils, especially dry organic soils, can ignite and be consumed by some fires, causing severe vegetation and site impacts.

Fuel load is an important factor when burning; higher fuel loads and more flammable fuels result in hotter, more intense, and potentially more damaging fires. Fire fuel commonly refers to live and dead plant material, litter, etc., but in the case of *in situ* burning would also include the spilled oil.

Potential for wind and water erosion should be considered during and after prescribed burns.

Soil loss or erosion following fire is affected by ground slope, plant cover type, the amount and size of bare areas, and storm (rainfall) intensity. The steeper the ground slope, the greater potential for erosion, especially if vegetation and litter are removed by fire. Heavy rains following burning can result in substantial erosion in some settings.

Fire can increase water yield from burned areas, increasing run-off.

Fire can negatively impact water quality and aquatic organisms in adjacent water bodies by affecting turbidity, sedimentation, water levels, water temperature, dissolved oxygen, nutrients, etc.

Burning up steep slopes is similar to burning in windy conditions; fires spread rapidly and can become intense and difficult to control.

Fire Ecology, Effects, and Management Points from Whelan (1995)

Direct fire tolerance in plants revolves around three characteristics: protection of sensitive (meristematic) plant tissues in insulating bark; protection of sensitive plant tissues in belowground parts insulated by soil; and the bearing of sensitive plant tissues at a height above the zone of fire impact. These characteristics may occur individually or in combination for plants described as fire tolerant.

In many trees, bark thickness is a major determinant of fire tolerance. Similarly, seedling, saplings, and young trees are often less fire resistant than larger trees since bark thickness increases with tree size.

Grasses (and similar monocots, such as sedges) have meristems (primary growth tissue) occurring at the leaf base while dicots (such as most flowering trees and shrubs) have meristems exposed and elevated as the plant grows. Therefore grasses, especially those with clump and tussock growth forms, often have sensitive growth tissues protected from fire, in contrast to many other plants.

Some woody plants, especially shrubs, "sacrifice" sensitive aboveground tissues to fire, but still tolerate fire by sprouting from previously suppressed buds in underground stems and roots insulated by soil.

Soil is a good insulator; plant parts buried deeper than 5 cm rarely experience significantly elevated temperatures as a result of fire.

Seasonality is important to consider during burning; many plants are more or less susceptible to fire damage, and more or less likely to recover, during different seasons. Seasonal factors to consider include: wet vs. dry season fire, dormant vs. growing season fire, and natural fire season vs. out of season fire (for fire prone communities).

During the dormant season, carbohydrate reserves are stored in roots or rhizomes and are available for sprouting either immediately after fire or during the onset of the next growing season. During the growing season, these reserves have been directed towards shoot growth, and little is available to support regrowth following fire. Growing season burns may eliminate, reduce, or slow plant recovery.

The natural fire season is an important consideration for fire-prone communities. Plants in fire-prone communities may have critical life-history periods timed to the season of natural fire occurrence; out of season fires may interfere with this timing, resulting in lesser fire tolerance, or reduced or slowed recovery.

Fire type is important. Example 1—slow-moving low intensity fires may in some cases be more damaging to vegetation than hot fast-moving fires (e.g., a slow, cool burn that consumed organic soil down to the bedrock could be more damaging to forest vegetation than an intense crown fire). Example 2—back-fires, ignited on the downwind side of the area to be burned, may be more damaging to trees than head-fires, ignited on the upwind side of the area to be burned, because they subject tree trunks to elevated temperatures for longer time-periods.

Fire frequency and recent fire history is important. A fire that occurs after another fire or series of fires may be more damaging than typically expected if plant or community characteristics such as belowground reserves, seedbank development, soil moisture, etc. have not returned to certain levels. Note that natural fire frequencies can vary widely for different plant species and communities, some may be burned annually, while others may typically burn only once in 10, 25, 100, or 500 years. Some plant communities can be burned annually for, say, three consecutive years, but will fail to recover if burned for four consecutive years.

Similar to the concept above, other disturbances or stresses either before, concurrent with, or after burning can affect vegetation recovery. The most often mentioned factor is grazing (especially over-grazing) after burning, since herbivores may be attracted to burned sites by increased access or new growth. Other factors might include other physical site disturbances, draining, drought, flooding, pest or pathogen infestation, pesticide application, etc.

The physical structure of the plant community, such as vertical layering, can be an important factor when burning. Trees in forests with open understories of low grasses and shrubs may be minimally affected by surface fires. In contrast, forests with well developed mid-story vegetation layers or dense shrub layers can result in fires that spread upwards into the canopy and tree crowns, damaging or killing large numbers of mature trees.

Exotic and/or nuisance species must be considered in some locations so that burning does not enhance their establishment or spread, especially since many of these species establish on disturbed sites, and some may be fire "adapted". As an example, Australian Melaleuca in southern Florida both establishes on disturbed sites and is proliferated by fire. Another example is Saltcedar, which may invade or dominate riparian areas in the southwestern United States following fire disturbance.

Table 4-1. Major plant species by ecoregion (McNab and Avers, 1994; Bailey, 1995), cross-referenced by community type. Ecoregion identification numbers prefixed by an "M" refer to mountain provinces, with different zones of vegetation occurring at different elevation levels.

Scientific Name	Common Name	Community Types
EcoRegion #212		
Abies balsamea	Balsam fir	Northern hardwood-spruce forest, northeastern spruce-fir forest, Great Lakes pine forest, Great Lakes spruce-fir forest
Acer saccharum	Sugar maple	Northern hardwood forest, northern hardwood-spruce forest, northeastern spruce-fir forest, Great Lakes pine forest, Great Lakes spruce-fir forest
Betula alleghaniensis	Yellow birch	Northern hardwood forest, northern hardwood-spruce forest, northeastern spruce-fir forest, Great Lakes spruce-fir forest
Fagus grandifolia	American beech	Northern hardwood forest, northern hardwood-spruce forest, northeastern spruce-fir forest, Great Lakes pine forest
Picea rubens	Red spruce	Northern hardwood-spruce forest, northeastern spruce-fir forest
Pinus strobus	Eastern white pine	Northern hardwood forest, northern hardwood-spruce forest, northeastern spruce-fir forest, Great Lakes pine forest, Great Lakes spruce-fir forest
Tsuga canadensis	Eastern hemlock	Northern hardwood forest, northern hardwoods-spruce forest, northeastern spruce-fir forest, Great Lakes pine forest, Great Lakes spruce-fir forest
Ecoregion #M212		
Abies balsamea	Balsam fir	Northern hardwood-spruce forest, northeastern spruce-fir forest
Acer saccharum	Sugar maple	Northern hardwood, northern hardwood-spruce, northeastern spruce-fir forest
Betula alleghaniensis	Yellow birch	Northern hardwood forest, northern hardwood-spruce forest, northeastern spruce-fir forest
Fagus grandifolia	American beech	Northern hardwood forest, northern hardwood-spruce forest, northeastern spruce-fir forest
Picea rubens	Red spruce	Northern hardwood-spruce forest, northeastern spruce-fir forest
Tsuga canadensis	Eastern hemlock	Northern hardwood forest, northern hardwoods-spruce forest, northeastern spruce-fir forest
Ecoregion #221		
Acer saccharum	Sugar maple	Mixed mesophytic forest
Aesculus sp.	Sweet buckeye	Mixed mesophytic forest
Chamaecyparis thyoides	Atlantic white-cedar	Pine-oak forest (mesic sites)

Table 4-1. Continued.

Scientific Name	Common Name	Community Types
Ecoregion #221 (continued)		
Fagus grandifolia	American beech	Mixed mesophytic forest
Liriodendron tulipifera	Tuliptree (yellow-poplar)	Mixed mesophytic forest
Pinus echinata	Shortleaf pine	Appalachian oak forest
Pinus rigida	Pitch pine	Pine-oak forest (pine barrens)
Quercus alba	White oak	Mixed mesophytic forest, Appalachian oak forest
Quercus coccinea	Scarlet oak	Appalachian oak forest
Quercus ilicifolia	Bear oak	Pine-oak forest (pine barrens)
Quercus marilandica	Blackjack oak	Pine-oak forest (pine barrens)
Quercus rubra	Northern red oak	Mixed mesophytic forest, Appalachian oak forest
Quercus stellata	Post oak	Appalachian oak forest
Quercus velutina	Black oak	Appalachian oak forest
Sassafras albidum	Sassafras	Pine-oak forest (pine barrens)
Tilia americana	American basswood	Mixed mesophytic forest
Tsuga canadensis	Eastern hemlock	Mixed mesophytic forest
Vaccinium pallidum	Blue Ridge (hillside) blueberry	Pine-oak forest (pine barrens)
Ecoregion #M221		
Acer rubrum	Red maple	Oak-hickory-pine forest
Abies fraseri	Fraser's fir	Southeastern spruce-fir forest
Acer saccharum	Sugar maple	Northern hardwood forest
Betula alleghaniensis	Yellow birch	Northern hardwood forest
Carya alba (tomentosa)	Mockernut hickory	Oak-hickory-pine forest
Carya glabra	Pignut hickory	Oak-hickory-pine forest
Fagus grandifolia	American beech	Northern hardwood forest
Liriodendron tulipifera	Tuliptree (yellow-poplar)	Mixed mesophytic forest
Picea rubens	Red spruce	Northeastern spruce-fir forest, southeastern spruce-fir forest
Pinus echinata	Shortleaf pine	Oak-hickory-pine forest
Pinus strobus	Eastern white pine	Northern hardwood forest
Quercus alba	White oak	Mixed mesophytic forest, Appalachian oak forest, oak-hickory-pine forest
Quercus coccinea	Scarlet oak	Appalachian oak forest
Quercus marilandica	Blackjack oak	Oak-hickory-pine forest

Table 4-1. Continued.

Scientific Name	Common Name	Community Types
Ecoregion #M221 (continued)		
Quercus rubra	Northern red oak	Mixed mesophytic forest, Appalachian oak forest
Quercus stellata	Post oak	Oak-hickory-pine forest
Quercus velutina	Black oak	Appalachian oak forest
Tilia americana	American basswood	Mixed mesophytic forest, northern hardwood forest
Tsuga canadensis	Eastern hemlock	Northern hardwood forest
Vaccinium pallidum	Blue Ridge (hillside) blueberry	Appalachian oak forest, oak-hickory-pine forest
Ecoregion #222		
Acer saccharum	Sugar maple	Beech-maple forest, maple-basswood forest
Andropogon gerardii	Big bluestem	Bluestem (tallgrass) prairie
Carya alba (tomentosa)	Mockernut hickory	Oak-hickory forest
Carya cordiformis	Bitternut hickory	Oak-hickory forest
Carya glabra	Pignut hickory	Oak-hickory forest
Carya ovata	Shagbark hickory	Oak-hickory forest
Cornus florida	Flowering dogwood	Oak-hickory forest
Fagus grandifolia	American beech	Beech-maple forest
Fraxinus pennsylvanica	Green ash	Northern floodplain forest
Juniperus virginiana	Eastern redcedar	Cedar glades, oak-hickory forest
Liriodendron tulipifera	Tuliptree (yellow-poplar)	Oak-hickory forest
Liquidambar styraciflua	Sweetgum	Oak-hickory forest
Ostrya virginiana	Eastern hophornbeam	Oak-hickory forest
Panicum virgatum	Switchgrass	Bluestem (tallgrass) prairie
Pinus echinata	Shortleaf pine	Oak-hickory forest
Platanus occidentalis	American sycamore	Northern floodplain forest
Populus deltoides	Eastern cottonwood	Northern floodplain forest
Quercus alba	White oak	Oak-hickory forest
Quercus coccinea	Scarlet oak	Oak-hickory forest
Quercus marilandica	Blackjack oak	Oak-hickory forest
Quercus rubra	Northern red oak	Oak-hickory forest
Quercus stellata	Post oak	Oak-hickory forest
Quercus velutina	Black oak	Oak-hickory forest
Sassafras albidum	Sassafras	Oak-hickory forest

Table 4-1. Continued.

Scientific Name	Common Name	Community Types
Ecoregion #222 (continued)		
Salix nigra	Black willow	Northern floodplain forest
Schizachyrium scoparium	Little bluestem	Bluestem (tallgrass) prairie, cedar glades
Sorghastrum nutans	Indiangrass	Bluestem (tallgrass) prairie
Spartina pectinata	Prairie cordgrass	Bluestem (tallgrass) prairie
Sporobolus heterolepis	Prairie dropseed	Bluestem (tallgrass) prairie
Tilia americana	American basswood	Maple-basswood forest
Ulmus americana	American elm	Oak-hickory forest, northern floodplain forest
Ecoregion #M222		
Carya glabra	Pignut hickory	Oak-hickory forest, oak-hickory-pine forest
Carya alba (tomentosa)	Mockernut hickory	Oak-hickory forest, oak-hickory-pine forest
Juniperus virginiana	Eastern redcedar	Oak-hickory forest
Pinus echinata	Shortleaf pine	Oak-hickory-pine forest
Quercus alba	White oak	Oak-hickory forest
Quercus coccinea	Scarlet oak	Oak-hickory-pine forest
Quercus marilandica	Blackjack oak	Oak-hickory-pine forest
Quercus rubra	Northern red oak	Oak-hickory forest
Quercus stellata	Post oak	Oak-hickory-pine forest
Quercus velutina	Black oak	Oak-hickory forest
Ecoregion #231		
Acer rubrum	Red maple	Oak-hickory-pine forest, southern mixed forest
Andropogon gerardii	Big bluestem	Bluestem-sacahuista prairie
Callicarpa americana	American beautyberry	Oak-hickory-pine forest, southern mixed forest
Carya alba (tomentosa)	Mockernut hickory	Oak-hickory-pine forest, southern mixed forest
Carya glabra	Pignut hickory	Oak-hickory-pine forest, southern mixed forest
Cornus florida	Flowering dogwood	Oak-hickory-pine forest, southern mixed forest
Ilex vomitoria	Yaupon	Oak-hickory-pine forest, southern mixed forest
Liquidambar styraciflua	Sweetgum	Oak-hickory-pine forest, southern mixed forest
Nyssa sylvatica	Black gum (tupelo)	Oak-hickory-pine forest, southern mixed forest
Panicum virgatum	Switchgrass	Bluestem-sacahuista prairie
Pinus echinata	Shortleaf pine	Oak-hickory-pine forest, southern mixed forest
Pinus taeda	Loblolly pine	Oak-hickory-pine forest, southern mixed forest

Table 4-1. Continued.

Scientific Name	Common Name	Community Types
Ecoregion #231 (continued)		
Quercus alba	White oak	Oak-hickory-pine forest, southern mixed forest
Quercus marilandica	Blackjack oak	Oak-hickory-pine forest, southern mixed forest
Quercus falcata	Southern red oak	Oak-hickory-pine forest, southern mixed forest
Quercus nigra	Water oak	Oak-hickory-pine forest, southern mixed forest
Quercus stellata	Post oak	Oak-hickory-pine forest, southern mixed forest
Ulmus alata	Winged elm	Oak-hickory-pine forest, southern mixed forest
Schizachyrium scoparium	Little bluestem	Bluestem-sacahuista prairie
Sorghastrum nutans	Indiangrass	Bluestem-sacahuista prairie
Vaccinium pallidum	Blue Ridge (hillside) blueberry	Oak-hickory-pine forest, southern mixed forest
Viburnum acerifolium	Mapleleaf viburnum	Oak-hickory-pine forest, southern mixed forest
Ecoregion #M231		
Carya alba (tomentosa)	Mockernut hickory	Oak-hickory-pine forest
Carya glabra	Pignut hickory	Oak-hickory-pine forest
Pinus echinata	Shortleaf pine	Oak-hickory-pine forest
Pinus taeda	Loblolly pine	Oak-hickory-pine forest
Quercus alba	White oak	Oak-hickory-pine forest
Quercus falcata	Southern red oak	Oak-hickory-pine forest
Quercus velutina	Black oak	Oak-hickory-pine forest
Ecoregion #232		
Acer rubrum	Red maple	Southern mixed forest, southern floodplain forest
Andropogon gerardii	Big bluestem	Bluestem-sacahuista prairie
Celtis laevigata	Sugarberry	Southern floodplain forest
Chamaecyparis thyoides	Atlantic white-cedar	Southern floodplain forest, pocosin
Cyrilla racemiflora	Cyrilla (titi)	Pocosin
Fraxinus pennsylvanica	Green ash	Southern floodplain forest
Ilex glabra	Bitter gallberry	Pocosin
Liquidambar styraciflua	Sweetgum	Southern mixed forest, southern floodplain forest
Magnolia grandiflora	Southern magnolia	Southern mixed forest
Magnolia virginiana	Sweetbay	Southern floodplain forest, pocosin
Myrica cerifera	Wax myrtle (southern bayberry)	Pocosin

Table 4-1. Continued.

Scientific Name	Common Name	Community Types
Ecoregion #232 (continued)		
Nyssa aquatica	Water tupelo	Southern floodplain forest
Nyssa biflora	Swamp tupelo	Southern floodplain forest
Nyssa sylvatica	Black gum (tupelo)	Southern floodplain forest
Panicum virgatum	Switchgrass	Bluestem-sacahuista prairie
Persea borbonia	Red bay	Southern floodplain forest, pocosin
Pinus elliottii	Slash pine	Southern mixed forest
Pinus palustris	Longleaf pine	Southern mixed forest
Pinus serotina	Pond pine	Pocosin
Pinus taeda	Loblolly pine	Southern mixed forest
Platanus occidentalis	American sycamore	Southern floodplain forest
Populus deltoides	Eastern cottonwood	Southern floodplain forest
Quercus laurifolia	Laurel oak	Southern floodplain forest
Quercus nigra	Water oak	Southern mixed forest, southern floodplain forest
Quercus texana	Nuttall oak	Southern floodplain forest
Quercus virginiana	Live oak	Southern mixed forest
Sabal palmetto	Cabbage palm	Southern mixed forest
Schizachyrium scoparium	Little bluestem	Bluestem-sacahuista prairie
Serenoa repens	Saw palmetto	Southern mixed forest
Sorghastrum nutans	Indiangrass	Bluestem-sacahuista prairie
Taxodium ascendens	Pondcypress	Southern floodplain forest
Taxodium distichum	Baldcypress	Southern floodplain forest
Ulmus americana	American elm	Southern floodplain forest
Ecoregion #234		
Acer rubrum	Red maple	Southern floodplain forest
Carya illinoensis	Pecan	Southern floodplain forest
Celtis laevigata	Sugarberry	Southern floodplain forest
Fraxinus pennsylvanica	Green ash	Southern floodplain forest
Liquidambar styraciflua	Sweetgum	Southern floodplain forest
Nyssa aquatica	Water tupelo	Southern floodplain forest
Nyssa biflora	Swamp tupelo	Southern floodplain forest
Platanus occidentalis	American sycamore	Southern floodplain forest

Table 4-1. Continued.

Scientific Name	Common Name	Community Types
Ecoregion #234 (continued)		
Populus deltoides	Eastern cottonwood	Southern floodplain forest
Quercus laurifolia	Laurel oak	Southern floodplain forest
Quercus nigra	Water oak	Southern floodplain forest
Quercus pagoda	Cherrybark oak	Southern floodplain forest
Quercus texana	Nuttall oak	Southern floodplain forest
Ulmus americana	American elm	Southern floodplain forest
Taxodium distichum	Baldcypress	Southern floodplain forest
Ecoregion #242		
Acer macrophyllum	Bigleaf maple	Cedar-Hemlock-Douglas-Fir Forests, Oregon Oakwoods, Alder-Ash Forests
Agrostis exarata	Spike bentgrass	Cedar-Hemlock-Douglas Fir Forests, Oregon Oakwoods, Foothills Prairie
Alnus rhombifolia	White alder	Oregon Oakwoods, Alder-Ash Forests
Alnus viridis ssp. sinuata	Sitka alder	Cedar-Hemlock-Douglas Fir Forests
Arbutus menziesii	Pacific madrone	Cedar-Hemlock-Douglas Fir Forest, Oregon Oakwoods
Dactylis glomerata	Orchard grass	Introduced species, Willamette Valley Grasslands (foothills prairie)
Danthonia intermedia	Timber oatgrass	Foothills Prairie
Danthonia spicata var. pinetorum	Poverty oatgrass	Alder-Ash Forests
Danthonia unispicata	Onespike oatgrass	Foothills Prairie
Deschampsia cespitosa	Tufted hairgrass	Cedar-Hemlock-Douglas Fir Forest, Oregon Oakwoods, Alder-Ash Forest, Foothills Prairie
Festuca idahoensis	Idaho fescue	Foothills Prairie
Koeleria macrantha	Prairie junegrass	Foothills Prairie
Populus trichocarpa	Black cottonwood	Cedar-Hemlock-Douglas Fir Forests, Alder-Ash Forests
Pseudotsuga menziesii var. menziesii	Coastal Douglas fir	Cedar-Hemlock-Douglas Fir Forests, Oregon Oakwoods, Alder-Ash Forests
Quercus garryana	Oregon white oak	Cedar-Hemlock-Douglas Fir Forests, Oregon Oakwoods
Salix lasiandra	Pacific willow	Alder-Ash Forests
Stipa columbiana	Columbia needle grass	Foothills Prairie

Table 4-1. Continued.

Scientific Name	Common Name	Community Types
Ecoregion #242 (continued)		
Stipa comata	Needle and thread grass	Foothills Prairie
Stipa thurberiana	Thurber needle grass	Foothills Prairie
Thuja plicata	Western red cedar	Cedar-Hemlock-Douglas Fir Forests
Tsuga heretophylla	Western hemlock	Cedar-Hemlock-Douglas Fir Forests
Ecoregion #M242		
Abies amabilis	Pacific silver fir	Cedar-Hemlock-Douglas Fir Forest, Silver Fir-Douglas Fir Forest, Fir-Hemlock Forest, Western Spruce-Fir Forest, Spruce-Cedar-Hemlock Forest
Abies concolor	White fir	Lodgepole Pine-Subalpine Forest
Abies grandis	Grand fir	Cedar-Hemlock-Douglas Fir Forest, Silver Fir-Douglas Fir Forest, Western Spruce-Fir Forest, Spruce-Cedar-Hemlock Forest
Abies lasiocarpa	Subalpine fir	Fir-Hemlock Forest, Alpine Meadows and Barren
Alnus rubra	Red alder	Cedar-Hemlock-Douglas Fir Forest, Silver Fir-Douglas Fir Forest, Spruce-Cedar-Hemlock Forest
Chamaecyparis nootkatensis	Alaska cedar	Cedar-Hemlock-Douglas Fir Forest, Silver Fir-Douglas Fir Forest, Fir-Hemlock Forest, Western Spruce-Fir Forest, Spruce-Cedar-Hemlock Forest
Picea engelmannii	Engelmann spruce	Fir-Hemlock Forest, Alpine Meadows and Barren, Western Spruce-Fir Forest
Picea sitchensis	Sitka spruce	Cedar-Hemlock-Douglas Fir Forest, Spruce-Cedar-Hemlock Forest
Pinus albicaulis	Whitebark pine	Fir-Hemlock Forest, Western Spruce-Fir Forest, Lodgepole Pine-Subalpine Forest
Pinus contorta var. contorta	Shore pine	Silver Fir-Douglas Fir Forest, Fir-Hemlock Forest, Lodgepole Pine-Subalpine Forest, Spruce-Cedar-Hemlock Forest
Pinus contorta var. murrayana	Sierra lodgepole pine	Cedar-Hemlock-Douglas Fir Forest, Fir-Hemlock Forest, Western Spruce-Fir Forest, Lodgepole Pine-Subalpine Forest, Spruce-Cedar-Hemlock Forest
Pinus ponderosa var. ponderosa	Pacific Ponderosa pine	Cedar-Hemlock-Douglas Fir Forest

Table 4-1. Continued.

Scientific Name	Common Name	Community Types
Ecoregion #M242 (continued)		
Populus tremuloides	Quaking aspen	Silver Fir-Douglas Fir Forest, Western Spruce-Fir Forest, Lodgepole Pine- Subalpine Forest
Populus trichocarpa	Black cottonwood	Cedar-Hemlock-Douglas Fir Forest, Silver Fir-Douglas Fir Forest, Fir-Hemlock Forest, Western Spruce-Fir Forest, Lodgepole Pine-Subalpine Forest, Spruce-Cedar-Hemlock Forest
Pseudotsuga menziesii var. menziesii	Coastal Douglas fir	Cedar-Hemlock-Douglas Fir Forest, Silver Fir- Douglas Fir Forest, Fir-Hemlock Forest, Spruce-Cedar-Hemlock Forest
Sequoia sempervirens	Redwood	Cedar-Hemlock-Douglass Fir Forest
Thuja plicata	Western red cedar	Cedar-Hemlock-Douglas Fir Forest, Silver Fir-Douglas Fir Forest, Fir-Hemlock Forest, Western Spruce-Fir Forest, Spruce-Cedar-Hemlock Forest
Tsuga heretophylla	Western hemlock	Cedar-Hemlock-Douglas Fir Forest, Silver Fir-Douglas Fir Forest, Fir-Hemlock Forest, Western Spruce-Fir Forest, Lodgepole Pine-Subalpine Forest, Spruce-Cedar-Hemlock Forest
Tsuga mertensiana	Mountain hemlock	Cedar-Hemlock-Douglas Fir Forest, Silver Fir-Douglas Fir Forest, Fir-Hemlock Forest, Lodgepole Pine-Subalpine Forest, Spruce-Cedar-Hemlock Forest
Ecoregion #251		
Andropogon gerardii	Big bluestem	Bluestem (tallgrass) prairie
Carya ovata	Shagbark hickory	Oak-hickory forest
Fraxinus pennsylvanica	Green ash	Northern floodplain forest
Panicum virgatum	Switchgrass	Bluestem (tallgrass) prairie
Populus deltoides	Eastern cottonwood	Northern floodplain forest
Quercus alba	White oak	Oak-hickory forest
Quercus velutina	Black oak	Oak-hickory forest
Salix nigra	Black willow	Northern floodplain forest
Schizachyrium scoparium	Little bluestem	Bluestem (tallgrass) prairie
Sorghastrum nutans	Indiangrass	Bluestem (tallgrass) prairie
Spartina pectinata	Prairie cordgrass	Bluestem (tallgrass) prairie

Table 4-1. Continued.

Scientific Name	Common Name	Community Types
Ecoregion #251 (continued)		
Sporobolus heterolepis	Prairie dropseed	Bluestem (tallgrass) prairie
Ulmus americana	American elm	Northern floodplain forest
Ecoregion #255		
Andropogon gerardii	Big bluestem	Cross timbers, bluestem-sacahuista prairie, blackland prairie
Carya alba (tomentosa)	Mockernut hickory	Oak-hickory forest, cross timbers
Carya glabra	Pignut hickory	Oak-hickory forest, cross timbers
Carya illinoensis	Pecan	Southern floodplain forest
Panicum virgatum	Switchgrass	Cross timbers, bluestem-sacahuista prairie, blackland prairie
Populus deltoides	Eastern cottonwood	Southern floodplain forest
Quercus marilandica	Blackjack oak	Oak-hickory forest, cross timbers
Quercus stellata	Post oak	Oak-hickory forest, cross timbers
Schizachyrium scoparium	Little bluestem	Cross timbers, bluestem-sacahuista prairie, blackland prairie
Sorghastrum nutans	Indiangrass	Cross timbers, bluestem-sacahuista prairie, blackland prairie
Ulmus americana	American elm	Southern floodplain forest
Ecoregion #261		
Adenostoma fasciculatum	Chamise	Chaparral, Coastal Sagebrush
Arctostaphylos glandulosa	Eastwood manzanita	Redwood Forests, Chaparral
Arctostaphylos viscida	Whiteleaf manzanita	Redwood Forests, Chaparral
Artemisia californica	California sagebrush	Chaparral, Coastal Sagebrush
Cupressus macrocarpa	Monterey cypress	Chaparral
Lithocarpus densiflora	Tanoak	Redwood Forest, Chaparral
Pinus muricata	Bishop pine	California Mixed Evergreen Forest, Chaparral
Pinus radiata	Monterey pine	California Oakwoods
Pinus torreyana	Torrey pine	Chaparral
Quercus chrysolepis	Canyon live oak	Montane Chaparral
Quercus garryana	Oregon white oak	Redwood Forest, Chaparral
Quercus virginiana	Live oak	Southern Oak Forest

Table 4-1. Continued.

Scientific Name	Common Name	Community Types
Ecoregion #261 (continued)		
Quercus wislizenii	Interior live oak	Redwood Forest, Chaparral, Coastal Sagebrush
Sequoia sempervirens	Redwood	Redwood Forest
Ecoregion #M261		
Abies concolor	White fir	California Mixed Evergreen Forest
Abies magnifica	California red fir	California Mixed Evergreen Forest
Alnus rhombifolia	White alder	Oregon Oakwoods, California Mixed Evergreen Forest, Chaparral, Sagebrush Steppe
Artemisia arbuscula ssp. arbuscula	Gray low sagebrush	Sagebrush Steppe
Artemisia tridentata ssp. tridentata	Basin big sagebrush	Sagebrush Steppe
Calocedrus decurrens	Incense cedar	Mixed Conifer Forest
Lithocarpus densiflora	Tanoak	California Mixed Evergreen Forest, Oregon Oakwoods, Chaparral
Pinus contorta var. murrayana	Sierra lodgepole pine	Mixed Conifer Forest
Pinus jeffreyi	Jeffrey pine	Mixed Conifer Forest, Subalpine Forest
Pinus lambertiana	Sugar pine	Montane Chaparral
Pinus monticola	Western white pine	Mixed Conifer Forest
Pinus ponderosa var. ponderosa	Pacific Ponderosa pine	Montane Chaparral
Populus tremuloides	Quaking aspen	California Mixed Evergreen Forest, Sagebrush Steppe
Pseudotsuga menziesii var. menziesii	Coastal Douglas fir	Oregon Oakwoods,California Mixed Evergreen Forest
Quercua vaccinifolia	Huckleberry oak	California Mixed Evergreen Forest
Quercus agrifolia	Coast live oak	California Mixed Evergreen Forest, Chaparral, Coastal Sagebrush, California Steppe
Quercus chrysolepis	Canyon live oak	California Mixed Evergreen Forest, Montane Chaparral
Quercus douglasii	Blue oak	Chaparral
Quercus garryana	Oregon white oak	Oregon Oakwoods, California Mixed Evergreen Forest, Chaparral

Table 4-1. Continued.

Scientific Name	Common Name	Community Types
Ecoregion #M261 (continued)		
Quercus wislizenii	Interior live oak	California Mixed Evergreen Forest, Chaparral, Montane Chaparral
Sequoiadendron giganteum	Giant sequoia	Mixed Conifer Forest
Ecoregion #262		
Avena barbata	Slender wild oat	Introduced annual grass, California Prairie, Valley Oak Savanna
Avena fatua	California wild oat	Introduced annual grass, California Prairie, Valley Oak Savanna
Atriplex joaquiniana	Saltbush	San Joaquin Saltbush
Bromus hordeaceus	Soft chess	Introduced annual grass, California Prairie, Valley Oak Savanna
Populus fremontii	Fremont cottonwood	Riparian forest
Quercus lobata	Valley oak	California Prairie, Valley Oak Savanna, Riparian Forest
Scirpus americanus	Olney threesquare (American bulrush)	Tule Marsh
Scirpus californicus	Bulrush	Tule Marsh
Stipa (Nassella) pulchra	Purple needlegrass	California Prairie, Valley Oak Savanna
Typha spp.	Cattail	Tule Marsh
Ecoregion #M262		
Adenostoma fasciculatum	Chamise	Chaparral, Juniper-Pinyon Pine, Coastal Sagebrush
Arbutus menziesii	Pacific madrone	Chaparral, Montane Chaparral
Cercocarpus betuloides	Birchleaf mountain mahogany	Chaparral, Juniper-Pinyon Pine, Mountain Chaparral, Coastal Sagebrush
Juniperus occidentalis	Western juniper	Juniper-Pinyon Pine
Lithocarpus densiflora	Tanoak	Chaparral
Pinus jeffreyi	Jeffrey pine	Mixed Conifer Forest
Pinus quadrifolia	Parry pinyon	Chaparral, Juniper-Pinyon Pine
Pinus sabiniana	Gray pine	Chaparral, Juniper-Pinyon Pine, Coastal Sagebrush, Montane Chaparral
Pseudotsuga macrocarpa	Big Cone Douglas fir	Chaparral, Coastal Sagebrush, Montane Chaparral

Table 4-1. Continued.

Scientific Name	Common Name	Community Types
Ecoregion #M262 (continued)		
Quercus agrifolia	Coast live oak	Chaparral, Coastal Sagebrush
Quercus chrysolepis	Canyon live oak	Mixed Conifer Forest, Juniper-Pinyon Woodland, Montane Chaparral
Quercus douglasii	Blue oak	Chaparral, Juniper-Pinyon Pine, Coastal Sagebrush
Quercus wislizenii	Interior live oak	Chaparral, Coastal Sagebrush
Umbellularia californica	California bay	Chaparral, Montane Chaparral
Ecoregion #263		
Arbutus menziesii	Pacific madrone	Redwood Forest, California Mixed Evergreen Forest
Gaultheria shallon	Salal	Redwood Forest, California Mixed Evergreen Forest
Lithocarpus densiflora	Tanoak	Redwood Forest, California Mixed Evergreen Forest
Polystichum munitum	Western sword fern	Redwood Forest, California Mixed Evergreen Forest
Pseudotsuga menziesii var. menziesii	Coastal Douglas fir	Redwood Forest, California Mixed Evergreen Forest
Quercus agrifolia	Coast live oak	Redwood Forest, California Mixed Evergreen Forest
Rhododendron macrophyllum	Pacific rhododendron	Redwood Forest, California Mixed Evergreen Forest
Sequoia sempervirens	Redwood	Redwood Forest, California Mixed Evergreen Forest
Tsuga heterophylla	Western hemlock	Redwood Forest
Ecoregion #311		
Andropogon gerardii var. paucipilus	Sand bluestem	Sandsage-Bluestem Prairie, Shinnery, Oak Savanna
Artemisia filifolia	Sand sagebrush	Sandsage-Bluestem Prairie
Quercus havardii	Sand shinnery oak	Shinnery, Sandsage-Bluestem Prairie
Quercus marilandica	Blackjack oak	Cross Timbers, Oak Savanna
Quercus stellata	Post oak	Cross Timbers, Oak Savanna

Table 4-1. Continued.

Scientific Name	Common Name	Community Types
Ecoregion #311 (continued)		
Quercus virginiana	Live oak	Shinnery, Oak Savanna
Schizachyrium scoparium	Little bluestem	Bluestem-Grama Prairie, Sandsage-Bluestem Prairie, Oak Savanna, Shinnery, Cross Timbers
Ecoregion #313		
Arctostaphylos pungens	Pointleaf manzanita	Chaparral
Artemisia tridentata ssp. tridentata	Basin big sagebrush	Great Basin Sagebrush, Blackbrush
Atriplex canescens	Four-wing saltbrush	Pinyon-Juniper Woodland, Great Basin Sagebrush, Blackbrush, Grama and Galleta Steppe, Foothills Prairie
Cercocarpus montanus	True mountain mahogany	Pinyon-Juniper Woodland, Great Basin Sagebrush
Coleogyne ramosissima	Blackbrush	Pinyon-Juniper Woodland, Great Basin Sagebrush, Blackbrush
Hilaria jamesii	Galleta	Pinyon-Juniper Woodland, Great Basin Sagebrush, Blackbrush, Foothills Prairie
Juniperus deppeana	Alligator juniper	Pinyon-Juniper Woodland
Pinus cembroides	Mexican pinyon	Pinyon-Juniper Woodland
Pinus contorta var. latifolia	Rocky Mountain lodgepole pine	Foothills Prairie
Pinus ponderosa var. scopulorum	Interior Ponderosa pine	Pinyon-Juniper Woodland, Great Basin Sagebrush, Grama and Galleta Steppe
Populus deltoides	Eastern cottonwood	Pinyon-Juniper Woodland, Great Basin Sagebrush
Populus tremuloides	Quaking aspen	Pinyon-Juniper Woodland, Great Basin Sagebrush
Quercus turbinella	Turbinella oak (Shrub live oak)	Pinyon-Juniper Woodland, Blackbrush
Sarcobatus vermiculatus	Black greasewood	Pinyon-Juniper Woodland, Great Basin Sagebrush, Blackbrush, Foothills Prairie
Yucca schidigera	Mojave yucca	Chaparral

Table 4-1. Continued.

Scientific Name	Common Name	Community Types
Ecoregion #M313		
Pinus engelmannii	Apache pine	Pinyon-Juniper Woodland, Oak-Juniper Woodland
Pinus flexilis	Limber pine	Pinyon-Juniper Woodland
Pinus leiophylla var. chihuahuana	Chihuahuan pine	Pinyon-Juniper Woodland, Oak-Juniper Woodland
Pinus ponderosa var. scopulorum	Interior Ponderosa pine	Pinyon-Juniper Woodland
Populus tremuloides	Quaking aspen	Pinyon-Juniper Woodland
Quercus gambelii	Gambel oak	Pinyon-Juniper Woodland
Quercus grisea	Gray oak	Pinyon-Juniper Woodland, Oak-Juniper Woodland
Ecoregion #315		
Andropogon gerardii var. gerardii	Big bluestem	Pinyon-Juniper Woodland, Grama-Buffalograss, Juniper-Oak Savanna
Andropogon gerardii var. paucipilus	Sand bluestem	Pinyon-Juniper Woodland, Grama and Galleta Steppe, Grama-Buffalograss, Shinnery
Artemisia spp.	Sagebrush	Juniper-Pinyon Woodland, Grama-Buffalograss
Bouteloua gracilis	Blue grama	Pinyon-Juniper Woodland, Grama-Buffalograss, Shinnery
Buchloe dactyloides	Buffalograss	Pinyon-Juniper Woodland, Grama and Galleta Steppe, Mesquite-Acacia Savanna, Grama-Buffalograss, Mesquite-Buffalograss
Hilaria jamesii	Galleta	Pinyon-Juniper Woodland, Grama-Buffalograss
Juniperus ashei	Ashe juniper	Juniper-Oak Savanna
Juniperus occidentalis	Western juniper	Juniper-Pinyon Woodland
Panicum virgatum	Switchgrass	Pinyon-Juniper Woodland, Grama-Buffalograss, Juniper-Oak Savanna, Bluestem-Sacahuista Prairie
Pinus edulis	True pinyon pine	Juniper-Pinyon Woodland
Populus deltoides	Eastern cottonwood	Pinyon-Juniper Woodland, Grama-Buffalograss
Prosopis glandulosa var. glandulosa	Honey mesquite	Mesquite-Acacia Savanna, Grama-Buffalograss, Shinnery, Mesquite-Buffalograss, Juniper-Oak Savanna

Table 4-1. Continued.

Scientific Name	Common Name	Community Types
Ecoregion #315 (continued)		
Quercus marilandica	Blackjack oak	Juniper-Oak Savanna
Quercus virginiana	Live oak	Mesquite-Acacia Savanna, Shinnery, Mesquite-Buffalograss
Schizachyrium scoparium	Little bluestem	Pinyon-Juniper Woodland, Grama and Galleta Steppe, Grama-Buffalograss, Shinnery, Juniper-Oak Savanna, Mesquite-Acacia Savanna, Bluestem-Sacahuista Prairie
Sorghastrum nutans	Indiangrass	Grama-Buffalograss, Juniper-Oak Savanna
Yucca baccata	Banana yucca	Pinyon-Juniper Woodland, Grama-Buffalograss
Ecoregion #321		
Agave lechuguilla	Lechuguilla	Trans-Pecos Shrub Savanna, Oak-Juniper Woodland, Creosotebush, Juniper-Pinyon Woodland
Bouteloua eriopoda	Black grama	Grama-Tobosa Grassland, Grama-tobosa Shrubsteppe, Creosote-Tarbush
Bouteloua gracilis	Blue grama	Grama-Tobosa Grassland, Grama-Tobosa Shrubsteppe
Bouteloua hirsuta	Hairy grama	Grama-Tobosa Grassland
Flourensia cernua	Tarbush	Trans-Pecos Shrub Savanna, Creosotebush-Tarbush
Fouquieria splendens	Ocotillo	Oak-Juniper Woodland, Creosotebush, Trans-Pecos Shrub Savanna
Hilaria mutica	Tobosagrass	Grama-Tobosa Grassland, Grama-Tobosa Shrubsteppe, Trans-Pecos Shrub Savanna, Creosote-Tarbush
Larrea tridentata	Creosotebush	Creosotebush, Trans-Pecos Shrub Savanna
Opuntia humifusa	Prickly pear cactus	Trans-Pecos Shrub Savanna, Oak Savanna, Juniper-Pinyon Woodland, Creosotebush
Populus fremontii ssp. mesetae	Fremont cottonwood	Juniper-Pinyon Woodland, Riparian Forest
Prosopis glandulosa var. glandulosa	Honey mesquite	Trans-Pecos Shrub Savanna
Yucca baccata	Banana yucca	Juniper-Pinyon Woodland, Oak-Juniper Woodland, Creosotebush, Trans-Pecos Shrub Savanna

Table 4-1. Continued.

Scientific Name	Common Name	Community Types
Ecoregion #321		
Ambrosia dumosa	White bursage	Creosotebush, Creosotebush-Bursage, Palo Verde-Cactus Shrub
Artemisia tridentata ssp. tridentata	Basin big sagebrush	Juniper-Pinyon Woodland, Blackbrush, Creosotebush
Atriplex canescens	Fourwing saltbush	Juniper-Pinyon Woodland, Blackbrush, Creosotebush
Carnegiea gigantea	Saguaro	Creosotebush, Creosotebush-Bursage, Palo Verde-Cactus Shrub
Cercidium floridum	Blue Palo Verde	Creosotebush, Creosotebush-Bursage, Palo Verde-Cactus Shrub
Coleogyne ramosissima	Blackbush	Juniper-Pinyon Woodland, Blackbrush, Creosotebush
Fouquieria splendens	Ocotillo	Creosotebush, Cresotebush-Bursage
Juniperus occidentalis	Western juniper	Juniper-Pinyon Woodland
Larrea tridentata	Creosotebush	Creosotebush, Cresotebush-Bursage
Pinus edulis	True pinyon	Juniper-Pinyon Woodland
Prosopis glandulosa var. torreyana	Western honey mesquite	Creosotebush, Cresotebush-Bursage
Purshia glandulosa	Desert bitterbrush	Juniper-Pinyon Woodland, Blackbrush, Creosotebush
Sarcobatus vermiculatus	Black greasewood	Juniper-Pinyon Woodland, Blackbrush, Creosotebush
Yucca brevifolia	Joshua tree	Creosotebush, Blackbrush, Juniper-Pinyon Woodland
Opunita imbricata	Walkingstick cholla	Creosotebush, Creosotebush-Bursage, Palo Verde-Cactus Shrub
Ecoregion #331		
Artemisia tridentata ssp. tridentata	Basin big sagebrush	Juniper-Pinyon Woodland, Saltbush-Greasewood, Grama-Needlegrass-Wheatgrass, Wheatgrass-Needlegrass
Bouteloua curtipendula	Sideoats grama	Eastern Ponderosa Forest, Juniper-Pinyon Woodland, Grama-Needlegrass-Wheatgrass, Grama-Buffalograss, Wheatgrass-Needlegrass, Wheatgrass-Bluestem-Needlegrass, Bluestem-Grama Prairie, Sandsage-Bluestem Prairie, Northern Floodplain Forest

Table 4-1. Continued.

Scientific Name	Common Name	Community Types
Ecoregion #331 (continued)		
Bouteloua gracilis	Blue grama	Douglas-Fir Forest, Eastern Ponderosa Forest, Juniper-Pinyon Woodland, Saltbush-Greasewood, Grama-Needlegrass-Wheatgrass, Grama-Buffalograss, Wheatgrass-Needlegrass, Bluestem-Grama Prairie, Sandsage-Bluestem Prairie, Northern Floodplain Forest
Bouteloua hirsuta	Hairy grama	Eastern Ponderosa Forest, Juniper-Pinyon Woodland, Grama-Needlegrass-Wheatgrass, Grama-Buffalograss, Wheatgrass-Needlegrass, Wheatgrass-Bluestem-Needlegrass, Sandsage-Bluestem Prairie
Buchloe dactyloides	Buffalograss	Juniper-Pinyon Woodland, Grama-Needlegrass-Wheatgrass, Grama-Buffalograss, Wheatgrass-Needlegrass, Wheatgrass-Bluestem-Needlegrass, Bluestem-Grama Prairie
Chrysothamnus viscidiflorus	Green rabbitbrush	Douglas-Fir Forests, Eastern Ponderosa Forest, Juniper-Pinyon Woodland, Saltbush-Greasewood, Grama-Needlegrass-Wheatgrass, Grama-Buffalograss, Wheatgrass-Bluestem-Needlegrass, Northern Floodplain Forest
Festuca idahoensis	Idaho fescue	Douglas-Fir Forest, Eastern Ponderosa Forest, Juniper-Pinyon Woodland, Wheatgrass-Needlegrass
Helianthus maximiliani	Maximilian sunflower	Eastern Ponderosa Forest, Juniper-Pinyon Woodland, Grama-Needlegrass-Wheatgrass, Grama-Buffalograss, Wheatgrass-Needlegrass, Wheatgrass-Bluestem-Needlegrass, Bluestem-Grama Prairie, Sandsage-Bluestem Prairie, Northern Floodplain Forest
Leymus cinereus	Basin wildrye	Eastern Ponderosa Forest, Juniper-Pinyon Woodland, Grama-Needlegrass-Wheatgrass, Wheatgrass-Needlegrass, Wheatgrass-Bluestem-Needlegrass, Douglas-Fir Forest, Northern Floodplain Forest, Saltbush-Greasewood, Grama-Buffalograss
Liatris punctata	Blazingstar	Eastern Ponderosa Forest, Juniper-Pinyon Woodland, Grama-Buffalograss, Wheatgrass-Needlegrass, Wheatgrass-Bluestem-Needlegrass, Bluestem-Grama Prairie, Sandsage-Bluestem Prairie, Northern Floodplain Forest

Table 4-1. Continued.

Scientific Name	Common Name	Community Types
Ecoregion #331 (continued)		
Oxytropis sericea	Whitepoint locoweed	Douglas-Fir Forest, Eastern Ponderosa Forest, Juniper-Pinyon Woodland, Grama-Needlegrass-Wheatgrass, Grama-Buffalograss
Pascopyrum smithii	Western wheatgrass	Eastern Ponderosa Forest, Juniper-Pinyon Woodland, Grama-Needlegrass-Wheatgrass, Wheatgrass-Needlegrass, Wheatgrass-Bluestem-Needlegrass, Douglas-Fir Forest, Northern Floodplain Forest, Saltbush-Greasewood, Grama-Buffalograss
Pinus ponderosa var. scopulorum	Interior Ponderosa pine	Eastern Ponderosa Forest, Juniper-Pinyon Woodland, Grama-Needlegrass-Wheatgrass, Wheatgrass-Needlegrass, Bluestem-Grama Prairie, Grama-Buffalograss
Populus deltoides	Eastern cottonwood	Eastern Ponderosa Forest, Juniper-Pinyon Woodland, Grama-Needlegrass-Wheatgrass, Grama-Buffalograss, Wheatgrass-Needlegrass, Wheatgrass-Bluestem-Needlegrass, Sandsage-Bluestem Prairie, Northern Floodplain Forest
Populus tremuloides	Quaking aspen	Douglas-Fir Forests, Eastern Ponderosa Forest, Juniper-Pinyon Woodland, Northern Floodplain Forest
Prunus virginiana	Chokecherry	Douglas-Fir Forests, Eastern Ponderosa Forest, Juniper-Pinyon Woodland, Saltbush-Greasewood, Grama-Buffalograss, Wheatgrass-Needlegrass, Wheatgrass-Bluestem-Needlegrass, Sandsage-Bluestem Prairie, Norhtern Floodplain Forest
Pseudoroegneria spicata	Bluebunch wheatgrass	Eastern Ponderosa Forest, Juniper-Pinyon Woodland, Grama-Needlegrass-Wheatgrass, Wheatgrass-Needlegrass, Wheatgrass-Bluestem-Needlegrass, Douglas-Fir Forest, Northern Floodplain Forest
Pseudotsuga menziesii var. glauca	Rocky Mountain douglas fir	Douglas-Fir Forest
Salsola kali	Russian thistle (tumbleweed)	Introduced species, common in many disturbed communities, particularly semi-arid regions and along coasts

Table 4-1. Continued.

Scientific Name	Common Name	Community Types
Ecoregion #331 (continued)		
Schizachyrium scoparium	Little bluestem	Eastern Ponderosa Forest, Juniper-Pinyon Woodland, Grama-Needlegrass-Wheatgrass, Grama-Buffalograss, Wheatgrass-Needlegrass, Wheatgrass-Bluestem-Needlegrass, Sandsage-Bluestem Prairie, Douglas-Fir Forest, Bluestem-Grama Prairie,Northern Floodplain Forest
Shepherdia argentea	Silver buffaloberry	Eastern Ponderosa Forest, Juniper-Pinyon Woodland, Grama-Needlegrass-Wheatgrass, Wheatgrass-Needlegrass, Wheatgrass-Bluestem-Needlegrass, Bluestem-Grama Prairie, Northern Floodplain Forest
Spartina pectinata	Prairie cordgrass	Eastern Ponderosa Forest, Juniper-Pinyon Woodland, Grama-Needlegrass-Wheatgrass, Wheatgrass-Needlegrass, Northern Floodplain Forest, Saltbush-Greasewood, Grama-Buffalograss, Sandsage-Bluestem Prairie
Sporobolus cryptandrus	Sand dropseed	Eastern Ponderosa Forest, Juniper-Pinyon Woodland, Grama-Needlegrass-Wheatgrass, Grama-Buffalograss, Wheatgrass-Needlegrass, Wheatgrass-Bluestem-Needlegrass, Sandsage-Bluestem Prairie, Northern Floodplain Forest, Saltbush-Greasewood
Stipa comata	Needle and thread grass	Eastern Ponderosa Forest, Juniper-Pinyon Woodland, Grama-Needlegrass-Wheatgrass, Grama-Buffalograss, Wheatgrass-Needlegrass, Wheatgrass-Bluestem-Needlegrass, Sandsage-Bluestem Prairie, Northern Floodplain Forest, Saltbush-Greasewood
Stipa (Nassella) viridula	Green needlegrass	Eastern Ponderosa Forest, Juniper-Pinyon Woodland, Grama-Needlegrass-Wheatgrass, Grama-Buffalograss, Wheatgrass-Needlegrass, Wheatgrass-Bluestem-Needlegrass, Sandsage-Bluestem Prairie, Douglas-Fir Forest, Northern Floodplain Forest
Symphoricarpos albus	Common snowberry	Douglas-Fir Forest, Eastern Ponderosa Forest, Juniper-Pinyon Woodland, Grama-Needlegrass-Wheatgrass, Wheatgrass-Needlegrass, Wheatgrass-Bluestem-Needlegrass, Northern Floodplain Forest

Table 4-1. Continued.

Scientific Name	Common Name	Community Types
Ecoregion #331 (continued)		
Symphoricarpos occidentalis	Western snowberry	Douglas-Fir Forest, Eastern Ponderosa Forest, Grama-Needlegrass-Wheatgrass, Wheatgrass-Needlegrass, Wheatgrass-Bluestem-Needlegrass, Bluestem-Grama Prairie, Sandsage-Bluestem Prairie, Northern Floodplain Forest
Thuja plicata	Western red cedar	Douglas-Fir Forest
Ecoregion #M331		
Abies lasiocarpa	Subalpine fir	Douglas-Fir Forest, Pine-Douglas-Fir Forest, Southwestern Spruce-Fir Forest, Alpine Meadows and Barren
Arnica cordifolia	Heartleaf arnica	Lodgepole Pine-Subalpine Forest, Douglas-Fir Forest, Western Spruce-Fir Forest, Southwestern Spruce-Fir Forest, Mountain-Mahogany Oak Scrub, Alpine Meadows and Barren, Pine-Douglas-Fir Forest, Pinyon-Juniper Woodland, Sagebrush Steppe
Artemisia tridentata ssp. vaseyana	Mountain big sagebrush	Douglas-Fir Forest, Western Spruce-Fir Forest, Pinyon-Juniper Woodland, Mountain-Mahogany Oak Scrub, Great Basin Sagebrush, Sagebrush Steppe, Wheatgrass-Needlegrass-Shrubsteppe
Artemisia tridentata ssp. wyomingensis	Wyoming big sagebrush	Mountain-Mahogany Oak Scrub, Great Basin Sagebrush, Sagebrush Steppe, Wheatgrass-Needlegrass-Shrubsteppe
Calamagrostis rubescens	Pinegrass	Mixed Conifer Forest, Lodgepole Pine-Subalpine Forest, Douglas-Fir Forest, Western Spruce-Fir Forest, Southwestern Spruce-Fir Forest, Mountain-Mahogany Oak Scrub, Alpine Meadows and Barren
Cercocarpus montanus	True mountain mahogany	Douglas-Fir Forest, Western Spruce-Fir Forest, Pine-Dougals-Fir Forest, Southwestern Spruce-Fir Forest, Pinyon-Juniper Woodland, Mountain-Mahogany Oak Scrub, Great Basin Sagebrush, Sagebrush Steppe, Wheatgrass-Needlegrass-Shrubsteppe

Table 4-1. Continued.

Scientific Name	Common Name	Community Types
Ecoregion #M331 (continued)		
Festuca idahoensis	Idaho fescue	Douglas-Fir Forest, Western Spruce-Fir Forest, Pine-Douglas-Fir Forest, Southwestern Spruce-Fir Forest, Pinyon-Juniper Woodland, Mountain-Mahogany Oak Scrub, Great Basin Sagebrush, Alpine Meadows and Barren, Sagebrush Steppe, Wheatgrass-Needlegrass-Shrub
Festuca ovina var. vivipara	Viviparous sheep fescue	Alpine Meadows and Barren
Kobresia simpliciuscula	Simple kobresia	Alpine Meadows and Barren
Mahonia repens	Oregon-grape	Lodgepole Pine-Subalpine Forest, Douglas-Fir Forest, Western Spruce-Fir Forest, Pine-Douglas-Fir Forest, Pinyon-Juniper Woodland, Great Basin Sagebrush
Picea engelmannii	Engelmann spruce	Douglas-Fir Forest, Pine-Douglas-Fir Forest, Southwestern Spruce-Fir Forest, Alpine Meadows and Barren, Western Spruce-Fir Forest
Pinus albicaulis	Whitebark pine	Lodgepole Pine-Subalpine Forest, Western Spruce-Fir Forest
Pinus contorta var. latifolia	Rocky Mountain lodgepole pine	Douglas-Fir Forest, Western Spruce-Fir Forest
Pinus edulis	True pinyon	Pine-Douglas-Fir Forest, Southwestern Spruce-Fir Forest, Pinyon-Juniper Woodlands, Mountain-Mahogany Oak Scrub, Great Basin Sagebrush
Pinus ponderosa var. scopulorum	Interior Ponderosa pine	Pine-Douglas-Fir Forest, Southwestern Spruce-Fir Forest, Pinyon-Juniper Woodland, Mountain-Mahogany Oak Scrub, Great Basin Sagebrush, Sagebrush Steppe, Wheatgrass-Needlegrass-Shrubsteppe
Populus tremuloides	Quaking aspen	Mixed Conifers Forest, Lodgepole Pine-Subalpine Forest, Douglas-Fir Forest, Western Spruce-Fir Forest, Pine-Douglas-Fir Forest, Southwestern Spruce-Fir Forest, Pinyon-Juniper Woodland, Mountain-Mahogany Oak Scrub, Great Basin Sagebrush, Sagebrush Steppe

Table 4-1. Continued.

Scientific Name	Common Name	Community Types
Ecoregion #M331 (continued)		
Pseudoroegneria spicata	Bluebunch wheatgrass	Douglas-Fir Forest, Western Spruce-Fir Forest, Pine-Douglas-Fir Forest, Southwestern Spruce-Fir Forest, Pinyon-Juniper Woodland, Mountain-Mahogany Oak Scrub, Great Basin Sagebrush, Alpine Meadows and Barren, Sagebrush Steppe, Wheatgrass-Needlegrass-Shrub
Pseudotsuga menziesii var. glauca	Rocky Mountain Douglas fir	Douglas-Fir Forest, Western Spruce-Fir Forest, Pine-Douglas Fir Forest
Purshia tridentata	Antelope bitterbrush	Douglas-Fir Forest, Western Spruce-Fir Forest, Pine-Douglas-Fir Forest, Southwestern Spruce-Fir Forest, Pinyon-Juniper Woodland, Mountain-Mahogany Oak Scrub, Great Basin Sagebrush, Sagebrush Steppe, Wheatgrass-Needlegrass-Shrubsteppe
Vaccinium scoparium	Grouse whortleberry	Douglas-Fir Forest, Western Spruce-Fir Forest, Pine-Douglas-Fir Forest, Southwestern Spruce-Fir Forest, Alpine Meadows and Barren
Ecoregion #332		
Ambrosia psilostachya	Western ragweed	Wheatgrass-Bluestem-Needlegrass, Nebraska Sandhills Prairie, Bluestem-Grama Prairie, Sandsage-Bluestem Prairie
Andropogen gerardii var. gerardii	Big bluestem	Wheatgrass-Bluestem-Needlegrass, Bluestem-Grama-Prairie, Sandsage-Bluestem Prairie, Nebraska Sandhills Prairie
Aristida purpurea	Purple three-awn	Wheatgrass-Bluestem-Needlegrass, Wheatgrass-Needlegrass, Sandsage-Bluestem Prairie, Bluestem-Grama Prairie
Bouteloua gracilis	Blue grama	Wheatgrass-Needlegrass, Nebraska Sandhills Prairie, Sandsage-Bluestem Prairie, Bluestem-Grama Prairie, Northern Flood Plain Forest
Bouteloua hirsuta	Hairy grama	Wheatgrass-Needlegrass, Wheatgrass-Bluestem-Needlegrass, Sandsage-Bluestem Prairie, Nebraska Sandhills Prairie
Buchloe dactyloides	Buffalograss	Wheatgrass-Needlegrass, Wheatgrass-Bluestem-Needlegrass, Bluestem-Grama Prairie, Nebraska Sandhills Prairie

Table 4-1. Continued.

Scientific Name	Common Name	Community Types
Ecoregion #332 (continued)		
Calamovilfa longifolia	Prairie sandreed	Wheatgrass-Bluestem-Needlegrass, Northern Flood Plain Forest, Nebraska Sandhills Prairie, Wheatgrass-Needlegrass, Sandsage-Bluestem Prairie
Elymus trachycaulus	Slendar wheatgrass	Wheatgrass-Bluestem-Needlegrass, Northern Flood Plain Forest, Wheatgrass-Needlegrass, Sandsage-Bluestem Prairie, Nebraska Sandhills Prairie, Bluestem-Grama Prairie
Helianthus maximiliani	Maximilian sunflower	Wheatgrass-Bluestem-Needlegrass, Northern Flood Plain Forest, Wheatgrass-Needlegrass, Sandsage-Bluestem Prairie, Nebraska Sandhills Prairie, Bluestem-Grama Prairie
Pascopyrum smithii	Western wheatgrass	Wheatgrass-Bluestem-Needlegrass, Northern Flood Plain Forest, Wheatgrass-Needlegrass
Schizachyrium scoparium	Little bluestem	Wheatgrass-Bluestem-Needlegrass, Northern Flood Plain Forest, Wheatgrass-Needlegrass, Nebraska Sandhills Prairie, Sandsage-Bluestem Prairie, Bluestem-Grama Prairie
Solidago missouriensis	Prairie goldenrod	Wheatgrass-Bluestem-Needlegrass, Northern Flood Plain Forest, Wheatgrass-Needlegrass, Sandsage-Bluestem Prairie, Nebraska Sandhills Prairie
Spartina pectinata	Prairie cordgrass	Wheatgrass-Needlegrass, Sandsage-Bluestem Prairie, Northern Flood Plain Forest
Sporobolus cryptandrus	Sand dropseed	Wheatgrass-Bluestem-Needlegrass, Northern Flood Plain Forest, Wheatgrass-Needlegrass, Sandsage-Bluestem Prairie
Stipa comata	Needle and thread grass	Wheatgrass-Bluestem-Needlegrass, Northern Flood Plain Forest, Wheatgrass-Needlegrass, Nebraska Sandhills Prairie, Sandsage-Bluestem Prairie
Stipa (Nassella) viridula	Green needlegrass	Wheatgrass-Bluestem-Needlegrass, Northern Flood Plain Forest, Wheatgrass-Needlegrass, Sandsage-Bluestem Prairie
Ecoregion #M332		
Abies grandis	Grand fir	Grand Fir-Douglas-Fir Forest, Western Spruce-Fir Forest
Abies lasiocarpa	Subalpine fir	Douglas-Fir Forest, Alpine Meadows and Barrens

Table 4-1. Continued.

Scientific Name	Common Name	Community Types
Ecoregion #M332 (continued)		
Artemisia tridentata ssp. vaseyana	Mountain big sagebrush	Douglas-Fir Forest, Eastern Ponderosa Forest, Western Spruce-Fir Forest, Great Basin Sagebrush, Sagebrush Steppe, Foothills Prairie
Cercocarpus montanus	True mountain mahogany	Western Ponderosa Forest, Douglas-Fir Forest, Western Spruce-Fir Forest, Eastern Ponderosa Forest, Great Basin Sagebrush, Sagebrush Steppe
Deschampsia cespitosa	Tufted hairgrass	Mixed Conifer Forest, Western Ponderosa Forest, Douglas-Fir Forest, Grand Fir-Douglas-Fir Forest, Western Spruce-Fir Forest, Eastern Ponderosa Forest, Great Basin Sagebrush, Alpine Meadows and Barrens, Sagebrush Steppe, Foothills Prairie
Festuca idahoensis	Idaho fescue	Western Ponderosa Forest, Douglas-Fir Forest, Western Spruce-Fir Forest, Juniper Steppe Woodland, Great Basin Sagebrush, Wheatgrass-Bluegrass, Sagebrush Steppe, Foothills Prairie, Alpine Meadows and Barrens
Festuca scabrella	Rough fescue	Western Ponderosa Forest, Douglas-Fir Forest, Eastern Ponderosa Forest, Great Basin Sagebrush, Sagebrush Steppe, Foothills Prairie
Juniperus occidentalis	Western juniper	Western Ponderosa Forest, Juniper Steppe Woodland
Koeleria macrantha	Prairie junegrass	Western Ponderosa Forest, Douglas-Fir Forest, Western Spruce-Fir Forest, Eastern Ponderosa Forest, Juniper Steppe Woodland, Great Basin Sagebrush, Wheatgrass-Bluegrass, Alpine Meadows and Barrens, Sagebrush Steppe, Foothills Prairie
Larix occidentalis	Western larch	Western Ponderosa Forest, Douglas-Fir Forest, Grand Fir-Douglas-Fir Forest, Western Spruce-Fir Forest
Pinus albicaulis	Whitebark pine	Western Spruce-Fir Forest
Pinus contorta var. latifolia	Rocky Mountain lodgepole pine	Western Ponderosa Forest, Douglas-Fir Forest, Grand Fir-Douglas-Fir Forest, Western Spruce-Fir Forest, Foothills Prairie
Pinus flexilis	Limber pine	Western Ponderosa Forest, Douglas-Fir Forest, Western Spruce-Fir Forest, Alpine Meadows and Barrens

Table 4-1. Continued.

Scientific Name	Common Name	Community Types
Ecoregion #M332 (continued)		
Pinus ponderosa var. ponderosa	Pacific Ponderosa pine	Mixed Conifer Forest, Western Ponderosa Forest, Douglas-Fir Forest
Poa secunda	Sandberg bluegrass	Mixed Conifer Forest, Western Ponderosa Forest, Juniper Steppe Woodland, Wheatgrass-Bluegrass
Pseudoroegneria spicata	Bluebunch wheatgrass	Western Ponderosa Forest, Douglas-Fir Forest, Western Spruce-Fir Forest, Eastern Ponderosa Forest, Juniper Steppe Woodland, Great Basin Sagebrush, Wheatgrass-Bluegrass, Sagebrush Steppe, Foothills Prairie
Pseudotsuga menziesii var. glauca	Rocky Mountain Douglas fir	Western Ponderosa Forest, Douglas-Fir Forest, Grand Fir-Douglas-Fir Forest, Western Spruce-Fir Forest
Symphoricarpos albus	Common snowberry	Mixed Conifer Forest, Western Ponderosa Forest, Douglas-Fir Forest, Western Spruce-Fir Forest, Great Basin Sagebrush, Wheatgrass-Bluegrass, Sagebrush Steppe, Foothills Prairie
Ecoregion #M333		
Abies grandis	Grand fir	Cedar-Hemlock-Douglas-Fir Forest, Cedar-Hemlock-Pine Forest, Grand Fir-Douglas-Fir Forest
Abies lasiocarpa	Subalpine fir	Douglas-Fir Forest
Larix occidentalis	Western larch	Western Ponderosa Forest, Douglas-Fir Forest, Cedar-Hemlock-Pine Forest, Grand Fir-Douglas-Fir Forest
Picea engelmannii	Engelmann spruce	Douglas-Fir Forest, Grand Fir-Douglas-Fir Forest
Pinus monticola	Western white pine	Cedar-Hemlock-Douglas-Fir Forest, Cedar-Hemlock-Pine Forest, Grand Fir-Douglas-Fir Forest, Douglas-Fir Forest
Pinus ponderosa var. ponderosa	Pacific Ponderosa pine	Cedar-Hemlock-Douglas-Fir Forest, Western Ponderosa Forest, Douglas-Fir Forests, Cedar-Hemlock-Pine Forest
Pseudotsuga menziesii var. menziesii	Coast Douglas fir	Cedar-Hemlock-Douglas-Fir Forest, California Mixed Evergreen Forest
Thuja plicata	Western red cedar	Cedar-Hemlock-Douglas-Fir Forest, Douglas-Fir Forest, Cedar-Hemlock-Pine Forest, Grand Fir-Douglas-Fir Forest

Table 4-1. Continued.

Scientific Name	Common Name	Community Types
Ecoregion #M333 (continued)		
Tsuga heretophylla	Western hemlock	Cedar-Hemlock-Douglas-Fir Forest, Douglas-Fir Forest, Cedar-Hemlock-Pine Forest, Grand Fir-Douglas-Fir Forest
Tsuga mertensiana	Mountain hemlock	Cedar-Hemlock-Douglas-Fir Forest, Cedar-Hemlock-Pine Forest
Ecoregion #M334		
Betula papyrifera	Paper birch	Black Hills Pine Forest
Celtis occidentalis	Hackberry	Black Hills Pine Forest
Pinus contorta var. latifolia	Rocky Mountain lodgepole pine	Black Hills Pine Forest
Pinus ponderosa var. scopulorum	Interior Ponderosa pine	Black Hills Pine Forest
Populus tremuloides	Quaking aspen	Black Hills Pine Forest
Quercus macrocarpa	Bur oak	Black Hills Pine Forest
Ecoregion #341		
Abies lasiocarpa	Subalpine fir	Alpine Meadows and Barren
Artemisia tridentata ssp. tridentata	Basin big sagebrush	Great Basin Pine Forest, Juniper-Pinyon Woodlands, Sagebrush Steppe, Saltbush-Greasewood, Galleta-Three Awn Shrub Steppe
Atriplex canescens	Fourwing saltbush	Juniper-Pinyon Woodlands, Saltbush-Greasewood, Sagebrush Steppe, Galleta-Three Awn Shrub Steppe
Atriplex confertifolia	Shadscale	Juniper-Pinyon Woodlands, Saltbush-Greasewood, Sagebrush Steppe, Galleta-Three Awn Shrub Steppe
Buchloe dactyloides	Buffalograss	Juniper-Pinyon Woodlands, Wheatgrass-Grama-Buffalograss
Chrysothamnus nauseosus	Rubber rabbitbrush	Juniper-Pinyon Woodlands, Saltbush-Greasewood, Sagebrush Steppe, Galleta-Three Awn Shrub Steppe
Ephedra nevadensis	Nevada ephedra	Blackbrush, Saltbush-Greasewood, Sagebrush Steppe, Galleta-Three Awn Shrub Steppe
Grayia spinosa	Spiny hopsage	Juniper-Pinyon Woodlands, Blackbrush, Saltbush-Greasewood, Sagebrush Steppe, Galleta-Three Awn Shrub Steppe
Juniperus occidentalis	Western juniper	Juniper-Pinyon Woodlands

Table 4-1. Continued.

Scientific Name	Common Name	Community Types
Ecoregion #341 (continued)		
Juniperus osteosperma	Utah juniper	Juniper-Pinyon Woodlands, Blackbrush, Saltbush-Greasewood, Sagebrush Steppe, Galleta-Three Awn Shrub Steppe
Picea engelmannii	Engelmann spruce	Alpine Meadows and Barren
Pinus edulis	True pinyon	Juniper-Pinyon Woodlands, Saltbush-Greasewood, Sagebrush Steppe, Galleta-Three Awn Shrub Steppe
Pinus flexilis	Limber pine	Great Basin Pine Forest, Juniper-Pinyon Woodlands, Alpine Meadows and Barrens
Pinus jeffreyi	Jeffrey pine	Ponderosa Shrub Forest
Pinus longaeva	Great Basin bristlecone pine	Great Basin Pine Forest
Pinus monophylla	Single leaf pinyon	Juniper-Pinyon Woodlands, Blackbrush, Sagebrush Steppe
Pinus ponderosa var. scopulorum	Interior Ponderosa pine	Great Basin Pine Forest, Juniper-Pinyon Woodlands, Sagebrush Steppe, Galleta-Three Awn Shrub Steppe, Wheatgrass-Grama-Buffalograss
Populus tremuloides	Quaking aspen	Great Basin Pine Forest, Juniper-Pinyon Woodlands, Sagebrush Steppe
Purshia tridentata	Antelope bitterbrush	Ponderosa Shrub Forest, Juniper-Pinyon Woodlands, Saltbush-Greasewood, Sagebrush Steppe
Sarcobatus vermiculatus	Black greasewood	Juniper-Pinyon Woodlands, Blackbrush, Saltbush-Greasewood, Sagebrush Steppe, Galleta-Three Awn Shrub Steppe
Tetradymia spinosa	Spiny horsebrush	Great Basin Pine Forest, Juniper-Pinyon Woodlands, Blackbrush, Saltbush-Greasewood, Sagebrush Steppe
Yucca baccata	Banana yucca	Juniper-Pinyon Woodlands, Blackbrush
Yucca brevifolia	Joshua tree	Juniper-Pinyon Woodlands, Blackbrush
Ecoregion #M341		
Artemisia nova	Black sagebrush	Juniper-Pinyon Woodlands, Great Basin Sagebrush, Saltbush-Greasewood
Artemisia tridentata ssp. tridentata	Basin big sagebrush	Great Basin Sagebrush, Saltbush-Greasewood, Juniper-Pinyon Woodland

Table 4-1. Continued.

Scientific Name	Common Name	Community Types
Ecoregion #M341 (continued)		
Atriplex canescens	Fourwing saltbush	Arizona Pine Forest, Great Basin Sagebrush, Saltbush-Greasewood
Atriplex confertifolia	Shadscale	Great Basin Sagebrush, Saltbush-Greasewood, Juniper-Pinyon Woodland
Chrysothamnus nauseosus	Rubber rabbitbrush	Great Basin Sagebrush, Saltbush-Greasewood, Juniper-Pinyon Woodland, Arizona Pine Forest
Grayia spinosa	Spiny hopsage	Juniper-Pinyon Woodlands, Great Basin Sagebrush, Saltbush-Greasewood
Picea engelmannii	Engelmann spruce	Western Spruce-Fir Forests, Spruce-Fir-Douglas-Fir Forest
Pinus longaeva	Great Basin bristlecone pine	Great Basin Pine Forest
Pinus ponderosa var. scopulorum	Interior Ponderosa pine	Arizona Pine Forest, Spruce-Fir-Douglas-Fir Forest, Juniper-Pinyon Woodland, Great Basin Sagebrush
Populus tremuloides	Quaking aspen	Arizona Pine Forest, Spruce-Fir-Douglas-Fir Forest, Juniper-Pinyon Woodland, Great Basin Sagebrush, Western Spruce-Fir Forests, Mixed Conifer Forest
Pseudotsuga menziesii var. glauca	Rocky Mountain Douglas fir	Western Spruce-Fir Forests, Arizona Pine Forest, Spruce-Fir-Douglas-Fir Forest
Sarcobatus vermiculatus	Black greasewood	Great Basin Sagebrush, Saltbush-Greasewood, Juniper-Pinyon Woodland
Tetradymia spinosa	Spiny horsebrush	Great Basin Sagebrush, Saltbush-Greasewood, Juniper-Pinyon Woodland
Ecoregion #342		
Artemisia tridentata ssp. vaseyana	Mountain big sagebrush	Douglas-Fir Forests, Saltbush-Greasewood, Sagebrush Steppe, Wheatgrass-Needlegrass-Shrubsteppe
Atriplex confertifolia	Shadscale	Saltbush-Greasewood, Wheatgrass-Bluegrass, Sagebrush Steppe, Wheatgrass-Needlegrass-Shrubsteppe, Grama-Needlegrass-Wheatgrass
Atriplex gardneri	Gardner's saltbush	Saltbush-Greasewood, Sagebrush Steppe, Grama-Needlegrass-Wheatgrass
Juniperus occidentalis	Western juniper	Juniper-Steppe Woodland

Table 4-1. Continued.

Scientific Name	Common Name	Community Types
Ecoregion #342 (continued)		
Oryzopsis hymenoides	Indian ricegrass	Douglas-Fir Forests, Pine and Douglas-Fir Forests, Saltbush-Greasewood, Wheatgrass-Bluegrass, Sagebrush Steppe, Wheatgrass-Needlegrass-Shrubsteppe
Pinus contorta var. latifolia	Rocky Mountain lodgepole pine	Douglas-Fir Forests
Pinus ponderosa var. scopulorum	Interior Ponderosa pine	Pine and Douglas-Fir Forests, Sagebrush Steppe, Wheatgrass-Needlegrass-Shrubsteppe, Grama-Needlegrass-Wheatgrass
Populus tremuloides	Quaking aspen	Mixed Conifer Forest, Douglas-Fir-Forest, Pine and Douglas-Fir Forest, Juniper-Steppe Woodland, Sagebrush Steppe
Pseudoroegneria spicata	Bluebunch wheatgrass	Douglas-Fir Forests, Pine and Douglas-Fir Forests, Juniper-Steppe Woodland, Wheatgrass-Bluegrass, Sagebrush Steppe, Wheatgrass-Needlegrass-Shrubsteppe, Grama-Needlegrass-Wheatgrass
Pseudotsuga menziesii var. glauca	Rocky Mountain Douglas fir	Douglas-Fir Forests, Pine and Douglas-Fir Forests
Purshia tridentata	Antelope bitterbrush	Douglas-Fir Forests, Pine and Douglas-Fir Forests, Juniper-Steppe Woodland, Saltbush-Greasewood, Sagebrush Steppe, Wheatgrass-Needlegrass-Shrubsteppe
Sarcobatus vermiculatus	Black greasewood	Saltbush-Greasewood, Wheatgrass-Bluegrass, Sagebrush Steppe, Wheatgrass-Needlegrass-Shrubsteppe, Pine and Douglas-Fir Forests
Stipa comata	Needle and thread grass	Saltbush-Greasewood, Wheatgrass-Needlegrass-Shrubsteppe, Sagebrush Steppe, Wheatgrass-Bluegrass, Pine and Douglas-Fir Forests, Grama-Needlegrass-Wheatgrass
Ecoregion #411		
Cladium jamaicense	Sawgrass	Everglades, cypress savanna
Persea borbonia	Red bay	Everglades, cypress savanna
Pinus elliottii	Slash pine	Subtropical pine forest
Sabal palmetto	Cabbage palm	Everglades, subtropical pine forest
Serenoa repens	Saw palmetto	Subtropical pine forest
Taxodium ascendens	Pond cypress	Everglades, cypress savanna

Section 5
FIRE ECOLOGY AND EFFECTS SUMMARIES FOR INDIVIDUAL PLANT SPECIES

SUMMARIES FOR MAJOR PLANT SPECIES OF U.S. ECOREGIONS

Summaries of fire ecology and effects for over 200 species of plants are listed in Table 5-1. This table is sorted by plant scientific name, and includes plant common name, growth form, fire tolerance and fire "adaptations," *in situ* burn potential, and detailed comments and considerations concerning fire ecology and prescribed burning for each species. Information is from the FEIS database unless otherwise specified. Please note that all information from FEIS, including the comments and considerations entries, are based on the effects of wildfire or prescribed fire in the absence of oil. The presence of oil as a fire fuel source can cause hotter, more intense fires, and would be likely to result in more severe results than those detailed in FEIS. Note that the "*in situ* burn potential" entries are not from FEIS, they are the opinion of the authors of this document, based on information provided in FEIS and considerable oil spill experience. Entries for *in situ* burning potential are relative among the species examined, entirely qualitative, and are based on the premise that recovery from oiling and burning should be short term (usually 2-3 years, but not more than ~ 10 years) and should not substantially change the plant community. In some cases, moderate changes in plant communities could be acceptable if native or desirable species were favored over non-native, noxious, or other species of lower natural resource value. Finally, it is important to recognize that for nearly all of the species considered the entries for *in situ* burning potential are theoretical, as little or no information currently exists on the response of the majority of these plants to oiling and burning. At the least, entries for *in situ* burning potential should help identify plant species and communities where burning might be feasible or less damaging, as well as settings where burning should definitely not be considered.

Many of the general points identified by Wright and Bailey (1982), Whelan (1995), and the *in situ* burn case histories and guidelines (Section 3) are reiterated for individual species in Table 5-1. It should be noted that complete information covering all potential aspects of the fire ecology of particular species was not always available in FEIS. For instance, the results of burning in different seasons is a major theme, but information on seasonality is not given for every species. It should not be assumed that a lack of information means that a species response to fire is not affected by season. The same reasoning applies to other factors and considerations. Another major point to notice is that fire tolerance is not always similar among related species, as might be expected. For instance, both pines and oaks have certain species that are very fire tolerant, as well as certain species that are easily damaged or killed by fire. Caution should be used when inferring a species fire tolerance based on the known tolerance of closely related species.

Major points and conclusions from the FEIS ecoregion species summaries on fire effects (in the absence of oil) are listed below.

Trees/Forests

Even if they are not killed by fire, trees generally take a long time to recover to pre-fire levels of structure and dominance relative to smaller, faster growing shrubs and grasses.

Fire may wound or scar trees, providing entry points for pathogens (fungi, insects, etc.) that could lead to delayed impacts or mortality as a result of fire.

In situ burning in most forested areas should be discouraged; however, for certain types of settings and communities, *in situ* burning of surface vegetation within forested areas may be quite reasonable.

In situ burning might be reasonable for open or savanna-like forest communities with tree species that are at least moderately fire tolerant, especially if fire threat to trees is minimal or actively minimized. As an example, some longleaf pines stands with grassy understories may fit this category. Some of the western pine communities, such as open, park-like ponderosa pine stands, might also present similar opportunities; as might some of the California oak woodlands.

In situ burning might also be reasonable for special fire-prone or fire "adapted" forest species or communities under certain conditions, even if trees will be directly at risk from fire. As an example, some pine barrens and pocosin communities might fit this category.

Shrubs and Associated Communities

Woody shrubs may be lumped with trees in certain respects, in that they look similar and may thus be perceived as fire sensitive; however, the shrubs examined as a part of this analysis showed a wide range of fire sensitivity, with many species being very fire tolerant. Several highly fire-tolerant species examined in this report might be good candidates for *in situ* burning.

Shrubs are usually top-killed by fire, but many sprout vigorously from belowground parts and recover quickly from fire. As noted by Whelan (1995), many shrubs "sacrifice" aboveground tissues to fire, but recover well by sprouting from previously suppressed underground buds.

It should be kept in mind that dense shrub thickets can create fire hazards and carry fire to unwanted areas. Also, some very fire "adapted" shrub species and communities are also highly flammable, presenting additional fire hazards. Chaparral is an extreme example. Chaparral communities contain many fire "adapted" species, but burning can create dangerous wildfire and flooding hazards. Expert fire practitioners should be consulted before burning in these types of communities.

Grasses/Grasslands

Many of the graminoids (grasses, sedges, etc.) examined in this report are fire tolerant and appear to be good candidates for *in situ* burning. Most of the species examined respond better during dormant season burns, and when soil conditions are moist or wet, so that roots, rhizomes, and organic soils are less likely to be damaged.

For native grasslands, natural and prescribed fires are typically low intensity and fast moving; high intensity, slow burning fires such as those that might be produced by *in situ* burning of oil may be more damaging than typical fires.

Although many grasses are fire tolerant, some species or growth forms can be much less so. In general, bunchgrass species or forms are often more fire sensitive than low-growing, rhizomatous grasses. Perennial needlegrasses (*Stipa* spp.) are reported to be the least fire tolerant of the bunchgrasses, and may not be good candidates for *in situ* burning.

Tallgrass prairie (bluestem) grasslands of the eastern plains appear to be more fire tolerant than mixed and shortgrass prairie (grama-buffalograss) grasslands of the central and western plains, where conditions are more arid. *In situ* burning may have greater potential in areas with tallgrass prairie, where damage to native vegetation is less likely.

Native grassland species described in this report include many warm season grasses, dormant in cool season months. Many non-native species which occur in prairies, pastures, fallow fields, etc. are cool season grasses, whose growing season may correspond or overlap with the typical dormant period of warm season species. The types of grass species present (warm season, cool season, or both) could be an important factor when plant dormancy and other seasonal concerns are considered in relation to *in situ* burning.

Desert Habitats/Cacti

Many desert or desert-like habitats do not burn very frequently, and plant communities in such areas are generally not fire "adapted", and may be severely damaged or eliminated by fire. Cacti for example often experience delayed mortality following fire, and should generally not be burned if they are to be maintained in the plant community. *In situ* burning of desert vegetation might not be advisable in many cases, although areas devoid of vegetation, such as in open spaces between individual plants or in dry channels of intermittent streambeds, may present good opportunities for *in situ* burning. It should be noted, however, that fire can alter or destroy important surface crusts of desert soils, causing unforeseen impacts, even in unvegetated areas.

FIRE EFFECTS SUMMARIES FOR WETLAND GRASSES AND SEDGES

In addition to the major vegetation types for each ecoregion, selected wetland species were examined. Wetland grasses and sedges were emphasized, since the feasibility of using *in situ* burning in oiled marshes and similar environments is high. Wetland grasses and sedges from across North America (including Alaska) were included. Summaries of fire ecology and effects for 24 species were prepared from the FEIS database, similar to those described previously (Table 5-2). The table is sorted by plant scientific name and includes plant common name, fire "adaptations", *in situ* burn potential, comments and considerations, and wetland habitat types where each species occurs. Again, the reader should note the explanations and qualifications described above and in Section 4.

The major conclusions drawn by Mendelssohn *et al.* (1995) for *in situ* burning of wetland grasses and sedges (listed below) are generally similar to those identified for individual species in Table 5-2 and would be expected to result in minimal long-term vegetation impacts in most species and cases:

- Growing season (especially late growing season) burns in marshes should be avoided; marsh recovery is greater for burns conducted when plants are dormant.
- Only rhizomatous herbaceous wetland species should be burned, not wetland shrub or tree species.
- Standing water should cover the marsh surface during burning to protect plant rhizomes and organic soils; root and peat burns in marshes should be avoided.
- Long-term increases in water levels should be avoided following marsh burns; several weeks of high water can kill burned plants if they are completely submerged.

Based on the information presented in Table 5-2, there are a few species which could potentially be burned under less than ideal conditions without greatly increasing the risk of long-term vegetation impact. In addition, there are a few other factors which may be important to consider when burning wetland grasses and sedges. Potential exceptions and additional factors are listed below:

- Herbivores can be controlled in some cases using a variety of techniques, including wildlife or livestock fencing and natural or synthetic chemical repellents. Local wildlife or range management officials should be contacted concerning appropriate and effective herbivores control.
- Some wetland species may be burned during the growing season without reducing or slowing vegetation recovery.
- Some wetland species may be burned without standing water present, as long as soils are wet or saturated, or the water table is close to the marsh surface. A very limited number of species may survive and/or quickly recover after peat burns.
- In addition to standing water and wet soil, burning in winter when ice or snow is present can protect plants and organic soils from damage.
- Erosion should be considered when burning streamside vegetation; periods of high rainfall intensity, snowmelt, etc. should be considered when burning wetland vegetation that provides soil stabilization.

- Direct and indirect wildlife impacts should be considered when burning wetlands, since many species use wetlands during critical life periods (see whitetop example, Table 5-2).

- Overgrazing can significantly damage some wetland species following fire, especially since herbivores may be attracted to burned sites.

- Other disturbances and stress factors, in addition to oiling and burning, should be considered, as these can drastically affect vegetation impacts and recovery. Such factors could include flooding and grazing (as previously mentioned), as well as physical disturbances (vegetation trampling), salinity fluctuation, oil residues, etc.

Table 5-1. Fire ecology and effects summaries for major plant species of U.S. ecoregions.

Scientific Name	Common Name	Growth Form	Fire Tolerant ? ("Adaptations")	*In Situ* Burn Potential	Comments and Considerations
Abies amabilis	Pacific silver fir	Tree	No; extremely fire sensitive	None	Thin bark, shallow roots, highly flammable foliage; fires kill most trees regardless of life stage, size, etc.
Abies balsamea	Balsam fir	Tree	No; fire sensitive	None	Thin, resinous, flammable bark and shallow roots, most fires kill trees and destroy seeds; may take 30-50 years until young plants become common again in the understory
Abies concolor	White fir	Tree	No; fire sensitive, but larger trees are moderately resistant (thicker bark, self-pruned lower branches)	None	Younger trees susceptible to even low intensity fire; trees killed by crown scorch, girdled stems, and root damage; trees must be 20-25 cm dbh and self-pruned before even moderately fire-resistant; damaged mature trees susceptible to insects and fungi
Abies fraseri	Fraser's fir	Tree	No; easily killed by fire	None	Easily killed by fire; burned sites may take decades to recover
Abies grandis	Grand fir	Tree	No; older trees somewhat resistant (thicker bark)	None	Low branches, flammable foliage, lichens, shallow roots, and dense stands result in fire sensitivity; burned trees susceptible to pathogens; larger trees more fire resistant; also resistant on dryer sites b/c deeper roots, thicker bark, and open stands
Abies lasiocarpa	Subalpine fir	Tree	No; very fire sensitive	None	High mortality from even low intensity fires; thin, flammable bark, shallow roots, low growing branches, dense stands, flammable foliage, heavy lichen growth all result in greater fire sensitivity
Abies magnifica	California red fir	Tree	Yes; older trees fire resistant (thick fire resistant bark, needles and branch tips are fire resistant)	None-low	Seedlings and saplings are easily killed by fire; large mature trees can withstand low-intensity fires, but can be killed by severe fires

Table 5-1. Continued.

Scientific Name	Common Name	Growth Form	Fire Tolerant ? ("Adaptations")	*In Situ* Burn Potential	Comments and Considerations
Acer macrophyllum	Bigleaf maple	Tree	Yes; resprouts from root crown after fire	None-low	Most trees are top-killed by fire; severe fires can damage root crown and prevent resprouting; often re-sprouts and survives on site, especially following light fires; fire may be less damaging on wetter sites
Acer rubrum	Red maple	Tree	No; fire intolerant	None	Even large trees killed by moderate fires
Acer saccharum	Sugar maple	Tree	No; fire sensitive	None	Thin bark results in injury/death from even light fires
Adenostoma fasciculatum	Chamise	Shrub	Yes; fire adapted (re-sprouts from dormant buds and stored supplies of energy, nutrients, and water; abundant production from seeds following fire; foliage has chemical, physical, and physiological characteristics that increase flammability)	moderate (caution, highly flammable)	Often regrows quickly; high intensity fire or frequent burning can result in high mortality; fall fires result in less damage/ mortality and better regrowth; planting (seeding) ryegrass after fire inhibits chamise recovery
Aesculus sp.	Sweet buckeye	Tree	Unknown	Unknown	Not in FEIS database
Agave lechuguilla	Lechuguilla	Shrub	No; not highly adapted to fire	None	Grows in dense stands which carry fire, burns hot, often suffers high mortality; regrowth from rhizomes limited; seedling establishment is rare
Agrostis exarata	Spike bentgrass	Graminoid	Yes (assumed)	High (assumed)	No specific information in FEIS, but similar species increase in abundance after fire; may need to control grazing pressure following fire to avoid damage
Alnus rhombifolia	White alder	Tree	No; not fire resistant	None	Most trees are killed by fire; little resprouting following fire
Alnus rubra	Red alder	Tree	Yes; fire resistant (fire resistant bark and foliage)	None	Fire resistant, but only against light fires; also has thin bark

Table 5-1. Continued.

Scientific Name	Common Name	Growth Form	Fire Tolerant ? ("Adaptations")	*In Situ* Burn Potential	Comments and Considerations
Alnus viridis ssp. sinuata	Sitka alder	Shrub/ Tree	Yes; fire resistant (nonflammable bark and nonresinous leaves, resprouting)	Moderate	Top-killed by low-moderate intensity fires, recovers by sprouting; severe fires can remove organic soil layers exposing and charring roots, eliminating sprouting; 5-7 years to recover from moderate-severe fires in some areas; an important nitrogen-fixing species
Ambrosia dumosa	White bursage	Shrub	No; fire sensitive	None	Generally killed by fire; limited sprouting and seedling establishment after fire; fires are infrequent within the growing region of this species
Ambrosia psilostachya	Western ragweed	Forb	Yes; (soil insulated roots, deep rhizomes)	High	Top-killed by fire, but deep rhizomes survive; seasonality is mixed, may either increase or decrease after spring burns, but generally increases after fall and winter burns; fire frequency also a factor; part of "fire adapted" prairie grassland community
Andropogon gerardii var. gerardii	Big bluestem	Graminoid	Yes; fire adapted (rhizome 2.5-5 cm below soil surface, fire plays role in maintaining plant community)	High	Natural and prescribed grassland fires are low intensity and fast moving; high intensity and/or slow fires may be more damaging; burning in late spring when still dormant is best, resulting in vigorous new growth and increase in flower stalks; summer growing season burns most damaging, regrowth is slower and less vigorous; drought conditions cause reduced growth after burning; similar effects can be seen in areas with naturally low precipitation
Andropogon gerardii var. paucipilus	Sand bluestem	Graminoid	Yes; fire tolerant (deep, well-developed rhizomes)	High	Burn in dormant season only, not during active growth (summer); increases in production/flowering after dormant season fire; on unstable soils (ex. sandhills), fire can result in erosion unless burning occurs near the end of the dormant season

Table 5-1. Continued.

Scientific Name	Common Name	Growth Form	Fire Tolerant ? ("Adaptations")	*In Situ* Burn Potential	Comments and Considerations
Arbutus menziesii	Pacific madrone	Tree	Yes; fire sensitive but recovers quickly (below-ground burl with energy reserves and dormant buds)	Low-moderate	Top-killed by fire; but resprouts aggressively via dormant buds; seedlings also readily establish after burning; fire injury can lead to entry of insects or disease
Arctostaphylos glandulosa	Eastwood manzanita	Shrub	Yes; fire adapted (re-sprouts from below-ground parts; fire-stimulated seed germination; leaves, stems, and fruits contain flammable resins)	Moderate-high (see caution)	Top-killed and consumed by fire but recovers within 4 years; part of fire "adapted" chaparral community; fires can be severe if fire suppression has led to high fuel buildup there is danger of extreme fire and downstream flooding
Arctostaphylos pungens	Pointleaf manzanita	Shrub	Yes; fire adapted (seed germination stimulated by fire, occurs in frequently burned areas, needs fire to regenerate)	Moderate-high (see caution)	Established plants may be killed or greatly reduced by fire; does not sprout after fire, but re-establishes by fire-stimulated seed, with numerous seedlings within 5 years. Not noted in FEIS, but possibly a fire hazard if high fuel buildup
Arctostaphylos viscida	Whiteleaf manzanita	Shrub	Yes; fire adapted (seed germination stimulated by fire, various morphological and chemical adaptations that encourage flammability)	Moderate-high (see caution)	Established plants killed by intense fire; re-establishes by fire-activated seeds, stands become dense 3-4 years after fire; repeated annual fires can eliminate the species; fire suppression and high fuel buildup result in extreme fire hazard
Aristida purpurea	Purple three-awn	Graminoid	No; (but soil seedbank is insulated from fire)	Low-moderate	Burning generally harms or kills this species, reducing its abundance for several years; recovers by tillering and seed germination; fire may stimulate seed production in surviving plants; fire may be less damaging if precipitation is above normal

Table 5-1. Continued.

Scientific Name	Common Name	Growth Form	Fire Tolerant ? ("Adaptations")	*In Situ* Burn Potential	Comments and Considerations
Arnica cordifolia	Heartleaf arnica	Forb	Yes; moderately fire resistant (resprouts from rhizomes, greater flowering and seedling establishment after fire)	Moderate-high	Top-killed by fire but rhizome often survives; abundant seedlings after fires also; can be reduced by high intensity fires; often becomes more abundant after fires and then declines over time as woody species return
Artemisia arbuscula ssp. arbuscula	Gray low sagebrush	Shrub	No; burns infrequently, some recovery from off-site seeds	None-low	Severely damaged or killed by fire; does not re-sprout after fire; recovery 2-5 years in favorable conditions, but can be more than 10 years; Sage grouse can be impacted by fire in sagebrush; erosion may be a problem on harsh sites with slow revegetation
Artemisia californica	California sagebrush	Shrub	Yes; fire adapted (some sprouting after fire, buried seed germination stimulated by burning)	Low	Top-killed usually, or killed by intense fires; weak sprouter, revegetates by seedlings; can be 10 years to recovery; burning in spring results in better sprouting and recovery b/c less intense heat; some concern that coastal sage scrub habitat is declining
Artemisia filifolia	Sand sagebrush	Shrub	Yes; fire tolerant, but conflicting information	Low	May or may not resprout after fire (conflicting information); seedlings rapidly occupy burn sites; fire during drought more damaging; possibly ecotypic and seasonal differences in fire recovery; grazing and erosion control may need to be considered after burning
Artemisia nova	Black sagebrush	Shrub	No; highly susceptible to fire	None-low	Killed by most fires; does not resprout following fire; burning not advised on winter ranges where this is an important forage plant; may only recover where fire burns limited areas or in mosaic pattern, allowing surviving plants to seed burned sites

Table 5-1. Continued.

Scientific Name	Common Name	Growth Form	Fire Tolerant ? ("Adaptations")	*In Situ* Burn Potential	Comments and Considerations
Artemisia tridentata ssp. tridentata	Basin big sagebrush	Shrub	No; highly susceptible to fire, some germination of on-site seed stored in soil	None-low	Easily killed by fire; recovers from on-site and nearby off-site seed; burning may result in more valuable forage species becoming prevalent (see related ssp.)
Artemisia tridentata ssp. vaseyana	Mountain big sagebrush	Shrub	No; fire sensitive, but perhaps some stimulation of seed germination	None-low	Easily killed by fire; does not resprout; recovers from on-site and nearby off-site seed; may be 15-20 or even 30 years for full recovery depending on site conditions (see related ssp.)
Artemisia tridentata ssp. wyomingensis	Wyoming big sagebrush	Shrub	No; highly susceptible to fire, some germination of on-site seed stored in soil	None-low	No specific information, see two related ssp. above
Atriplex canescens	Four-wing saltbush	Shrub	Yes; fire tolerant and resistant (resprouts vigorously, low flammability)	High	Above-ground portions may be consumed by fire, but often recovers quickly and fully (within 2-3 years) by sprouting from below-ground parts; there is great ecotypic variability in this species so fire response may vary
Atriplex confertifolia	Shadscale	Shrub	Yes (assumed); very similar to *A. canescens* and other saltbush species	High (assumed)	No specific information in FEIS, but similar morphologically to A. canescens and other saltbush species; most saltbush species recover within 2-3 years
Atriplex gardneri	Gardner's saltbush	Shrub	Yes; fire tolerant and resistant (resprouts vigorously, low flammability)	High	Sprouts prolifically if top-killed; no other specific information on recovery; however most saltbush species recover within 2-3 years
Atriplex joaquiniana	Saltbush	Shrub	Unknown	High (assumed)	Not in FEIS; most saltbush species recover within 2-3 years after fire

Table 5-1. Continued.

Scientific Name	Common Name	Growth Form	Fire Tolerant ? ("Adaptations")	*In Situ* Burn Potential	Comments and Considerations
Avena barbata	Slender wild oat	Graminoid	Unknown	High (assumed)	Not in FEIS; introduced annual climax species in California Central Valley grasslands; affect of fire not known, probably little direct affect; season of burn and precipitation may be important; in some cases, fire may favor annual forbs or native perennial grasses over introduced grasses
Avena fatua	California wild oat	Graminoid	Unknown	High (assumed)	Not in FEIS; introduced annual climax species in California Central Valley grasslands; affect of fire not known, probably little direct affect; season of burn and precipitation may be important; in some cases, fire may favor annual forbs or native perennial grasses over introduced grasses
Betula alleghaniensis	Yellow birch	Tree	No; fire sensitive, yet opportunistic	None-low	Thin bark, easily damaged/killed by fire; but rapid colonizer after fire due to enhanced germination and seedling establishment
Betula papyrifera	Paper birch	Tree	Yes; fire adapted (seedling establishment, sprouting, recolonizes quickly)	Low (unless young stand, then moderate-high)	Mainly top-killed or killed by fire; re-sprouts but ability decreases with age; colonizes from off-site seed sources; rapidly re-establishes; within 3-5 years post-fire adequate browse is available for wildlife, probably much longer to attain mature forest structure
Bouteloua curtipendula	Sideoats grama	Graminoid	Yes; fire tolerant (especially bunchgrass variety, recovers from buried rhizome and seed)	Moderate-high	Variable fire effects; one variety is decreased by fire, takes 2-3 years to recover; other variety thrives after fire and may increase in abundance; different geographic/community type responses, short and mixed-grass prairies (grama decreased by fire) versus tallgrass prairie (grama unaffected); fire damaging in dry years, better recovery in wet years; better recovery during dormant season (esp. early spring) fires

Table 5-1. Continued.

Scientific Name	Common Name	Growth Form	Fire Tolerant ? ("Adaptations")	*In Situ* Burn Potential	Comments and Considerations
Bouteloua eriopoda	Black grama	Graminoid	Yes; mildly fire tolerant	Moderate	Most fire-sensitive species of southwestern grasses; can be slow to recover, especially in dry periods or more arid locations; drought or dry periods after fire can seriously damage or eliminate black grama; recovery time is 2-3 years, probably under good conditions; moderate grazing after fire can be damaging, should be avoided until two consecutive years of good summer precipitation (Wright and Bailey, 1982)
Bouteloua gracilis	Blue grama	Graminoid	Yes; fire tolerant (recovers from rhizome, may be stimulated by fire)	High	Best when burned during dormant season, (esp. early spring); burning should be avoided during drought; recovery time is 1-4 years depending on conditions, better and faster recovery in wetter years; grama should not be grazed for 3-4 months after burning
Bouteloua hirsuta	Hairy Grama	Graminoid	Yes; fire tolerant (rhizomes)	High	Different fire recovery for different varieties/growth forms; fire damaging in dry years, better recovery in wet years; better recovery for dormant season burns (esp. early spring); recovery can take up to 3 years depending on conditions; grazing shortly after fire can be damaging
Bromus hordeaceus	Soft chess	Graminoid	Yes; fire tolerant	High	Introduced annual climax species in California Central Valley grasslands; fire has little direct affect on soft chess, may be unharmed or reduced by fire depending on other factors; season of burn and precipitation are important; in some cases, fire may favor annual forbs or native perennial grasses over introduced grasses

Table 5-1. Continued.

Scientific Name	Common Name	Growth Form	Fire Tolerant ? ("Adaptations")	*In Situ* Burn Potential	Comments and Considerations
Buchloe dactyloides	Buffalograss	Graminoid	Yes; fire tolerant (vegetative regeneration from below-ground parts, protected basal meristems, seeds protected in enclosed bur)	High	Fire generally favors or does not effect buffalograss; positive results observed in different seasons; burns during drought periods are more damaging, however; presence of woody species can increase chance of damage and mortality; backfires (slow moving fires) may be more damaging than headfires
Calamagrostis rubescens	Pinegrass	Graminoid	Yes; fire tolerant (rhizome)	High	Typically more abundant on burned sites; fires that consume the duff layer can kill rhizomes; may bloom profusely after fire and often invades burned areas
Calamovilfa longifolia	Prairie sandreed	Graminoid	Yes; fire tolerant, when dormant (rhizome)	Moderate-high	May increase or slightly decrease after early spring burning; fire effects may be more positive in tallgrass versus mixed-grass prairie; sandreed damaged by summer and fall burns in general; found on sandy soils, water stress may occur if litter layer is removed by fire
Callicarpa americana	American beautyberry	Shrub	Yes; fire adapted (rapid recovery/re-colonization after fire, mainly from seed bank)	High	Top-killed by low severity fires; killed by severe fires that consume organic soil layers and char roots; within one growing season abundance is greater post-fire
Calocedrus decurrens	Incense-cedar	Tree	No; highly susceptible to fire	None	Seedlings, saplings have flammable bark and foliage; considered a decreaser after fire; bark of mature trees thick enough to provide some fire protection; but damaged foliage, buds, and twigs are not replaced; susceptible to insects, pathogens after fire

Table 5-1. Continued.

Scientific Name	Common Name	Growth Form	Fire Tolerant ? ("Adaptations")	*In Situ* Burn Potential	Comments and Considerations
Carnegiea gigantea	Saguaro	Cactus	No; but some morphological features may aid survival (folded tissue and spines, thick cortex, some woody "bark" at base of plant)	None	Often mortally wounded by fire, but death may be delayed several years (impacts often underestimated for this and other cacti); absorption of rain after fire injury causes splitting, opening plant to insects and infection; fire may remove spines making plant vulnerable to herbivory; saguaro may be considered somewhat rare in parts of its range
Carya alba (tomentosa)	Mockernut hickory	Tree	No; extremely fire sensitive	None	Low insulation bark makes trees fire sensitive
Carya cordiformis	Bitternut hickory	Tree	No; fire susceptible	None	Thin bark makes trees fire sensitive
Carya glabra	Pignut hickory	Tree	Yes; marginally (larger trees with thick bark)	None	Less fire resistant than oaks, only larger trees very fire resistant
Carya illinoensis	Pecan	Tree	No; fire susceptible	None	Low insulating bark causes trees to be easily top-killed; heavy burns kill trees 25-30 cm dbh and wound others; very hot fires can kill nearly all mature trees
Carya ovata	Shagbark hickory	Tree	No; fire susceptible	None	Thin bark makes trees fire sensitive
Celtis laevigata	Sugarberry	Tree	No; fire sensitive	None	Thin bark, easily damaged by fire
Celtis occidentalis	Hackberry	Tree	No; fire sensitive	None	May be killed by fire; fire opens the way for wood decay organisms
Cercidium floridum	Blue paloverde	Tree	No; fire susceptible	None	Probably easily top-killed or killed by fire due to thin, photosynthetic bark; may sprout after fire; may die several months after burning; recovery may take 20 years for desert plant communities where paloverde occurs

Table 5-1. Continued.

Scientific Name	Common Name	Growth Form	Fire Tolerant ? ("Adaptations")	*In Situ* Burn Potential	Comments and Considerations
Cercocarpus betuloides	Birchleaf mountain mahogany	Tree/ Shrub	Yes; fire adapted (resprouts vigorously)	High	Top-killed by fire; high survival and fast recovery by sprouting; sprouts independent of growing season a few days post fire; sprouts grow quickly; excessive browsing can kill new sprouts
Cercocarpus montanus	True mountain-mahogany	Tree/ Shrub	Yes; fire adapted (sprouts vigorously)	Moderate-high	Top-killed by fire; sprouts vigorously; better recovery following dormant season burns; make take several years to recover fully
Chamaecyparis nootkatensis	Alaska cedar	Tree	No; fire sensitive	None	Thin bark, usually killed by fire; after fire in sub-alpine environments, Alaska cedar is slow to recover
Chamaecyparis thyoides	Atlantic white-cedar	Tree	Yes; fire sensitive yet very fire dependent (buried fire-activated seeds, fire removes competitors)	Low	Trees readily killed by fire; mature stands on wet sites in the South may survive low intensity fire; intense burns, especially during dry season or when water table is low, can kill buried seeds and ignite and consume upper layers of organic soils
Chrysothamnus nauseosus	Rubber rabbitbrush	Shrub	Yes; fire tolerant (sprouts from underground buds)	Moderate	May sprout after fire; sensitivity varies among subspecies; drought after fire causes mortality; biomass may remain low 1-3 years after fire then increase rapidly; sensitive to competition, released by fire; not long-lived and usually not a long-term dominant unless disturbance is frequent
Chrysothamnus viscidiflorus	Green rabbitbrush	Shrub	Yes; fire adapted (resprouts vigorously from underground buds)	Moderate-high	Sprouts after fire; increases in abundance after fire; drought after fire causes mortality; biomass may remain low 1-3 years after fire then increase rapidly; sensitive to competition, released by fire; not long-lived and usually not a long-term dominant unless disturbance is frequent

Table 5-1. Continued.

Scientific Name	Common Name	Growth Form	Fire Tolerant ? ("Adaptations").	*In Situ* Burn Potential	Comments and Considerations
Cladium jamaicense	Sawgrass	Graminoid (sedge)	Yes; fire adapted and dependent (deep rhizomes; insulated meristems; rapidly sprouts and grows quickly after fire)	High	Fires on dry soils can kill meristems; fires on very dry soils during droughts or in drained areas kill rhizomes and consume peat, eliminating sawgrass and lowering soil level; best to burn when standing water is present, this protects plants and peat soils and controls fire spread; maidencane (*Panicum*) can expand at the expense of sawgrass following peat burns; quickest sawgrass recovery and best growth seen following winter and spring burns; elevated water levels following fire can kill plants if new growth is submerged; head fires and spot fires recommended for prescribed burns, these are fast burning and less likely to dry-out and ignite elevated areas of organic soils
Coleogyne ramosissima	Blackbrush	Shrub	No; very susceptible to fire	None	Often killed by fire; if survives does not sprout; very slow to reestablish; burning blackbrush can destroy cryptogamic crust that stabilizes desert soils
Cornus florida	Flowering dogwood	Tree/ Shrub	Conflicting information	None (assumed)	Thin bark; even mature trees damaged/ killed by fire; however, species reported to be favored by fire (Wright and Bailey, 1982)
Cupressus macrocarpa	Monterey cypress	Tree	Yes; fire adapted (serotinous cones)	None-low	Most trees killed by fire; some larger trees might survive surface fire; seeds are protected by cones and released by fire in large numbers; fire followed by intensive grazing could eliminate cypress groves; occurs in only two natural stands in Monterey Co., California, but widely planted and naturalized; considered a rare species

Table 5-1. Continued.

Scientific Name	Common Name	Growth Form	Fire Tolerant ? ("Adaptations")	*In Situ* Burn Potential	Comments and Considerations
Cyrilla racemiflora	Cyrilla (titi)	Tree/ Shrub	Yes; fire adapted	Moderate-high	Top-killed by fire; high severity fire can kill shallow root system, killing the plant; peat burns are probably most destructive, otherwise plants usually regenerate
Dactylis glomerata	Orchard grass	Graminoid	Yes (assumed)	High	Introduced species; cool season grass (summer dormant); increases or remains stable after burning; often seeded in burned areas to control erosion; seeding not always appropriate depending on site, natural community type, and management goals
Danthonia intermedia	Timber oatgrass	Graminoid	Yes; moderately fire resistant	Moderate	May increase after fire; but can also take 5-10 years to return to preburn abundance or coverage; seasonal information unclear, described as both warm-season (dormant in winter) and cool season species, increases reported for both spring and summer burns
Danthonia spicata var. pinetorum	Poverty oatgrass	Graminoid	Yes (assumed); probably moderately resistant to fire	Moderate (assumed)	Little information available, probably similar to related species; may increase in cover following disturbance
Danthonia unispicata	Onespike oatgrass	Graminoid	Yes (assumed); probably moderately resistant to fire	Moderate (assumed)	Little information available; in one case, reported to increase in cover after spring burn
Deschampsia cespitosa	Tufted hairgrass	Graminoid	Yes; fire adapted (resprouts, leaf tufts protect basal buds)	Moderate-high	Survives all but the most severe fire; recovers within a few years
Elymus trachycaulus	Slender wheatgrass	Graminoid	Yes; fire adapted (reestablishes from tillers and soil-stored seeds)	High	Favored by summer or fall fires (dormant season); growing season (spring) fires damaging; bunch grass variety more sensitive to fire than short, sparse form; recovers or increases in abundance within 2 years after fire

Table 5-1. Continued.

Scientific Name	Common Name	Growth Form	Fire Tolerant ? ("Adaptations")	*In Situ* Burn Potential	Comments and Considerations
Ephedra nevadensis	Nevada ephedra	Shrub	Yes; fire adapted (resprouts from roots or crown)	Moderate	Recovers by vigorous sprouting; however, hot fires may eliminate regenerative structures; recovery by sprouting can be rapid; summer fires more damaging, limited recovery; increased precipitation prior to burning can contribute to increased stand flammability (fuel) by promoting the growth of annuals
Fagus grandifolia	American beech	Tree	No; fire intolerant	None	Thin bark; easily damaged/killed by fire; fire scars serve as entry sites for pathogens
Festuca idahoensis	Idaho fescue	Graminoid	No; fire sensitive	Low	Dense growth form may result in hotter fire and smoldering for several hours; may be killed by fire or reduced in abundance; severely damaged by summer or fall fires; more fire sensitive in drier regions, taking many years to recover; in wetter climates, can be more fire resistant and quicker to recover; spring burning best
Festuca ovina var. vivipara	Viviparous sheep fescue	Graminoid	Unknown	Unknown	No information available
Festuca scabrella	Rough fescue	Graminoid	Yes; moderate fire resistance	Moderate-high (conditional on ecotype)	Foothills ecotype (bunchgrass) is fire sensitive; plains ecotype (rhizomatous) is fire resistant; adapted to periodic burning; recovery within 2-3 years; growing season burns are more damaging; dormant season burns are best, especially in early spring; burning during dry periods can cause severe damage
Flourensia cernua	Tarbush	Shrub	Unknown	Unknown	Little information in FEIS. Recovery time of desert communities where tarbush occurs may be slow

Table 5-1. Continued.

Scientific Name	Common Name	Growth Form	Fire Tolerant ? ("Adaptations")	*In Situ* Burn Potential	Comments and Considerations
Fouquieria splendens	Ocotillo	Shrub	No; moderately fire sensitive (but can resprout from root crown)	None-low	Top-killed or killed by fire; degree of resprouting dependent on fire severity; bark contains resin and wax allowing it to burn easily; seedlings do not establish in burned areas; fires during dormant (leafless) season are less damaging
Fraxinus pennsylvanica	Green ash	Tree	Yes; limited fire resistance, but opportunistic (abundant sprouting after fire, colonizes by seed)	None-low	Thin bark; easily top-killed and/or girdled by fire; mature trees killed by even low severity ground fires; more fire tolerant during dormant season
Gaultheria shallon	Salal	Shrub	Yes; fire tolerant (resprouts after fire)	Low-moderate	Top-killed by fire; resprouting can be abundant or slow after fire; recovery probably within a few years depending on fire severity
Grayia spinosa	Spiny hopsage	Shrub	Yes; fire tolerant (resprouts after fire)	Unknown	Little information available; resprouts after top-kill; least susceptible to fire during summer dormancy
Helianthus maximiliani	Maximilian sunflower	Forb	Yes; good fire tolerance in dormant state (rhizomes)	High	Top-killed by fire; sprouts from rhizome after burning; enhanced by fire; increases in cover after burning; burning may be most beneficial/least damaging in spring
Hilaria jamesii	Galleta	Graminoid	Yes; fire tolerant (rhizomes)	High	Resprouts from rhizomes; recovery is usually complete within 2 years; burning during dry periods/drought can be damaging

Table 5-1. Continued.

Scientific Name	Common Name	Growth Form	Fire Tolerant ? ("Adaptations")	*In Situ* Burn Potential	Comments and Considerations
Hilaria mutica	Tobosagrass	Graminoid	Yes; fire tolerant (sod-forming grass with deep, well developed rhizome)	High	Very resistant to fire mortality; recovers quickly within first growing season; increases greatly after fire with sufficient precipitation, no increase seen in drier locations; a warm season grass often associated with floodplains, burning is best in early-spring when still dormant and soil is wet; generally burns hot but intensity of fire does not influence plant response; important reserve forage for livestock (cattle/horses) in drought years; broom-weed growing in tobosagrass areas can present fire hazard as it will burn and roll, spreading fire
Ilex glabra	Bitter gallberry	Shrub	Yes; fire survivor (rhizome, dormant buds)	High	Top-killed entirely or partially by fire, but recovers quickly from dormant buds and rhizomes; winter fires are less damaging
Ilex vomitoria	Yaupon	Shrub/ Tree	Yes; moderately fire adapted (sprouts vigorously, increased fruit production after fire)	Moderate (see caution)	Top-killed by mild fires; severe fires that consume organic soil layers cause mortality; may quickly recover/increase after fire; dense thickets or understories of yaupon promote fire intensity and spread
Juniperus ashei	Ashe juniper	Tree/ Shrub	No; not well adapted to fire	None	Thin bark easily damaged by fire, low-hanging foliage, nonsprouting; scorching 60 percent of the crown will kill most trees; tree-to-tree spread of fire will occur if they are less than 7.9 m apart
Juniperus deppeana	Alligator juniper	Tree	Yes; fire resistant, survive fires of even high intensity (prolific sprouter)	Low-moderate	Sprouts prolifically after above-ground vegetation is consumed; may quickly regain dominance on burned sites; small trees may be vulnerable to fire; larger trees, 79 cm dbh or larger, do not resprout and so may be killed; however, larger trees are probably top-killed less often; fire more damaging during hot, dry months

Table 5-1. Continued.

Scientific Name	Common Name	Growth Form	Fire Tolerant ? ("Adaptations")	*In Situ* Burn Potential	Comments and Considerations
Juniperus occidentalis	Western juniper	Tree	No; some larger trees moderately resistant to fire	None	Young trees have thin bark, easily killed by fire; does not resprout; larger trees with thicker bark and higher foliage may survive low-intensity fires
Juniperus osteosperma	Utah juniper	Tree	No; fire sensitive	None	Readily killed by fire; does not resprout; larger trees with thicker bark and higher foliage may survive low-intensity fires
Juniperus virginiana	Eastern redcedar	Tree	No; very fire sensitive	None	Thin bark and highly flammable foliage causes most trees to be killed; high flammability creates hazard during fires
Kobresia simpliciuscula	Simple kobresia	Graminoid	Unknown	Unknown	No information available
Koeleria macrantha	Prairie junegrass	Graminoid	Yes; fire resistant (coarsely textured foliage, small clump size, recolonizes by seed)	Moderate-high	A bunchgrass, but shows little change or increases slightly following fire; recovery is moderate to very rapid and occurs within 1-8 years by seed; late spring burns are most damaging; early spring, summer, fall, or winter fires are less so; junegrass may be favored by winter fire
Larix occidentalis	Western larch	Tree	Yes (thick bark with little resin, high and open branching habit, deep roots, low-flammability foliage, self-pruning of lower branches)	Moderate	Mature trees survive most fires; younger trees more sensitive; fire damaged trees may suffer insect attack and disease; surviving mature trees are seed source for rapid restocking; fire favors with larch seedling establishment
Larrea tridentata	Creosotebush	Shrub	No; poorly adapted to fire	None	Fire kills many creosotebush; little sprouting ability; very flammable foliage; summer fires more damaging; fire used to control, eliminate creosotebush
Leymus cinereus	Basin wildrye	Graminoid	Yes (coarse stems insulate buds, coarse leaves, sprouting)	High	Resprouts from basal buds and rhizomes; recovers quickly; burning during dormancy is best; early spring and fall burning is least damaging

Table 5-1. Continued.

Scientific Name	Common Name	Growth Form	Fire Tolerant ? ("Adaptations")	*In Situ* Burn Potential	Comments and Considerations
Liatris punctata	Blazing star	Forb	Yes; fire tolerant (rhizomes)	High	Top-killed but sprouts from rhizomes; thrives in open, sunny conditions created by fire; increases after fire; fire less damaging during dormant season; recovery hindered during dry periods/drought
Lithocarpus densiflora	Tanoak	Tree	Yes; fire adapted but sensitive (sprouting from dormant buds underground, extensive taproot system)	Moderate	Thin bark, so mostly top-killed by fire; re-sprouts with rapid and aggressive recovery after fire; may dominate sites where it was abundant within 3-6 years after burn; more susceptible when under a conifer over-story, less so when growing in open; fire-wounds can allow entry of insects and disease
Liquidambar styraciflua	Sweetgum	Tree	No; highly fire susceptible	None	Thin bark; trees susceptible to fire damage/mortality; usually top-killed; hot summer fire especially damaging; carbohydrate reserves of surviving trees become depleted, killing them
Liriodendron tulipifera	Tuliptree (yellow-poplar)	Tree	Yes; mature trees very fire resistant (thick bark)	Moderate	Trees 8-10+ cm dbh survive most fires; seeds stored in forest floor are released by fire; early post-fire colonizer
Magnolia grandiflora	Southern magnolia	Tree	Yes; moderately fire resistant (fire resistant cork under thin bark)	Low	Usually top-killed by fire; dominant in closed-canopy moist forest types where fire is infrequent or suppressed, otherwise it is replaced by a more open fire-tolerant community
Magnolia virginiana	Sweetbay	Tree/ Shrub	Yes; moderately fire resistant (fire resistant cork under thin bark)	Low	Mature trees can be top-killed by severe fire; dominant in closed-canopy moist forest types where fire is infrequent or suppressed

Table 5-1. Continued.

Scientific Name	Common Name	Growth Form	Fire Tolerant ? ("Adaptations")	*In Situ* Burn Potential	Comments and Considerations
Mahonia repens	Oregon-grape	Shrub	Yes (sprouts from dormant buds on rhizomes)	Moderate	Survives all but the most severe fires; recovers by sprouting; may increase in abundance several years after fire, but may decrease or be killed by severe fires; may be suppressed in areas seeded to grass following fire; this should be considered before seeding grasses in areas where Oregon-grape is important wildlife food
Myrica cerifera	Wax myrtle (southern bayberry)	Tree/ Shrub	Yes; fire survivor (hardy below-ground portions survive and sprout)	Moderate (see caution)	Easily top-killed by fire, but recovers quickly; extremely intense fire can kill root stock; winter fires are less damaging; caution–aromatic leaves are highly flammable, can make this species a fire hazard; caution–this species has nitrogen-fixing bacterial/root system, important community component on nutrient limited sites, consider this if severe fire may eliminate wax myrtle
Nyssa aquatica	Water tupelo	Tree	Unknown	None-low (assumed)	Not in FEIS database, assumed similar to black gum
Nyssa biflora	Swamp tupelo	Tree	Unknown	None-low (assumed)	Not in FEIS database, assumed similar to black gum
Nyssa sylvatica	Black gum (tupelo)	Tree	Yes; fire adapted (larger trees have thick bark)	None-low	Usually top-killed by fire; severe fires during dry periods/droughts kill or deform trees; prescribed fire is used to control/eliminate black gum
Opuntia humifusa	Prickly pear cactus	Cactus	No; fire sensitive	None	Killed by most fires; may survive light fires and sprout; mortality can be delayed for several years; fire wounds provide entry points for insects, disease

Table 5-1. Continued.

Scientific Name	Common Name	Growth Form	Fire Tolerant ? ("Adaptations")	*In Situ* Burn Potential	Comments and Considerations
Opuntia imbricata	Walkingstick cholla	Cactus	No; fire sensitive	None	Not in FEIS, information from Wright and Bailey (1982); similar to prickly pear; often killed by fire; fire-mortality can be delayed for several years; fire wounds provide entry points for insects, disease; may take 13+ years to recover after fire
Oryzopsis hymenoides	Indian ricegrass	Graminoid	Yes; fire adapted (reestablishes by off-site seed, stemmed habit, low culm density)	High	Little information available; recovery time is 2-4 years; fire in spring less damaging, summer fires can be more so
Ostrya virginiana	Eastern hophornbeam	Tree	No; fire sensitive	None	Severe fire can kill and permanently eliminate trees from burned area
Oxytropis sericea	Whitepoint locoweed	Forb	Unknown	Unknown	No information available in FEIS
Panicum virgatum	Switchgrass	Graminoid	Yes; fire adapted (sod-forming ecotype has rhizome 5-13 cm below soil surface, fire plays role in maintaining plant community)	High (conditional on ecotype)	Natural and prescribed grassland fires are low intensity and fast moving; high intensity and/or slow fires may be more damaging; burning in late spring when still dormant is best, get increased growth (moderately) and seedstalk density; summer growing season burns are most damaging, apical meristems are above soil surface and are consumed and carbohydrate reserves in rhizomes are low; drought/dry conditions cause reduced regrowth following burning and increased chance of injuring below-ground parts; sod-forming ecotypes are fire tolerant, some bunch-forming ecotypes are not
Pascopyrum smithii	Western wheatgrass	Graminoid	Yes; fire adapted (rhizomatous, new shoot growth stimulated by fire)	High	Regrows quickly after fire; abundance and density increase after fire; spring burns damage new growth

Table 5-1. Continued.

Scientific Name	Common Name	Growth Form	Fire Tolerant ? ("Adaptations")	*In Situ* Burn Potential	Comments and Considerations
Persea borbonia	Red bay	Tree/ Shrub	No; fire sensitive	None (see caution)	Top-killed or killed by all but mild fires; caution–aromatic leaves and dense shrubby growth form result in intense fires
Picea engelmannii	Engelmann spruce	Tree	No; very fire sensitive	None	Thin flammable bark; shallow roots; low-growing branches; dense stands; fire-damaged trees susceptible to pathogens
Picea rubens	Red spruce	Tree	No; fire sensitive	None	Thin bark, shallow roots, flammable needles, lack of self pruning causes trees to be easily killed; trees that survive fire die later if surface roots are exposed by the consumption of ground litter
Picea sitchensis	Sitka spruce	Tree	No; very fire sensitive	None	Thin bark and shallow roots; most trees die as a result of fire
Pinus albicaulis	Whitebark pine	Tree	No; fire sensitive (although open stands and little undergrowth provide some protection)	None	Thin bark, susceptible to heat damage
Pinus cembroldes	Mexican pinyon	Tree	Yes; mature trees with some fire tolerance	None-low	Thin bark, but mature trees survive light fires; infection with dwarf mistletoe increases flammability and fire hazard
Pinus contorta var. contorta	Shore pine	Tree	No; fire sensitive	None	Most trees killed by fire; foliage is flammable
Pinus contorta var. latifolia	Rocky Mountain lodgepole pine	Tree	Yes; fire sensitive, but serotinous cones	None	Thin bark, damaged by ground fires; injured trees susceptible to insects and fungi
Pinus contorta var. murrayana	Sierra lodgepole pine	Tree	No; fire sensitive	None	Thin bark, shallow roots increase fire sensitivity; susceptible to insects after fire

Table 5-1. Continued.

Scientific Name	Common Name	Growth Form	Fire Tolerant ? ("Adaptations")	*In Situ* Burn Potential	Comments and Considerations
Pinus echinata	Shortleaf pine	Tree	Yes; fire resistant (thick bark, high open crowns, seedlings with basal crooks can survive fire due to soil protected buds, dormant buds in winter that sprout following fire)	Moderate	Mature trees killed only by high severity crown fires; trees killed if 70 percent or more crown scorch; summer fires kill more trees than winter fires; stands with red-cockaded woodpeckers should not be burned if southern pine beetles present (fire damage can increase/induce infestation)
Pinus edulis	True pinyon pine	Tree	No; very fire sensitive	None	Most trees killed by fire; recovery can take decades
Pinus elliottii	Slash pine	Tree	Yes; fire resistant (thick scaly bark, high open crowns, mature trees often survive even if crown scorched)	Moderate, moderate-high (South Florida variety)	10-12 year old trees survive most fires, and are killed only by crown fires or if exposed or near-surface roots are scorched; young stands should not be prescribed burned until they are at least 5 years old or 3.7-4.6 m tall; South Florida variety more fire resistant than typical, its grass-stage seedlings have dense tuft of needles that protect the terminal bud, seedlings and saplings have thicker bark, and stands are often open (savanna-like)
Pinus engelmannii	Apache pine	Tree	Yes; mature trees are fire resistant (thick bark, deep roots)	Moderate-high	Mature trees endure most fires and become dominant when other species are eliminated; sites with intense grazing and fire suppression (creating dense, stunted forests) are more susceptible to fire damage
Pinus flexilis	Limber pine	Tree	Yes; fire adapted (thick bark in mature trees, grows in open stands, with sparse undergrowth)	Low	Young trees have thin bark, are usually killed by fire; mature trees have thick bark and survive low severity fires; fire less damaging on open stands with sparse undergrowth

Table 5-1. Continued.

Scientific Name	Common Name	Growth Form	Fire Tolerant ? ("Adaptations")	*In Situ* Burn Potential	Comments and Considerations
Pinus jeffreyi	Jeffrey pine	Tree	Yes; fire resistant (thick, corky bark, tall erect bole free of lower limbs, buds with thick scales)	Moderate-high	Mature trees can survive most fires, suffering only bole scorch; severe fires during high stress periods are fatal; very susceptible to insect attack for 2 years after fire
Pinus lambertiana	Sugar pine	Tree	Yes; fire resistant (thick bark, open stands)	High	Mature trees survive most fires; low susceptibility to insects after fire
Pinus leiophylla var. chihuahuana	Chihuahua pine	Tree	Yes; fire adapted (some serotinous cones, very good sprouting ability)	Moderate-high	Mature trees unaffected by most fires; sprouts vigorously after fire; dominates post-burn community; dwarf mistletoe infection can increase flammability/fire hazard
Pinus longaeva	Great Basin bristlecone pine	Tree	No; not fire resistant	None	Little information in FEIS, fire is rare in communities where this species occurs; not described as fire resistant or resilient in McCune (1988)
Pinus monophylla	Single leaf pinyon	Tree	No; very fire sensitive	None	Decades to 100+ years to reach recovery/ dominance after fire
Pinus monticola	Western white pine	Tree	Yes; somewhat resistant (thick bark, evanescent lower limbs, tree height)	None-low	Light fires result in kills of scattered trees, but survivors susceptible to pathogens; dense stands, lichen growth, resinous bark increases fire damage
Pinus muricata	Bishop pine	Tree	Yes; fire adapted (thick bark, some serotinous cones)	Low-moderate	Older trees with thick bark can survive fire, especially in open woodland or savanna-like habitats; when growing in dense stands, high chance of fire damage and lethal crown fires; does not resprout

Table 5-1. Continued.

Scientific Name	Common Name	Growth Form	Fire Tolerant ? ("Adaptations")	*In Situ* Burn Potential	Comments and Considerations
Pinus palustris	Longleaf pine	Tree	Yes; fire resistant (thick scaly bark, high open crowns, often grows in open stands with under-story grasses; grass stage seedlings with moist, dense tuft of needles that protect the bud, buds also have protective scales and heat reflective surface)	High	Saplings 3 m tall are very fire tolerant; mature trees 25 cm dbh or greater survive all but the most severe fires, many will even survive high severity crown fires
Pinus ponderosa var. ponderosa	Pacific ponderosa pine	Tree	Yes; fire resistant (thick bark, open crown, self-pruning, insulated bud scales, light lichen growth)	High	Mature trees survive most fires; crown damage is most severe in spring and early summer; large trees can often survive crown scorch if their buds are not heat killed; trees become dormant in fall and are more fire-resistant; open park-like stands are less susceptible to fire than stands with dense understory
Pinus ponderosa var. scopulorum	Interior ponderosa pine	Tree	Yes; fire adapted (resinous needles; thick, exfoliating bark; self-pruning branches; deep roots; open crown; insulated bud scales)	High	Mature trees can survive extensive crown scorch when dormant; overall, burning is least damaging in fall when trees are dormant, most harmful in early spring; site quality and stand density effect survival; open stands are more fire tolerant; trees with heavy cone crops are more prone to fire mortality because resources are diverted to cone development rather than recovery
Pinus rigida	Pitch pine	Tree	Yes; fire resilient and dependent (thick bark, extensive roots, basal sprouts, serotinous cones, seedlings with basal crooks can survive fire due to protected buds)	Moderate-high	Trees have low-moderate fire tolerance, but regenerate quickly; mature trees survive most fires; hot dry season fires can kill entire tree; burns are risky if stands are less than 3.7 m tall; trees vary in fire tolerance and adaptations in different regions and community types

Table 5-1. Continued.

Scientific Name	Common Name	Growth Form	Fire Tolerant ? ("Adaptations")	*In Situ* Burn Potential	Comments and Considerations
Pinus quadrifolia	Parry pinyon	Tree	No; fire sensitive	None	Thin bark, low branches, no resprouting ability
Pinus radiata	Monterey pine	Tree	Yes; fire adapted (serotinous cones, few branches near ground, leaves have low volatility)	Moderate	Most mature trees survive fire unless crown scorch is severe; can be damaged by heat even if not burned
Pinus sabiniana	Gray pine	Tree	Yes; fire adapted (thick bark, self-pruning limbs, seed germination increased by fire)	None-low	Highly flammable needles, high resin and pitch content makes gray pine susceptible to fire damage; significant number of trees killed by mod-severity fires, only larger trees survive; susceptible to insects after severe scorching
Pinus serotina	Pond pine	Tree	Yes; well-adapted to fire (trees very fire resistant, serotinous cones open after fire, fire greatly improves seedling establishment, sprouts and reforms crown following top-kill)	Moderate-high	Mature trees survive most wet season fires, even high severity ones which cause defoliation; fire is essential for adequate generation of pond pine; frequent or high severity fire in dry periods can kill mature trees and seeds
Pinus strobus	Eastern white pine	Tree	Yes; moderately fire resistant (thick bark, branch free boles, moderately deep roots)	Low	Large trees (18+ m) can withstand fires of low-moderate severity; total scorching of foliage kills trees; deep-burning ground fires can cause severe root injuries and death
Pinus taeda	Loblolly pine	Tree	Yes; fire resistant (thick bark, high crowns, roots insulated by mineral soil; dormant buds in winter that sprout following fire)	Moderate	Trees >10 cm dbh may survive high severity fire; crown fires in mature trees top kill them and destroy seeds; exposed roots more likely to result in tree injury/ mortality; summer fires kill more trees than winter fires
Pinus torreyana	Torrey pine	Tree	No; fire intolerant	None	Low severity fires kill trees up to 52 cm dbh even if no crown damage; severe fires kill trees of all sizes

Table 5-1. Continued.

Scientific Name	Common Name	Growth Form	Fire Tolerant ? ("Adaptations")	*In Situ* Burn Potential	Comments and Considerations
Platanus occidentalis	American sycamore	Tree	No; fire sensitive	None	Thin bark, shallow roots, easily damaged by fire
Poa secunda	Sandberg bluegrass	Graminoid	Yes; fire tolerant (sparse litter, small bunch size)	High	Usually unharmed by fire; can see increases after fire, favored by fire; burns are less damaging during dormancy; plants may be damaged by fire if litter has accumulated at the base of the plant or if plants are old and pedestaled; large bunches more susceptible to fire than small ones
Polystichum munitum	Western sword fern	Fern	Yes; fire adapted (resprouts from stout, woody rhizomes; spores)	Low	Can survive intense fires; generally top-killed, but takes several years before above-ground vegetation recovers fully; can be greatly reduced and slow to recover (15+ years) after some severe fires
Populus deltoides	Eastern cottonwood	Tree	Yes (older mature trees have bark up to 10 cm thick)	None-low (older, larger trees)	Trees less than 15-20 years old are fire susceptible; trees 15-25 cm dbh killed by moderate severity fires; mature trees may be scarred or wounded, providing entry sites for pathogens
Populus fremontii	Fremont cottonwood	Tree	Yes; somewhat fire adapted (sprouting)	None	Often killed by fire, especially hot fires; sprouting ability declines with age; cotton-wood often replaced by non-native saltcedar (*Tamarix sp.*) following fire/ disturbance in riparian areas of the southwestern U.S.
Populus tremuloides	Quaking aspen	Tree	Yes; fire adapted (sprouts rapidly, stands are self-thinning; generally moist fuel within aspen stands)	Moderate	Fire sensitive, due to thin bark; usually top-killed by severe fire; however, highly competitive on burned sites; often domi-nates plant community after fire; new stands can develop within 10 years after fire; over-browsing of sprouts by deer/elk can limit post-fire regeneration in some areas

Table 5-1. Continued.

Scientific Name	Common Name	Growth Form	Fire Tolerant ? ("Adaptations")	*In Situ* Burn Potential	Comments and Considerations
Populus trichocarpa	Black cottonwood	Tree	Yes; somewhat (10 to 20+ year old trees may have bark thick enough to afford some fire protection)	None-low (perhaps for older, larger trees)	Highly susceptible to fire due to thin bark and shallow root system; mature trees may survive moderately intense fires, but all sizes killed by high intensity fire; can sprout following top-kill, but not well-documented; fire wounds provide entry sites for pathogens which can kill tree
Prosopis glandulosa var. glandulosa	Honey mesquite	Tree/ Shrub	Yes; fire adapted (underground buds, resprouts vigorously after fire)	Moderate	Trees 3.5 years old or older very tolerant of intense fire; younger trees also quite tolerant; plants stressed by drought or other factors are more sensitive to fire damage
Prosopis glandulosa var. torreyana	Western honey mesquite	Tree/ Shrub	Yes; fire adapted (dormant buds underground, resprouts after fire)	Low	Older, larger trees more tolerant of fire; recovers slowly, sprouting and growth after fire are much less vigorous than for honey mesquite (above); in riparian areas, can be replaced by non-native saltcedar (*Tamarix sp.*) after fire or other disturbance
Prunus virginiana	Chokecherry	Tree/ Shrub	Yes; well adapted to fire (resprouts from root crown and rhizomes)	High	Top-killed but sprouts vigorously; typically increases after fire; burns least damaging during dormancy and under high soil moisture conditions; after burning, coverage may show an initial decline, but by the 2nd postfire season, coverage is greater than prefire
Pseudoroegneria spicata	Bluebunch wheatgrass	Graminoid	Yes; fire tolerant (coarse leaves and large stems, basal buds, rhizomes)	Moderate	Survives most fires, regenerates vegetatively; plant response varies, may increase or decrease in abundance and dominance in the first few years after fire; sensitive to defoliation (by fire, cutting, etc.) in late spring when major growth occurs; burning probably less damaging during dormant season

Table 5-1. Continued.

Scientific Name	Common Name	Growth Form	Fire Tolerant ? ("Adaptations")	*In Situ* Burn Potential	Comments and Considerations
Pseudotsuga macrocarpa	Big cone douglas fir	Tree	Yes; fire adapted (resprouts from branches or bole, dormant buds are insulated by thick bark)	None-low	Pole and saw-timber sized trees are fire resistant; recovers by sprouting; natural regeneration can take decades, however
Pseudotsuga menziesii var. glauca	Rocky Mountain douglas-fir	Tree	Yes; older, larger trees (40+ years) are fire tolerant (thick, corky bark)	None	Low growing branches and flammable foliage, susceptible to crown fires; fire more severe in dense stands; fire damaged trees are subject to insect attack; stands with dwarf mistletoe at greater risk from fire
Pseudotsuga menziesii var. menziesii	Coastal douglas fir	Tree	Yes; fire resistant (thick, corky bark on lower bole and roots; majority of foliage in older, larger trees is in upper bole, making it difficult for fire to reach crown	Low	Trees 100+ years old survive most fires; crown scorching from summer fires is more damaging than late summer or fall fires because more buds are killed. Recovers by seedling establishment, probably slow
Purshia glandulosa	Desert bitterbrush	Shrub	Yes; fire adapted (resprouts quickly from roots)	High	After complete top-kill, sprouts frequently and abundantly, even during dry periods; spring burns less damaging than fall burns, summer burns very damaging; decumbent growth forms resprout and layer more successfully than erect growth forms; freely interbreeds with antelope bitterbrush causing reduced sprouting, little sprouting seen in areas dominated by antelope bitterbrush
Purshia tridentata	Antelope bitterbrush	Shrub	Yes; fire adapted (regenerates by sprouting or from off-site seed dispersed by rodents)	Low-moderate	Killed outright or top-killed by fire; sprouting more successful and lower mortality observed for the decumbent growth form as compared to erect form; plants at higher elevation may respond more favorably to fire; good soil moisture during and after fire is beneficial; does more poorly after fire in juniper communities, possibly due to grazing by rodents/rabbits

Table 5-1. Continued.

Scientific Name	Common Name	Growth Form	Fire Tolerant ? ("Adaptations")	*In Situ* Burn Potential	Comments and Considerations
Quercus agrifolia	Coast live oak	Tree/ Shrub	Yes; outstanding fire resistance (evergreen leaves, thick bark, protected roots, vigorous sprouting)	Moderate-high	Most fire resistant of all California oaks, larger trees are not top-killed by severe fire; trees often survive crown fires; burning least harmful in winter, most damaging in fall; crown densities return to 80 percent cover within 10 years on favorable sites; damage and mortality greater on sites with or adjacent to shrubby undergrowth, such as chaparral communities
Quercus alba	White oak	Tree	Yes; moderately fire resistant (rough scaly bark is fire resistant)	Low	Stands with high vigor and low density result in fewer damaged/ killed trees; dormant season fires are less damaging
Quercus chrysolepis	Canyon live oak	Tree/ Shrub	Yes; fire resistant (resprouts prolifically, evergreen leaves)	Low	Generally top-killed by fire; may be killed or severely damaged (girdled) by some light fires (probably because longer burn duration); dead, flaky outer bark is extremely flammable; trunk is sensitive to heat damage; winter fires, during non-growing season are least damaging; basal scars allow insect and fungal invasions
Quercus coccinea	Scarlet oak	Tree	No; low fire resistance	None	Thin bark, even low severity surface fires can cause severe basal damage and high mortality
Quercus douglasii	Blue oak	Tree	Yes; fire adapted (resprouts)	Moderate	Mature trees resistant to quick heat of grassland fires, but are top-killed or killed by the sustained heat of chaparral fires; mature trees that are crown scorched during grassland fires replace leaves with no observed negative effects; there can be differences in fire response for different blue oak ecotypes; species is generally "adapted" to cool or low-intensity ground-surface fires of grassland communities

Table 5-1. Continued.

Scientific Name	Common Name	Growth Form	Fire Tolerant ? ("Adaptations")	*In Situ* Burn Potential	Comments and Considerations
Quercus falcata	Southern red oak	Tree	No; fire susceptible	None	Thin bark makes this species more susceptible to fire than many other oaks
Quercus gambelii	Gambel oak	Tree	Yes; extremely fire tolerant (resprouts vigorously, protected lignotubers and rhizome)	Moderate-High	Seldom killed by fire, only likely to be killed by extremely severe fire; sprouting is extremely rapid after disturbance; recovery may take 6-40 years; recovery generally better on lower elevations on warmer, south-facing slopes; summer burns during rapid growth period are most damaging
Quercus garryana	Oregon white oak	Tree/ Shrub	Yes, fire resistant and dependent	Moderate	Crown fires kill most trees; mature trees generally survive moderate severity ground fires; younger trees vigorously sprout after top-kill; occupies fire "dependent" savanna-like woodlands with understory grasses
Quercus grisea	Gray oak	Tree/ Shrub	Unknown	Unknown	Little information available; probably top-killed by fire; shrubby growth forms may resprout after fire
Quercus havardii	Sand shinnery oak	Tree/ Shrub	Yes; very fire tolerant (sprouts from underground stems or rhizomes)	Moderate	Sprouts vigorously after fire, grows in savanna-like setting with understory grasses; no acorns produced first year after fire, this can effect wild turkey and lesser prairie chicken populations over the short term
Quercus ilicifolia	Bear oak	Shrub/ Tree	Yes; fire adapted; fire favors this species (Wright and Bailey, 1982)	Moderate-high	Not in FEIS database; major understory shrub in Pine Barrens communities dominated by pitch pine, assumed similar fire tolerance
Quercus laurifolia	Laurel oak	Tree	No; fire intolerant	None	Thin bark, poor pruner, easily damaged by fire; dry-season surface fires in hydric hammock habitats can burn the organic soil down to bedrock

Table 5-1. Continued.

Scientific Name	Common Name	Growth Form	Fire Tolerant ? ("Adaptations")	*In Situ* Burn Potential	Comments and Considerations
Quercus lobata	Valley oak	Tree	Yes; fire resistant (thick, furrowed bark; re-sprouts)	Moderate	Larger trees (50+ cm dbh) are fire resistant and survive moderate severity fires; those with extensive internal rot may be killed by hot surface fires; crown fires kill many trees; younger top-killed trees sprout after fire; recovery may be impaired during drought conditions; naturally occurs in savanna-like setting with understory grasses, invasion of conifers, shrubs, etc. increases fire severity and impact
Quercus macrocarpa	Bur oak	Tree	Yes; fire resistant (thick bark, resprouts)	Moderate	Larger trees often survive fire, but may be killed by severe fire; sprouts vigorously after fire, even if severely damaged; may be favored by fire, grows in some fire tolerant savanna and pine barrens communities
Quercus marilandica	Blackjack oak	Tree	Yes; occurs in some fire prone/dependent communities	Low	Usually top-killed by fire; trees die entirely if root stock is burned or scorched
Quercus nigra	Water oak	Tree	No; fire sensitive	None	Thin bark, trees top-killed or killed by light fires; large trees that survive fire have increased incidence and spread of pathogens
Quercus pagoda	Cherrybark oak	Tree	Unknown	Unknown	Not in FEIS database
Quercus rubra	Northern red oak	Tree	Yes; somewhat tolerant of periodic fire	Low	Tight solid bark makes species more susceptible to fire than other oaks; stands with high vigor and low density result in fewer damaged/ killed trees; dormant season fires are less damaging
Quercus stellata	Post oak	Tree	Yes; moderately fire resistant (medium bark thickness)	None-low	Slightly more fire resistant than southern red oak
Quercus texana	Nuttall oak	Tree	Unknown	Unknown	Not in FEIS database

Table 5-1. Continued.

Scientific Name	Common Name	Growth Form	Fire Tolerant ? ("Adaptations")	*In Situ* Burn Potential	Comments and Considerations
Quercus turbinella	Turbinella oak (Shrub live oak)	Tree	Yes; fire adapted (resprouts)	Moderate-High	Difficult to kill by burning; resprouts vigorously; more susceptible to fire on drier, sedimentary/volcanic substrates, less so on thin, rocky soils with good moisture; recovery time is 4-8+ years, with some increases in cover observed within 5 years
Quercus vaccinifolia	Huckleberry oak	Shrub	Yes; fire adapted (resprouts)	Low-moderate (See: Caution)	Top-killed by fire but resprouts; recovery time not documented; leaves are resinous and flammable; low spreading growth form encourages fire; this species can act as a fire hazard/ladder fuel--aids in the spread of surface and crown fires
Quercus velutina	Black oak	Tree	Yes; moderately fire resistant (thick bark)	Low	Trees to 10.2 cm dbh easily top-killed; severe fire may top-kill large mature trees; basal wounding common; multi-stemmed forms (clumps) more susceptible to fire damage than single stem forms
Quercus virginiana	Live oak	Tree	No; fire sensitive	None	Thin bark; fire top-kills most live oak; kills many out-right
Quercus wislizenii	Interior live oak	Tree/ Shrub	Yes; fire-resistant (ever-green leaves, resprouts)	None-low	Thin bark and small diameter trunk; trunk and crown are extremely sensitive to fire; generally top-killed by fire; multi-stemmed growth form may be more fire tolerant; spring and winter fires less damaging; new sprouts are extremely vulnerable to herbivores (goats, deer) after fire
Rhododendron macrophyllum	Pacific rhododendron	Tree/ Shrub	Yes; fire adapted (resprouts)	None	Survives light fires but is very scarce after more severe fires; generally decreases in abundance and cover after fire, for at least several years; often grows on infertile soils that can be damaged by fire (loss of nutrients)

Table 5-1. Continued.

Scientific Name	Common Name	Growth Form	Fire Tolerant ? ("Adaptations")	*In Situ* Burn Potential	Comments and Considerations
Sabal palmetto	Cabbage palm	Tree	Yes; fire resistant (fire resistant trunk, well-protected deeply imbedded terminal bud held aloft on trunk, may form pure stands following frequent burning and invade mixed species areas)	High	Survives most fires, receiving only superficial damage; if organic soils are consumed by severe fire (such as on some wetland sites) trees may die from root damage or lack of mechanical support; crown fires should be avoided when burning cabbage palm stands
Salix lasiandra	Pacific willow	Tree	Yes (resprouts)	Moderate-high	Top-killed by fire but resprouts prolifically; frequency and cover usually increase after fire, but can be several years to regain full height; extreme fire can consume organic soils and char roots, killing the trees; exposed roots increase vulnerability during fire
Salix nigra	Black willow	Tree/ Shrub	Yes; mildly fire adapted, but also fire susceptible	Low	Low severity fires can wound trees; high severity fires can kill entire stands; prescribed burning is used to control/inhibit willow and maintain tallgrass prairies; fire also used to control willow invasion of some wetland types
Salsola kali	Russian thistle (tumbleweed)	Forb	Yes; adapted to and dependent on disturbance such as fire	Moderate-high (See: Cautions)	Killed by fire, but colonizes and dominates burned sites quickly, within 1-3 years; considered a fire hazard, burns easily and spreads fire by rolling, can carry fire across fire breaks
Sarcobatus vermiculatus	Black greasewood	Shrub	Yes; fire tolerant (resprouts vigorously)	High	Only slightly harmed or undamaged by fire, rarely killed; may increase in growth rate after fire
Sassafras albidum	Sassafras	Shrub/ Tree	Yes; moderately fire resistant, fire resilient	High	Injured and top-killed by moderate-high severity fire; rapid recovery through sprouting and seeds; plant density increased by fire

Table 5-1. Continued.

Scientific Name	Common Name	Growth Form	Fire Tolerant ? ("Adaptations")	*In Situ* Burn Potential	Comments and Considerations
Schizachyrium scoparium	Little bluestem	Graminoid	Yes; fire adapted (buried rhizome, buds inside insulated crowns, increased seed germination after fire, fire plays role in maintaining plant community)	High	Natural and prescribed grassland fires are low intensity and fast moving, high intensity and/or slow fires may be more damaging; burning in late spring when still dormant is best, get vigorous new growth and increase in flower stalks; summer growing season burns most damaging, apical meristems are 2-3 cm above soil surface and are consumed; drought/dry conditions cause reduced regrowth following burning and increased chance of injuring buds which are below the soil surface
Scirpus americanus (olneyi)	Olney threesquare (American bulrush)	Graminoid	Yes; fire tolerant (deep-buried rhizome)	High	Extreme peat fires can scorch or consume rhizomes, killing the plant; rhizomes occur deeper than those of saltmeadow cordgrass (*Spartina patens*), Olney threesquare suffers less mortality than cordgrass during burns on drained or dry soils, may expand at the expense of cordgrass following fire in mixed species marshes; prescribed burning is used to maintain brackish Olney threesquare marshes, keeping community from succeeding to saltmeadow cordgrass; can burn Olney threesquare during all seasons (assuming soil is submerged or wet); standing water not necessary for bulrush survival during burning, can burn when water table is just below the soil surface
Scirpus californicus	Bulrush	Graminoid	Yes (assumed)	High (assumed)	Not in FEIS; assumed similar to other bulrushes, with deep-buried rhizome; probably best to burn when standing water or saturated soils present, and when plants are dormant

Table 5-1. Continued.

Scientific Name	Common Name	Growth Form	Fire Tolerant ? ("Adaptations")	*In Situ* Burn Potential	Comments and Considerations
Sequoia sempervirens	Redwood	Tree	Yes; fire adapted and resilient (thick bark, great height, sprouts from dormant buds under bark along the bole and branches)	Moderate-high	Mature trees very resilient to fire; survives most fires but severe burns can cause top-kill (especially in smaller trees); survives crown scorch; after crown fires, resprouts from dormant buds under the bark along the bole and branches; fire wounding can provide entry to pathogens
Sequoiadendron giganteum	Giant sequoia	Tree	Yes; fire resistant (rapid growth, fire resistant bark, elevated canopies, self-pruning lower branches, latent buds, serotinous cones)	Moderate-high	Mature trees resistant to fire, little mortality after fire; severe fire may scorch or burn crown; fire wounding can provide entry to pathogens
Serenoa repens	Saw palmetto	Shrub	Yes; exceptionally fire resistant (rhizomes survive fire and have large carbohydrate reserves, plants resprout immediately after fire, can break winter dormancy to resprout and even flower and fruit after fire)	High (See: Caution)	Most fires defoliate and top-kill plants, but they recover quickly; unusually severe fires that consume organic soils can expose and/or kill the rhizomes preventing regeneration; recovers more quickly from winter burns than from summer burns; caution–very flammable foliage, overgrown saw palmetto understories are fire hazards, tall dense stands can carry fire into the crowns of pine trees
Shepherdia argentea	Silver buffaloberry	Tree/ Shrub	Yes; some fire tolerance (resprouts)	Low	Fair fire tolerance in dormant state; recovers by sprouting; typically killed by severe fires; abundance can be greatly reduced by severe fire
Solidago missouriensis	Prairie goldenrod	Forb	Yes; fire adapted (persistent rhizomes/ caudex, seed colonizes bare ground created by fire)	High	Good fire tolerance in dormant state, especially on moister sites; typically increases after fire; some studies, however, indicate no effect or some negative effects after fire

Table 5-1. Continued.

Scientific Name	Common Name	Growth Form	Fire Tolerant ? ("Adaptations")	*In Situ* Burn Potential	Comments and Considerations
Sorghastrum nutans	Indiangrass	Graminoid	Yes; fire adapted (protected rhizome, fire plays role in maintaining plant community)	High	Natural and prescribed grassland fires are low intensity and fast moving, high intensity and/or slow fires may be more damaging; burning in late spring when dormant is best, causing increased plant abundance; burning in other seasons can increase flowering stems, but can also decrease abundance; if not burned for several years, Indian grass is replaced by bigstem bluegrass
Spartina pectinata	Prairie cordgrass	Graminoid	Yes; fire tolerant (deep buried rhizomes)	High	Increased vegetative production and flowering on burned sites; survival and vegetation recovery are greater for burns during the wet season, when standing water is present; vegetation damage is minimized for burns when plants are dormant; lack of burning may result in invasion by willow and other species, at the expense of prairie cordgrass; (additional information from Johnson and Knapp, 1995)
Sporobolus cryptandrus	Sand dropseed	Graminoid	Yes; fire tolerant (loosely clustered, coarse culms, recovers by stored seed)	Moderate-high	Fire usually consumes dry vegetation to ground level; species favored by spring fires in some locations; good recovery in wetter years; however, several studies show reductions in sand dropseed several years after burning

Table 5-1. Continued.

Scientific Name	Common Name	Growth Form	Fire Tolerant ? ("Adaptations")	*In Situ* Burn Potential	Comments and Considerations
Sporobolus heterolepis	Prairie dropseed	Graminoid	Yes; fire "increaser"	High	Vegetation sprouts and increases in flower production, height, and cover after spring or winter (dormant season) fires, but decreases after summer or fall (growing season) fires; in some areas, burning in early spring has been recommended, after plants have dried out but while soils are still frozen; timing of burn important–burning too early may expose soils to late winter storms, increasing erosion risk, burning too late may damage emerging growth
Stipa columbiana	Columbia needle grass	Graminoid	No; fire sensitive (but few culms per clump make it less so)	Low	Perennial needlegrasses (*Stipa spp.*) are among the least fire resistant of bunchgrasses; Columbia needlegrass is slightly to moderately damaged by fire; larger plants are more susceptible to fire; damage probably most severe in midsummer, least in late spring and fall; abundant rainfall before and/or after fire can improve recovery; close proximity of shrubby plants (ex. sagebrush) increases fire damage; overall, if not killed outright, recovery is relatively slow, 3-5 years
Stipa comata	Needle and thread grass	Graminoid	No; fire sensitive	None-low	Perennial needlegrasses (*Stipa spp.*) are among the least fire resistant of bunchgrasses; larger plants are more susceptible to fire; damage is most severe in midsummer, least in late spring and fall; damage is more severe during dry periods, abundant rainfall before and/or after fire can improve recovery; this species is generally killed or severely damaged; if not killed, recovery is slow, 3-8 years

Table 5-1. Continued.

Scientific Name	Common Name	Growth Form	Fire Tolerant ? ("Adaptations")	*In Situ* Burn Potential	Comments and Considerations
Stipa (Nassella) pulchra	Purple needlegrass	Graminoid	Yes; assumed fire tolerant (Wright and Bailey, 1982)	Unknown	Not in FEIS, though mentioned under other species; native perennial grass of the California Central Valley, now a "remnant" community type; may be well-adapted to fire; fire may favor this species over introduced annual grasses in some cases
Stipa thurberiana	Thurber needle grass	Graminoid	No; fire sensitive	None-low	Perennial needlegrasses (*Stipa spp.*) are among the least fire resistant of bunch-grasses; Thurber needlegrass is slightly to severely damaged by fire; larger plants are more susceptible to fire; damage is most severe in midsummer, least in spring and fall; abundant rainfall before and/or after fire can improve recovery; close proximity of shrubby plants (ex. sagebrush) increases fire damage; overall, if not killed outright, recovery is relatively slow, 3+ years; grazing can impair recovery
Stipa (Nassella) viridula	Green needlegrass	Graminoid	Yes; somewhat or "variably" tolerant of fire	Low-moderate	Perennial needlegrasses (*Stipa spp.*) are among the least fire resistant of bunch-grasses; larger plants are more susceptible to fire; damage is probably most severe in midsummer, least in late spring and fall; burning during drought years is more damaging, abundant rainfall before and/or after fire can improve recovery; overall, green needle grass is damaged or killed by fire and reduced over the short-term; recovery or increased abundance may occur in 2+ years
Symphoricarpos albus	Common snowberry	Shrub	Yes; fire resistant (resprouts from rhizomes and root crown)	Moderate	Survives low to moderate intensity fires, may not survive severe fires; sprouts vigorously from rhizomes; may increase after fire; fire on dry sites may be more damaging

Table 5-1. Continued.

Scientific Name	Common Name	Growth Form	Fire Tolerant ? ("Adaptations")	*In Situ* Burn Potential	Comments and Considerations
Symphoricarpos occidentalis	Western snowberry	Shrub	Yes; fire resistant (resprouts from rhizomes and root crown)	Moderate	May be top-killed or killed by severe fires; sprouts vigorously and recovers quickly; typically increases after infrequent burning; spring fires may be less damaging than fall burning
Taxodium ascendens	Pondcypress	Tree	Yes; fire resistant/adapted (shaggy bark, adventitious branching and root sprouting after fire, seed production possibly stimulated by fire) (Ewel, 1993)	Low	Not in FEIS database; top-killed by severe fire; less likely to occur on deep peat soils, roots possibly more insulated by mineral soils; would be best to burn when standing water present (Ewel, 1995)
Taxodium distichum	Baldcypress	Tree	Conflicting information, fire sensitive yet mildly fire resistant	None-low	Mature trees top-killed, root girdled by fire; dry-season fires may kill most cypress, even large mature trees, especially if peat burns; willow and other hardwoods may invade following fire, especially if cypress killed; best to burn when standing water present (additional information from Ewel, 1995)
Tetradymia spinosa	Spiny horsebrush	Shrub	Yes; fire resistant (sprouts from rhizomes)	Moderate-high	Dormant most of the year in dry ranges where it occurs; burns rapidly with little heat transfer to roots; sprouts with rapid regrowth; recovers in 2-5 years, may surpass pre-fire abundance; in addition to sprouting, has dynamic postfire seedling establishment
Thuja plicata	Western red cedar	Tree	Yes; somewhat fire resistant due to large size	None	Thin bark, shallow root system, low dense branching habitat, and highly flammable foliage make trees susceptible to fire damage, larger trees may survive some fires; commonly killed by root charring or crown scorch; burned roots can lead to fungal infection, chronic stress, and growth losses
Tilia americana	American basswood	Tree	No; fire sensitive	None	Thin bark, shallow roots cause trees to be damaged/killed by fire

Table 5-1. Continued.

Scientific Name	Common Name	Growth Form	Fire Tolerant ? ("Adaptations")	*In Situ* Burn Potential	Comments and Considerations
Tsuga canadensis	Eastern hemlock	Tree	No; fire sensitive	None	Thin bark, shallow roots, low branches, and heavy litter make trees very susceptible to injury/death, even from low intensity fires
Tsuga heretophylla	Western hemlock	Tree	No; fire sensitive	None	Thin bark, shallow roots, highly flammable foliage, low-branching habitat, dense growth, and branches covered with lichens makes trees vulnerable to fire; burning commonly kills western hemlock trees; fire wounds provide entry to pathogens
Tsuga mertensiana	Mountain hemlock	Tree	Yes; somewhat resistant (thick bark)	None	Low-hanging branches, flammable foliage, dense growth make trees vulnerable to fire damage; easily killed by fire; often killed by root charring or crown scorch; fire wounds provide entry for pathogens/insects; slow to recover after fire
Typha spp.	Cattail	Graminoid	Yes; fire tolerant (buried rhizome, thick stem bases are slow to dry out and do not burn easily)	High	Can burn cattail when the marsh is drained or dry as long as organic soil is not consumed; peat burns can kill *Typha*; burning in winter when rhizomes are buried in ice or in frozen soil can ensure plants are not killed, snow buildup over ice also protects the plant stalks; burning during the dormant season (fall, winter) may be less damaging and result in quicker recovery; however, burning can be conducted at other times of year also; flooding (submerging) cattail stubble after fire kills the plants; prescribed burning is used in cattail marshes to improve wildlife use (food, cover)
Ulmus alata	Winged elm	Tree	Unknown	Unknown	Not in FEIS database
Ulmus americana	American elm	Tree	No; easily damaged by fire	None	Top-killed or killed outright by fire; fire wounds provide entry sites for pathogens

Table 5-1. Continued.

Scientific Name	Common Name	Growth Form	Fire Tolerant ? ("Adaptations")	*In Situ* Burn Potential	Comments and Considerations
Umbellularia californica	California bay	Tree/ Shrub	Yes (resprouts rapidly)	Moderate (assumed)	Thin bark; easily top-killed but trees rapidly recover through sprouting; flowers often appear on first year sprouts
Vaccinium pallidum	Blue Ridge (hillside) blueberry	Shrub	Yes; fire adapted (protected rhizome, buds resistant to heat damage, rapid recovery after fire)	High	Vegetation increases following fire; persists on sites with soil contamination, increases following fire on these sites even though other fire tolerant species do not
Vaccinium scoparium	Grouse whortleberry	Shrub	Yes; fire resistant (sprouts from rhizomes)	None-low	Moderately fire resistant, but seriously damaged or killed by hot or severe fires due to shallow rhizomes; berries are important wildlife food source
Viburnum acerifolium	Mapleleaf viburnum	Shrub	No; fire sensitive	None	Top-killed by fire; fire is harmful; vegetation frequency and biomass decreases after fire
Yucca baccata	Banana yucca	Shrub	Yes; fire adapted (resprouts from basal stem buds underground or rhizomes)	Low-moderate (assumed)	Easily top-killed by fire, but the ability to sprout has allowed plant to survive in and sometimes dominate fire-prone ecosystems; little other information available
Yucca brevifolia	Joshua tree	Tree	Yes; numerous specialized fire adaptations (flaky, alligator-like bark; terminal buds protected by height of older trees; buds protected by thick green sheaths; sprouts vigorously from root, stump, and rhizomes)	Moderate (assumed)	Becomes more fire resistant with age, generally survives most fires; fire important in producing and maintaining large stands; no information on recovery time
Yucca schidigera	Mojave yucca	Tree/ Shrub	Yes; fire adapted (resprouts from roots or surviving tissue at stem base)	Low-moderate	Survives most fires, sprouts prolifically, but growth can be slow; may take 5-6 years to recover to pre-burn cover, but many more to regain height and biomass; grazing of new growth by small mammals can limit recovery in some areas

Table 5-2. Fire ecology and effects summaries for selected wetland grasses and sedges of North America (including Alaska).

Scientific Name	Common Name	Fire "Adaptations"	*In Situ* Burn Potential	Comments and Considerations	Habitat Types
Arundinaria gigantea	Giant cane	Rhizome survives fire; grows vigorously after fire; flowers after fire	High	Can probably burn cane during any season, with little difference in recovery; can be susceptible to frost the fall following burning; susceptible to over grazing following fire; temporarily replaces wetland shrubs in habitats such as pocosins due to vigorous growth rate after fire; pure stands only persist if fire returns every few years; control of cane fires can be difficult due to their speed and intensity	Bottomlands, riparian habitats, swamps, shrub-tree bogs and bays, sloughs, bayous, pocosins, mesic to wet savannas
Carex aquatilis	Water sedge	Protected rhizomes; quick recovery after most fires; also revegetates from seed; vegetation increases after fire	High	Recovers in one year or less from fires that consume aboveground vegetation only; rhizomes (and plant) may be killed by intense fire that consumes organic soil; water sedge most vulnerable to fire during the dry season (late summer, fall); also vulnerable to fire on drained sites; caution should be used when burning along streambanks where water sedge provides erosion control; high spring run-off periods should also be considered where water sedge provides soil stabilization	Swamps, wet meadows, floodplains, fens, marshes, sedge meadow tundra
Carex rostrata	Beaked sedge	Deep-buried rhizome; survives most fires; (even peat burns); increases after fire	Very high	Typically survives fires that burn peat or organic soil layers; fire does little to change plant composition in beaked sedge habitats; use caution when burning along streambanks where beaked sedge provides erosion control	Wet meadows, marshes, riparian habitats, mats of floating vegetation
Carex stricta	Tussock sedge	Buried rhizomes; also revegetates from seed; vegetation increases after fire	High	Rhizomes (and plant) may be killed by severe fires that ignite peat or organic soil layers; burning not advised during severe droughts or on sites that have been partially or completely drained, due to	Bogs, wet meadows, swales, floodplains, marshes, wet woodlands

Table 5-2. Continued.

Scientific Name	Common Name	Fire "Adaptations"	*In Situ* Burn Potential	Comments and Considerations	Habitat Types
Carex stricta (continued)	Tussock sedge			increased risk of peat burn; burning during dormant season less damaging, though plants may still recover quickly from burns occurring after new shoot emergence	
Cladium jamaicense	Sawgrass	Deep rhizomes; meristems insulated by surrounding tightly overlapping leaves; rapidly sprouts and grows quickly following fire	High	Fires on dry soils can kill meristems; fires on very dry soils during droughts or in drained areas kill rhizomes and consume peat, eliminating sawgrass and lowering soil level; best to burn when standing water is present–this protects plants and peat soils, and controls fire spread; maidencane (*Panicum*) can expand at the expense of sawgrass following peat burns; quickest sawgrass recovery and best growth seen following winter and spring burns; elevated water levels following fire can kill plants if new growth is submerged; head fires and spot fires recommended for prescribed burns–these are fast burning and less likely to dry-out and ignite elevated areas of organic soils	Freshwater marsh, brackish marsh
Distichlis spicata	Saltgrass	Buried rhizome; buried seeds survive fire; revegetates from sprouting and/or seeds; vegetation increases after fire	Very high	Standing water during burning may not be necessary for saltgrass survival; drained sites showed typical recovery after prescribed fire (note–response may depend on fire intensity); flooding following burning kills rhizomes (and plant) by interrupting gas exchange; after burning and flooding, saltgrass may still regenerate, as it's seeds survive fire and it is an initial colonizer on disturbed wetland sites; saltgrass may become dominant on mixed species sites following intense fire	Prairie and grassland swales, salt flats, desert playas, intermittent ponds, saline meadows, riparian habitats, brackish marsh, salt marsh

Table 5-2. Continued.

Scientific Name	Common Name	Fire "Adaptations"	*In Situ* Burn Potential	Comments and Considerations	Habitat Types
Eleocharis palustris	Common spikerush	Rhizome; increases after fire	High	Fires that burn organic soils may kill rhizome and plant; burning when standing water is present protects plant and organic soil	Marshes, riparian habitats, floodplains, wet meadows
Eleocharis rostellata	Beaked spikerush	Rhizome survives low severity fire and resprouts; also revegetates from seed	High	Rhizomes (and plant) may be damaged or killed by high severity fire; high severity fires that result in root burns eliminate dense climax salt marsh species, allowing colonization by *Eleocharis* and *Scirpus*; fires resulting in peat burns create open-water habitat without marsh vegetation; fire maintains early successional salt marsh plants such as *Eleocharis*	Salt marsh, brackish marsh, alkaline and desert seeps, bogs, fens, riparian habitats, hot springs, swamps
Eriophorum vaginatum	Sheathed cottonsedge	Growing points insulated by tightly bunched dead and live tillers, stem sheaths, and scales; elevated position of tussocks increases resistance to ground fire; sprouts from burned tillers and establishes from seed after fire; increased tiller production, flowering, and site importance after fire	Very high	Fire important in maintaining growth and survival of cottonsedge; relatively fast recovery after fire; severe fire may kill cottonsedge tussocks; however, fire enhances establishment from seed; viable seeds available regardless of the depth of peat burn due to both shallow and deeply buried seed; burned peat is ideal seedbed; cottonsedge benefits from burns that melt soil ice, deepening the active soil layer; off-road vehicle traffic should be prohibited in cottonsedge habitats except in winter when soils are frozen	Tundra bogs, muskegs, boreal forest
Eriophorum viridicarinatum	Green-keeled cottongrass	Rhizomes; tightly bunched basal leaves may protect plant from severe damage during ground fires	High (assumed)	Fire generally kills aboveground plant parts; otherwise little information available (assumed it sprouts from rhizomes following most fires)	Cold calcareous spagnum bogs, swamps, meadows, permafrost tussocks

Table 5-2. Continued.

Scientific Name	Common Name	Fire "Adaptations"	*In Situ* Burn Potential	Comments and Considerations	Habitat Types
Juncus balticus	Baltic rush	Rhizome; may increase after fire	High	Occurs in many habitats where standing water is not present–it is assumed that standing water is not mandatory during burns; however the closer the water table is to the surface, the less chance there should be of damaging or killing the rhizomes	Desert seeps, wet meadows, riparian habitats, freshwater marsh, brackish marsh, some dry flats and meadows
Juncus roemerianus	Needle (black) rush	Rhizome survives	High	Severe fires during dry periods (when soil not saturated) can consume organic soils and kill rhizomes eliminating entire stands; may recover more slowly than species of cordgrass (*Spartina*); fire can result in bulrushes (*Scirpus*) such as Olney threesquare increasing at the expense of needle rush, especially in mixed species marshes	Salt marsh, brackish marsh
Panicum hemitomon	Maidencane	Rhizome survives and sprouts within 3-4 days; growth and cover increase after fire; fire stimulates seedstalk production, also revegetates from seed	High	During dry season or extreme drought when water table is more than 10 cm below the soil surface, fire may kill the rhizome (and plant) and consume organic soils; there should be at least 2.5 cm of water over the soil surface during prescribed burns; flooding following burning can reduce growth, slowing recovery; maidencane can be burned during the growing season; however, burning in the late growing season is more damaging; root and peat burns that kill maidencane rhizomes can allow earlier successional species to invade; however maidencane can expand at the expense of sawgrass (*Cladium*) after peat burns; burning maidencane can improve wildlife habitat (food and cover)	Freshwater marsh, swamp, riparian habitats, wet/moist disturbed sites

Table 5-2. Continued.

Scientific Name	Common Name	Fire "Adaptations"	*In Situ* Burn Potential	Comments and Considerations	Habitat Types
Paspalum distichum	Knot grass	Rhizome	High (assumed)	Fire consumes aboveground plant parts (assumed it sprouts from rhizomes following most fires); prescribed burns in one study were performed in winter, (plants probably were dormant)	Freshwater marsh, brackish marsh, salt marsh, beaches, dunes, semiarid freshwater wetlands
Phragmites australis	Common reed	Buried rhizome	High	Prescribed fire is used to reduce common reed, opening up stands to improve wildlife habitat; extreme dry season fires may damage or kill rhizome (and plant) and consume organic soils; during droughts deep peat fires can eliminate reed stands; can burn reed when standing water is not present; burning on wetter soils less likely to cause damage; burning during extreme dry periods or drought, when water table is low, should be avoided; reed can be burned during the growing season; however, burning during the peak of the growing season (early to mid-summer), when carbohydrate stores are lowest, can slow recovery to 2-4 growing seasons, rather than 1	Freshwater marshes, swales, riparian habitats
Scirpus americanus (olneyi)	Olney threesquare (American bulrush)	Deep-buried (to 15 cm) rhizome; seeds in soil survive fire; often sprouts within a week of burning; may return to pre-fire levels within 1 month	High	Prescribed burning is used to maintain brackish Olney threesquare marshes, keeping community from succeeding to saltmeadow cordgrass; extreme peat fires can scorch or consume rhizomes, killing the plant; rhizomes occur deeper than those of saltmeadow cordgrass (*Spartina patens*), Olney threesquare suffers less mortality than cordgrass during burns on drained or dry soils, may expand at the expense of cordgrass following fire in	Brackish marsh, freshwater marsh, wet meadows, playas

Table 5-2. Continued.

Scientific Name	Common Name	Fire "Adaptations"	*In Situ* Burn Potential	Comments and Considerations	Habitat Types
Scirpus americanus (olneyi) (continued)	Olney threesquare (American bulrush)			mixed species marshes; can burn Olney threesquare during all seasons (assuming soil is submerged or wet); standing water not necessary for bulrush survival during burning, can burn when water table is just below the soil surface	
Scirpus robustus	Saltmarsh bulrush	Deep-buried rhizome	High	Rhizomes occur deeper than those of saltmeadow cordgrass (*Spartina patens*), saltmarsh bulrush suffers less mortality than cordgrass during burns on drained or dry soils, may expand at the expense of cordgrass following fire in mixed species marshes; fall burning recommended; winter burning used to enhance *Scirpus* marshes as a wildlife food source; *Scirpus* can be an important food for waterfowl and small semi-aquatic mammals	Brackish marsh
Scirpus validus	Soft-stem bulrush	Rhizome	High	Standing water during burning may not be necessary for bulrush survival; drained sites showed typical recovery after prescribed fire (note: response may depend on fire intensity and depth to water table); *Scirpus* can be reduced/ damaged from overgrazing by waterfowl and muskrats, especially following fire (burning improves the food value of bulrush for wildlife)	Freshwater marsh, brackish marsh, riparian habitats, wet meadows
Scolochloa festucacea	Whitetop	Rhizome	High (conditional, wildlife use)	Rhizomes can be damaged by fire during droughts when soil is dry and litter moisture content is low; plants can be killed by peat burns; whitetop most often burns in late summer and early fall when no longer flooded (but soil still wet); greater recovery following fall (dormant season) burns than spring (early growing season)	Wet meadows, prairie potholes, marshes, riparian habitats

Table 5-2. Continued.

Scientific Name	Common Name	Fire "Adaptations"	*In Situ* Burn Potential	Comments and Considerations	Habitat Types
Scolochloa festucacea (continued)	Whitetop			burns; fall burning can be detrimental to wildlife that use ponds in spring: water levels are dependent on snowfall trapped by standing dead vegetation, burning whitetop reduces the amount of snow caught, reducing the amount of melt water available in spring; spring fires can destroy bird (probably waterfowl) nests	
Spartina alterniflora	Smooth cordgrass	Rhizome	High	Severe fires may kill rhizomes (and the plant); the classic Gulf of Mexico marsh burn types (cover burns, root burns, and peat burns) are based on this species; cover burns–standing water present, aboveground parts consumed, plant sprouts new shoots from rhizome, marsh recovery normal; root burns–standing water not present, burn severe enough to kill rhizomes, plant dies, marsh recovery slowed; peat burns–standing water not present, water table generally lower than for root burns, fire severe enough to kill rhizomes (and plant) and consume organic soil, marsh surface level lowered, marsh recovery even slower, community type possibly changed	Salt marsh, brackish marsh
Spartina patens	Saltmeadow cordgrass	Rhizome	Moderate-high	Recovers from rhizomes following light burns; severe fires may kill rhizomes (and the plant); survives cover burns (standing water present); species of bulrush (*Scirpus*) may expand at the expense of saltmeadow cordgrass for 2-3 years following light (cover) burns, or longer/ permanently following root or peat burns; prescribed cover burns usually conducted in fall or winter; note high salt marsh (and	Brackish marsh, high salt marsh, low dunes

Table 5-2. Continued.

Scientific Name	Common Name	Fire "Adaptations"	*In Situ* Burn Potential	Comments and Considerations	Habitat Types
Spartina patens (continued)	Saltmeadow cordgrass			dune) habitats may be flooded only irregularly, and soil that saltmeadow cord-grass is growing in may not be very wet–burning this species in high salt marsh and dune habitats probably should be avoided	
Spartina pectinata	Prairie cordgrass	Deep buried rhizomes, increased vegetative production and flowering on burned sites	High	Survival and vegetation recovery are greater for burns during the wet season, when standing water is present; vegetation damage is minimized for burns occurring when plants are dormant; lack of burning may result in invasion by willow and other species at the expense of prairie cordgrass; (additional information from Johnson and Knapp, 1993)	Wet bluestem prairie, marshes, seeps, floodplains, riparian habitats
Typha angustifolia	Narrow-leaved cattail	Rhizome; thick stem bases are slow to dry out and do not burn easily	High	Fire reduces stem density; can burn cattail when the marsh is drained or dry as long as organic soil is not consumed, peat burns can kill *Typha*; burning in winter when rhizomes are buried in ice or in frozen soil can ensure plants are not killed; snow buildup over ice also protects the plant stalks; burning during the dormant season (fall, winter) may be less damaging and result in quicker recovery, however, burning can be conducted at other times of year also; flooding (submerging) cattail stubble after fire kills the plants; prescribed burning is used in cattail marshes to improve wildlife use (food, cover)	Freshwater marsh, brackish marsh, wet meadows, fens, bogs

Table 5-2. Continued.

Scientific Name	Common Name	Fire "Adaptations"	*In Situ* Burn Potential	Comments and Considerations	Habitat Types
Typha latifolia	Common cattail	Rhizome; thick stem bases are slow to dry out and do not burn easily	High	Can burn cattail when the marsh is drained or dry as long as organic soil is not consumed; peat burns can kill *Typha*; burning in winter when rhizomes are buried in ice or in frozen soil can ensure plants are not killed, snow buildup over ice also protects the plant stalks; burning during the dormant season (fall, winter) may be less damaging and result in quicker recovery, however, burning can be conducted at other times of year also; flooding (submerging) cattail stubble after fire kills the plants; prescribed burning is used in cattail marshes to improve wildlife use (food, cover)	Freshwater marsh, brackish marsh, wet meadows, fens, bogs

Section 6
CONCLUSIONS ON THE ENVIRONMENTAL EFFECTS OF *IN SITU* BURNING

In situ burning can be a valuable oil spill cleanup tool in inland and upland environments, particularly under certain conditions. *In situ* burning can be considered when oil needs to be removed quickly to prevent the spread of contamination or further environmental damage. *In situ* burning may also be appropriate when spill locations are remote or have restricted access due to terrain, weather conditions, or other factors. *In situ* burning also appears to be an important alternative when other cleanup options prove ineffective or threaten to be more harmful to the environment.

The *in situ* burning case histories presented in this report outline the state of the practice concerning where and when *in situ* burning is feasible and environmentally acceptable. *In situ* burning is clearly suited towards use in certain environmental settings and habitats, but not others. Some wetland types (especially marshes), other open grassy areas (fields, agricultural land), and unvegetated sites present good opportunities for *in situ* burning. Other sites, such as most forests and populated areas, are less suitable. Conditions that influence the appropriateness of *in situ* burning in terms of environmental damage include such things as water level and soil moisture conditions, the potential for erosion, and factors relating to vegetation condition and response in the spill/burn area. In terms of vegetation, plant type (herbaceous vs. woody), seasonality (dormant vs. growing season), and the potential impacts of remaining oil residue on shoot emergence and seed germination, stand out as important considerations that should be evaluated for each spill.

Given the available case-history information (31 cases), the overall knowledge and information base concerning *in situ* burning of inland and upland environments is still limited. To help add to this knowledge base, summary information from the fields of fire ecology and prescribed burning (in the absence of oil) were included in this report. In addition, information on fire effects and ecology of more than 200 dominant plant species of the United States were summarized from a USDA Forest Service database. These non-oil related sources serve mainly to broaden and deepen the information available to oil spill responders concerning the potential response of different habitat types and plant species to *in situ* burning.

Similar to the case histories, the fire ecology and prescribed burning literature indicate that herbaceous wetlands and open grassland communities are the most obvious areas where *in situ* burning may be feasible and environmentally acceptable. However, not all terrestrial grassland communities and species are good candidates for *in situ* burning. Important differences in growth form and life-history, as well as other factors such as season, recent precipitation patterns, substrate/soil type, fuel load, and fire history can make some grassland habitats more appropriate than others for burning. Also, surprisingly, a wide variety of habitats dominated by woody shrubs, and even some tree species, could potentially support *in situ* burning without undue environmental damage. Several shrub communities are highly fire tolerant and recover quickly following burning. However, some fire-adapted shrub habitats are also highly flammable and present serious fire hazards. Several tree species that occur in open or savanna-like settings in association with understory grasses or other herbaceous vegetation, or in special fire dependent communities, may be appropriate for *in situ* burning of oil on the ground surface.

The information gleaned from the fire ecology and effects section of this report comes with a strong disclaimer. Fire sensitive vegetation types where *in situ* burning should definitely not be used were clearly identified; however, the appropriateness of burning of oil in plant communities described as fire tolerant or resistant is largely untested (except for a few wetland marsh species). Due to the complexity of fire science and prescribed burning in general, and fire ecology and environmental effects in particular, we suggest that prescribed fire practitioners be consulted when *in situ* burning is planned, to provide valuable knowledge and experience not likely possessed by spill responders. The use of standard fire behavior and effects computer models could also enhance the planning and application of *in situ* burning.

Finally, because relatively few case histories were available (most of them in wetland or agricultural environments), and information borrowed from the fire ecology and prescribed burning literature is largely untested in terms of adding oil to the equation, we strongly suggest that all future applications of *in situ* burning be thoroughly documented and the results made available to the response community. Pre- and post-burn considerations are outlined in Section 3 of this report, and an *in situ* burn observation checklist has been developed (Appendix C), which in combination should serve as general guidelines for conducting burns and collecting meaningful information to document the environmental effects and effectiveness of *in situ* burning.

Additionally, we recommend that concepts developed in this report be tested both experimentally and during spills of opportunity where *in situ* burns are employed or at least tested. Study designs that compare oiled and un-oiled sites that are burned, left alone, and treated with other cleanup methods separately or in addition to burning would be invaluable and could greatly improve the best application of *in situ* burning in the future. Since it is difficult to design and implement rigorous scientific studies during spill emergencies, it is suggested that simple monitoring programs be developed as part of pre-planning for use of *in situ* burning. The study designs could consist of several tiers of data collection, from time-series photo-quadrats and transects, to measurements of species abundance and diversity indices, to chemical analysis of sediments. Implementation of monitoring studies could be required as part of the approval process for use of *in situ* burning, particularly for habitats or conditions which are unusual. Efforts in the past have focused on the capability for monitoring of air quality during burns. Monitoring of the effects of burning oil on the vegetation and substrate has been inadequate. Perhaps having some simple guidelines and study plans available will encourage better documentation of the effects of *in situ* burning and support future decisions on when *in situ* burning is a suitable response option.

REFERENCES

American Petroleum Institute and National Oceanic and Atmospheric Administration, 1994, Inland oil spills-options for minimizing environmental impacts of freshwater spill response. 126 pp. + appendices.

Bailey, R.G. 1983. Delineation of Ecosystem Regions. *Environmental Management* 7(4):365-373.

Bailey, R.G. 1995. *Description of the Ecoregions of the United States, 2nd Edition.* Miscellaneous Publication No. 1391, USDA Forest Service, Washington, D.C., 108 pp. with separate map at 1:7,500,000.

Benner, Jr., B.A., N.P. Bryner, S.A. Wise, G.W. Mulhonlland, R.C. Lao, and M.F. Fingas. 1990. Polycyclic aromatic hydrocarbon emissions from the combustion of crude oil on water. Environmental Science & Technology, Vol. 24, No. 9, pp. 1418-1427.

Blenkinsopp, S., G. Sergy, P. Lambert, Z. Wang, S.C. Zoltai, and M. Siltanen. 1996. Long-term Recovery of Peat Bogs Oiled by Pipeline Spills in Northern Alberta. *Proceedings*, Nineteenth Arctic and Marine Oil Spill Program Technical Seminar, Calgary, Alberta, June 12-14, 1996. Environment Canada, Ottawa, Ontario. Vol. 2, pp. 1335-1354.

Buhite, T.R. 1979. Cleanup of a Cold Weather Terrestrial Pipeline Spill. *Proceedings*, 1979 International Oil Spill Conference, Los Angeles, CA, March 19-22, 1979. pp. 367-369.

Burns, R.C. 1988. Cleanup and Containment of a Diesel Fuel Spill to a Sensitive Water Body at a Remote Site Under Extreme Winter Conditions. *Proceedings*, 11th Arctic and Marine Oil Spill Program Technical Seminar, Vancouver, British Columbia, June 7-9, 1988. Environment Canada, Ottawa, Ontario. pp. 209-220.

Cerulean, S.I. and R.T. Engstrom. 1995. Fire in Wetlands, A Management Perspective. *Proceedings*, 19th Tall Timbers Fire Ecology Conference, Tallahassee, FL. 171 pp.

Eufemia, Steven. 1993. Brunswick Naval Air Station JP-5 Aviation Fuel Discharge, *In Situ* Burn of Fuel Remaining in Fresh Water Marsh, 6-8 April 1993. Maine Department of Environmental Protection, Portland, ME. 4 pp.

Ewel, K.C. 1995. Fire in Cypress Swamps in the Southeastern United States. In S.I. Cerulean and R.T. Engstrom, eds. Fire in Wetlands, A Management Perspective. *Proceedings*, 19th Tall Timbers Fire Ecology Conference, Tallahassee, FL. pp. 111-116.

Fingas, M.F., K. Li, F. Ackerman, P.R. Campagna, R.D. Turpin, S.J. Getty, M.F. Soleki, M.J. Trespalacios, J. Pare, M.C. Bissonnette, and E.J. Tennyson. 1993.

Emissions from mesoscale *in situ* oil fires: the Mobile 1991 and 1992 tests. *Proceedings*, Sixteenth Arctic and Marine Oil Spill Program Technical Seminar, Calgary, Alberta, June 7-9. 1993. Environment Canada, Ottawa, Ontario. pp. 749-822.

Fingas, M.F., F. Ackerman, K. Li, P. Lambert, Z. Wang, M.C. Bissonnette, P.R. Campagna, P. Boileau, N. Laroche, P. Jojuty, R. Nelson, R.D. Turpin, M.J. Trespalacios, G. Halley, J. Belanger, J. Pare, N. Vanderkooy, E.J. Tennyson, D. Aurand, and R. Hiltabrand. 1994. The Newfoundland offshore burn experiment - NOBE preliminary results of emissions measurement. *Proceedings*, Seventeenth Arctic and Marine Oil Spill Program Technical Seminar, June 8-10, Vancouver, British Columbia. Environment Canada, Ottawa, Ontario. pp. 1099-1164.

Fischer, W.C. (compiler). 1992. The Fire Effects Information System Database. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Intermountain Fire Sciences Laboratory, Missoula, Montana.

Gonzalez, M.F. and G.A. Lugo. 1995. Texas Marsh Burn: Removing Oil from a Salt Marsh using *In Situ* Burning. *Proceedings*, 1995 International Oil Spill Conference, Long Beach, CA, February 27-March 2, 1995. pp. 39-42.

Hartley, A.E., Sr. 1996. Overview of the Kolva River Basin 1995 Oil Recovery and Mitigation Project. *Proceedings*, Nineteenth Arctic and Marine Oil Spill Program Technical Seminar, Calgary, Alberta, June 12-14, 1996. Environment Canada, Ottawa, Ontario. Vol. 2, pp. 1301-1307.

Henry, C.B. 1993. *Characterization of Weathered JP-5 Fuel Oil Before and After IN SITU Burning.* Technical Report (IES93-06), Institute for Environmental Studies, Louisiana State University, Baton Rouge, LA. 10 pp.

Henry, C.B. 1997. *Vermilion Oil Spill: IN SITU Burn and Monitoring Study.* Chemistry Report IES/RCAT97-30. Institute for Environmental Studies, Louisiana State University, Baton Rouge, LA. 3 pp.

Hess, T.J., I. Byron, H.W. Finley, and C.B. Henry. 1997. The Rockefeller Refuge Oil Spill: A Team Approach to Incident Response. *Proceedings*, 1997 International Oil Spill Conference, Fort Lauderdale, FL, April 7-10, 1997. pp. 823-828.

Johnson, S.R. and A.K. Knapp. 1995. The Role of Fire in *Spartina pectinata*-Dominated Tallgrass Prairie Wetlands. In S.I. Cerulean and R.T. Engstrom, eds. *Fire in Wetlands, a Management Perspective. Proceedings*, 19th Tall Timbers Fire Ecology Conference, Tallahassee, FL. pp. 92-101

Kuchler, A.W. 1964. Potential Natural Vegetation of the Conterminous United States, Manual to Accompany the Map. American Geographical Society Special Publication 36, New York, NY. 116 pp.

Labay, A. 1997. *Pollution Complaint Detailed Report, Event ID 19973A332v1*. Texas Parks and Wildlife Department, Resource Protection Division, Austin, TX. 2 pp.

Lael, T. 1997. Personal Communication. Office of Pipeline Safety, Department of Transportation, Washington, D.C.

May, V.L. and J.R. Wolfe. 1997. Field Experience with Controlled Burning of Inland Oil Spills. *Proceedings*, 1997 International Oil Spill Conference, Fort Lauderdale, FL, April 7-10, 1997. pp. 811-816.

McCauley, C.A. and R.C. Harrel. 1981. Effects of Oil Spill Cleanup Techniques on a Salt Marsh. *Proceedings*, 1981 International Oil Spill Conference, Atlanta, GA, March 2-5, 1981. pp. 401-407.

McCune, B. 1988. Ecological diversity in North American pines. American Journal of Botany, Vol. 75, No. 3, pp. 353-368.

McNab, W.H. and P.E. Avers. 1994. *Ecological Subregions of the United States: Section Descriptions*. Administrative Publication WO-WSA-5, USDA Forest Service, Washington, D.C. 267 pp.

Mendelssohn, I.A., M.W. Hester, and J.W. Pahl. 1995. *Environmental Effects and Effectiveness of IN SITU Burning in Wetlands: Considerations for Oil Spill Cleanup*. Louisiana Oil Spill Coordinator's Office, Louisiana Applied Oil Spill Research and Development Program, Baton Rouge, LA. 57 pp.

Moir, M.E. and B. Erskin. 1994. *In-situ* Burning of Oil Spills on Land: A Case Study. *Proceedings*, Seventeenth Arctic and Marine Oil Spill Program Technical Seminar, Vancouver, British Columbia, June 8-10, 1994. Environment Canada, Ottawa, Ontario. Vol. 1, pp. 651-655.

Pahl, J.W., I. Mendelssohn, and T.J. Hess. 1997. The Application of *In Situ* Burning to a Louisiana Coastal Marsh Following a Hydrocarbon Product Spill: Preliminary Assessment of Site Recovery. *Proceedings*, 1997 International Oil Spill Conference, Fort Lauderdale, FL, April 7-10, 1997. pp. 823-828.

S.L. Ross Environmental Research Ltd. and Peter Devenis and Associates. 1996. Literature Review on *In Situ* Burning of Oil in Wetlands. The *In Situ* Marsh Burn Working Group, Calgary, Alberta, Canada. 73 pp.

Sveum, Per, C. Bech, and M. Thommasen. 1991. Burning of Oil in Snow: Experiments and Implementation in a Norsk Hydro Drilling Contingency Plan. *Proceedings*, Fourteenth Arctic and Marine Oil Spill Program Technical Seminar, Vancouver, British Columbia, June 12-14, 1991. Environment Canada, Ottawa, Ontario. pp. 399-410.

Tunnell, J.W. Jr., B. Hardegree, and D.W. Hicks. 1995. Environmental Impact and Recovery of a High Marsh Pipeline Oil Spill and Burn Site, Upper Copano Bay, Texas. *Proceedings*, 1995 Oil Spill Conference, Long Beach, CA, February 27-March 2, 1995. pp. 133-138.

Tunnell, J.W. Jr., D.W. Hicks, and B. Hardegree. 1994. *Environmental Impact and Recovery of the Exxon Pipeline Oil Spill and Burn Site, Upper Copano Bay, Texas: Year One*. TAMU-CC-9402-CCS, Center for Coastal Studies, Texas A&M University - Corpus Christi, Corpus Christi, TX. 75 pp.

Tunnell, J. W. Jr., K. Withers, and B. Hardegree. 1997. *Environmental Impact and Recovery of the Exxon Pipeline Oil Spill and Burn Site, Upper Copano Bay Texas: Final Report.* TAMU-CC-9703-CCS, Center for Coastal Studies, Texas A&M University - Corpus Christi, Corpus Christi, TX. 81 pp.

Whelan, R.J. 1995. *The Ecology of Fire.* Cambridge University Press, Cambridge, UK. 346 pp.

Williams Pipeline Co. (undated report). *Burning as an Initial Response to a Petroleum Release on Land and Water.* 3 pp. plus appendix (photos).

Wright, H.A. and A.W. Bailey. 1982. *Fire Ecology, United States and Southern Canada.* John Wiley and Sons, Inc., New York, NY. 501 pp.

Appendix A
LIST OF CONTACTS

COMMERCIAL CONTACTS

CONTACT NAME	AFFILIATION	ADDRESS	TELEPHONE
John Danchertsen	Williams Pipeline	8001 College Boulevard Suite 2000 Overland Park, KS 66210	(913) 663-1640
Don Davis	Louisiana State University	Wetland Biogeochemistry Institute Baton Rouge, LA 70803	(504) 388-3481
Ron Delaune	Louisiana State University	Wetland Biogeochemistry Institute Baton Rouge, LA 70803	(504) 388-8810
Ispva Devai	Louisiana State University	Wetland Biogeochemistry Institute Baton Rouge, LA 70803	(504) 388-8800
David Fritz	Amoco	200 East Randolph Drive Post Office Box 87703 Chicago, IL 60680-0703	(312) 856-7786
Ron Goodman	Imperial Oil	3535 Research Road N.W. Calgary, Alberta Canada T2L 2K8	(403) 932-4331
Charlie Henry[1]	Louisiana State University	Institute of Environmental Studies Room 42 Atkinson Hall Baton Rouge, LA 70803	(504) 388-4295
Jerry Langley	Williams Energy Group	Health, Safety, and Environment One Williams Center Post Office Box 3448 Tulsa, OK 74101-3448	(918) 588-3381
Scott Launsbury	Lakehead Pipe Line	21 W. Superior Street Duluth, MN 55802-2085	(218) 725-0145
Vicki May	Marathon Pipeline Company	RR 40 Martinsville, IL 62442	(217) 382-4911 Ext. 236
Irv Mendelssohn	Louisiana State University	Wetland Biogeochemistry Institute Baton Rouge, LA 70803	(504) 388-6425

1 Charlie Henry is currently with the National Oceanic and Atmospheric Administration, NOAA Scientific Support Coordinator's Office, Eighth Coast Guard District (LA SSC), 501 Magazine Street, New Orleans, Louisiana 70130-3396; Telephone: (504) 589-4414. An alternate contact at LSU is Paulene Roberts.

CONTACT NAME	AFFILIATION	ADDRESS	TELEPHONE
Alexis Steen	American Petroleum Institute	1220 L Street, N.W. Washington, D.C. 20005	(202) 682-8339
John W. Tunnell, Jr.	Texas A&M University Corpus Christi	Center for Coastal Studies 6300 Ocean Drive Corpus Christi, TX 78412	(512) 944-2470

FEDERAL CONTACTS

CONTACT NAME	AFFILIATION	ADDRESS	TELEPHONE
Ron Britton	U.S. Fish and Wildlife Service	USFWS	(703) 358-2148
Sharon Christopherson	National Oceanic and Atmospheric Administration	Hazardous Materials Response and Assessment Division 7600 Sand Point Way N.E. Bin C15700 Seattle, WA 98115	(206) 526-6829
Gordon Goff	U.S. Environmental Protection Agency	Region 4 Atlanta Federal Center 61 Forsyth Street, S.W. Atlanta, GA 30303-3104	(404) 562-8735
John Kaperick	National Oceanic and Atmospheric Administration	Hazardous Materials Response and Assessment Division 7600 Sand Point Way N.E. Bin C15700 Seattle, WA 98115	(206) 526-6800
Tom Lael	Transportation Safety Institute	6500 South MacArthur Blvd. Oklahoma City, OK 73125-5050	(405) 869-0988
Steve Lehmann	National Oceanic and Atmospheric Administration	Commander (mep) 1st CG District 408 Atlantic Avenue Boston, MA 02110	(617) 223-8016
Scott Lundgren	U.S. Coast Guard	Commander (mep) 1st CG District 408 Atlantic Avenue Boston, MA 02110	(617) 223-8434
Kevin McGrattan	National Institute for Standards and Testing	POLY A345 Gaithersburg, MD 20899	(301) 975-2712

CONTACT NAME	AFFILIATION	ADDRESS	TELEPHONE
Dorothy Paar	U.S. Environmental Protection Agency	Region 1 John F. Kennedy Building Boston, MA 02203	(617) 573-5768
Bill Sites	National Oceanic and Atmospheric Administration	c/o USCG Marine Safety Division AJC Federal Building 1240 E. 9 Street Cleveland, OH 44199	(216) 522-7760
Doug Walton	National Institute for Standards and Testing	POLY A345 Gaithersburg, MD 20899	(301) 975-6872
Gerry Wheaton	National Oceanic and Atmospheric Administration	c/o USCG Commandant (G-MEP) 2100 2nd Street S.W. Room 2500 Washington, DC 20593	(202) 267-1321
Ann Whelan	U.S. Environmental Protection Agency	Region 5 77 W. Jackson Boulevard Chicago, IL 60604	(312) 886-7258

STATE CONTACTS

CONTACT NAME	AFFILIATION	ADDRESS	TELEPHONE
David Barker	Texas Natural Resource Conservation Commis- sion	12100 East Park 35 Circle Post Office Box 13087 Austin, TX 78573	(512) 239-2510
Joe Boesphlug	North Dakota State Fire Marshal	State Fire Marshal Post Office Box 1054 Bismarck, ND 58502-1054	(701) 328-5555
Norman Brown	Missouri Department of Natural Resources	Environmental Services Post Office Box 176 Jefferson City, MO 65102	(573) 526-3374
Richard Clark	Texas Natural Resource Conservation Commission	12100 East Park 35 Circle Post Office Box 13087 Austin, TX 78573	(512) 239-2368
Bill Clements	Kentucky Department of Environmental Protection	Division of Air Quality 803 Shenkel Lane Frankfort, KY 40601	(502) 573-3382
Chuck Collins	Wyoming Department of Environmental Quality	Air Quality Division 122 West 25th Street Herschler Building Cheyenne, WY 82002	(307) 777-7391

CONTACT NAME	AFFILIATION	ADDRESS	TELEPHONE
Cindy Contreras	Texas Parks and Wildlife	4200 Smith School Road Austin, TX 78744	(512) 912-7095
Larry Dietrick	Alaska Department of Environmental Conservation	410 Willoughby Avenue Suite 105 Juneau, AK 99806	(907) 465-5220
Doreen Fairtucker	Minnesota Pollution Control Agency	520 Lafayette Road St. Paul, MN 55155-4194	(612) 297-8656
Doug Friez	North Dakota Division of Emergency Management	Post Office Box 5511 Bismarck, ND 58502-5511	(701) 328-3300
Larry Gales	Oklahoma Department of Environmental Quality	100 NE 10th Street Oklahoma City, OK 73117-1212	(405) 271-7380
John Grump	Wisconsin Department of Natural Resources	Western District Headquarters 1300 W. Clairemont Avenue Eau Claire, WI 54702-4001	(715) 839-3775
Jeff Hauge	North Dakota Health Department	Environmental Health Services 1200 Missouri Ave Post Office Box 5520 Bismarck, ND 58506-5520	(701) 328-5211
Tom Hess	Louisiana Department of Wildlife and Fisheries (Rockefeller Wildlife Refuge)	5476 Grand Chenier Highway Grand Chenier, LA 70643	(318) 538-2276
Tim Hickin	Ohio Environmental Protection Agency	Post Office Box 1049 Columbus, OH 43216-1049	(614) 644-2080
Charlie High	Pennsylvania Department of Environmental Protection	Rachel Carson State Office Building 400 Market Street Harrisburg, PA 17101	(717) 787-5027
Larry Knoche	Kansas Department of Health and Environment	Bureau of Environmental Remediation Assessment and Restoration Section Building 740, Forbes Field Topeka, KS 66620-0001	(913) 296-1662
Ron Kozel	Iowa's Department of Natural Resources	Wallace Building 502 E. 9th Street Des Moine, IA 50319-6034	(515) 281-8883
Andrew Labay	Texas Parks and Wildlife	Post Office Box 947 San Marcos, TX 78667-0947	(512) 353-3474

CONTACT NAME	AFFILIATION	ADDRESS	TELEPHONE
Steve Lee	Minnesota Pollution Control Agency	520 Lafayette Road St. Paul, MN 55155-4194	(612) 297-8610
Kirk Manual	Louisiana Department of Environmental Quality	3519 Patric Street Suite 265 Lake Charles, LA 70605	(318) 475-8644
Jim O'Brien	Illinois Environmental Protection Agency	1021 North Grand Avenue East Springfield, IL 62794-9276	(217) 785-0830
David Ojé	Louisiana Department of Environmental Quality	3501 Chateau Blvd. - West Wing Kenner, LA 70065	(504) 471-2800
Chris Peeler	Louisiana Department of Environmental Quality	7290 Bluebonnet Boulevard Baton Rouge, LA 70810	(504) 765-0671
Chuck Phipps	Indiana Office of Environmental Response	Post Office Box 6015 Indianapolis, IN 46206	(317) 308-3027
Lawrence Robinson	Wyoming Department of Environmental Quality	122 West 25th Street Herschler Building Cheyenne, WY 82002	(307) 777-7075
Mike Rose	Minnesota Pollution Control Agency	Southeast Regional Office 2116 Campus Drive Rochester, MN 55904	(507) 285-7343
David Sait	Maine Department of Environmental Protection	17 Statehouse Station AMMI Complex - Ray Building Augusta, ME 04333-0017	(207) 287-7190
Peter Samuel	Texas General Land Office	1700 North Congress Avenue Austin, TX 78701	(512) 465-5047
Joe Schmidt	Kentucky Department of Environmental Protection	ERT 18 Raleigh Road Frankfurt, KY 40601	(502) 564-2380
Robin Schmidt	Wisconsin Department of Natural Resources	Environmental Quality 101 S. Webster Street	(608) 267-7569
Katie Smith	Indiana Department of Natural Resources	Department of Natural Resources 402 W. Washington Street Indianapolis, IN 48204	(317) 232-8160
Keri St. Pé	Louisiana Department of Environmental Quality	104 Lococ Drive Raceland, LA 70344	(504) 532-6206

CONTACT NAME	AFFILIATION	ADDRESS	TELEPHONE
Gus Stacy	Louisiana Oil Spill Control Office	1885 Wooddale Boulevard Baton Rouge, LA	(504) 922-3230
Ken Teeter	Missouri Department of Natural Resources	Environmental Services Post Office Box 176 Jefferson City, MO 65102	(573) 526-3375
John Tentara	Texas Railroad Commission	1701 North Congress Avenue Austin, TX 78701	(512) 463-6765
Steve Thompson	Oklahoma Department of Environmental Quality	100 NE 10th Street Oklahoma City, OK 73117-1212	(405) 271-8056

Appendix B
INCIDENT SUMMARY SHEETS
FOR *IN SITU* BURN CASE HISTORIES

INCIDENT SUMMARY SHEET

Name: Black Lake, West Hackberry

Date of Spill: 21 September 1978

Location: West Hackberry Strategic Petroleum Reserve Complex. Louisiana

Quantity Spilled/Burned: 11,447,086 L (72,000 bbl)/Unknown quantity burned

Oil Product/Type: Light Arabian crude

Environmental Setting: Lacustrine and fringing marsh

Spill Incident Summary:

- Mechanical failure at the Strategic Petroleum Reserve Complex caused a well blowout at a salt-dome storage cavern, resulting in a major fire and release of oil.
- Much of the oil released was burned. A quantitative estimate was not available.
- It was not documented whether the oil was burned intentionally.

Burn Evaluation:

- Field sampling was conducted 1, 16, 29, and 53 weeks after the spill.
- Sediment samples were collected from the lake bottom and showed no indications of increased contamination by the fire (they were at normal background levels).
- Samples of foliage within several miles of the incident site at 1 and 16 weeks post-burn showed evidence of fallout from the fire, but the new growth at 29 weeks showed no contamination.

Reference(s):

Overton, E.B., J.A. McFall, S.W. Mascarella, C.F. Steele, S.A. Antoine, I.E. Politzer, and J.L. Laseter. 1981. Identification of Petroleum Residue Sources After a Fire and Oil Spill. *Proceedings*, 1981 International Oil Spill Conference, Atlanta, Ga., March 2-5, 1981. pp. 541-546.

INCIDENT SUMMARY SHEET

Name: Brunswick Naval Air Station

Date of Spill: 26-29 March 1993

Location: Brunswick, Maine

Quantity Spilled/Burned: 240,389 L (1,512 bbl)/79,494 L (500 bbl)

Oil Product/Type: JP-5 Aviation fuel

Environmental Setting: Herbaceous freshwater wetland

Spill Incident Summary:

- Fuel was discharged from a pipeline valve at a newly constructed tank farm.
- The oil was contained in a freshwater pond and wetland dominated by cattails, bur-reed, mud plantain, loosestrife, and coontail.
- Road access to the spill site was limited, and shallow water and ice precluded the use of all but small unpowered watercraft, making response operations difficult.
- About 1 m of snow covered the ground and marsh, and ice covered most of the pond.
- Mechanical cleanup methods (vacuum trucks) were used to recover about 158,987 L (1,000 bbl) of oil in the accessible areas of the marsh within the first week after the release.
- The decision to burn the remaining oil was made based on the limited access of the spill site.
- A firebreak was put in place on the upstream portion of the marsh to protect power lines.
- A test burn on 5 April confirmed that the fuel could be readily ignited.
- The actual burn was conducted on 6 April (8 days after the release). The oil was ignited and burned for 5 hours. The surrounding snow and ice helped to contain the fire within the oiled portions of the wetland.
- During the burn, the weather was clear with westerly light winds.
- Smaller burns were conducted on 7-8 April to consume additional oil released from beneath the ice.

- Sorbent material on the water surface was ignited, which then ignited the oil.
- Information pertaining to the exact water level in the marsh at the time of the burn was not reported but where it was not covered by ice the water was deep enough to float a small skiff.

Burn Evaluation:

- It was estimated that 1,750 L (11 bbl) remained within the wetland following the burns.
- USEPA monitored airborne volatile organic compounds (below detectable limits), total organic compounds (0.2 to 1.0 benzene-equivalent units both before and during the burn), combustible gas, and total airborne particulates (0.039 mg/m^3 before the burn and 0.3 mg/m^3 during the burn).
- Post-burn oil composition was the same as weathered oil, except for slight increase in 3-, 4-, and 5-ringed compounds, probably from soot which fell back onto the oiled marsh.
- Surveys in July and August 1993 found the vegetative distribution to be similar to what was commonly found in Northeastern marshes.
- Surveys showed relatively normal communities of animals in the burned area.
- Soil samples taken in July and August 1993 showed elevated values for TPH (260 ppm) in low flow areas of a connected stream, but none in the burned wetland. There were several sites in the marsh with low levels of PAHs.

Reference(s):

Eufemia, Steven. 1993. Brunswick Naval Air Station JP-5 Aviation Fuel Discharge, *In Situ* Burn of Fuel Remaining in Fresh Water Marsh, 6-8 April 1993. Maine Department of Environmental Protection, Portland, ME. 4 pp.

Henry, C.B. 1993. *Characterization of Weathered JP-5 Fuel Oil Before and After In Situ Burning*. Technical Report IES93-06, Institute for Environmental Studies, Louisiana State University, Baton Rouge, LA. 10 pp.

Roy F. Weston, Inc. 1993. *Brunswick Naval Air Station Response, JP-5 Fuel Burn, Brunswick, Maine: 6 April 1993*. TDD No. 01-9304-03, Roy F. Weston, Inc., 7 pp. + appendices.

Metzger, R.S. 1994. *1993 Ecological Assessment, Naval Air Station Brunswick, Brunswick, Maine*. Halliburton NUS Environmental Corporation, Wayne, PA. 28 pp. + appendices.

INCIDENT SUMMARY SHEET

Name: California crude spill

Date of Spill: Not reported

Location: Not reported

Quantity Spilled/Burned: 794,937 L (5,000 bbl)/636-954 L (4-6 bbl)

Oil Product/Type: Heavy crude oil (API 13)

Environmental Setting: Dry creek bed

Spill Incident Summary:

- Cause of spill was a pipeline break.
- Oil ran down into a dry creek bed and did not penetrate the sediments.
- The weather at the time of the burn was cool with a heavy fog. Visibility was less than 0.5 km.
- At the request of the fire department, a burn was initiated several days after the spill.
- A pool of 636-954 L (4-6 bbl) of oil was burned and 20 L of solvent were needed to ignite the pool.
- Oil coating the ditch was burned after it was saturated with solvent.
- Information concerning the duration of the burn was not reported.

Burn Evaluation:

- A heavy residue remained after burn and required an extensive cleanup operation.

Reference(s):

Lael, T. 1997. Personal Communication. Office of Pipeline Safety, Department of Transportation, Washington, D.C.

INCIDENT SUMMARY SHEET

Name: Chiltipin Creek, Texas

Date: January 7, 1992

Location: Chiltipin Creek, adjacent to the Aransas River, Copano Bay, Texas

Quantity Spilled/Burned: 469-012 L (2,950 bbl)/182,835 L (1150 bbl)

Oil Product/Type: South Texas light crude oil

Environmental Setting: High elevation brackish- to saline marsh

Spill Incident Summary:

- Cause of the spill was a breach in a 40 cm underground pipeline.
- Approximately 11.1 hectares of marsh were oiled. Plant species included *Distichlis spicata*, *Monanthochloe littoralis*, and *Salicornia virginica*.
- It was estimated that 198,734 L (1,250 bbl) of oil were recovered from the blow-out hole, 79,500 L (500 bbl) were recovered by pumping, and 7,950 L (50 bbl) were recovered in sorbent material. Before manual removal could be completed, heavy rains were forecast. The state was concerned that the oil would be flushed into the Aransas River and affect sensitive resources. Thus they ordered the fire department to burn the remaining oil.
- Mineral spirits were used as the accelerant.
- The burn was started at 5:50 pm on 11 January 1992 (4 days after the spill). The burn lasted approximately 21 hours.
- From post-burn inspection of the site, it was estimated that 80 to 85 percent of the oil had been removed. Three small pools of oil remained and were ignited. They burned for about 4 hours with similar removal percentages.
- The residue was an asphaltic material which was very sticky.
- Post-burn cleanup operations involved the use of pom-poms and sorbent sweeps to absorb the final remnants of floating oil residue. The amount recovered during these mop-up operations was unknown.

Burn Evaluation:

- The spill occurred a period of above-normal precipitation, which continued through June 1993. A tropical storm caused local flooding, with high tides inundating the marsh under as much as 1 m of brackish water.
- An oiled and unburned site was set aside as a control, but burned anyway.
- Between October 1992 and July 1994, Tunnell *et al.* (1995, 1997) sampled for plant species occurrence 6 times, vegetation biomass 11 times, and soil TPH 2 times.
- Although total plant biomass showed good recovery at the oiled and burned site relative to the (unoiled) control site, plant community composition of the oiled and burned sites shifted to a less diverse community, dominated by *Distichlis spicata* and *Scirpus maritimus.*
- Regrowth in the impacted area was nearly complete after two growing seasons, but the species composition was much different than control areas. Tunnell *et al.* (1995, 1997) predicted that total recovery in the burned areas would take 4 years.
- Tunnell *et al.* (1995, 1997) reported a significantly higher plant biomass in the control site than the oiled and burned site. Having more woody-stemmed perennials in the control site may have contributed to the higher biomass.

Reference(s):

Gonzalez, M.F. and G.A. Lugo. 1995. Texas Marsh Burn: Removing Oil From a Salt Marsh using *In Situ* Burning. *Proceedings*, 1995 International Oil Spill Conference, Long Beach, Calif., February 27-March 2, 1995. pp. 39-42.

Mendelssohn, I.A., M.W. Hester, and J.W. Pahl. 1995. *Environmental Effects and Effectiveness of IN-SITU Burning in Wetlands: Considerations for Oil Spill Cleanup.* Louisiana Oil Spill Coordinator's Office, Louisiana Applied Oil Spill Research and Development Program, Baton Rouge, LA. 57 pp.

Tunnell, J. W. Jr., K. Withers, and B. Hardegree. 1997. *Environmental Impact and Recovery of the Exxon Pipeline Oil Spill and Burn Site, Upper Copano Bay Texas: Final Report.* TAMU-CC-9703-CCS Center for Coastal Studies, Texas A&M University - Corpus Christi, Corpus Christi, TX. 81 pp.

Tunnell, J.W. Jr., B. Hardegree, and D.W. Hicks. 1995. Environmental Impact and Recovery of a High Marsh Pipeline Oil Spill and Burn Site, Upper Copano Bay, Texas. *Proceedings*, 1995 Oil Spill Conference, Long Beach, Calif., February 27-March 2, 1995. pp. 133-138.

INCIDENT SUMMARY SHEET

Name: *ESSO Bayway*, Port Neches, Texas

Date of Spill: 28 January 1979

Location: Bessie Heights Marsh on the lower Neches River near Port Neches, Texas

Quantity Spilled/Burned: 1,040,572 L (6,545 bbl)/Unknown

Oil Product/Type: Light Arabian crude oil

Environmental Setting: Brackish marsh

Spill Incident Summary:

- The spill occurred when a tanker struck an unidentified object.
- The oil was carried into a nearby *Spartina patens* marsh by southerly winds.
- Cleanup of the oil began immediately. Low-pressure flushing and sorbents were used during initial cleanup operations and the amount of oil recovered was not reported.
- Following initial cleanup operations, three experimental cleanup methods (burning, vegetation cutting, and natural recovery) were used and evaluated.
- In the burning experiment, two small marsh islands were burned, one with oil and one without oil.
- The type of ignitor used and the duration of the burn were not reported. There was no report of the type or amount of residue from the burn.
- Water depth in the marsh was reported to be "at ground level on the day the experimental plots where set up."

Burn Evaluation:

- Wetland scientists conducted studies of vegetation and macroinvertebrates during the peak growing season starting 37 days after the burn (April-August 1978). Triplicate plots were established in oiled and burned, burned only, and oiled only areas. Parameters examined included water depth, percent cover of vegetation, growth of vegetation, number of macroinvertebrates, and signs of animal use.
- Heavy rainfall following the spill resulted in high water levels throughout the study period.

- Vegetation growth was minimal in all burned plots. Percent cover was never more than two percent. Unoiled and untreated control plots had up to 35 percent cover by the end of the time period. The oiled only sites had up to 90 percent cover by the end of sampling.
- Oiled untreated had the highest vegetation biomass (166 g/m^2) and unoiled burned had the lowest (2 g/m^2). There was no statistical difference between the oiled/burned and unoiled/burned sites.
- In general, the burned areas (oiled and unoiled) had lower numbers of macroinvertebrates than any other area.
- Burning appeared to be the most detrimental mitigation/cleanup method, possible as a result of high water levels post-burn. Natural recovery was the least damaging.

Reference(s):

McCauley, C.A. and R.C. Harrel. 1981. Effects of Oil Spill Cleanup Techniques on a Salt Marsh. *Proceedings*, 1981 International Oil Spill Conference, Atlanta, Ga., March 2-5, 1981. pp. 401-407.

INCIDENT SUMMARY SHEET

Name: Friendship II Pipeline Spill

Date: 20 January 1988

Location: Kékcse area, Hungary

Quantity Spilled/Burned: 422,470 L (2657 bbl)/ 4823 L (30 bbl)

Oil Product/Type: Crude oil

Environmental Setting: Peat and bog area

Spill Incident Summary:

- A pipeline break resulted in oiling of a 300 m by 180 m area of peat and bog wetland (mostly sedges and reeds). To prevent the oil from spreading in the soil and groundwater, a ditch was dug around the area.
- 360,000 L (2264 bbl) of oil were collected prior to burning and reinjected into the pipeline. The collection method was not identified.
- Approximately 4823 L (30 bbl) was burned. The ignitor used and the water level in the wetland were not reported.
- The oil burned at a rate of 2941 L (18 bbl) per hour. The smoke plume rose to a height of 25-75 m. Wind speed during the burn was 2.0-2.27 m/sec.
- Approximately 57647 L (36 bbl) remained in the soil following the burn.
- 1.5 years following the burn, a 2-km long canal was dug to lower the water level to allow for fertilization and tilling of the sediments.

Burn Evaluation:

- Air quality was monitored during the burn at a station set up 1.9 km downwind at an elevation of 8 m. The levels of selected pollutants did not exceed air quality standards. The standards were: Soot 50 $\mu g/m^3$; SO_2 150 $\mu g/m^3$; CO 5000 $\mu g/m^3$; NO_x 85 $\mu g/m^3$.
- The sedge and reed vegetation recovered to near the original plant density in 1.5 years, before the tilling and fertilization.

Reference(s):

Nagy, P. 1991. Environmental Pollution Caused by Crude Oil Pipelines. *Proceedings*, National Environmental Protection Conference, Balatonaliga, Hungary.

INCIDENT SUMMARY SHEET

Name: Imperial Oil Spill

Date: 15 June 1990

Location: British Columbia, Canada

Quantity Spilled/Burned: 133,549 L (840 bbl)/Unknown quantity burned

Oil Product/Type: Crude oil

Environmental Setting: Freshwater wetland (bog)

Spill Incident Summary:

- A closed valve caused oil to backup and overflow the bermed containment area of the tank battery site, and enter a stream feeding a nearby bog.
- Approximately 5 acres of bog and 1450 m of stream were impacted.
- Initial recovery operations involved draining of the bog, which had standing water due to recent heavy rains. The amount of oil recovered was not reported.
- It was determined that removal operations would severely impact the organic rich underlying soil of the bog, so the decision to burn was made.
- Permission was obtained and burning commenced two days after the spill.
- A 3-6 m fire guard was constructed to encircle the site, and fire fighting equipment was staged to combat secondary fires. This had the additional benefit of raising the water level in the bog.
- The bog was completely flooded, but information on the exact water level in the bog during the burn was not reported.
- A small amount of gasoline was used as an accelerant on the original burn. After 10 minutes, the burn started to affect power lines near the fire. The lines were disconnected and the fire restarted. The site burned for several more hours at which time the majority of the oil had been burned.
- Spot burning, using a 1:1 mixture of gasoline and diesel as an accelerant and sorbent pads, was used to remove remaining oil and burn residues. Over the next 10 days, all oiled debris collected was also burned.
- The fire guard was then dismantled, and water flowing from the bog flushed any remaining oil out of the stream.

- The site was re-contoured, seeded, and fertilized roughly two weeks after cleanup efforts concluded.

Burn Evaluation:

- Water samples were taken during and after cleanup efforts and no trace of oil was detected.
- Although the burn took place in a wooded area, secondary fires were not a problem due to the saturated conditions.
- Only minor impacts to the surrounding vegetation occurred, including the burning of some trees beside the burn site and death of several other trees within 6 m of the burn site due to heat stress.
- New vegetation appeared within the burn site five days after the spill. Vegetation was recovering the following spring, and no oil was apparent in the bog or stream.
- Cleanup costs, including seeding and fertilizing, totaled $65,000. In comparison, conventional measures would have cost in excess of $250,000 and taken the entire summer to complete.

Reference(s):

Moir, M.E. and B. Erskin. 1994. *In-situ* Burning of Oil Spills on Land: A Case Study. *Proceedings*, Seventeenth Arctic and Marine Oil Spill Program Technical Seminar, Environment Canada, Ottawa, Ontario. Vol. 1, pp. 651-655.

INCIDENT SUMMARY SHEET

Name: Kolva River Basin Pipeline Spill: Site 5

Date: Pipeline leaked from 1986-1994

Location: Kolva River, in the Komi Republic of northern Russia

Quantity Spilled/Burned: Large volume (exact quantity not reported)/Unknown

Oil Product/Type: Mixture of crude oil and formation water

Environmental Setting: Freshwater wetland (muskeg swamp with no outlet)

Spill Incident Summary:

- The spill was the result of multiple leaks in the pipeline over a period of several years.
- A large quantity of oil impacted roughly 30 hectares to a thickness of 1 m.
- Containment strategies involved the construction of a series of low earthen dikes creating cells of oil. Ditches were dug on the inside toe of the dikes to facilitate oil collection.
- The type of ignitor used was not reported.
- The burn involved six hectares and burned for 20 hours.
- There was no standing water on the wetland surface at the time of the burn. The depth of the water table was not reported.

Burn Evaluation:

- The burn proved to be unsuccessful because it created so much heat that the oil was driven into the organic substrate.
- The burn residue remaining on top of the peat mat was extremely viscous and oily. No further cleanup of burned areas was attempted because the oil residues could not be flushed, and the peaty substrate was too soft to support any foot or vehicular traffic.

Reference(s):

Hartley, Sr., A.E. 1996. Overview of the Kolva River Basin 1995 Oil Recovery and Mitigation Project. *Proceedings*, Nineteenth Arctic and Marine Oil Spill Program Technical Seminar, Environment Canada. Vol. 2, pp. 1301-1307.

INCIDENT SUMMARY SHEET

Name: Lafitte Oil Field, Louisiana: Site 1

Date: June 1992

Location: Texaco Lafitte Oil Field, Lafitte, Louisiana

Quantity Spilled/Burned: Less than 158 L (1 bbl)/ Less than 158 L (1 bbl)

Oil Product/Type: South Louisiana crude oil

Environmental Setting: Coastal brackish marsh

Spill Incident Summary:

- The cause of the spill was not reported.
- Diesel fuel was reportedly used as an ignitor.
- The duration of the burn was not reported.
- The marsh was dominated by *Spartina patens*, *Distichlis spicata*, and *Juncus roemerianus*.
- Water level in the marsh at the time of the burn was not reported.

Burn Evaluation:

- Field sampling was conducted on 2 November 1994 (29 months after the spill and burn), as part of a LOSCO-sponsored study on the environmental effects and effectiveness of *in situ* burning of oil in wetlands.
- Sampling transects were established in the *in situ* burn marsh site and a suitable control marsh site. The control site was identified from aerial photography and was ground-truthed for suitability.
- Soil TPH levels were: 3.9 mg/g at the control site and 4.5 mg/g at the oiled and burned site, indicating no significant differences between the oiled/ burned site and the control site.
- Live plant biomass values were: 1,085 g/m^2 at the control site and 579 g/m^2 at the oiled/burned site, but the difference was not statistically significant.
- Total plant biomass values were: 2,102 g/m^2 at the control site and 710 g/m^2 at the oiled and burned site, but the difference was not statistically significant.

- Species richness values were: 4.4 species per plot at the control site and 4.0 species per plot at the oiled and burned site, indicating similar plant communities between the sites.

- Live-to-dead plant biomass ratios were: 1.1 at the control site and 5.0 at the burned site, indicating that the oiled and burned marsh had not accumulated as much standing dead plant biomass as the control site.

- There was moderate to good recovery at this site. There was no statistically significant difference in biomass, but there was a trend for lower biomass in the oiled and burned site than the control site.

Reference(s):

Mendelssohn, I.A., M.W. Hester, and J.W. Pahl. 1995. *Environmental Effects and Effectiveness of IN-SITU Burning in Wetlands: Considerations for Oil Spill Cleanup.* Louisiana Oil Spill Coordinator's Office, Louisiana Applied Oil Spill Research and Development Program, Baton Rouge, LA. 57 pp.

INCIDENT SUMMARY SHEET

Name: Lafitte Oil Field, Louisiana: Site 2

Date: May 1983

Location: Texaco Lafitte Oil Field, Lafitte, Louisiana

Quantity Spilled/Burned: 44,834 L (282 bbl)/Unknown

Oil Product/Type: South Louisiana crude oil

Environmental Setting: Coastal brackish marsh

Spill Incident Summary:

- The cause of the spill was not reported.
- Oil mops, skimmers, sorbent pads, and hay were used during oil recovery operations but the amount of oil recovered was not reported.
- Diesel fuel was used as an ignitor.
- The duration of the burn was not reported.
- Water level in the marsh at the time of the burn was not reported.
- The marsh was dominated by *Spartina patens* and *Distichlis spicata.*

Burn Evaluation:

- Field sampling was conducted on 17 November 1994 (11 years after the spill and burn), as part of a LOSCO-sponsored study on environmental effects and effectiveness of *in situ* burning of oil in wetlands.
- Sampling transects were established in the burned marsh site and a suitable control marsh site. The control site was identified from aerial photography and was ground-truthed for suitability.
- Soil TPH levels were: 10.7 mg/g at the control site and 18.1 mg/g at the oiled and burned site. The elevated TPH value at the control site was determined to be indicative of a past release.
- Live plant biomass at the control site (876 g/m^2) was not significantly different from the oiled and burned site (554 g/m^2).
- Total plant biomass values were: 1,845 g/m^2 at the control site and 1,222 g/m^2 at the oiled and burned site, but the difference was not significant.

- Species richness values were: 4.8 species per plot at the control site and 7.6 species per plot at the oiled and burned site. Plant community composition was slightly different between the control site and burn site, but the difference was not statistically significant.

- Live-to-dead plant biomass ratios were: 0.97 at the control site and 0.9 at the burned site. Because of the long time period (11 years) following the burn, the oiled and burned marsh site accumulated nearly as much standing dead plant biomass as the control site.

- Recovery was described as good with complete recovery of biomass and species composition.

Reference(s):

Mendelssohn, I.A., M.W. Hester, and J.W. Pahl. 1995. *Environmental Effects and Effectiveness of IN-SITU Burning in Wetlands: Considerations for Oil Spill Cleanup*. Louisiana Oil Spill Coordinator's Office, Louisiana Applied Oil Spill Research and Development Program, Baton Rouge, LA. 57 pp.

INCIDENT SUMMARY SHEET

Name: Lafitte Oil Field, Louisiana: Site 3

Date: September 1986

Location: Texaco's Lafitte Oil Field, Lafitte, Louisiana

Quantity Spilled/Burned: 636 L (4 bbl)/Unknown

Oil Product/Type: South Louisiana crude oil

Environmental Setting: Coastal brackish marsh

Spill Incident Summary:

- The cause of the spill was not reported.
- Booms and sorbent pads were used during cleanup operations but the amount of oil recovered was not reported.
- Diesel fuel was used as an ignitor.
- The duration of the burn was not reported.
- Water level in the marsh at the time of the burn was not reported.
- The marsh was dominated by *Spartina alterniflora* and *Disitichlis spicata*.

Burn Evaluation:

- Field sampling was conducted on November 17, 1994 (8 years after the spill and burn), as part of a LOSCO-sponsored study on environmental effects and effectiveness of *in situ* burning of oil in wetlands.
- Sampling transects were established in the burned marsh site and a suitable control marsh site. The control site was identified from aerial photography and was ground-truthed for suitability.
- Soil TPH levels were: less than 2 mg/g at the control site and 162 mg/g at the oiled and burned site. The oiled and burned site had significantly higher concentrations. Some of the oil may have been from a post-burn spill.
- Live plant biomass values were: 665 g/m^2 at the control site and 799 g/m^2 at the oiled and burned site, with no significant difference between the sites.

- Total plant biomass values were: 1,423 g/m^2 at the control site and 1,484 g/m^2 at the oiled and burned site, also having no significant difference.

- Species richness values were: 6.6 species per plot at the control site and 2.8 species per plot at the oiled and burned site. The control marsh had a significantly higher species richness.

- Live-to-dead plant biomass ratios were: 1.3 at the control site and 1.4 at the burned site, indicating there had been adequate time (8 years) for accumulation of standing dead plant material.

- In general, there was good recovery but species richness was lower in the oiled and burned site than the control.

Reference(s):

Mendelssohn, I.A., M.W. Hester, and J.W. Pahl. 1995. *Environmental Effects and Effectiveness of IN-SITU Burning in Wetlands: Considerations for Oil Spill Cleanup*. Louisiana Oil Spill Coordinator's Office, Louisiana Applied Oil Spill Research and Development Program, Baton Rouge, LA. 57 pp.

INCIDENT SUMMARY SHEET

Name: Marathon Pipeline, Gillespie Facility

Date of Spill: 6 December 1995

Location: Bridgeport, Illinois (Lawrence County)

Quantity Spilled/Burned: 795 (5 bbl)/158 L (1 bbl)

Oil Product/Type: Illinois crude oil

Environmental Setting: Cultivated field

Spill Incident Summary:

- The spill was caused when the pipeline was ruptured by a chisel plow.
- The oil spread over 70 m^2 of a plowed field. The soil type or moisture level was not reported.
- Approximately 637 L (4 bbl) of oil were recovered by vacuum truck.
- The forecast of rain on the evening of the spill prompted the decision to burn the remaining oil.
- The duration of the burn and the type of ignitor used was not reported.

Burn Evaluation:

- No air monitoring was carried out during the burn; no problems were reported. Conditions were cloudy with a temperature of 4°C and 1.3 - 2.2 m/s winds
- Field sampling was conducted on 20 August 1996 (9 months following the spill and burn).
- TPH-DRO (diesel range organics) concentration in composite soil samples from the burn site were 476-10,677 ppm; background samples were below detectable limits. BTEX values were 0.009-9.05 ppm in the burned area.
- Following the burn, the impacted and burned area was fertilized, limed, and tilled. Normal farming activities resumed during the following spring.

Reference(s):

Marathon Pipeline release reports.

INCIDENT SUMMARY SHEET

Name: Marathon Pipeline, Noble Gathering

Date of Spill: 12 January 1995

Location: Noble, Illinois (Richland County), Noble Gathering Station

Quantity Spilled/Burned: 795 L (5 bbl)/ 677 L (3 bbl)

Oil Product/Type: Illinois crude oil

Environmental Setting: Agricultural field (bean) and drainage ditch

Spill Incident Summary:

- The spill was caused by a break in the pipeline from external corrosion.
- The oil impacted approximately 70 m^2 of field and 140 m^2 of drainage ditch.
- Approximately 318 L (2 bbl) of oil were recovered from the ditch by a vacuum truck prior to burning.
- The remainder of the oil was trapped in bean stubble and dense grass in the ditch.
- The muddy/wet conditions in the bean field, along with a forecast for more rain, prompted the decision to burn the remaining oil.
- Information concerning the duration of the burn and the type of ignitor used was not reported.

Burn Evaluation:

- No air monitoring was carried out during the burn; no problems were reported. Conditions were overcast with a temperature of 13°C and winds of 3.5-4.5 m/s.
- Field sampling was conducted on 21 July 1995 (7 months after the burn).
- The TPH-DRO concentrations in composite soil samples from the burn site were 157-740 ppm, with background levels below detectable limits.
- Of the BTEX, only toluene registered, ranging from below detectable limits to 0.007 ppm.

- The burn area was tilled and normal farming activities resumed the following spring.
- Photodocumentation of the site on 13 August 1996 showed a healthy crop.

Reference(s):

May, V.L. and J.R. Wolfe. 1997. Field Experience with Controlled Burning of Inland Oil Spills. *Proceedings*, 1997 International Oil Spill Conference, Fort Lauderdale, Fla., April 7-10, 1997. pp. 811-816.

Marathon Pipeline release reports.

INCIDENT SUMMARY SHEET

Name: Marathon Pipeline, Noble S. Gathering

Date of Spill: 14 January 1995

Location: Cisne, Illinois (Wayne County), Noble Gathering Facility

Quantity Spilled/Burned: 477 L (3 bbl)/318 L (2 bbl)

Oil Product/Type: Illinois crude oil

Environmental Setting: Agricultural field (bean) and drainage ditch

Spill Incident Summary:

- The spill was caused by a break in the pipeline from external corrosion.
- The oil impacted 1,160 m^2 of a wet and muddy bean stubble field and 980 m^2 of drainage ditches which contained water at the time of the spill.
- Siphon dams were constructed in the ditches and an estimated 158 L (1 bbl) of oil were recovered using a vacuum truck and sorbents. No cleanup was conducted in the bean field prior to the burn.
- Burning was determined to be the most feasible means of cleaning up the oil in the bean field. The duration of the burn and the type of ignitor used were not reported.

Burn Evaluation:

- No air monitoring was carried out during the burn; no problems where reported. Conditions were overcast with a temperature of 7°C and winds of 0.9 m/s.
- Field sampling was conducted on 12 August 1996 (1.5 years after the burn).
- TPH-DRO levels in soil samples were 28 ppm (background) to 1,011 ppm (in the ditch). BTEX levels were below detection limits for all samples.
- Normal cultivation (tilling, fertilizing, and planting) resumed in the spring. Photodocumentation of the site on 12 April 1996 showed a healthy crop.

Reference(s):

May, V.L. and J.R. Wolfe. 1997. Field Experience with Controlled Burning of Inland Oil Spills. *Proceedings*, 1997 International Oil Spill Conference, Fort Lauderdale, Fla., April 7-10, 1997. pp. 811-816.

INCIDENT SUMMARY SHEET

Name: Marathon Pipeline, Patterson

Date of Spill: 4 April 1995

Location: Clay City, Illinois (Wayne County)

Quantity Spilled/Burned: 795 L (5 bbl)/477 L (3 bbl)

Oil Product/Type: Illinois crude oil

Environmental Setting: A slough in an agricultural field

Spill Incident Summary:

- The spill was caused by a break in the pipeline from external corrosion.
- The oil impacted 306 m^2 of a slough containing standing water. Approximately 318 L (2 bbl) of oil were recovered from the slough with a vacuum truck and sorbents.
- The remaining oil was inaccessible, prompting a decision to burn it.
- The initial burn was conducted one day after the spill and consumed approximately 477 L (3 bbl) of oil. A subsequent burn was conducted three days after the spill and consumed an estimated 38-57 L (<1 bbl).
- The duration of the burn and the type of ignitor used were not reported.
- For a month after the burn, oil residues (20-25 cm patches) were cleaned with sorbent material. The slough was then fertilized, limed, and tilled.

Burn Evaluation:

- No air monitoring was carried out; no problems were reported. Weather was clear with temperatures of 10-17°C and winds at 1.3-2.2 m/s.
- Field sampling was conducted 1.5 years after the burn. TPH-DRO levels in soil were 742-7,178 ppm. BTEX values were below detection to 0.2 ppm.
- Photo documentation 16 months after the spill showed healthy crops.

Reference(s):

May, V.L. and J.R. Wolfe. 1997. Field Experience with Controlled Burning of Inland Oil Spills. *Proceedings*, 1997 International Oil Spill Conference, Fort Lauderdale, Fla., April 7-10, 1997. pp. 811-816.

INCIDENT SUMMARY SHEET

Name: Marathon Pipeline, Roy Gill Site

Date of Spill: 25 March 1994

Location: Clay City, Illinois (Wayne County), Roy Gill Gathering Facility

Quantity Burned/Spilled: 79 L (0.5 bbl)/79 L (0.5 bbl)

Oil Product/Type: Illinois crude oil

Environmental Setting: Agricultural field (corn stalks and stubble)

Spill Incident Summary:

- The spill was caused by a break in the pipeline from external corrosion.
- Oil impacted a 0.3 m wide by 90 m long area of the dry corn field.
- Responders decided that burning was the most feasible cleanup method. Oil was in corn stalks and unable to be picked up by other means.
- The duration of the burn and the type of ignitor used were not reported.

Burn Evaluation:

- No air monitoring was carried out during the burn; no problems were reported. The weather was clear with light winds (1.3-2.2 m/s).
- Field sampling was conducted on 23 August 1996 (2.5 years after the spill).
- TPH-DRO concentrations in soil samples ranged from less than 20 ppm (background) to 2,083 ppm (middle of spill area).
- BTEX levels were below detection limits, except for samples in the middle of the spill site, which had 0.009-0.031 ppm.
- The area was tilled, and normal farming activity was resumed that season.
- Photo documentation of the site on 23 August 1996 showed a healthy crop.

Reference(s):

May, V.L. and J.R. Wolfe. 1997. Field Experience with Controlled Burning of Inland Oil Spills. *Proceedings*, 1997 International Oil Spill Conference, Fort Lauderdale, Fla., April 7-10, 1997. pp. 811-816.

INCIDENT SUMMARY SHEET

Name: Marathon Pipeline, Sanders Lease

Date of Spill: 6 April 1995

Location: Allendale, Illinois (Wabash County)

Quantity Spilled/Burned: 1590 L (10 bbl)/80 L (0.5 bbl)

Oil Product/Type: Illinois crude oil

Environmental Setting: Agricultural field (corn) and adjacent road

Spill Incident Summary:

- The spill was caused by a break in the pipeline from external corrosion.
- The oil impacted 223 m^2 of a corn field. The ground was dry and covered by ruts, weeds, and corn stubble.
- Trenches were dug to contain the spill, and oil was vacuumed from the trenches. The area was then flushed, and the water-product mixture recovered.
- Approximately 1510 L (9.5 bbl) of product were recovered, leaving behind an oil residue of 80 L (0.5 bbl), trapped in ruts, weeds, and corn stubble.
- Responders decided to burn the remaining residue.
- The Illinois EPA was notified, an emergency burn permit was obtained, and the remaining oil residue was burned on the day of the spill.
- The duration of the burn and the type of ignitor used were not reported.
- The day of the burn was sunny with a temperature of 18°C and winds of 2.2 m/s.

Burn Evaluation:

- No air monitoring was carried out during the burn; no problems where reported.
- Field sampling was conducted on 26 May 1995 (1.5 months after the burn).
- TPH-DRO concentrations in soil samples, in the burned area, ranged from less than 20 ppm to 342 ppm, with background samples below detection limits.

- The BTEX values ranged from below detection limits to 0.159 ppm.
- The burned area was fertilized and tilled. Normal farming activities resumed during the following the spring.
- Photo documentation taken 16 months after the spill on 13 August 1996 showed healthy crops.

Reference(s):

May, V.L. and J.R. Wolfe. 1997. Field Experience with Controlled Burning of Inland Oil Spills. *Proceedings*, 1997 International Oil Spill Conference, Fort Lauderdale, Fla., April 7-10, 1997. pp. 811-816.

Marathon Pipeline release reports.

INCIDENT SUMMARY SHEET

Name: Meire Grove, Minnesota

Date: September 1992

Location: The southern extent of the prairie pothole region of north central Minnesota near the town of Meire Grove

Quantity Spilled/Burned: 397,468 L (2,500 bbl)/Unknown

Oil Product/Type: A mixture of fuel oil and gasoline

Environmental Setting: Freshwater wetland and pond

Spill Incident Summary:

- A pipeline leaked for approximately 10 days, allowing the petroleum product to enter a drainage tile, travel underground for roughly 1 km, empty into a drainage ditch, flow into a 0.8 hectare pond (impacting the southeastern shore), and flow out of the pond through a drainage tile along the north shore of the pond.
- The burn was started within 16 hours of when the leak was detected and reported by the property owner.
- The type of ignitor used was not reported. No accelerants were necessary for this fairly volatile mixture of petroleum products.
- The burn lasted approximately three hours.
- Sorbent pads were used in mop-up operations. Some vegetation clearing and soil excavation occurred in the area of the pipeline leak, but reportedly not in the wetland.
- A fair amount of foot traffic resulted in trampling of the marsh and pond bottom during ignitions and subsequent cleanup operations.

Burn Evaluation:

- Field sampling was conducted on 10-11 October 1994, two years post-burn, as part of a LOSCO-sponsored study on the environmental effects and effectiveness of *in situ* burning of oil in wetlands.
- Residual signs of trampling were visible along the southeastern shore and pond bottom.

- Soil TPH levels were: 0.7 mg/g at the control site and 2.8 mg/g at the oiled and burned site, but the difference was not statistically significant.

- Live plant biomass values were: 262 g/m^2 at the control site and 7.5 g/m^2 at the oiled and burned site. Live plant biomass had still not recovered at the burned site.

- Total plant biomass values were: 536 g/m^2 at the control site and 10 g/m^2 at the oiled and burned site. There was significantly less plant biomass at the oiled and burned site.

- Live-to-dead plant biomass ratios were: 1.0 at the control site and 2.2 at the burned site, which were not significantly different.

- Surveys of the benthic macroinvertebrate communities in the control pond and the impacted pond were conducted in October 1992 and August 1993.

- In 1992, more taxa were collected from the control site (19) than the oiled and burned site (11). The control site yielded 701 individuals (865/m^2). Thirty-nine individuals (48/m^2) were recovered from the oiled and burned site. The taxonomic composition of the invertebrate communities also varied. Eleven of the 19 taxa in the control site were insects, while 8 of 11 taxa in the oiled and burned site were insects.

- In 1993, the results of invertebrate sampling suggested that the impacted pond had undergone considerable recovery after oiling and burning. The aquatic community had become established with pioneering plant species, such as water plantain, and introduced species of invertebrates.

Reference(s):

Delta Environmental Consultants, Inc. 1993. *Benthic Invertebrate Survey.* Meire Grove Pipeline Project, 7 pp. plus figures and appendices.

Mendelssohn, I.A., M.W. Hester, and J.W. Pahl. 1995. *Environmental Effects and Effectiveness of IN-SITU Burning in Wetlands: Considerations for Oil Spill Cleanup.* Louisiana Oil Spill Coordinator's Office, Louisiana Applied Oil Spill Research and Development Program, Baton Rouge, LA. 57 pp.

INCIDENT SUMMARY SHEET

Name: Nipisi Bog Pipeline Spill

Date: Discovered on 6 September 1972

Location: Approximately 250 miles northwest of Edmonton, in the Lesser Slave Lake area of northern Alberta, Canada (Peace River Oil Pipeline)

Quantity Spilled/Burned: 9,539,238 L (60,000 bbl)/Unknown

Oil Product/Type: Nipisi crude oil

Environmental Setting: Ombrotrophic (rain-fed) bog with very limited drainage

Spill Incident Summary:

- A rupture in the underground 8 inch (20 cm) pipeline caused the spill.
- Over 10 hectares of bog were impacted.
- During initial cleanup attempts, a central pit and auxiliary pits were dug and connected by trenches. Small pumps were used to pump oil from the auxiliary pits to the central pit.
- A skimmer was used to remove oil from the water surface in the central pit, and roughly 794,937 L (5,000 bbl) were recovered.
- In early 1973, a berm was constructed around the site.
- The area was trampled by foot and vehicular traffic during cleanup operations and suffered extensive physical damage.
- The decision not to burn was made in early 1973. The entire spill area was designated a research site and studied for three years.
- The site was burned in November 1976 to reduce free oil in the central and southern parts of the spill site to reduce the fire hazard.
- Another release occurred in 1980, adjacent to the 1972 spill site. Less than 159,000 L (1,000 bbl) were released over a 0.9 hectare area. Shortly after the spill, the area was burned (duration not reported) and roto-tilled.
- The type of ignitors used and the duration of the burns were not reported.
- Water level in the wetland at the time of the burn was not reported.

Burn Evaluation:

- Field sampling was conducted in July 1995.
- Soil samples were obtained from the side walls of shovel-cut pits and surface grabs. Water samples were also collected. A total of 22 samples were collected for oil analysis.
- TPH levels in the upper 4 cm ranged from 20,000-256,000 ppm (highly contaminated). The surface oil was highly weathered.
- TPH levels in subsurface samples (to 40 cm) ranged from 10,000-165,000 ppm (highly contaminated). The subsurface oil was lightly weathered.
- TPH values in samples taken below 80 cm ranged from 12-673 ppm (lightly contaminated).
- The burn residue consisted of a waxy crust of variable thickness.
- The remaining underground oil was still relatively "fresh" due to low biodegradation rates caused by the largely anaerobic conditions of the peat substrate (acidic and water saturated).
- Vegetation observations recorded native plants for the most part, with one exception, the southeast corner of the site contained agricultural grasses due to a re-seeding effort that was conducted in this area.
- Vegetation present at the site seemed remarkably tolerant of oil on the top of the water table or within the water-saturated zone.
- When evacuated, plants that had colonized the edges of heavily oiled patches appeared to grow through the oiled layer into the relatively clean substrate, indicating that their roots were tolerant of oil contamination.
- Several areas remained unvegetated or showed minimal vegetative recovery for several reasons: presence of a thick waxy residue on burned surfaces; extreme physical site disturbance after the initial cleanup; water saturation of the soil as a result of berming; and periodic re-oiling of low-lying areas by subsurface oil after periods of high rainfall.

Reference(s):

Blenkinsopp, S., G. Sergy, P. Lambert, Z. Wang, S.C. Zoltai, and M. Siltanen. 1996. Long-term Recovery of Peat Bogs Oiled by Pipeline Spills in Northern Alberta. *Proceedings*, Nineteenth Arctic and Marine Oil Spill Program Technical Seminar, Environment Canada. Vol. 2, pp. 1335-1354.

INCIDENT SUMMARY SHEET

Name: Norsk Hydro Experiment

Date: April-May 1990

Location: Spitsbergen, Norway

Quantity Spilled/Burned: 954 L (6 bbl) for each test burn/95L (6 bbl) for each burn

Oil Product/Type: Marine diesel oil and Oseberg crude oil

Environmental Setting: Ice-covered fjord and snow-covered moraine terrain

Spill Incident Summary:

- The experiments were conducted to develop practical documentation of *in situ* burning of oil in snow.
- Ten experiments were performed using diesel fuel and crude oil.
- Eight of the experiments dealt with oil that was pumped onto or under the snow surface and allowed to spread naturally. Two smaller scale experiments involved oil artificially mixed into the snow and placed in small vessels. The latter two experiments evaluated the effects of oil content in snow on the burning efficiency and method of ignition.
- A gasoline-soaked rag was used as the ignitor.
- For surface spills, the oiled snow was either collected into heaps and ignited, or left undisturbed and ignited.
- For subsurface oil, small trenches were excavated; oil flowed into these trenches and was ignited.
- The snow depth varied from 30 cm to 1.5 m and the porosity ranged from 0.4 to 0.5. The ice formed an impermeable layer.
- The "response time", i.e., the time between the release of oil and the time of ignition, varied from 4 to 13 days to simulate real conditions where response is often limited by environmental or logistical restraints.

Burn Evaluation:

- The success of the burn was very much dependent on the success of ignition.

- The burning efficiency was difficult to determine but was evaluated from the amount of residue left on the meltwater pool and by comparing the size of the pool with the spreading area of the oil. It was estimated to be 90 percent.

- Burning of oil on snow differs from burning of oil on water, because oil mixed in snow does not emulsify, which is characteristic of oil on water. The evaporation rate is also slower with snow.

- For ignition and sustained burning in snow/oil conditions, the oil must first be ignited, and then must generate enough heat to melt the snow, which releases oil and forms a meltwater pool.

- The ignition success depends on the formation of a sufficient layer of oil on the surface of the meltwater pool. The thickness of this layer is governed by the area of the pool and the concentration of oil in the snow.

- The melting process is influenced by the affect of wind on flame deflection and distribution of radiated heat. Melting proceeds in a downwind direction. The wind also herds the oil.

- The properties of the snow affect ignition. As ice formation is induced, the heat needed for melting the oil/snow (ice) increases, and heat loss rises, requiring a greater effort to ignite the oil.

- The burning process begins when enough snow has melted and the oil layer is thick enough to maintain the temperature required to begin gasification. It is the gas released from the oil that is actually being burned.

- Oil-film thickness, and thus burning efficiency, is controlled by the supply of oil from melting snow, the increase in meltwater pool area, and wind control of the spatial distribution of the oil on the pool.

- A steady state situation prevails if the melting process supplies the same amount of oil as is removed by combustion.

- In small-scale experiments on oil/snow mixtures in vessels, the burning efficiency could be precisely evaluated because all the oil was collected and measured volumetrically after settling out of the collected water phase.

- The burn efficiency in the controlled experiments ranged from 92.0-99.9 percent for the diesel and 89.0-98.3 percent for the crude. Oil concentrations in these experiments ranged from 3.1-100 percent by weight.

- The amount of gasoline necessary for successful ignition depended on the oil concentration and the degree of evaporation. In vessels with lower concentrations of oil in snow, ignition could be achieved by increasing the amount of gasoline on the rag.

- The small-scale experiments were varied, with a prevailing wind speed of approximately 10 m/sec. The walls of the vessel acted as containment, and a pronounced wind herding effect was observed but not quantified.

- No differences in the overall burning pattern between the two oil types were found, although the crude oil had a slightly lower burning efficiency than the diesel oil. In both cases, maximum efficiency was close to 100 percent.

Reference(s):

Bech, Cathe and P. Sveum. 1991. Spreading of Oil in Snow: A Field Experiment. *Proceedings*, Fourteenth Arctic and Marine Oil Spill Program Technical Seminar, Environment Canada. pp. 57-71.

Sveum, Per, C. Bech, and M. Thommasen. 1991. Burning of Oil in Snow: Experiments and Implementation in a Norsk Hydro Drilling Contingency Plan. *Proceedings*, Fourteenth Arctic and Marine Oil Spill Program Technical Seminar, Environment Canada. pp. 399-410.

INCIDENT SUMMARY SHEET

Name: Old Peace River Fen Pipeline Spill

Date: 1970

Location: Approximately 250 miles northwest of Edmonton, in the Lesser Slave Lake area of northern Alberta, Canada

Quantity Spilled/Burned: 1,589,873 L (10,000 bbl)

Oil Product/Type: Nipisi crude oil

Environmental Setting: Wet meadow/thin peat and poor fen

Spill Incident Summary:

- The cause of the release was not reported.
- Over 1.6 hectares of wet meadow/peat were impacted.
- The burn was reportedly conducted within one year of the spill (mid-1971).
- The duration of the burn and the type of ignitor used were not reported.
- Water level in the wetland during the time of the spill was not reported.
- There were no reports of extensive physical damage at the site.

Burn Evaluation:

- Field sampling was conducted in July 1995 (24 years post-burn).
- Soil samples were obtained from the side walls of shovel-cut pits and surface grabs. Water samples were also collected. A total of three samples were collected for oil analysis.
- The surface sample from the meadow was moderately weathered; the other surface sample (from a site that appeared to be hydrologically isolated) was only lightly weathered and degraded. The subsurface sample was highly degraded and weathered.
- Vegetation (native plants) was present at the site and seemed remarkably tolerant of oil on top of the water table or within the water-saturated zone.
- When excavated, plants that had colonized the edges of heavily oiled patches appeared to grow through the oiled layer into the relatively clean

substrate, indicating that their roots were somewhat tolerant of oil contamination.

- Healthy plant cover was fairly well established. An oily sheen was visible on water which filled the footprints of the survey group. This observation may indicate that the plants were able to tolerate some level of oily water and sediments.

- Plants were not established on the thick waxy crust (residue) on the burned surfaces.

Reference(s):

Blenkinsopp, S., G. Sergy, P. Lambert, Z. Wang, S.C. Zoltai, and M. Siltanen. 1996. Long-term Recovery of Peat Bogs Oiled by Pipeline Spills in Northern Alberta. *Proceedings*, Nineteenth Arctic and Marine Oil Spill Program Technical Seminar, Environment Canada. Vol. 2, pp. 1335-1354.

INCIDENT SUMMARY SHEET

Name: Pass-a-Loutre, Louisiana

Date: 31 August 1990 (date of burn)

Location: Southeast Pass region of the Mississippi River Delta

Quantity Spilled/Burned: Several thousand liters/Unknown quantity burned

Oil Product/Type: South Louisiana crude oil

Environmental Setting: Brackish-water marsh

Spill Incident Summary:

- A pipeline blowout caused the spill.
- Flares were used to start the fire. The burn lasted one hour and went out once all of the oiled vegetation was burned.
- Water level in the wetland during the time of the spill was not reported.

Burn Evaluation:

- Vegetative recovery was evaluated from videotapes taken 18 and 34 months after the burn. Site visits were conducted on 28-29 July 1994 (four years after the burn). Two control sites were used for comparison.
- Soil TPH levels were: 2.5 mg/g at control site A; 24.6 mg/g at control site B; and 13.8 mg/g at the oiled and burned site. The elevated TPH level at control site B was believed to be due to a previous oil release.
- Live plant biomass values were: 1,030-1,170 g/m^2 at the control sites and 2,167 g/m^2 at the oiled and burned site, indicating substantial recovery.
- Total plant biomass values were: 1,892-1,974 g/m^2 at the control sites and 3,431 g/m^2 at the oiled and burned site, indicating substantial recovery.
- Live-to-dead plant biomass ratios were: 1.7 at the control sites and 2.6 at the oiled and burned sites, and were not significantly different.

Reference(s):

Mendelssohn, I.A., M.W. Hester, and J.W. Pahl. 1995. *Environmental Effects and Effectiveness of IN-SITU Burning in Wetlands: Considerations for Oil Spill Cleanup.* Louisiana Oil Spill Coordinator's Office, Louisiana Applied Oil Spill Research and Development Program, Baton Rouge, LA. 57 pp.

INCIDENT SUMMARY SHEET

Name: Rainbow Fen Pipeline Spill

Date: 1970

Location: Approximately 250 miles northwest of Edmonton, in the Lesser Slave Lake area of northern Alberta, Canada

Quantity Spilled/Burned: 3,179,746 L (20,000 bbl)/Unknown quantity burned

Oil Product/Type: Nipisi crude oil

Environmental Setting: Poor (transitional) fen drained by subsurface seepage

Spill Incident Summary:

- The cause of the release was not reported.
- Over 9.7 hectares of wetland were impacted.
- The burn was reportedly conducted within one year of the spill (mid-1971).
- The duration of the burn and the type of ignitor used was not reported.
- Water level in the wetland during the time of the spill was not reported.
- There were no reports of extensive physical damage at this site.

Burn Evaluation:

- Field sampling was conducted in July 1995 (24 years post-burn).
- Soil samples were obtained from the side walls of shovel-cut pits and surface grabs. Water samples were also collected. Nine samples were collected for oil analysis.
- TPH levels in soil samples were <673 ppm (lightly contaminated). The degree of weathering decreased with depth.
- Plants were not established on the thick waxy crust (residue) on the burned surfaces.
- Vegetation (native plants) was present at the site and seemed remarkably tolerant of oil on top of the water table or within the water-saturated zone.
- When excavated, plants that had colonized the edges of heavily oiled patches appeared to grow through the oiled layer into the relatively clean

substrate, indicating that their roots were somewhat tolerant of oil contamination. Vegetation was noted as growing well on a wet, oily substrate.

- Healthy plant cover was fairly well established. An oily sheen was visible on water, which filled the footprints of the survey group. This observation may indicate that the plants were able to tolerate some level of oily water and sediments.

Reference(s):

Blenkinsopp, S., G. Sergy, P. Lambert, Z. Wang, S.C. Zoltai, and M. Siltanen. 1996. Long-term Recovery of Peat Bogs Oiled by Pipeline Spills in Northern Alberta. *Proceedings*, Nineteenth Arctic and Marine Oil Spill Program Technical Seminar, Environment Canada, Vol. 2, pp. 1335-1354.

INCIDENT SUMMARY SHEET

Name: Rockefeller Wildlife Refuge

Date of Spill: 13 March 1995

Location: Rockefeller Wildlife Refuge, Cameron Parish, Louisiana

Quantity Spilled/Burned: 6360 L (40 bbl)/4770 L (30 bbl)

Oil Product/Type: Condensate oil

Environmental Setting: Brackish-water marsh

Spill Incident Summary:

- The spill was caused by a pipeline break.
- The oil impacted approximately 20 hectares of densely vegetated brackish marsh (*Distichilis spicata*, *Spartina patens*, and *Scirpus spp.*).
- Access to the area was limited to air boat and marsh buggy.
- Mechanical recovery was relatively ineffective, with only 1590 L (10 barrels) being recovered after seven days using portable skimmer pumps and sorbent material (boom and pads).
- Justifications for burning were:
  1. Cleanup personnel could not remove condensate from the vegetated marsh using conventional methods.
  2. Forecasted rain could cause condensate to migrate to environmentally sensitive aquatic areas and further limit the window of opportunity for oil recovery.
  3. Prescribed burning is an accepted wildlife management practice in coastal Louisiana.
  4. Wildlife contamination by condensate was imminent.
  5. Water levels, approximately 5 to 10 cm above the marsh floor, would buffer plant root damage from heat.
- The burn plan was approved five days after the spill and the burn proceeded that same day.
- Hay was used as an ignitor.

- The duration of the intense burn was 2 hours, but the area smoldered throughout the night.
- On the day following the burn, small amounts of remaining condensate were recovered using sorbents and skimmers.

Burn Evaluation:

- Air monitoring was conducted during the burn, but the results were not published. On-scene responders indicated that all parameters were below detection levels (personal communication).
- The burn plan included a vegetation impact study.
- Follow-up surveys were conducted on 22 July 1995 and 6 October 1995.
- Species specific vegetative cover, stem density, and biomass were measured both before and after the burn.
- For all of the measurements taken, the burned area had lower values than the unburned or control areas. However, the burned area also had a greater vegetation increase from summer to fall than the other areas.

Reference(s):

Hess, T.J., I. Byron, H.W. Finley, and C.B. Henry. 1997. The Rockefeller Refuge Oil Spill: A Team Approach to Incident Response. *Proceedings*, 1997 International Oil Spill Conference, Fort Lauderdale, Fla., April 7-10, 1997. pp. 823-828.

Pahl, J.W., I. Mendelssohn, and T.J. Hess. 1997. The Application of *In Situ* Burning to a Louisiana Coastal Marsh Following a Hydrocarbon Product Spill: Preliminary Assessment of Site Recovery. *Proceedings*, 1997 International Oil Spill Conference, Fort Lauderdale, Fla., April 7-10, 1997. pp. 823-828.

INCIDENT SUMMARY SHEET

Name: SIROCO Pipeline Break, Texas

Date of Spill: 3 January 1997

Location: Unnamed creek near DeBerry, Texas

Quantity Spilled/Burned: 7950 L (50 bbl)/7950 L (50 bbl)

Oil Product/Type: Texas sweet crude oil

Environmental Setting: Forested upland and intermittent creek

Spill Incident Summary:

- The spill was caused by a pipeline break.
- The oil flowed approximately 200 m down a hillside and along 300 m of creek bed. The oil spilled at least 4 days before it was reported.
- No mechanical recovery was attempted since it would have resulted in more damage than was acceptable.
- There was light to moderate rain or sleet, with air temperatures near freezing, at the time of the burn.
- Pear burners were used to ignite the oil. It took some time to heat the oil enough to carry combustion.
- The burn lasted three hours.
- An estimated 90 percent of the oil was burned. The remaining oil and ash were recovered manually.

Burn Evaluation:

- No air monitoring was conducted during the burn.
- Small trees along the creek were singed or killed by the heat of the fire.
- Because of the wet conditions, fire did not spread beyond the oiled area.

Reference(s):

Labay, A. 1997. *Pollution Complaint Detailed Report, Event ID 19973A332v1*. Texas Parks and Wildlife Department, Resource Protection Division, Austin, TX. 2 pp.

INCIDENT SUMMARY SHEET

Name: Trans-Alaska Pipeline, Fairbanks

Date of Spill: 15 February 1978

Location: Fairbanks, Alaska

Quantity Spilled/Burned: 2,543,797 L (16,000 bbl)/ 79,500 L (500 bbl)

Oil Product/Type: Prudhoe Bay crude oil

Environmental Setting: Ponded tundra

Spill Incident Summary:

- The spill was a result of a hole blown in the pipeline by an explosive charge.
- The oil was immediately contained by construction of berms in low-lying areas.
- At the time of the spill, the temperature ranged from -26°C to -17°C, with a 45 cm snow pack.
- Vegetation was predominantly sedges and alder, with scattered white spruce, black spruce, and birch.
- Free oil was collected by vacuum truck and re-injected into the pipeline or transported to a recovery station.
- By 15 March, the oiled area was contained by a berm 245 m-long, 4.5 m wide, and 1.5 m high, isolating the area from pending spring thaw drainage.
- On 14 April, highway load restrictions went into effect, which prevented transport of the oil, curtailing vacuuming activities.
- A proposal was submitted on 13 April to burn the remaining 500 bbl.
- A fire break berm was established to provide an 24.5 m buffer between the burn area and the pipeline.
- The site was ignited with two highway flares on 18 April (63 days post-spill). The entire area (~1 hectare) was engulfed in flames in five minutes and burned for two hours.

Burn Evaluation:

- Oil burned readily on the water surface.
- As water heated, more globules of oil were released from ground level and burned.
- Oil burned rapidly on the ice, with very little melting.
- The tundra thawed to a depth of several centimeters.
- Tundra was later disked and re-burnt.
- Light sheen was collected from the ponded area several times during the summer.
- The entire contaminated area was fertilized, but was not re-seeded. Natural recolonization covered about 50 percent of area by the end of the first growing season. Water appeared to be a limiting factor in recolonization.

Reference(s):

Buhite, T.R. 1979. Cleanup of a Cold Weather Terrestrial Pipeline Spill. *Proceedings*, 1979 International Oil Spill Conference, Los Angeles, Calif., March 19-22, 1979. pp. 367-369.

INCIDENT SUMMARY SHEET

Name: Vermilion 16 Oil Spill

Date of Spill: 21 June 1997 (reported)

Location: Freshwater City, Louisiana

Quantity Spilled/Burned: 79,500 L (500 bbl)/79,500 L (500 bbl)

Oil Product/Type: API 50 condensate

Environmental Setting: Brackish-water marsh

Spill Incident Summary:

- The oil leaked from an Apache Vermilion 16 oil line. It was possible that the oil had been leaking for four months.
- Oil impacted 3-4 hectares of marsh dominated by *Scirpus spp.*, *Spartina patens*, and *Distichlis spicata*.
- A firebreak was made along the perimeter by flattening the grasses with an airboat.
- The marsh had 5-10 cm of standing water at the time of the burn.
- The area was ignited with three bundles of dried grass soaked in diesel.
- The burn was conducted on 2 July 1997 and lasted for 45 minutes.
- The day of the burn was hot (no temperature reported) and sunny.

Burn Evaluation:

- Very few patches or pools of oil remained following the burn, although soot was present at the site.
- Six months after the burn, there was very little vegetation re-growth; the site looked like an open pond. Plant death was attributed to the four months of exposure to the light oil, rather than the burn.

Reference(s):

Henry, C.B. 1997. *Vermilion Oil Spill: IN SITU Burn and Monitoring Study*. Chemistry Report IES/RCAT97-30, Institute for Environmental Studies, Louisiana State University, Baton Rouge, LA. 3 pp. + photos.

INCIDENT SUMMARY SHEET

Name: Warwick Lake Diesel Spill

Date of Spill: 16 January 1983

Location: Warwick Lake, Ontario, Canada

Quantity Spilled/Burned: 58,825 L (370 bbl)/49,922 L (314 bbl)

Oil Product/Type: Diesel fuel

Environmental Setting: Streambed and frozen lake

Spill Incident Summary:

- The spill was caused by overflow in a tank farm. The spilled fuel flowed through a breach in the containment basin and followed an old stream bed (under 1 m of snow) to a frozen, snow-covered lake.
- The bottom 15 cm of snow, in the stream bed and on the lake, soaked up the fuel.
- The spill area was remote, and the only access was by plane (no larger than DC-3).
- The cleanup operations were restricted to manual labor.
- Temperatures were between -35°C and -50°C.
- Removal of oil from the site was not feasible, so oiled snow was burned in a large rock basin.
- A "Tiger Torch" was used to ignite the oiled snow, and additional fuel had to be added to facilitate the ignition.
- Cleanup began four days after the spill was discovered. Oil in the water was collected in 55 gallon drums. This product was about 99 percent diesel fuel.
- When the rock basin filled with oily water, a drum of oil recovered from the lake was poured in the basin and ignited, evaporating all water in the basin.
- After all the major oil was removed; pockets of oil that appeared on the lake during the spring thaw were burned.
- After the snow had been removed, the creek bed was burned using wood and sawdust.

- Approximately 49,922 L (314 bbl) were recovered and burned.

Burn Evaluation:

- No formal studies were conducted either during or following the burning.
- There was no contamination on the lake shore, or evidence of oil in the lake.
- The creek bed was slightly contaminated with fuel penetrating 2-4 cm into the sediment. There was dead vegetation along the creek bed.
- The rock basin was scorched and had some soot, but no other evidence of the burn was reported.

Reference(s):

Burns, R.C. 1988. Cleanup and Containment of a Diesel Fuel Spill to a Sensitive Water Body at a Remote Site Under Extreme Winter Conditions. *Proceedings*, 11th Arctic and Marine Oil Spill Program Technical Seminar, Environment Canada, Ottawa, Ontario, Canada. pp. 209-220.

INCIDENT SUMMARY SHEET

Name: Williams Pipeline Co. Surface Spill, Barnsdall, Oklahoma

Date: 5 August 1995

Location: Orange Co., Oklahoma (approximately 1 hour northwest of Tulsa, Oklahoma)

Quantity Spilled/Burned: Approximately 11,924 L (75 bbl)/2862 L (18 bbl)

Oil Product/Type: Jet fuel (Q-Grade)

Environmental Setting: Open field, ditch, and small stream

Spill Incident Summary:

- The release was from a shallow pipeline fitting, within 2 cm of the ground surface. Once the product surfaced, it flowed off-site across a field into a ditch, and entered a stream tributary.
- The product impacted approximately 1.6 km of ditch and tributary and 1,858 m^2 of field.
- Subsurface impacts were limited to the area immediately adjacent to the release point, and less than 15 cm in depth in the impacted field.
- Sorbent boom was deployed in the tributary. An underflow dam was constructed at a point down gradient of the farthest extent of free product. Vacuum trailers were used for product recovery where possible.
- Oil recovery prior to burning was approximately 9,062 L (57 bbl).
- Burning was suggested as a viable alternative to facilitate site cleanup and limit the exposure of the product to water and land.
- The local fire department was present for most of the burning activities and controlled the heat of the fire under power lines.
- Steps taken prior to burning included: the installation of additional boom to pool the product in several places to help control the burning; utilization of leaf blowers to herd the product into several collection areas; flushing the ditch, tributary, and sand and gravel bars to aid in the removal of product from these areas; and blocking the nearby roads and re-routing traffic away from the scene.

- Several product pools in the ditch and tributary were ignited using blow torches, both to initiate and maintain the fires.
- The duration of the burn was not reported.
- The product on the field that could not be recovered by vacuum trucks was ignited (upwind) using a blowtorch.
- 2,862 L (18 bbl) of product were consumed during the burn (based on the initial estimates of product released and recovered by other methods).

Burn Evaluation:

- The field was completely remediated after the burn. Tilling and re-seeding were necessary to return the field to pre-burn conditions.
- After burning the product on the water, there was very little evidence of the spill. Some areas had soot and extremely weathered product and these areas were flushed. Liberated product was recovered with sorbent pads.
- The underflow dam was left in place for several rain events. No product accumulations or rainbow sheens were noted on the water following the next several rain events. Cleanup activities ceased at this time.

Reference(s):

Williams Pipeline Co. (undated report). *Burning as an Initial Response to a Petroleum Release on Land and Water.* 3 pp. plus appendix (photos).

INCIDENT SUMMARY SHEET

Name: Williams Pipeline Company Subsurface Gasoline Spill

Date: Not reported

Location: Barjenbruch Property, Mexico, Missouri (72 km NE of Columbia, Missouri)

Quantity Spilled/Burned: Approximately 14,300 L (90 bbl)/Unknown

Oil Product/Type: Regular, unleaded gasoline

Environmental Setting: Open field

Spill Incident Summary:

- The release occurred as a result of external corrosion on a 30-cm pipeline.
- After the subsurface soil became saturated, gasoline flowed across the ground surface. A creek was located approximately 67 m down gradient of the release point.
- The areal extent of the subsurface impact was 836 m^2 and the surface impact was 186 m^2. No pooling of the product occurred.
- Trenches were excavated to intercept and collect the free phase flow occurring below grade. A vacuum truck was used to remove free product and water accumulating in the trenches. The amount recovered during these operations was not reported.
- Oiled sediments were excavated and stockpiled on-site for land application (site conditions were ideal for land application: hot, dry, and windy). The amount of oil in these sediments was not reported.
- Free phase product was not encountered in the subsurface until the trenches were excavated further down gradient of the pipelines.
- Based on limited understanding of the site geology/hydrogeology at the time of the emergency response activity, there was a concern about the rapid migration of the product toward the creek (impact to surface water) so burning was suggested.
- The Missouri Department of Natural Resources was reluctant to grant approval to burn at this site but reconsidered given the concern about the oil reaching surface water and granted approval to burn over a five day period with a stipulation that a remedial approach be prepared and implemented when the burning period expired.

- The local fire department was placed on notice and the gasoline accumulation in the trenches was ignited and burned.
- The duration of the burn and the type of ignitor was not reported.

Burn Evaluation:

- The total amount of oil burned was unknown.
- The benefits of burning, versus potential subsurface impacts from burning, were described as follows:
  1) lessen groundwater contamination;
  2) prevent migration of the spill through the substrate and possible surface water contamination; and
  3) be a quicker and more continuous method of handling and removing free phase spill product.

Reference(s):

Williams Pipeline Co., (undated report). *IN-SITU Burning as a Method to Control Subsurface Petroleum Product Migration during Emergency Response.* 2 pp. plus appendix (photos).

Appendix C
IN SITU BURN OBSERVATION CHECKLIST

The following is a list of parameters and information that should be documented during *in situ* burning of spilled oil in inland and upland habitats.

- Cause of the spill
- Location of the spill and burn (list both if different)
- Date of the spill and burn (list both if different)
- Date and time of the burn
- Quantity of the spill/quantity of the spill which was burned
- Product type
- Environmental setting of the spill site and burn site (forested upland, marsh [salt, brackish, or fresh], peat bog, agricultural field, open field, etc.)
- Meteorological conditions at the time of the spill (wind speed, temperature, precipitation, etc.).
- Dominant plant species on site (if known) or vegetation types (trees, shrubs, grass)
- Ground slope of burned area (flat, gentle, steep, vertical, etc.)
- Substrate soil type (peat, sand, loam, clay, etc.)
- Moisture content of substrate (dry, moist, saturated)
- If flooded, the depth of water covering the substrate, and if the water is stagnant or moving
- If snow/ice covered, the properties of the snow/ice
- Mechanical methods used prior to burning, with an estimate as to how much oil was removed using these methods
- Reasons for the burn
- Burn preparation, including safety and control precautions taken prior to and during the burn
- Ignition source and accelerant type (if one was used)
- Air temperature during the burn
- Weather during the burn (wind speed and direction, rainfall, etc.)
- Burn duration
- Residue type and volume (if any) remaining following the burn
- Depth of water after the burn
- Visible impacts to area (vegetation, substrate, wildlife, erosion, etc.)
- Air quality monitoring results (500-1,000 m downwind of the burn)
- Post-burn activities, including type of cleanup, restoration, etc.
- Results of any long-term monitoring conducted at the site

American Petroleum Institute
1220 L Street, Northwest
Washington, D.C. 20005
202-682-8000
http://www.api.org

Order No. I46840

RO PUBL 4684-ENGL 1 0732290 0614217 045