SPECIAL REPORT 281

# Transmission Pipelines and Land Use

## *A Risk-Informed Approach*

TRANSPORTATION RESEARCH BOARD

OF THE NATIONAL ACADEMIES

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Committee for Pipelines and Public Safety:
Scoping Study on the Feasibility of Developing
Risk-Informed Land Use Guidance near
Existing and Future Transmission Pipelines

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*OF THE NATIONAL ACADEMIES*

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This report has been reviewed by a group other than the authors according to the procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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## Committee for Pipelines and Public Safety: Scoping Study on the Feasibility of Developing Risk-Informed Land Use Guidance near Existing and Future Transmission Pipelines

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# Preface

Over the past 10 years, energy demands have increased by about 35 percent, and recent estimates indicate that the demand for energy fuels may increase by another 36 percent between 2002 and 2010. The nation's projected demand for energy, particularly in fast-growing metropolitan areas, implies that many additional miles of transmission pipelines will be needed. In addition, increasing urbanization is resulting in more people living and working closer to pipelines. Thus, public safety near pipelines remains an issue and is likely to become even more important.

Pipelines, particularly gas distribution lines, are widespread in this country. However, the consequences of incidents that involve large-diameter, high-pressure *transmission* pipelines can be significant for public safety and the environment. A number of high-profile incidents involving transmission pipelines in urban and environmentally sensitive areas have recently focused public attention on pipeline safety and the need to examine land use practices to determine whether they can be modified to reduce the likelihood and impacts of catastrophic pipeline incidents.

In 1988, the Transportation Research Board (TRB) published *Special Report 219: Pipelines and Public Safety,* which assessed the adequacy of measures used to protect the public near pipelines. The report examined land use adjacent to pipelines that transport hazardous commodities and methods that could be used to increase the safety of the public in the vicinity of pipelines. A number of damage prevention, land use, and emergency preparedness measures to help reduce the risks due to pipeline accidents were proposed.

The Transportation Equity Act for the 21st Century, signed into law on June 9, 1998, authorized the U.S. Department of Transportation to undertake a study of damage prevention practices associated with existing one-call notification systems. The study was to determine which practices were most effective in protecting the public, excavators, and the environment, while preventing disruptions to public services and underground facilities. The Common Ground Task Force, which consisted of nine task teams each focusing on one subset of attributes of one-call systems and damage prevention processes, identified 133 best practices. They are discussed in the consensus report *Common Ground Study of One-Call Systems and Damage Prevention Best Practices* published in 1999. The report identified a wide range of useful strategies in the planning and design phase of development projects, including such practices as underground facilities surveys; clear marking of pipelines; the inclusion of pipeline easements on plat maps; conferences among builders, owners, and regulators; and prior consultations with utility managers by designers and contractors. The report did not, however, cover such topics as recommended setbacks and zoning near transmission pipelines.

The primary objectives of pipeline-related land use measures are to reduce the risk of damaging the pipelines by keeping human activity away from their immediate vicinity and to minimize the exposure of those living and working near a transmission pipeline in the event of an accident. Jurisdiction over land use matters traditionally rests with local governments, which results in wide variations in practices. However, most local governments do not address pipeline issues; when they do, they have few or no data on which to base land use regulations.

The few localities that have attempted to address the issue of pipeline safety have either adopted land use measures that border on being arbitrary and not based on the actual risk posed by a particular pipeline or have been stymied altogether by legal barriers that prevent any local regulation of pipeline operations. This situation might change if localities had access to objective, risk-informed guidance. Such guidance could help them assess the actual degree of risk posed by a particular class or type of pipeline and establish reasonable ordinances and regulations that could be effective in reducing that risk and protecting the property interests of landowners and pipeline operators.

## APPROACH OF THE STUDY

The Pipeline Safety Improvement Act of 2002 (Section 11, P.L. 107-355, December 17, 2002) requires the Secretary of Transportation, in conjunction with the Federal Energy Regulatory Commission (FERC) and in consultation with other relevant agencies, to conduct a study of population encroachment on rights-of-way. Before passage of the act, the Research and Special Programs Administration's Office of Pipeline Safety (OPS) had asked TRB to examine evidence of the risks to the public of increased development and population in proximity to pipelines; to understand how these risks vary on the basis of differences in product, pipeline characteristics, and other features; and to explore the feasibility of establishing development setbacks that local governments might use to regulate encroaching development around existing pipelines. After passage of the act, the TRB study was modified to assist in meeting the legislative mandate.

Specifically, the committee was tasked to consider the feasibility of developing risk-informed guidance that could be used in making land use-related decisions as one means of minimizing or mitigating hazards and risks to the public, pipeline workers, and the environment near existing and future hazardous liquids and natural gas transmission pipelines. In assessing the feasibility of such an approach, the committee considered such factors as existing or proposed land use and zoning practices; competing needs of compatible uses, including multiple uses of rights-of-way; pipeline design, age, diameter, pressurization, and burial depth; and commodity transported. The committee also considered the various hazards posed by transmission pipelines to life, property, and the environment in the vicinity of these pipelines, as well as the need to balance pipeline safety and environmental resource conservation issues (e.g., preservation of trees and habitat) in pipeline rights-of-way (recognizing operators' regulatory obligations to patrol rights-of-way, including inspection by air and land). The study did not address security standards, and the committee was not adequately composed to identify them.

Given the nature of this scoping study, the committee briefly considered other industries but did not undertake assessments to determine the generalizability of information in those fields to transmission pipelines. For example, although high-voltage electricity transmission lines are also linear utilities, the committee does not believe that there is much applicability to natural gas and hazardous liquids transmission pipelines because the factors, the threats, and the costs (i.e., impacts) of failures are not comparable. Because high-voltage electricity transmission lines are aboveground, highly visible, and sometimes audible, there is less probability of third-party damage to these lines than to transmission pipelines.

To fulfill the charge, TRB appointed a committee that included individuals with expertise in management and safety of pipeline operations, materials science, risk assessment, land use planning and zoning, law, ecology and environmental science, and development. (Biographical sketches of the committee members can be found at the end of the report.) The committee required individuals with an understanding of how pipelines are constructed, maintained, operated, and regulated and individuals with technical expertise in materials properties, explosion damage, geotechnical engineering, and land use. The committee met four times—in September and December 2003 and February and April 2004—and a subgroup of the committee met in November 2003.

## ACKNOWLEDGMENTS

The work of this committee has been greatly helped by the thoughtful advice and background information provided by all of the meeting presenters (a list of presentation topics and presenters can be found in Appendix A), as well as other government and industry officials who were consulted during the study. The committee gratefully acknowledges the contributions of time and information provided by the sponsor liaisons and the many individuals within and outside government who are interested or involved in pipeline and public safety issues. The committee particularly thanks the liaison representatives Steven Fischer and Jeff Wiese of OPS in the U.S. Department of Transportation and Rich Hoffmann, Mark Robinson, and Douglas Sipe of FERC. The committee is especially indebted to Terry Boss, Interstate Natural Gas Association of America, and Ben Cooper, Association of Oil Pipe Lines and American Petroleum Institute, who responded promptly and with a generous spirit to the committee's numerous requests for information.

In addition, the committee thanks the many pipeline industry, trade association, and state and local government representatives who provided input: Debbie Bassert and Keyvan Izadi, National Association of Home Builders; Sarah Bolton, National Association of State Fire Marshals; Skip Brown and Herb Wilhite, Cycla Corporation; William Roger Buell, Jim Fahey, and Peter King, American Public Works Association; Steve Burkett, Randy Russell, and Steve Troch, Baltimore Gas and Electric; Rod Dyck, National Transportation Safety Board; Stacey Gerard and John Pepper, OPS; Bob Kipp, Common Ground Alliance; Pam Lacey and George Mosinskis, American Gas Association; Chuck Lesniak, City of Austin, Texas; Nick Manetto, Congressman Christopher Smith's Office; Kris Mayes, Arizona Corporation Commission; Terry Mock, International Right-of-Way Association; Chuck Mosher, Bellevue, Washington; Bob Rackleff, Leon County, Florida; Jim Schwab, American Planning Association; Captain Dean Sherick, Fairfax County Fire and Rescue; Julie Ufner, National Association of Counties; and Jim Wunderlin, Southwest Gas Corporation.

The study was performed under the overall supervision of Stephen R. Godwin, TRB's Director of Studies and Information Services. Beverly Huey managed the study and, with Stephen Godwin, drafted the report under the guidance of the committee. The committee gratefully acknowledges the work and support of Alan Crane, who provided assistance in the committee nomination process; Suzanne Schneider, Associate Executive Director of TRB, who managed the review process; Senior Editor Norman Solomon, who edited the report; Jennifer J. Weeks, Senior Editorial Assistant; and Javy Awan, Director of Publications.

The report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making the published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process.

The committee thanks the following individuals for their review of this report: George E. Apostolakis, Massachusetts Institute of Technology, Cambridge; Steven N. Handel, Rutgers University, New Brunswick, New Jersey; Chris Hendrickson, Carnegie Mellon University, Pittsburgh, Pennsylvania; Robert G. Paterson, University of Texas at Austin; Malcolm Rivkin, University of Maryland, College Park; and Bernd J. Selig, Bloomfield, Connecticut. Although these reviewers provided many constructive comments and suggestions, they were not asked to endorse the findings and conclusions, nor did they see the final draft before its release.

The review of this report was overseen by C. Michael Walton, University of Texas, Austin. Appointed by the National Research Council, he was responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

Don E. Kash, *Chair*
Committee for Pipelines and Public Safety:
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# Glossary

A number of technical terms that may be unfamiliar to the reader are used in this report. Some, such as "right-of-way," are legal terms that normally have a specific meaning differing from their lay usage. In such cases, the committee has chosen the more colloquial usage. Other terms are defined strictly in accordance with their usage in the context of pipelines. Below are the meanings subscribed to by the committee.

**Easement.** A legal instrument giving a pipeline operator a temporary or permanent right to use a right-of-way for the construction, operation, and maintenance of a pipeline. It may also include temporary permits, licenses, and other agreements allowing the use of one's property.

**Encroachment.** A use (e.g., human activity), structure, facility, or other physical improvement that intrudes onto a pipeline right-of-way or in proximity thereto.

**Fee simple.** The maximum ownership interest one can hold in real estate. As used in this report, it connotes the permanent, underlying interest in the land across which a right-of-way runs and to which an easement applies.

**Hazardous liquid.** Petroleum, petroleum products, or anhydrous ammonia (49 CFR 195.2), or liquid natural gas or a liquid that is flammable or toxic (49 CFR 193.2).

**Incident.** A release of product from a pipeline that may or may not result in death, injury, or damage to property or the environment. The term does not address intentionality or unintentionality of individuals in the release of the product. To many people, "accident" implies unintentionality; "incident" is considered to be more encompassing and includes terrorist attacks, sabotage, and other events that are intentional, in addition to unintentional acts.

**Nonconforming use or structure.** A use or structure that is impermissible under current zoning restrictions but that is allowed because the use or structure existed lawfully before the restrictions took effect.

**Reportable hazardous liquids pipeline incident.** An event or failure in a pipeline system that must be reported to the Office of Pipeline Safety and that results in the release of a hazardous liquid or carbon dioxide and in any of the following:

1. Explosion or fire not intentionally set by the operator;
2. Release of 5 gallons (19 liters) or more of hazardous liquid or carbon dioxide, except that no report is required for a release of less than 5 barrels (0.8 cubic meters) resulting from a pipeline maintenance activity if the release is
   – Not otherwise reportable under this section (i.e., 49 CFR 195.50),
   – Not one described in 49 CFR 195.52(a)(4),
   – Confined to company property or pipeline right-of-way, and
   – Cleaned up promptly;
3. Death of any person;
4. Personal injury necessitating hospitalization;
5. Estimated property damage, including cost of cleanup and recovery, value of lost product, and damage to the property of the operator or others, or both, exceeding $50,000 (49 CFR 149.50).

**Reportable natural gas pipeline incident.** An event in the natural gas pipeline system that must be reported to the Office of Pipeline Safety and

1. Involves a release of gas from a pipeline or of liquefied natural gas (LNG) or gas from an LNG facility and results in

- Death, or personal injury necessitating in-patient hospitalization; or
- Estimated property damage, including cost of gas lost, and damage to the property of the operator or others, or both, of $50,000 or more.

2. Results in an emergency shutdown of an LNG facility.
3. Is significant, in the judgment of the operator, even though it did not meet the criteria of (1) or (2) above (49 CFR 191.3).

**Right-of-way.** A piece of property, usually consisting of a narrow, unobstructed strip or corridor of land of a specific width, which a pipeline company and the fee simple landowner both have legal rights to use and occupy.

**Right-of-way agreement.** See *Easement.*

**Risk-based approach.** An approach in which decisions or regulations are heavily based on risk assessment calculations, without other considerations.

**Risk-informed approach.** An approach in which risk insights are used in conjunction with other information, both quantitative and qualitative, in making safety decisions.

**Setback.** The minimum amount of space required between a lot line and a building line (e.g., a 12-foot setback). As used in this report, it generally refers to the minimum distance between a pipeline and a building or other structure.

**Transmission pipeline.** A pipeline, other than a gathering line, that transports natural gas or hazardous liquids from producing areas to refineries and processing facilities and then to consumer areas and local distribution systems.

# Contents

# Executive Summary

The United States is heavily dependent on transmission pipelines to distribute energy because they are the safest mode available for transporting energy fuels. Virtually all natural gas, which accounts for about 28 percent of energy consumed annually, and two-thirds of petroleum products are transported by transmission pipelines, which make up 20 percent of the 1.8 million total miles of pipelines in the United States. Energy demand has increased by about 35 percent in the last decade, and recent estimates indicate that the demand for energy fuels may increase by another 36 percent between 2002 and 2010.

The nation's projected demand for energy, particularly in new and fast-growing metropolitan areas, may require many additional miles of transmission pipelines. Increasing urbanization, which is accompanying the increasing demand, is resulting in more people living and working closer to pipelines. In many cases, development near pipelines is occurring in formerly rural, unincorporated areas long after pipelines have been constructed but before local agencies develop land use regulations that take into account the risks of allowing such development to occur. Given these projections and the fact that pipeline incidents occur almost daily in the United States, regulatory agencies at the national level view pipeline safety as an issue that needs to be addressed.

In recent years major pipeline incidents have occurred, and public opposition to the construction of new pipeline rights-of-way has increased. These events have focused more attention on the need to assess carefully and rationally the actual risks associated with living and working in proximity to transmission pipelines and to consider land use controls near pipelines that will allow people and pipelines to coexist in a manner that does not pose undue risk to each other. In December 2002, Congress enacted the Pipeline Safety Improvement Act of 2002, which requires the Secretary of Transportation, in conjunction with the Federal Energy Regulatory Commission and in consultation with other relevant agencies, to conduct a study of population encroachment on rights-of-way. The Office of Pipeline Safety (OPS) in the U.S. Department of Transportation (USDOT) requested the Transportation Research Board (TRB) to assist in meeting this legislative mandate. Specifically, TRB was asked to convene a committee to consider the feasibility of developing risk-informed guidance that could be used in making land use-related decisions as one means of minimizing or mitigating hazards and risks to the public, pipeline workers, and the environment near existing and future hazardous liquids and natural gas transmission pipelines. In addition, the committee was asked to consider environmental resource conservation issues (e.g., preservation of trees and habitat) in pipeline rights-of-way.

## DATA

Transportation of energy fuels via transmission pipelines is safer than transportation via other modes, but a significant failure can result in loss of life, personal injury, property damage, and environmental damage. In the last 3 years, hazardous liquids pipeline incidents have resulted in an average of 2 deaths, 11 injuries, and $97 million in property damage each year; natural gas transmission pipeline incidents have resulted in an annual average of 6 deaths, 10 injuries, and $20 million in property damage. From 2000 through 2002, the annual average number of gross barrels of hazardous liquids lost was 100,000, a decrease from the annual average of 270,000 gross barrels lost in the 1986 to 1989 time period. There are many causes and contributors to pipeline failures, including construction errors, material defects, internal and external corrosion, operational errors, malfunctions of control systems or relief equipment, and outside force damage (e.g., by third parties during excavation). Excavation and construction-related damage to pipelines remain the leading causes of pipeline failure. Such failures in 2003 were estimated by USDOT to contribute 22 percent of hazardous liquids and 24 percent of natural gas transmission pipeline incidents. With the growth in population, urbanization, and land development activity near transmission pipelines and the addition of new facilities, the likelihood of pipeline damage due to human activity and the exposure of people and property to pipeline failures may increase.

## LAND USE MEASURES

Awareness is growing among federal agencies and the pipeline industry that risk-based approaches to managing pipeline safety should be considered for the following reasons:

- The exposure to hazards associated with proximity to transmission pipelines carrying various commodities involves significant uncertainties.
- More people are living and working closer to transmission pipelines.
- Some new transmission pipelines will be constructed in densely populated areas.

Recently, OPS implemented the Integrity Management Program, a regulatory approach that requires pipeline operators to comprehensively assess, identify, and address the safety of pipeline segments that are located in areas where the consequences of a pipeline failure could be significant. However, this effort does not incorporate land use measures (e.g., comprehensive plans, zoning, and setbacks) that could be employed to manage the risks because such measures are primarily the responsibility of state and local governments.

The terms "land use" and "land use practices" are normally used to describe policies and practices of local governments that regulate the planning, development, and use of land. The committee expanded this definition to include a broader range of actions taken by all stakeholders—pipeline operators, regulators, contractors, private property owners, and the public—affecting the immediate vicinity of pipelines.

Under such a definition, the most common land use measures employed to preserve the integrity of pipelines involve actions taken by pipeline operators to create, inspect, and enforce their own pipeline rights-of-way. Pipeline companies typically negotiate easements with individual property owners that give the pipeline operator authority to use the rights-of-way for construction and operation of the pipeline, including the right to repair and maintain it. The authority of pipeline operators to control the use of the right-of-way is determined by the terms of the easement agreement; control does not extend to any property not covered by the easement/license.

Land use measures can reduce the risk of disturbing the pipelines by keeping human activity away from the immediate vicinity of the pipelines and by minimizing the exposure of those living and working near a transmission pipeline in the event of an incident. Some states set land use policy or mandate various kinds of land use and development regulation to protect against natural hazards.

Most local governments do not address pipeline issues. For those that do, there are few or no standards on which to base zoning ordinances and other development regulations. Some communities that have experienced pipeline incidents are implementing ordinances and other policies to reduce the perceived risks attributable to transmission pipelines, but these proposed ordinances do not appear to be based on a systematic assessment of risks and costs.

Although there is a lack of risk-based technical guidance for making land use decisions near transmission pipelines, the committee noted that much can be learned from hazard mitigation management techniques and strategies that have been adopted by state and local governments in other areas. These may be instructive in applying a risk-informed approach to land use measures for managing pipeline risks. At present, numerous local governments employ building standards, site design requirements, land use controls, and public awareness measures to reduce losses due to natural hazards (such as earthquakes and floods). However, state and local officials lack guidance for pipelines, other than rules of thumb and existing practice concerning appropriate setbacks.

## RISK-INFORMED GUIDANCE

While there is a general recognition that pipelines pose a hazard to people, property, and the environment, the extent of the danger is not well understood. Risk is inherent in the pipeline system—it can be reduced and managed, but it cannot be eliminated. Risk assessment practice attempts to answer the following questions:

- What can go wrong?
- How likely is it?
- What are the consequences?

Regulatory approaches can be risk-based, risk-informed, risk-informed performance-based, or other variations of these. In the risk-based approach, decisions or regulations are heavily based on risk assessment calculations, without other considerations. Because such an approach places a heavy burden on risk computation, which may suffer from lack of data or models or imperfect consideration of scenarios, its application is limited. In the risk-informed approaches, risk insights are used in conjunction with other information, both quantitative and qualitative, in making safety decisions. Because risk-informed approaches allow for the logical structuring of decisions by including relevant factors, they are of more practical value.

Effective use of a risk-informed approach requires an understanding of the relevant factors and the relationships among these factors. In a risk assessment, which is a systematic and comprehensive approach, the likelihood of initiating events, as well as the likelihood of the various outcomes that may result from each initiator, is a concern. In assessing likelihood, a fundamental issue is the metric to be used. Likelihood can be expressed in terms of probability, and the combinations needed to yield the various outcomes can be computed by the use of logic and probability theory. However, the data that go into such calculations may entail significant uncertainties. Unless these uncertainties are explicitly acknowledged, the viability of the whole approach in decision making is compromised.

Local governments are increasingly faced with issues of land use. It appears beneficial for them to have available an easy-to-apply means for making decisions in a manner that allows flexibility in choosing the level of risk deemed appropriate. This is possible if the decision process is structured in a risk framework as outlined above. In addition, most local governments have neither the resources nor the in-house expertise to develop such a structure. Rather, a national-level effort is needed to develop a risk-informed approach and provide an appropriate level of abstraction that is easy to understand and use at all levels of government. Following implementation of selected options, system performance can be monitored to determine whether risk control measures are effective. This iterative process can, over time, continue to reduce overall risk.

For the pipeline system, there are many stakeholders—policy makers, planners and system design experts, pipeline workers, local officials, property owners, residents, pipeline companies, and trade associations. They all should be knowledgeable about the risks so that informed guidance can be provided. Involvement and a shared commitment among these interested parties, effective communication, training, and procedures can make managing the risks associated with pipeline operations more effective. A well-thought-out risk management framework that measures the risks and identifies a set of risk mitigation alternatives would facilitate discussions among the stakeholders.

## FINDINGS

1. **Pipeline incidents have potential for significant impact on life, property, and the environment.**
2. **Just as transmission pipelines pose a risk to their surroundings, so does human activity in the vicinity of pipelines pose a risk to pipelines. These risks increase with growth in population, urban areas, and pipeline capacity and network.**
3. **Land use decisions can affect the risks associated with increased human activity in the vicinity of transmission pipelines.**
4. **Pipeline safety and environmental regulation have generally focused on (*a*) the design, operation, and maintenance of pipelines and (*b*) incident response. They have not directed significant attention to the manner in which land use decisions can affect public safety and the environment.**
5. **For the most part, state and local governments have not systematically considered risk to the public from transmission pipeline incidents in regulating land use.**
6. **Risk-informed approaches are being used effectively in other domains (e.g., natural hazard mitigation, industrial hazard mitigation, nuclear reactor and waste disposal programs, tanker safety).**

**These techniques are also being used to address other aspects of pipeline safety (e.g., pipeline integrity), but they have not been used to make informed land use decisions.**

7. **Currently, decision makers lack adequate tools and information to make effective land use decisions concerning transmission pipelines.**
8. **Many different forms of pipeline easements are in effect, and the terms and conditions vary widely. To the extent that an easement lacks clarity, enforcement of the right-of-way is more difficult.**
9. **Encroachments and inappropriate human activity within the right-of-way can adversely affect pipeline safety. There appears to be variability in the quality and extent of inspections, maintenance, and enforcement of rights-of-way.**

## CONCLUSIONS

**Conclusion 1. Judicious land use decisions can reduce the risks associated with transmission pipelines by reducing the probabilities and the consequences of incidents.**

Pipeline safety is a shared responsibility. Land use decisions and control of activities and development near transmission pipelines may be undertaken by the pipeline operator, safety regulators, state and local officials, and the property developers and owners. Appropriate land use measures applied by local governments could bolster and complement a pipeline company's efforts to protect the right-of-way and preclude uses that could pose a public safety risk.

Rational land use decisions that provide appropriate physical separation between people and pipelines could reduce the risk associated with the increasing numbers of people in proximity to transmission pipelines. Possible land use techniques include, for example, establishing setbacks; regulating or prohibiting certain types of structures (such as schools, hospitals, and apartment buildings) and uses near transmission pipelines; and encouraging, through site and community planning, other types of activities and facilities (e.g., linear parks, recreational paths) within or in the vicinity of pipeline rights-of-way. Utilization of such tools can be legitimate exercises of the local jurisdictional police power if they are appropriately instituted, particularly if such exercises are grounded in objective, scientifically derived data.

**Conclusion 2. It is feasible to use a risk-informed approach to establish land use guidance for application by local governments.**

Various forms of risk-informed management of pipeline safety are already in wide use within the pipeline industry. Moreover, the integrity management regulations governing liquids and natural gas pipelines recently promulgated by OPS require private operators to prioritize enhanced risk-reduction efforts by using risk assessment.

The probability of failure of any transmission pipeline is a function of several distinct but interrelated factors including materials of construction, fabrication, corrosion, effectiveness of pipeline coatings and cathodic protection systems, pressurization, and depth of cover. Data and models are lacking for making precise predictions about specific lines, but estimates can be developed at an aggregate level and adjusted to account for local conditions. The possible consequences of an event could be estimated on the basis of the product carried, degree of pressurization, depth of cover, surrounding development, and other considerations. The appropriateness and acceptable cost of various measures to reduce probability and consequence could be derived from local values. Although such a risk-informed approach may be somewhat simplistic initially, it could be improved over time to a sufficient degree to help government officials regulate land use. The committee envisions an ongoing process that would involve risk assessment experts and stakeholders in the development, ongoing refinement, and application of such information.

**Conclusion 3. The federal government could serve a useful role by providing leadership in the development of risk-informed land use guidance for application by local, state, and federal governments.**

Pipeline safety is a national issue because the United States is traversed by 380,000 miles of transmission pipelines transporting numerous products, most of which could pose a threat to life, property, and the environment in the event of a pipeline failure. Because of the numerous stakeholders concerned about pipeline safety and their divergent interests and the national breadth of the concerns, the federal government may be best positioned to initiate an open process of developing risk-informed guidance. OPS has already played a similar role in fostering and initially supporting the Common Ground Alliance. Land use policies relevant to transmission pipelines are made at all levels of government and need to be based on an unbiased, scientific analysis of the risks posed by pipelines to their immediate surroundings. Local governments generally lack the resources and incentives to undertake such an effort on their own. The advantage of consistent guidance across jurisdictional lines also argues for federal leadership.

**Conclusion 4. There is clear evidence that guidelines can be developed that would assist in preserving habitat while maintaining rights-of-way in a state that facilitates operations and inspection.**

As an adjunct to its main charge, the committee was asked to consider the problem of habitat loss when rights-of-way are initially cleared and subsequently maintained to allow for inspection, which is required by federal law. Right-of-way maintenance facilitates such inspection, usually conducted by aerial surveillance, and reduces the potential for tree roots to interfere with pipelines, which may contribute to failure. Rights-of-way can provide useful and functional habitat for plants, nesting birds, small animals, and migrating animals. In developed or urban areas, the ecological function of such rights-of-way may be useful but can be marginal, in large part because of the narrowness of the right-of-way and the already extensive habitat fragmentation. There is an overriding environmental benefit in effective inspection of pipelines to avoid incidents with consequent releases and environmental damage.

## RECOMMENDATIONS

**Recommendation 1. OPS should develop risk-informed land use guidance for application by stakeholders. The guidance should address**

- **Land use policies affecting the siting, width, and other characteristics of new pipeline corridors;**

- **The range of appropriate land uses, structures, and human activities compatible with pipeline rights-of-way;**
- **Setbacks and other measures that could be adopted to protect structures that are built and maintained near pipelines; and**
- **Model local zoning ordinances, subdivision regulations, and planning policies and model state legislation that could be adopted for land uses near pipelines.**

**Such a risk-informed guidance system should include three interrelated components:**

1. **A decision framework informed by risk analysis,**
2. **Guidelines based on the analysis, and**
3. **Alternative actions that could be taken on the basis of the guidelines.**

**Recommendation 2. The process for developing risk-informed land use guidance should (*a*) involve the collaboration of a full range of public and private stakeholders (e.g., industry and federal, state, and local governments); (*b*) be conducted by persons with expertise in risk analysis, risk communication, land use management, and development regulation; (*c*) be transparent, independent, and peer reviewed at appropriate points along the way; and (*d*) incorporate learning and feedback to refine the guidance over time.**

**Recommendation 3. The transmission pipeline industries should develop best practices for the specification, acquisition, development, and maintenance of pipeline rights-of-way. In so doing, they should work with other stakeholders. With regard to the specific maintenance issue of clearing rights-of-way to allow for inspection, the federal government should develop guidance about appropriate vegetation and environmental management practices that would provide habitat for some species, avoid threats to pipeline integrity, and allow for aerial inspection.**

# 1

# Introduction

Pipeline incidents,[1] population growth, urbanization, increasing energy demands, and increasing public opposition to the siting of new pipelines have combined to focus greater attention on the need for increased land use controls in the vicinity of pipelines and led to the request for this study. The purpose of this scoping study is to consider the feasibility of developing risk-informed guidance as one means of minimizing or mitigating hazards and risk to the public, pipeline workers, and the environment near existing and future transmission pipelines carrying natural gas, petroleum, and other hazardous liquids. The study was requested by the Office of Pipeline Safety (OPS) of the U.S. Department of Transportation (USDOT) to assist OPS and the Federal Energy Regulatory Commission (FERC) in developing guidance for use by states, counties, cities, and towns that have existing or proposed transmission pipelines.

## BACKGROUND

The United States depends heavily on hydrocarbon fuels and petrochemicals transported through 1.8 million miles of pipelines. The main transmission pipelines,[2] which make up 20 percent of this pipeline mileage, crisscross the nation. Many of the largest lines originate on the

[1] The term "incident" (rather than "accident" or "event") is used throughout the report to refer to any release of product from a pipeline, whether or not it results in death, injury, property damage, or environmental damage. To many people, the term "accident" implies nonintentionality; incident is considered to be more encompassing and includes terrorist attacks, sabotage, and other events that are intentional, in addition to unintentional acts.

[2] This study addresses only transmission pipelines—pipelines that carry natural gas and liquids from producing areas to refineries and processing facilities, and then to consumer areas and local distribution systems. It does not address local distribution systems or gathering systems.

Gulf Coast and extend to the major metropolitan areas of the Northeast and Midwest. The system operates largely outside of the public's consciousness, perhaps because pipelines are buried and are considerably safer than surface modes for transporting freight, and most incidents receive little national attention.

Although relatively few fatalities and injuries are due to pipeline incidents in the United States each year, such incidents occur almost daily. Most state and local governments do not perceive transmission pipelines to be a significant hazard unless pipeline incidents resulting in death, injury, or extensive property damage have occurred in their communities. Nevertheless, some communities that have experienced or been affected by a serious pipeline incident consider pipeline safety to be an important issue that is currently not adequately addressed.

The regulatory agencies at the national level view pipeline safety as an important issue because a pipeline incident could result in a significant number of casualties and extensive property damage. (See Box 1-1 for descriptions of seven transmission pipeline incidents that have occurred in the last 15 years. The descriptions present a range of effects in terms of number of deaths and extent of property and other environmental damage.) Given increasing urbanization, more and more land development is encroaching on transmission pipeline rights-of-way, resulting in more people living and working closer to pipelines. In addition, the nation's projected increasing demand for energy, particularly in new and fast-growing metropolitan areas, implies that many additional miles of transmission pipelines (with their concomitant cost, property rights, and environmental and jurisdictional issues) will be needed to serve these areas. Awareness is growing that risk-based approaches to managing pipeline safety should be considered, for the following reasons:

- The exposure to hazards associated with proximity to pipelines carrying various commodities is not well established.
- More people are living and working closer to transmission pipelines.
- Some new transmission pipelines will be constructed in densely populated areas.

The remainder of this chapter provides information on the safety record of pipelines, projections for energy demand, trends in land devel-

BOX 1-1

## Examples of Transmission Pipeline Accidents

**San Bernardino, California**

In May 1989, a Southern Pacific train derailed in San Bernardino, California, plowing through a residential neighborhood and killing four people. The train landed on top of a pipeline operated by Calnev Pipeline Company, an interstate carrier that transports petroleum from California to Nevada. Thirteen days after the train derailment and after train service had been restored, the pipeline exploded in the same location, killing two people, destroying 10 homes, and injuring dozens of people.

**Fredericksburg, Virginia**

Colonial Pipeline Company operates more than 5,317 miles of petroleum pipeline in 13 states and the District of Columbia, with its major lines running from Texas to New York. In the 1980s, two spills of hazardous liquids affected the water supply of Fredericksburg, Virginia. The first spill occurred on March 6, 1980, when a 32-inch petroleum line ruptured in two places, one near Manassas, Virginia, causing the release of 336,000 gallons of kerosene, and a second near Locust Grove in Orange County, Virginia. Before the first spill could be contained, kerosene flowed into Bull Run and entered the Occoquan Reservoir, which supplied drinking water for Fairfax County, Virginia. The second rupture caused 92,000 gallons of fuel oil to spill into the Rapidan and Rappahannock Rivers. The city of Fredericksburg, Virginia, which draws its water supply from the Rappahannock River, about 20 miles downstream of the rupture, was forced to shut down its water treatment plant for more than a week and had to transport drinking water from a neighboring county.

Nine years later, on December 18, 1989, another rupture occurred on the pipeline in Locust Grove, releasing 212,000 gallons

(*continued on next page*)

BOX 1-1 (*continued*)
**Examples of Transmission Pipeline Accidents**

of kerosene into the Rapidan and Rappahannock Rivers. Colonial Pipeline Company erected two containment dams and attempted to recover the spilled product; however, these efforts were impeded by the inaccessibility of the spill site and ice on the river. On New Year's Eve, after a rapid thaw and heavy rains, the containment dams broke, and kerosene flowed downstream toward Fredericksburg, 20 miles away. Again, fish and game were killed, and Fredericksburg's water supply was contaminated; drinking water had to be hauled in from Stafford County for 7 days.

**Edison, New Jersey**
On March 23, 1994, a 36-inch-diameter pipeline owned and operated by Texas Eastern Transmission Corporation ruptured catastrophically in Edison Township, New Jersey, within the property of Quality Materials, Inc., an asphalt plant. The force of the rupture and of natural gas escaping at a pressure of about 970 pounds per square inch gauge excavated the soil around the pipe and blew gas hundreds of feet into the air, propelling pipe fragments, rocks, and debris more than 800 feet. Within 1 to 2 minutes of the rupture, the gas ignited, sending flames upward 400 to 500 feet. Heat radiating from the massive fire ignited several building roofs in a nearby apartment complex. Occupants, alerted to the emergency by noises from escaping gas and rocks hitting the roofs, fled from the burning buildings. The fire destroyed eight buildings. Approximately 1,500 apartment residents were evacuated. Although none of the residents suffered a fatal injury, response personnel evacuated 23 people to a local hospital and another estimated 70 apartment residents made their own way to hospitals. Most of the injuries were minor foot burns and cuts resulting from the hot pavement and glass shards as residents fled the complex.

The National Transportation Safety Board (NTSB) determined that the probable cause of the rupture was mechanical damage to the surface of the pipe, which reduced its wall thickness and created a crack that grew to critical size over time. Contributing to the accident was the inability of the pipeline operator to promptly stop the flow of natural gas to the rupture. The postaccident investigation revealed "teeth marks" on the pipe possibly caused by excavation equipment. Further excavation of the site exposed a great amount of debris around the pipe including a crushed Ford Ranger pickup that had been reported stolen in 1990.

(Source: NTSB 1995.)

**Reston, Virginia**

On March 28, 1993, Colonial Pipeline Company's 36-inch pipeline ruptured in Reston, Virginia, causing the release of about 407,700 gallons of diesel fuel into Sugarland Run, a tributary of the Potomac River. The release caused significant environmental damage and threatened water supplies in parts of Northern Virginia, Maryland, and the District of Columbia. According to NTSB, the probable cause of the break was excavation damage that had taken place at some undetermined time. During the 6-year period before the rupture, more than 200 contractors and groups had worked in the vicinity of the section of pipeline that ruptured, constructing a medical complex.

**Houston, Texas**

Between October 14 and October 21, 1994, some 15 to 20 inches of rain fell on the San Jacinto River floodplain near Houston, Texas, resulting in dangerous flooding. As reported by NTSB, the floods forced more than 14,000 people to evacuate their homes and resulted in 20 deaths. The flooding exposed 17 underground pipelines, four of which broke. Gasoline from Colonial Pipeline Company's 40-inch pipeline ignited, sending flames down the

(*continued on next page*)

BOX 1-1 (*continued*)
**Examples of Transmission Pipeline Accidents**

river and destroying homes, trees, and barges. Because of the flooding, 8 pipelines ruptured and 29 others were undermined at river crossings, and new channels were created in the floodplain. More than 35,000 barrels (1.47 million gallons) of petroleum and petroleum products were released into the river. Ignition of the released products within flooded residential areas resulted in 547 people receiving (mostly minor) burn and inhalation injuries. The spill response costs were in excess of $7 million and estimated property damage losses were about $16 million.

(Source: NTSB 1996.)

**Bellingham, Washington**

About 3:28 p.m., June 10, 1999, a 16-inch-diameter steel pipeline owned by Olympic Pipe Line Company ruptured and released about 237,000 gallons of gasoline into a creek that flowed through Whatcom Falls Park in Bellingham, Washington. About 1½ hours after the rupture, the gasoline ignited and burned approximately 1½ miles along the creek. Three people died and eight were injured. One home and Bellingham's water treatment plant were severely damaged. Property damage was estimated to be at least $45 million. According to NTSB, the rupture was probably caused by excavation-related damage done to the pipeline by IMCO General Construction, Inc., during the 1994 Dakin-Yew water treatment plant modification project; and Olympic Pipe Line Company's (*a*) inaccurate evaluation of inline pipeline inspection results, (*b*) failure to pretest all safety devices associated with the Bayview products facility under approximate operating conditions, and (*c*) practice of performing database development work on the supervisory control and data acquisition system while the system was being used to operate the pipeline.

(Source: NTSB 2002.)

**Carlsbad, New Mexico**

At 5:26 a.m., August 19, 2000, a 30-inch-diameter natural gas transmission pipeline operated by El Paso Natural Gas Company ruptured adjacent to the Pecos River near Carlsbad, New Mexico. The released gas ignited and burned for 55 minutes. Twelve persons who were camping under a concrete-decked steel bridge that supported the pipeline across the river were killed and their vehicles destroyed. Two nearby steel suspension bridges for gas pipelines crossing the river were extensively damaged. According to El Paso Natural Gas Company, property and other damages or losses totaled $998,296. According to NTSB, the probable cause of the rupture and subsequent fire was a significant reduction in pipe wall thickness due to severe internal corrosion. Contributing to the accident were ineffective inspections that did not identify deficiencies in the company's internal corrosion control program.

(Source: NTSB 2003.)

opment and land use, and safety-focused regulatory approaches. This is followed by a brief introduction to the concept of risk-informed guidance and how it might be used in managing the increased proximity of pipelines and people. The structure of the report is summarized in the final section. (The events leading to the request for this study and a description of the statement of task that the committee followed in conducting this project can be found in the Preface.)

## SAFETY RECORD OF THE PIPELINE INDUSTRY

Pipeline incidents can result in loss of life, serious injury, property damage, and environmental damage, although major incidents are infrequent. For the 3-year period 1999 through 2001, hazardous liquids pipeline incidents resulted in an annual average of 2 deaths, 11 injuries, and $97 million in property damage. During the same time period, natural gas transmission pipeline incidents resulted in an annual average of

**TABLE 1-1** Approximate Fatality Rate by Mode, 2000

| | Truck[a] | Rail[b] | Water | Oil Pipeline (Hazardous Liquids) | Gas Pipeline (Transmission) |
|---|---|---|---|---|---|
| Deaths | 5,282 | 937 | 119 | 1 | 15 |
| Ton miles (billions)[c] | 1,249 | 1,546 | 646 | 577 | 276 |
| Deaths/billion | 4.229 | 0.606 | 0.135 | 0.002 | 0.091 |

[a] Truck deaths include all drivers and motorists involved in fatal crashes with trucks weighing 10,000 pounds or more.

[b] Rail deaths include trespassers, motorists killed at grade crossings, and rail workers.

[c] Ton mile and ton mile equivalent for natural gas pipelines as calculated by the Bureau of Transportation Statistics.

SOURCE: *Transportation Statistics 2001 Annual Report* (truck, p. 159; rail, p. 174; water and pipeline deaths, p. 142).

6 deaths and 10 injuries—much lower than in other transportation modes—and $20 million in property damage (OPS 2003).[3] According to the General Accounting Office (GAO 2002, 3), "Although pipeline incidents resulted in an average of about 24 fatalities [and 83 injuries] per year from 1989 to 2000,[4] the number of pipeline incidents is relatively low when compared with those involving other forms of freight transportation. On average, about 66 people die each year in barge accidents, about 590 in railroad accidents, and about 5,100 in truck accidents." Table 1-1 provides data on fatalities and estimated fatality rates by freight transportation mode for 2000.

From 1989 through 2000, the total number of incidents in the United States per 10,000 miles of pipeline decreased by 2.9 percent annually, while the number of reportable pipeline incidents (those resulting in a fatality, an injury, or property damage of $50,000 or more) per 10,000 miles of pipeline increased by 2.2 percent annually (GAO 2002). According to OPS, the increase in major incidents over this period can be attributed to growth in the volume of products transported by pipelines (due to

[3] To date, no studies have estimated comprehensively the environmental damage caused by pipeline spills in the United States (Pates 1996; Pates 2000).

[4] This includes all hazardous liquids and natural gas, not just transmission, pipelines. All pipeline-related deaths account for only 0.02 percent of the 45,000 transportation-related deaths that occur annually in the United States.

increased energy consumption) and population growth near pipelines (GAO 2000). The reader is referred to Appendix B for a more detailed discussion of safety data and trends in the pipeline industry and associated safety data tables.

There are many causes and contributors to pipeline failures, including construction errors, material defects, internal and external corrosion, operational errors, malfunctions of control systems or relief equipment, and outside force damage (e.g., by third parties during excavation). Of these, excavation and construction-related damage to pipelines are the leading causes of pipeline failure. Including operator excavation, third-party excavation, vandalism, and other outside forces, such failures in 2003 were estimated by USDOT to contribute 22 and 24 percent of hazardous liquids and natural gas transmission pipeline incidents, respectively. With increasing urbanization, land development activity near transmission pipelines, and the addition of new facilities to serve growing populations, the likelihood of construction-related pipeline damage may increase, and more people and property may be exposed to pipeline failures.

## TRENDS AND PROJECTIONS

### Energy Demand

The United States currently consumes about 63 billion cubic feet of natural gas daily (more than 23 trillion cubic feet annually), nearly all of which is transported by pipeline. This accounts for approximately 28 percent of energy consumed annually in the United States. The Department of Energy's (DOE's) Energy Information Administration statistics indicate that natural gas consumption increased 35 percent during the last decade (EIA 2003), and DOE projects that natural gas consumption will increase by 36 percent between 2002 and 2010 (DOE 2003; EIA 2003; EIA 2004). The pipeline system will need to be expanded to meet this increased demand. In 1999, the National Petroleum Council estimated that 38,000 miles of new interstate natural gas transmission lines could be required by 2015 to move natural gas from the Rocky Mountain states, Alaska, and Canada (where large quantities are known to exist) to areas in the East that have increasing demand.

Each day, about 19.5 million barrels of petroleum products are consumed in the United States.[5] In the next 20 years, this demand is expected to increase by 48 percent to 29 million barrels per day (EIA 2003). To accommodate the projected pipeline growth, the availability of suitable rights-of-way will be necessary despite increasing urbanization. In addition, the existing infrastructure must be maintained, and sections of existing pipelines will need to be upgraded or replaced.

## Land Development

The primary areas of concern for this study are land use, land development, and population growth around existing transmission pipelines and the need to locate new transmission lines to serve growing metropolitan centers. Good measures of the increase in numbers of people in proximity to transmission pipelines are not currently available.[6] However, certain trends are suggested by aggregate statistics.

Major liquid petroleum and natural gas pipelines traverse almost all states, but the greatest concentration is in the Gulf Coast states, where most production and import facilities are located. There are two major transmission line trajectories in the United States. One extends from Texas, Louisiana, Mississippi, and Oklahoma into the Midwest. The other extends through the south Atlantic states into the Northeast, where it serves major population centers such as Washington, Philadelphia, New York, and Boston (USDOT 1990, Figures 15-2 and 15-3). Other lines extend from the Gulf Coast states to the Northeast through Tennessee, Kentucky, West Virginia, and Pennsylvania. In addition, major pipelines extend between California and Texas, traversing Arizona and New Mexico, and from Canada into the northern and eastern states.

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5 A modest-sized pipeline transporting 150,000 barrels per day moves a volume equivalent to 750 tanker truckloads per day (i.e., one delivered every 2 minutes, 24 hours per day) or a daily train of 75 rail tank cars. Liquids pipelines can be used to transport a single commodity, multiple grades of a single commodity, or a range of commodities. Depending on its configuration, a pipeline can carry material from a single source or from multiple sources to one or more destinations. In total, oil pipelines transport 17 percent of U.S. freight at a cost of only 2 percent of the nation's freight bill (Wilson 2001).

6 OPS is building a geographic information system database for this purpose, but it was not complete during the course of this study.

Many transmission lines were laid decades ago through sparsely populated states in the Sun Belt and through West Coast states. These areas are now experiencing rapid population growth, raising concern about increased numbers of people living or working close to pipelines. Moreover, many lines that serve major cities and that run through heavily developed areas were constructed in what were then sparsely populated, rural areas. Few of these areas had extensive land use or zoning regulation in place at the time the lines were laid. The fastest-growing metropolitan areas, which now often incorporate their formerly outlying counties, are concentrated in the southern and western states where most transmission pipelines are located (U.S. Census Bureau 2002, Table 30); however, some states (such as Texas) have urban populations where minimal or no land use controls are in place. Examples of metropolitan areas that grew 20 percent or more between 1990 and 2000 are cited in Box 1-2. Incorporated places include many jurisdictions that are too small to be classified as metropolitan areas but that, nonetheless, have more than 100,000 residents.

Incorporated localities that grew more than 40 percent during the last decade are located primarily in Arizona, California, Colorado, North

BOX 1-2

### Growing Metropolitan Areas

Examples of metropolitan areas that grew 20 percent or more between 1990 and 2000 include Albuquerque, New Mexico; Atlanta, Georgia; Austin, Texas; Charlotte, North Carolina; Colorado Springs, Colorado; Dallas–Forth Worth–Arlington, Texas; Denver–Boulder–Greeley, Colorado; Fayetteville–Springfield–Rogers, Arkansas; Houston–Galveston–Brazoria, Texas; Las Vegas, Nevada; McAllen–Edinburg–Mission, Texas; Nashville, Tennessee; Phoenix–Mesa, Arizona; Portland–Salem, Oregon; Provo–Orem, Utah; Raleigh–Durham–Chapel Hill, North Carolina; Reno, Nevada; Riverside–San Bernardino, California; Salt Lake City–Ogden, Utah; and Tucson, Arizona.

Carolina, Texas, and Nevada (U.S. Census Bureau 2002, Table 33). In addition to gaining the most population over the last two decades, southern and western states are projected to grow between 27 and 33 percent by 2025 compared with 7 to 14 percent growth in the East and Midwest (Burchell et al. 2002, Table 3-3). These trends in population growth and the location of this growth imply the need to manage the increasing number of people near transmission pipelines.

### Environmental Issues Concerning Rights-of-Way

In built-up communities traversed by transmission pipelines, the right-of-way itself can become a natural buffer between properties, especially as the intensity of development increases. These rights-of-way can become sources of habitat and provide pathways for animal migration. Residents accustomed to mature vegetation can be dismayed when pipeline companies periodically clear trees and other vegetation to allow for visual inspection by aircraft. Companies are required by federal regulation to inspect their rights-of-way on a regular basis; they often do so by using aircraft, especially for properties lacking public access. Without regular clearing of the rights-of-way, such inspection can be ineffective. Tree roots can also be a source of outside damage to pipelines, so allowing mature trees in rights-of-way poses a safety hazard.

The congressional request to OPS and FERC that led to this study included a provision that would "address how to best preserve environmental resources in conjunction with maintaining pipeline rights-of-way, recognizing pipeline operators' regulatory obligations to maintain rights-of-way and to protect public safety" (H.R. 3609, Section 3609, 107th Congress). Evidence cited in Chapter 2 indicates that rights-of-way can be useful habitat, but little formal guidance is available from federal agencies concerning strategies that protect both safety and environmental features of rights-of-way.

## SAFETY REGULATORY SYSTEM

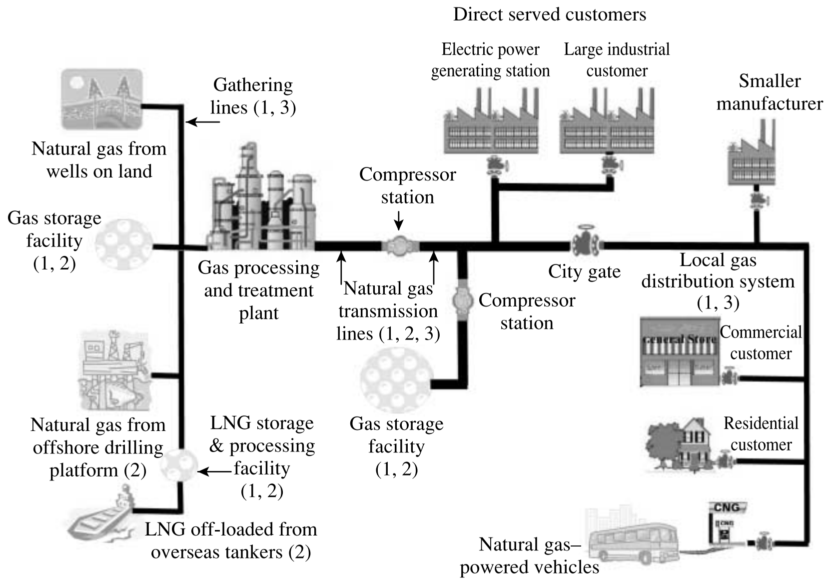
Many federal, state, and local agencies are responsible for regulating various aspects of the design, siting, construction, and operation of pipelines. In addition, specific needs during pipeline operation may require oversight by certain local or federal agencies (e.g., the National Transportation Safety Board may be involved in the oversight of certain accident investigations). The regulation of natural gas pipelines differs from that of liquids lines. Even within the natural gas pipeline network, the regulating agencies differ depending on the specific portion of the pipeline system (Figure 1-1). This section provides a brief overview of the regulation of natural gas and liquids transmission pipelines.

The areas of responsibility of various regulatory agencies with respect to the pipelines are indicated in Table 1-2. While there are clear lines of authority in certain aspects of pipeline regulation, there may be some overlap. For example, both OPS and FERC may be interested in certain aspects of pipeline operations. Four major aspects of regulation can be considered: design, siting, and construction; operations; special needs; and economic/tariff. More than one agency can regulate the pipelines. Furthermore, in regulating the pipelines, these agencies often rely on consensus standards, such as those of the American Society of Mechanical Engineering, the American Petroleum Institute, the American National Standards Institute, the National Association of Corrosion Engineers International, and others for specification of materials, operations, documentation, and integrity management.

The first major congressional action aimed at dealing with pipeline safety was the Natural Gas Pipeline Safety Act of 1968. This act gave the Federal Power Commission[7] jurisdiction over the siting of new interstate natural gas pipelines and required USDOT to establish minimum federal safety standards for interstate natural gas transmission and distribution lines. At present, FERC must examine and approve proposed routes of interstate natural gas pipelines and consider any significant environmental impacts. No similar federal approval is required for new liquids pipelines unless they cross federal lands. Some state and local governments address the siting of new liquids pipelines, but many states have no such requirements.

In 1979, Congress enacted the Hazardous Liquid Pipeline Safety Act—the first comprehensive safety regulatory program for oil pipelines in the United States (49 U.S.C. Appx. §2001). The act gave USDOT jurisdic-

[7] In 1977, the Federal Power Commission was reorganized and renamed the Federal Energy Regulatory Commission.




(1) - OPS is responsible for regulating the safety of natural gas transportation pipelines and liquefied natural gas (LNG) facilities, including safety aspects related to design, construction, operation, and maintenance. Minimum safety requirements for gas pipelines and LNG facilities are prescribed by 49 CFR Parts 191, 192, and 193.

(2) - FERC is responsible for the regulation of interstate natural gas pipelines, siting for pipelines, storage, and onshore LNG import facility construction. FERC is also responsible for regulation of natural gas transportation in interstate commerce; issuing certificates of public convenience and necessity to prospective companies providing energy services or constructing and operating interstate pipelines and storage facilities; regulation of facility abandonment; establishment of rates for services; regulation of the transportation of natural gas as authorized by the Natural Gas Policy Act and the Outer Continental Shelf Lands Act; and oversight of the construction and operation of pipeline facilities at U.S. points of entry for the import or export of natural gas.

(3) - Rates for natural gas sold by local distribution companies to end users are generally established by state regulatory authorities (e.g., public service or public utility commissions) or local utility districts, municipalities, or natural gas authorities. States also have a key role in regulating and ensuring intrastate pipeline safety. Some states act as interstate agents for OPS in the regulation of interstate transmission lines. States are involved in environmental permitting and local routing decisions for new pipelines, emergency response planning, training, and exercises.

**FIGURE 1-1 Regulation of various parts of natural gas pipeline systems.** (SOURCE: INGAA 2003; personal communication, Herb Wilhite, Cycla Corporation, July 12, 2004.)

**TABLE 1-2** Overview of Regulatory Agencies for Natural Gas and Oil Pipelines in the United States

| Industry | Aspect of Industry | Primary | Others |
|---|---|---|---|
| Natural gas transmission—onshore | Siting and construction | FERC | OPS, EPA, BLM, OSHA, USACE |
| | Design, operations, and maintenance | OPS | State or public utility commissions (e.g., Texas Railroad Commission) |
| | Special needs (incidents, sensitive sites, etc.) | NTSB | OSHA, EPA, Homeland Security |
| | Economic/tariff | FERC | |
| Natural gas transmission—offshore | Design, construction, operations, and maintenance | OPS | State public utilities, USCG, NOAA, FWS, OSHA |
| | Siting | MMS | FERC |
| Liquids transmission—onshore | Design, siting, and construction | OPS | BLM, EPA, OSHA, USACE |
| | Operations | OPS | EPA, state or local |
| | Special needs (incidents, sensitive sites, etc.) | NTSB, EPA | OSHA, Homeland Security |
| | Economic/tariff | FERC | |
| Liquids transmission—offshore | Design, construction, operations, and maintenance | OPS | State public utilities, USCG, NOAA, FWS, OSHA |
| | Siting and oil spill prevention | MMS | |
| | Special needs (incidents, sensitive sites, etc.) | NTSB, EPA | OSHA, Homeland Security |
| | Economic/tariff | MMS | FERC |

NOTE: BLM = Bureau of Land Management, EPA = Environmental Protection Agency, FERC = Federal Energy Regulatory Commission, FWS = Fish and Wildlife Service, MMS = Minerals Management Service, NOAA = National Oceanic and Atmospheric Administration, NTSB = National Transportation Safety Board, OPS = Office of Pipeline Safety, OSHA = Occupational Safety and Health Administration, USACE = U.S. Army Corps of Engineers, USCG = U.S. Coast Guard.

tion to regulate the design, construction, maintenance, and operation of intrastate and interstate hazardous liquids pipelines. It allows a limited degree of shared governmental responsibility for pipeline safety by permitting OPS to certify states to perform inspection and administrative duties.

The Pipeline Safety Act of 1992 extended USDOT's authority over natural gas and hazardous liquids pipelines to include protection of the environment as part of its mission and identified specific issues that were to be addressed. This act provided OPS, whose mission is "to ensure the safe, reliable, and environmentally sound operation of the nation's pipeline transportation system," an opportunity to establish more stringent safety standards and environmental protection measures for high-risk areas. OPS, thus, is mandated to regulate hazardous liquids, gas transmission, and gas distribution pipelines, as well as liquefied natural gas operators (CFR Parts 192 and 195).

OPS has no authority over land use practices outside of pipeline rights-of-way. However, it attempts to reduce the dangers posed to people who live and work near transmission pipelines by, for example, requiring more stringent design (e.g., thicker pipeline wall) and operating (e.g., reduced pressurization) standards for a natural gas pipeline in areas of high building density and by requiring additional depth of cover for new liquids pipelines located within 50 feet of private dwellings, industrial buildings, and places of assembly.

At present, the OPS pipeline safety program has a number of elements: regulatory development (including implementation of the Integrity Management Program), inspection and enforcement, the state pipeline safety grant program, research and development, damage prevention and public education, training, oil spill preparedness and response, and data analysis and trending. The Integrity Management Program is a new regulatory approach that requires pipeline operators to comprehensively assess, identify, and address, where necessary, the safety of pipeline segments that are located in areas where the consequences of a pipeline failure could be significant (i.e., where a leak or rupture would have the greatest impact). These areas are called "high consequence areas" (GAO 2002). Under this program, "pipeline operators are required to, among other things, identify all segments of the pipeline that pass through a high consequence area, conduct a baseline assessment of the integrity of these segments, address any safety issues, reassess the integrity of the pipeline at intervals not to exceed 5 years, and establish performance measures to measure the program's effectiveness" (GAO 2001, 5). This program includes new, rigorous testing requirements; repair and mitigation requirements for transmission pipelines; a risk-based approach to focusing attention; and expanded and enhanced oversight.

State and local governments have a more limited role in pipeline safety. States have jurisdiction over the safety regulation of intrastate pipelines. Under provisions of federal law, states can act as agents of the federal government in some areas of interstate pipeline regulation, such as in safety inspections. Local governments are largely restricted to regulating land uses near pipelines. Neither state nor local regulation of interstate pipeline operations can supersede that of the federal government.

## A RISK-INFORMED APPROACH

The local government approach to pipeline safety is currently either nonexistent or developed in response to specific incidents. (See Box 1-3 for a description of approaches used in Bellingham, Washington, and Austin, Texas.) A better approach is needed to manage effectively the risks to the public and to pipelines. The purpose of this study is to determine whether a risk-informed approach could be an effective tool in making land use decisions to manage or reduce the risks associated with pipeline failures.

Sound risk assessment practice attempts to answer the following questions:

- What can go wrong?
- How likely is it?
- What are the consequences?

The result of the risk assessment process is often termed "risk insights," which can be used in decision making or in regulation. Advances in risk assessment methods have resulted in the implementation of regulations that consider the three questions. The regulatory approaches can be risk-based, risk-informed, risk-informed performance-based, or other variations of these.

BOX 1-3

## Land Use Approaches in Bellingham, Washington, and Austin, Texas, in Response to Pipeline Incidents

### Bellingham, Washington, Example

Following the deaths of three boys resulting from a ruptured gasoline transmission line and the subsequent ignition of the fuel in June 1999 in Bellingham, Washington, the community and state began addressing the need for more effective state and local scrutiny of pipeline operations. One of the outgrowths of that effort was a directive by the state legislature that a model ordinance be developed for consideration and use by local governments (Municipal Research and Services Center of Washington n.d.). The model ordinance recommends a minimum setback of 50 feet for hazardous liquids. For gas transmission lines, in contrast, it recommends setback distances "consistent with the hazard area radius" for pipelines of various diameters and pressurization that were developed in a report for the Gas Research Institute (Stephens 2000). Furthermore, it would require setback distances to be doubled for buildings where the public gathers for education, recreation, sports, conventions, hospitalization, or worship. OPS has ruled that these setbacks would exceed federal requirements and are therefore preempted by federal law.

The model ordinance also encourages local government to exercise more influence over pipeline operators through the negotiations that accompany the granting of franchise agreements. The ordinance outlines a number of requirements too detailed to summarize here. Worth noting are the provisions related to construction in or near rights-of-way: in general they would require grantees to develop and implement detailed plans for closely monitoring and reporting on any excavation activity in the right-of-way.

Other outgrowths of the Bellingham incident include the development of an active citizen action group, Safe Bellingham (www.safebellingham.org), and the Washington City and County

Safety Consortium (www.pipelinesafetyconsortium.org), a collection of local governments in Washington State concerned about pipeline safety. Both organizations have developed websites that include technical reports, press releases, letters, testimony, links, and other materials of interest to concerned citizens and public officials.

**Austin, Texas, Example**

The city of Austin developed a new, more aggressive ordinance concerning transmission pipelines in response to a proposal in 2000 by Longhorn Partners Pipeline LP to convert a crude oil pipeline traversing the city to one for shipping refined petroleum products. The pipeline runs through a heavily populated area in south Austin and through the environmentally sensitive drinking water protection zone. The ordinance is a three-part performance-based approach that applies to areas near hazardous liquids pipelines: (*a*) subdivision requirements, (*b*) zoning uses/site plan construction, and (*c*) financial responsibility. Subdivision requirements prohibit platted lots or structures within the pipeline easement and specify minimum setbacks for special populations (e.g., those with limited mobility). The zoning uses part establishes requirements within 200 and 500 feet of the pipeline. These distances are based on fire modeling and development requirements set to meet fire safety standards. For example, the ordinance bans new buildings within 25 feet of a hazardous liquids pipeline and increases construction and building standards on most structures within 200 feet of a pipeline. The ordinance forbids new structures requiring extra evacuation assistance, such as schools and hospitals, within 200 feet of a pipeline. A council-approved variance is required for such structures within 500 feet of a pipeline. The city's attempt to force the pipeline operator to carry at least $90 million in accident insurance, the third part of the ordinance, was struck down in federal court in October 2003. The ordinance's other pro-

(*continued on next page*)

BOX 1-3 (*continued*)
**Land Use Approaches in Bellingham, Washington, and Austin, Texas, in Response to Pipeline Incidents**

visions, however, remain intact. The ordinance does not apply to structures existing before April 21, 2003; these preexisting structures may be repaired, rebuilt, or added to without complying with ordinance structural requirements.

In the risk-based approach, decisions or regulations are heavily based on risk assessment calculations, without other considerations. Because such an approach places a heavy burden on risk computation, which may suffer from lack of data or models or imperfect consideration of scenarios, its application is limited. In the risk-informed approach, risk insights are used in conjunction with other information, both quantitative and qualitative, in making safety decisions. Because it allows for the logical structuring of decisions by including relevant factors, the risk-informed approach is of more practical value.

To determine how to maximize safe and economic regulation of pipelines, the complete pipeline system and its environs must be considered. Doing so provides a balanced view of the interaction among the various components involved in pipeline operations. Effective use of a risk-informed approach requires an understanding of the relevant factors and the relationships among them. Managing the risks associated with pipeline siting and operations may be more effective when there is involvement and a shared commitment among interested parties—policy makers, planners and system design experts, public works officials, pipeline companies, property owners, and trade associations—as well as effective communication, training, and procedures.

## STRUCTURE OF THE REPORT

An overview of approaches that are being used to manage land use near transmission pipelines at the state and local levels is contained in Chapter 2. A risk management framework for pipelines and the risk communication process needed to raise the level of understanding of relevant issues or actions among the various stakeholders are described in Chapter 3. In Chapter 4, the committee's findings, conclusions, and recommendations addressing the feasibility of developing risk-informed guidance that could be used in making land use–related decisions to manage risks to the public, pipeline workers, and the environment near existing as well as future transmission pipelines are given. Pipeline safety data and trends and information about the pipeline industries in the United States can be found in Appendices B and C, respectively.

In this report a basis is provided for additional work to further develop promising approaches for governments to use in minimizing or mitigating hazards from incidents involving natural gas and liquids transmission pipelines. The report is not intended to provide answers. Rather, it provides a high-level perspective on how those answers might be provided.

## REFERENCES

***Abbreviations***

| | |
|---|---|
| DOE | Department of Energy |
| EIA | Energy Information Administration |
| GAO | General Accounting Office |
| INGAA | Interstate Natural Gas Association of America |
| NTSB | National Transportation Safety Board |
| OPS | Office of Pipeline Safety |
| USDOT | U.S. Department of Transportation |


Burchell, R. W., G. Lowenstein, W. R. Dolphin, C. C. Galley, A. Downs, S. Seskin, K. G. Still, and T. Moore. 2002. *TCRP Report 74: Costs of Sprawl—2000.* Transportation Research Board, National Research Council, Washington, D.C.

DOE. 2003. *Natural Gas Fundamentals from Resource to Market.* Washington, D.C.

EIA. 2003. Energy Outlook 2003. www.eia.doe.gov.

EIA. 2004. www.eia.doe.gov/neic/quickfacts/quickgas.htm.

GAO. 2000. *Pipeline Safety: The Office of Pipeline Safety Is Changing How It Oversees the Pipeline Industry.* Report to the Ranking Minority Member, Committee on Commerce, House of Representatives. GAO/RCED-00-128. Washington, D.C., May.

GAO. 2001. *Pipeline Safety—Progress Made but Significant Requirements and Recommendations Not Yet Complete.* GAO-01-1075. Washington, D.C., Sept.

GAO. 2002. *Pipeline Safety: Status of Improving Oversight of the Pipeline Industry.* GAO-02-517T. Washington, D.C., March.

INGAA. 2003. www.ingaa.org/images/main/fromthewellhead.gif.

Municipal Research and Services Center of Washington. n.d. Model Setback and Depth Requirements Ordinance for Transmission Pipelines. www.msrc.org.

NTSB. 1995. *Texas Eastern Transmission Corporation Natural Gas Pipeline Explosion and Fire, Edison, New Jersey, March 23, 1994.* Pipeline Accident Report. PB95-916501, NTSB/PAR-95/01. Washington, D.C.

NTSB. 1996. *Evaluation of Pipeline Failures During Flooding and of Spill Response Actions, San Jacinto River Near Houston, Texas, October 1994.* Pipeline Special Investigation Report. PB96-917004, NTSB/SIR-96/04. Washington, D.C.

NTSB. 2002. *Pipeline Rupture and Subsequent Fire in Bellingham, Washington, June 10, 1999.* Pipeline Accident Report. PB2002-916502, NTSB/PAR-02/02. Washington, D.C.

NTSB. 2003. *Natural Gas Pipeline Rupture and Fire near Carlsbad, New Mexico, August 19, 2000.* Pipeline Accident Report. PB2003-916501, NTSB/PAR-03/01. Washington, D.C.

OPS. 2003. Pipeline Safety Statistics. primis.rspa.dot.gov/pipelineInfo/safety.htm.

Pates, J. 1996. Out of Sight, Out of Mind: What Every Local Government Should Know About Pipeline Safety. Talk given before the International Municipal Attorneys Association, Little Rock, Ark., Oct. 8.

Pates, J. M. 2000. Testimony on behalf of the National Pipeline Reform Coalition before the U.S. Senate Committee on Commerce, Science, and Transportation. May 11.

Stephens, M. J. 2000. *A Model for Sizing High Consequence Areas Associated with Natural Gas Pipelines.* GRI-00/0189. Gas Research Institute, Oct.

U.S. Census Bureau. 2002. *Statistical Abstract of the United States.* U.S. Department of Commerce, Washington, D.C.

USDOT. 1990. *National Transportation Strategic Planning Study.* Washington, D.C., March.

Wilson, R. A. 2001. *Transportation in America,* 18th ed. Eno Transportation Foundation, Inc., Washington, D.C.

# 2

# Potential Land Use Approaches to Pipeline Safety and Environmental Management

Land uses around transmission pipelines are regulated by the terms of rights-of-way agreements negotiated between pipeline owners and landowners and, to a limited extent, by a variety of state and local land use regulations. A database of state and local practices with regard to land uses and activities near transmission pipelines and literature evaluating the effectiveness of various approaches to keeping people and pipelines separated at a "safe" distance are lacking. Therefore, this chapter presents a discussion of tools that can be used. The discussion is drawn from notable recent examples and, by analogy, from state and local efforts to protect against natural and industrial hazards. Of principal concern are strategies to manage land use and the proximity of people to pipelines to help prevent severe accidents caused by the disturbance of pipelines and to minimize damage when accidents occur. A brief description of the safety and environmental issues that arise in managing existing pipeline rights-of-way is included.

## CURRENT AND PROSPECTIVE LAND USE CONTROLS

### Rights-of-Way

The only consistently applied land use control over transmission pipelines is the management and use of the pipeline right-of-way itself. A right-of-way is "a piece of property in which a pipeline company and a landowner both have a legal interest. Each has a right to be there, although each has a different type of use for the land" (API 2004, 2). The right-of-way used during construction is generally 75 to 100 feet wide, although extra space is usually required at road or stream crossings or because of terrain or soil conditions. The permanent right-of-way usually ranges from 25 to 50 feet wide, but this may vary because it is negotiated with each property owner on the basis of each pipeline company's internal policies, type of pipeline, regulatory requirements, and the needs and demands of each property owner. In some cases, the dimensions of the rights-of-way are not mentioned.

Rights-of-way have traditionally been established by pipeline operators for the purposes of constructing, inspecting, and repairing pipelines in an economical manner. Right-of-way agreements typically establish "legal rights to pass through grounds or property owned by another" (*Black's Law Dictionary*). Although it is customary for a company to use a "standardized form," the terms can vary dramatically on the basis of a number of factors, including the time of negotiation of the agreement. For example, many older right-of-way agreements are far less specific with regard to uses prohibited on the right-of-way than are the agreements negotiated today.

The most common form of right-of-way agreement is called an *easement,* which usually gives the operator a permanent legal right to use the right-of-way for construction and operation of the pipeline, including the right to repair and maintain the pipeline. The authority of pipeline operators to control the use of the right-of-way is limited by the terms of the easement agreement; control does not extend to any property not covered by the easement (e.g., adjoining property).

A pipeline easement usually describes its purpose, its duration, the boundaries of the easement area, renewal fees, rights of the pipeline company to gain access to and use the easement area, rights of the landowner, the number and size of the pipelines, materials that may be transported in the pipeline, rights for expansion, procedures for communications among parties, and procedures for abandonment (definition and responsibilities) (Rabinow 2004). Many older easements are much more vague or ill-defined. Public authorities generally have no input into the contents of such easements and no copies of the recorded instruments; however, most easement agreements are on record with the county register of deeds. As a practical matter, many subsequent fee simple owners of the property may not take the initiative to learn whether such easements exist or what they specify.

A liquids pipeline company desiring to invest in a new line has a number of options for acquiring a right-of-way. Whichever approach is pursued, an analysis of the alternative routes and the issues associated with each is the starting point. Once a preferred route has been selected, the pipeline company has the option of buying the right-of-way in fee, in which case the company becomes the landowner and maintains full control. This option is expensive and rarely utilized. Alternatively, the pipeline company can approach the landowners along the proposed right-of-way and negotiate voluntary agreements for easements. If that fails for one or more tracts along the route and the proposed pipeline will be a common carrier, the pipeline company may, as a last resort, use its right of eminent domain as spelled out in the statutes of the particular state. Eminent domain usually involves a court proceeding, which can be time-consuming and expensive. However, under many states' laws, the pipeline operator may obtain access to the property to keep the project moving forward before all issues as to just compensation to the landowner are determined. Although this discussion has focused on private landowners, the permitting process for the use of public lands usually has many similar features.

In contrast, for interstate natural gas transmission pipelines, there is a federally granted power of eminent domain to establish rights-of-way. The Federal Energy Regulatory Commission (FERC) delegates its power of eminent domain to the pipeline operator to acquire necessary rights-of-way. FERC requires a permanent right-of-way of 50 feet for inspection and maintenance.

## Land Use Within and Near the Pipeline Right-of-Way

Land use regulation is widely viewed as an exclusively local government prerogative, though, in fact, local land use practices derive from powers delegated to cities, towns, villages, and counties by their states. In some states, the states themselves set land use policy on subjects such as growth management or mandate various kinds of land use and development regulation to protect sensitive and critical environments and mitigate natural hazards (Burby et al. 1997). Moreover, the federal government has strongly influenced land use in legislation and regulation affecting coastal zones, floodplains, and wetlands. The federal government also frequently preempts state and local prerogatives in interstate commerce, and this is particularly true in pipeline regulation. For example, FERC is empowered to override private landowners, as well as state and local governments if need be, in siting new interstate natural gas transmission pipelines. Even so, the principal agent of land use regulation is local government, and this is particularly true in the case of separating people and pipelines.

Many local governments set forth general principles and guidelines for land development through comprehensive plans. In principle, comprehensive plans can guide urban development away from pipeline rights-of-way when other equally suitable areas are available to satisfy demands for land for urban growth and development. Plans are implemented, in the main, through zoning ordinances, decisions by zoning boards about requests for variances, and subdivision regulations. Local governments that do not have comprehensive plans nonetheless shape development through zoning and subdivision ordinances and their handling of applications for individual parcels.

Most land use planning and regulatory practices developed in the United States during the 20th century. Often they were driven by development and population growth that had already occurred. Land use planning is, therefore, typically most fully developed in urban and metropolitan areas. In contrast, formerly rural areas that are traversed by transmission pipelines laid 25 to 50 years ago and that are in the path of metropolitan expansion often have had or are experiencing development that has little or no zoning or subdivision requirements. Indeed, anecdotal evidence of building development, including schools, adjacent to transmission pipelines suggests that managing the risks to the public near pipelines has not been considered by many local governments.

Information from federal pipeline safety regulators, representatives of pipeline companies, and local officials provided to the committee over the course of its meetings indicated a few examples of actions taken by local governments. For instance, some only allow the lowest-density development around transmission pipelines and locate walking paths, bike paths, and recreational areas along pipeline rights-of-way. Some local government proposals have gone considerably further, often in reaction to spills and explosions. In general, however, the few examples of local governments' attempting more stringent controls have not been based on a systematic analysis of risk or of benefits and costs.

There is a considerable tradition in land use regulation of relying on distance to separate the public from industrial hazards. Local government zoning and other land use regulations attempt to separate industrial facilities from residences and other sensitive facilities and apply performance standards to provide protection from industrial harm (e.g., Chapin 1965; O'Harrow 1981; Rolf Jensen & Associates 1982; Schwab 1989). Buffers contained in zoning regulations vary widely. In Baton Rouge, Louisiana, for example, industrial uses are required to be separated by 25-foot buffers from adjacent uses. In Durham, North Carolina, facilities for the storage of flammable liquids and gases must be set back 100 feet from the property line. Facilities for the storage of explosives must be set back 200 feet from residences, but railroad cars carrying explosive or flammable material must not be parked within 1,000 feet of residences, hospitals, or other buildings used for public assembly. Similarly, Denver, Colorado, requires a 1,000-foot setback from aboveground fuel tanks. [See Schwab (1989) for extracts from these ordinances.] Data compiled by the Louisiana Advisory Committee to the U.S. Commission on Civil Rights (1993) indicate that 17 states have regulations specifying buffers around major facilities where accidents can harm surrounding land uses. Such buffers range from 500 feet to 3 miles. States also have established buffer zone requirements for hazardous waste facilities that range from 150 feet to ½ mile, with the most common being 200 feet.

The Bellingham, Washington, and Austin, Texas, ordinance examples (described in Box 1-3 of Chapter 1) illustrate common actions to establish large setbacks in response to pipeline accidents and new uses for existing pipelines. Setbacks, which are the recommended minimum distances from particular structures to the center of the pipeline (API 2004), are only one element of zoning and subdivision ordinances. However, they are of particular interest because they specify a minimum standard for separating development from pipelines. As illustrated in the examples from Bellingham and Austin, setbacks expand on an existing right-of-way or easement by limiting what a property owner may do with his or her property. For transmission pipelines, there are limits on construction or excavation that involve separating activities such as planting of trees or digging foundations some number of feet from the pipeline. API recommends setbacks of 50 feet from petroleum and hazardous liquids lines for new homes, businesses, and places of public assembly (API 2003). It also recommends 25 feet for garden sheds, septic tanks, and water wells and 10 feet for mailboxes and yard lights. As of the most recent report examining these issues, setbacks of 25 feet from residential property lines were the most common examples in practice (TRB 1988).

The committee was unable to find examples of comprehensive analytical efforts to establish setbacks from pipelines on the basis of risk. Research conducted during the 1980s with regard to liquids pipelines showed that two-thirds of deaths and damage and three-fourths of injuries occurred within 150 feet of the point of discharge; only 8 percent of deaths, none of the injuries, and 6 percent of property damage extended as far as ½ mile from the pipeline (Rusin and Savvides-Gellerson 1987 cited in TRB 1988). The example from the Municipal Research and Services Center of Washington model ordinance (see Box 1-3 in Chapter 1) is a beginning at developing a risk-informed setback, but it accounts only for the probable area of effect should an explosion occur, without taking into account the probability of such an event. As indicated in Chapter 3, the probability of such an event has not been formally estimated and would be a challenge to develop.

Establishing an appropriate setback would not be a simple task. Consider the following:

- Rights-of-way/setbacks for high-pressure natural gas transmission and hazardous liquids pipelines would have to be wide to minimize risk as a result of a high-consequence event and therefore could be costly if interpreted as a regulatory "taking" requiring compensation to property owners.
- A cost-benefit analysis of setbacks wider than current practice has not been conducted.
- Setbacks based on, or informed by, some level of risk assessment could be complex to account for given the variation in product, pipe dimensions, pressurization, depth of cover, and related characteristics.
- Local governments generally prefer simple, rather than complex, regulatory approaches.

- Increased land and housing costs reduce the number of households that can afford to purchase homes—by 424,000 for every $1,000 increase in the price of a new home costing $100,000 or more (Emrath and Eisenberg 2002). In some cases, this adverse effect can be avoided if localities provide adequate housing densities in areas not at risk from pipeline accidents.

New requirements may render many existing homes nonconforming, a status that could reduce their value and inhibit their opportunity to make improvements.

Thus, there are many practical and cost implications of introducing setbacks significantly greater than already exist. The next chapter suggests a risk-informed approach that would take into account issues such as those described above.

## Safety-Related Practices

State and local governments can implement a wide range of measures in addition to setbacks to ensure that awareness of the existence of pipelines is heightened and best practices followed during digging in rights-of-way. Many practical suggestions were made in the report *Pipelines and Public Safety* (TRB 1988). Furthermore, new guidance on these topics has already been developed by the Common Ground Task Force and is now being promoted by the Common Ground Alliance (CGA), a nonprofit organization dedicated to fostering shared responsibility in preventing damage to underground utilities.

### *Collective Action—CGA*

The Common Ground Task Force, sponsored by the Office of Pipeline Safety (OPS) in accordance with the Transportation Equity Act for the 21st Century, Public Law 105-178, was a joint government-industry quality team (consisting of 160 members) whose purpose was to identify and validate existing best practices for the safe and reliable construction, operation, maintenance, and protection of underground facilities.

The Common Ground Task Force's mission was based on the assumption that damage prevention should be a shared responsibility of all stakeholders (e.g., state agencies, one-call system operators, underground facility owners/operators, contractor associations). More accurate information and consistent communication between excavators and operators of underground facilities are essential (OPS 1999). In carrying out its task, the Common Ground Task Force formed a steering team, a linking team, and nine task teams—planning and design, one-call center, locating and marking, excavation, mapping, compliance, public education and awareness, reporting and evaluation, and emerging technologies—each of which developed a set of best practices. The steering team provided senior-level representation and support for the study, while the linking team served as a review board and was responsible for facilitating the sharing of information across teams. Each task team identified and evaluated best practices specific to its area of focus and discussed new practices, equipment, or methodologies that appeared promising in terms of improving damage prevention efforts. The prospective technologies, however, could not be included as best practices because their effectiveness could not be evaluated.

To further the work of the Common Ground Task Force, CGA was formed. CGA, which is currently composed of more than 900 individuals and 125 member organizations, established a Best Practices Committee to add to the best practices identified by the task force and to publish the CGA *Best Practices* guide (2004). This report is a restatement of the best practices found in the earlier report (OPS 1999). The guide will be updated periodically as new practices and technologies emerge.

CGA's major mission has been to develop and promote the use of one-call systems throughout the country. These systems foster much greater knowledge by excavators and contractors about the presence of underground utilities, and according to Zelenak et al. (2003) and others, they have resulted in a downtrend of reportable incidents for natural gas transmission and gathering systems pipelines from 1985 through 2000. CGA also keeps current a guidebook of best practices, which includes such strategies as better mapping of underground utilities, markers of transmission lines, notation of pipelines on plat maps and plans, disclosure of rights-of-way and related easements on land transactions, and so forth. The practices recommended in the guide are too numerous to detail here. A list of the subjects covered is provided below; more information about them is available at www.commongroundalliance.com.

Best practices identified in the CGA report that are relevant to the committee's work include the following:

- Planning and design (e.g., plat designation of underground facility easements, markers for underground facilities),
- One-call center practices (e.g., proactive public awareness, public education, and damage prevention activities),
- Location and marking practices (e.g., safe location and marking, visual inspections, documentation),
- Excavation practices (e.g., one-call facility locate request, locate verification, documentation, maintenance/replacement of markings disturbed, damage notification, notification of emergency personnel, backfilling), and
- Public education practices (e.g., marketing, target audiences, mailings, advertising, strategic relationships with stakeholders).

CGA has also entered into a cooperative agreement with OPS, initiated the CGA Regional Partner Program, assisted OPS in closing seven outstanding National Transportation Safety Board recommendations, played a role in incorporating the establishment of three-digit dialing into the Pipeline Safety Improvement Act of 2002, and finalized development of the CGA Damage Information Reporting Tool to serve as a national repository for underground damage data.

***Industry Recommendations***

Another useful precedent in this area is an effort undertaken by the American Petroleum Institute (API), a trade association of oil companies, in developing best practices for petroleum pipelines. API's *Recommended Practice 1162* (RP 1162), which is now approved by the American National Standards Institute, focuses on public awareness programs for key stakeholders along existing transmission pipelines, establishes minimum recommended practices for all pipeline operators, and provides guidelines for supplemental recommended practices where conditions suggest a more intensive effort. RP 1162 identifies audiences (e.g., public officials, local and state emergency response agencies, the public, commercial and agricultural excavators) to be contacted, effective messages and communications methods, and information for evaluating and updating public awareness programs (API 2003). OPS intends to incorporate the guidance provided in RP 1162 into pipeline safety regulations. OPS issued a Notice of Proposed Rulemaking to this effect on June 24, 2004.

## Government Requirements for Pipeline Operators: Land Use

Surrounding land uses and population densities are incorporated in some existing regulations of pipeline operations. For example, 49 CFR 192, which applies to natural gas pipelines, defines area classifications on the basis of population density in the vicinity of a natural gas pipeline and specifies more rigorous requirements as human population density increases. A class location unit is defined as an area that extends 220 yards, or ⅛ mile, on either side of the centerline of any continuous 1-mile length of natural gas pipeline (49 CFR 192.5). Class locations are categorized by the extent and type of development within the boundaries—the more dense the development, the more stringent the requirements. There are four area classifications:

Class 1. Locations with 10 or fewer buildings intended for human occupancy;

Class 2. Locations with more than 10 but fewer than 46 buildings intended for human occupancy;

Class 3. Locations with 46 or more buildings intended for human occupancy or where the pipeline lies within 100 yards of any building or small, well-defined outside area occupied by 20 or more people during normal use; and

Class 4. Locations where buildings with four or more stories aboveground are prevalent.

Natural gas pipelines constructed on land in Class 1 locations must be installed with a minimum depth of cover of 30 inches in normal soil or 18 inches in consolidated rock; pipelines installed in navigable rivers, streams, and harbors must have a minimum cover of 48 inches in soil or 24 inches in consolidated rock. Pipelines in Class 2, 3, and 4 locations must be installed with a minimum depth of cover of 36 inches in normal soil or 24 inches in consolidated rock. In addition, pipe wall thickness, pipeline design pressures, hydrostatic test pressures, maximum allowable operating pressure, valve spacing, frequency of inspection and testing of welds, and frequency of pipeline patrols and leak surveys must conform to higher standards in more populated areas. According to API (2004), 48-inch cover over pipelines is required where a vehicle crossing is to be made for axle loads up to 15,000 pounds; 72-inch cover is required for railroads. However, ground cover is not to exceed 72 inches unless approved by the pipeline operator. Liquids pipelines do have depth of cover requirements based on the nature of the area, but class locations are not part of the liquids pipeline safety regulations.

Despite the lack of risk-based technical guidance for making land use decisions near transmission pipelines, the committee noted that much can be learned from hazard mitigation management techniques and strategies that have been adopted by state and local governments, some of which might be effective in managing pipeline risks. At present, numerous local governments employ building standards, site design requirements, land use controls, and public awareness measures to reduce losses due to natural hazards. Many heavily populated areas of the country are subject to natural disasters such as flooding, earthquakes, mudslides, and storms (hurricanes, tornadoes, and so forth). Natural disasters bear some similarities to pipeline accidents, although the analogy is not perfect. Both involve a degree of risk that is difficult to calculate. Although the risk may be low, it is not zero. Incidents of loss of life and limb and damage to property result from natural disasters with sufficient frequency that some jurisdictions require management of land uses and development to prevent or minimize damage (Burby 1998). Box 2-1 contains a brief description of risk management for floodplains.

States such as California, North Carolina, and Florida require development permits in risk-prone areas. North Carolina, Florida, and other states require buildings in areas at high risk for hurricanes to meet standards for wind resistance. California has seismic building codes and prohibits building construction on unstable soils. Florida has established a coastal building zone and requires buildings to meet standards for wind resistance (Burby et al. 1997). Many localities, in compliance with requirements of the National Flood Insurance Program, greatly restrict or do not allow development within identified floodways and floodplains. The type of risk assessment the committee envisions, however, goes well beyond the current practice of insurance companies.

BOX 2-1

### The Floodplain Scenario

Many heavily populated areas of the country are subject to natural disasters such as flooding, earthquakes, mud slides, and storms (hurricanes, tornadoes, and so forth). Natural disasters bear some similarities to pipeline accidents, although the analogy is not perfect. Both involve a degree of risk that is difficult to calculate and predict.

The Federal Floodplain Management System is a risk-based land use program that was established by Congress in 1968. Thousands of localities use and enforce this program, which enables property owners to obtain flood insurance in areas at risk from periodic flooding. To use the risk-analysis framework outlined here, the national flood maps show a predicted elevation above sea level that floodwaters will reach in a scenario (the 100-year flood).

The likelihood or probability of water reaching this specific level is once every 100 years ("the 100-year floodplain"). The consequence in such a scenario is that a building or structure built below this elevation will likely be damaged or destroyed. Localities deal with these possible consequences by requiring property owners to flood-proof their property or take other damage mitigation measures to protect life and property.

Thus, the federal flood insurance program is a land use program based on the management of risk. The scenarios, probabilities, and consequences of pipeline incidents are, of course, very different from those of floods and therefore require very different factors, but the conceptual process is the same.

State and local government awareness of the risk and a commitment to planning accordingly are critical. According to Burby et al. (1997), local governments with land use plans employ more development management techniques than do local governments without such plans, and the mix of techniques is different. Governments with plans demonstrate a greater ability to guide the location and nature of land development before it occurs and are more likely to use "measures for structural hazard control, which have been adopted in greater number than either land use or site design measures. This is important because it indicates that plans help communities develop balanced programs of hazard mitigation that use a full range of mitigation techniques" (Burby et al. 1997, 122).

As with many public policies that involve multiple levels of government, the formulation of effective strategies is difficult due to the different incentives at different levels of government. States, for example, might be more compelled to impose controls to protect public safety, while local jurisdictions might have a greater incentive to encourage development and less incentive to enforce mandates that restrict development because of the low probability of the risks. Even so, the hazard mitigation efforts of the states provide better and worse models of cross-governmental implementation (Berke 1998).

## ENVIRONMENTAL ISSUES WITHIN RIGHTS-OF-WAY

The need to keep rights-of-way cleared to permit inspection and maintenance of the pipelines must be balanced against the need to allow a degree of ecological function and vegetation growth. Installation of transmission pipelines requires that the work area be cleared of vegetation and graded, if necessary, to accommodate construction activities. This usually results in a loss of habitat in the area during construction of the pipeline. After installation, the work area is typically seeded to a mixture of grasses, and within a short time a grassland community develops that provides habitat to a wildlife community adapted to this early successional vegetative stage (Adams and Geis 1979). In addition, these open, grassy areas are attractive nesting and feeding areas for a number of woodland wildlife species (Everett et al. 1979; Ladino and Gates 1979). The extent of change depends in large part on the type of vegetative cover that is traversed by the pipeline. Small changes occur in active agricultural fields, and the greatest changes occur when forested areas are cleared to accommodate construction activities.

During operation of the transmission pipeline, the portion of the land atop the pipeline is typically maintained in a grassland community to facilitate inspection. Shrub communities on utility rights-of-way can provide a source of browse to certain woodland wildlife species (Lunseth 1987) and have been found to increase the abundance and diversity of wildlife species in adjacent wooded areas (Hanowski et al. 1993). In addition, because the outer edges of the right-of-way are not maintained, they often revert to shrub communities and provide habitat to a diverse wildlife community (Schreiber et al. 1976; Santillo 1993).

The installation and subsequent maintenance of a transmission pipeline can bring about a change in habitat along a narrow linear corridor. This can result in a change in wildlife species composition along the pipeline but typically does not have an adverse effect on the abundance or distribution of regional wildlife populations (Hanowski et al. 1993). However, in certain situations a particular habitat is sensitive to disturbance, and pipeline construction and maintenance activities could have a negative impact on wildlife species. For example, threatened or endangered species habitat or unique wetlands, if disturbed by construction activities, could adversely affect wildlife populations that rely on these sensitive habitats. Rights-of-way can also act as disturbance corridors for the movement and spread of invasive species.

From a landscape ecology perspective, rights-of-way in urban and suburban settings can provide enough natural habitat so that they become wildlife corridors and allow the movement of animals from one patch of natural habitat to another. In this setting they are important landscape management features for increasing the number of native flora and fauna species existing in an area. The more the rights-of-way are maintained in a natural state, the better wildlife corridor they become.

In contrast, pipeline rights-of-way in rural settings and the wide-open spaces of the West often function as one more landscape fragmentation feature, along with roads, canals, and power lines. Thus, in this setting rights-of-way tend to retard the movement of certain animals within their habitat.

Most pipeline regulations have to do with construction and remediation of any damage the construction causes. They are intended to prevent such losses as wetland destruction, excessive soil erosion, agricultural soil structure alteration, and river and stream bottom changes. The regulations do not prevent such ecological changes as increases in exotic or invasive vegetation species, so from an ecological perspective, they do not address completely the issues of preservation of resources and habitat. Some regulations require monitoring to be carried out after construction to ensure that basic environmental characteristics (plant cover, sedimentation control, hydrologic features) have returned to preconstruction status.

Once a pipeline is in place there is little guidance or regulation as to how the right-of-way should be managed to protect the environment or encourage habitat preservation. Many guidelines are available for the construction of pipelines in regard to the natural environments through which the pipelines run, whether uplands or wetlands (e.g., FERC 2003a; FERC 2003b; Moorhouse 2000; Van Dyke et al. 1994). In addition, many studies are being conducted on the impact of pipeline construction on habitats (e.g., Hinkle et al. 2000). Because the potential for damage is significant in the wetland environments, there is much more literature and debate about construction of pipeline rights-of-way through wetland than through upland environments (e.g., see www.fpb.gov.bc.ca/COMPLAINTS/IRC08/irc08s.htm). However, stricter regulations and more "watchdog" groups are widely believed to have brought about a reduction in the damage caused by the construction of pipelines though wetlands (see, for example, www.es.anl.gov/htmls/wetlands.html). None of the federal land managing agencies has guidelines that require habitat management. Many pipeline operators consider right-of-way management to be a maintenance task with structural goals but no ecological goals.

A growing body of information is available on how to restore damaged ecosystems (see www.ser.org), on landscape ecology and management, and on the ecology of species and communities. Such information would make feasible the development of guidelines that would assist in preserving habitat and species. It should be possible to develop guidance allowing certain types of vegetation—other than large trees—that would provide some habitat and natural buffer between properties while allowing for visual inspection of the pipeline. A path directly above the pipeline might be maintained free of woody vegetation, but the path need not be very wide. Shrubs, vines, grasses, and other similar native woody vegetation could be allowed to grow on either side of the path. Pruning would still be required periodically to make the path visible from above.

## SUMMARY

Local and state governments have little or no technical guidance available to assist them in managing the risk of the increasing number of people in proximity to pipelines through regulations and other tools governing land use, planning, zoning, and subdivision. Some local governments are proposing and developing new approaches to managing risk. However, state governments could take more of a leadership role, both in providing technical assistance and in requiring local governments to develop plans and regulations to prevent and mitigate damage from pipeline spills and explosions.

Local and state governments could adopt and promote best practices, such as those identified in the CGA *Best Practices* guide that encourage better "visibility" of transmission lines and major distribution lines in all real estate transactions. One-call centers have facilitated the reduction in pipeline breaks due to excavation damage. Federal law requires most categories of excavators to "call before they dig." Municipal workforces, however, are exempt under many states' laws. This exemption bears reexamination.

It appears feasible to allow certain types of vegetation within rights-of-way that would provide some habitat and yet permit visual inspection of rights-of-way by air. Government and industry could collaborate in the development of such guidance.

## REFERENCES

***Abbreviations***

| | |
|---|---|
| API | American Petroleum Institute |
| CGA | Common Ground Alliance |
| FERC | Federal Energy Regulatory Commission |
| OPS | Office of Pipeline Safety |
| TRB | Transportation Research Board |

Adams, L. W., and A. D. Geis. 1979. Roads and Roadside Habitat in Relation to Small Mammal Distribution and Abundance. *Proc., Second Symposium on Environmental Concerns in Rights-of-Way Management,* Ann Arbor, Mich.

API. 2003. *Public Awareness Programs for Pipeline Operators, API Recommended Practice 1162.* Washington, D.C., May.

API. 2004. *Guidelines for Property Development.* Washington, D.C.

Berke, P. 1998. Reducing Natural Hazard Risks Through State Growth Management. *Journal of the American Planning Association,* Vol. 64, No. 1, Winter, pp. 76-88.

Burby, R. (ed.) 1998. *Cooperating with Nature.* National Academy Press, Washington, D.C.

Burby, R., P. May, P. Berke, L. Dalton, S. French, and E. Kaiser. 1997. *Making Governments Plan: State Experiments in Managing Land Use.* Johns Hopkins University Press, Baltimore, Md.

CGA. 2004. *Best Practices,* Version 1.0. www.commongroundalliance.com/docs/s8/p0002/BP%201.0_FINAL_120103.pdf.

Chapin, F. S., Jr. 1965. *Urban Land Use Planning* (2nd ed.). University of Illinois Press, Urbana.

Emrath, P., and E. F. Eisenberg. 2002. *Household Priced-Out Analysis for the USA.* NAHB Housing Policy Department, Washington, D.C.

Everett, D. D., D. W. Speake, and W. K. Maddox. 1979. Use of Rights-of-Way by Nesting Wild Turkeys in North Alabama. *Proc., Second Symposium on Environmental Concerns in Rights-of-Way Management,* Ann Arbor Mich.

FERC. 2003a. *Upland Erosion, Control, Revegetation, and Maintenance Plan.* Washington, D.C., Jan.

FERC. 2003b. *Wetland and Waterbody Construction and Mitigation Procedures.* Washington, D.C., Jan.

Hanowski, J. M., G. J. Niemi, and J. G. Blake. 1993. Seasonal Abundance and Composition of Forest Bird Communities Adjacent to a Right-of-Way in Northern Forests USA. *Proc., Fifth Symposium on Environmental Concerns in Rights-of-Way Management,* Montreal, Quebec, Canada.

Hinkle, R., S. Albrecht, E. Nathanson, and J. Evans. 2000. *Direct Relevance to the Natural Gas Industry of the Habitat Fragmentation/Biodiversity Issue Resulting from the Construction of New Pipelines.* GRI Contract 5097-250-4070. URS Corporation, Wayne, N.J.

Ladino, A. G., and J. E. Gates. 1979. Responses of Animals to Transmission Line Corridor Management Practices. *Proc., Second Symposium on Environmental Concerns in Rights-of-Way Management,* Ann Arbor, Mich.

Louisiana Advisory Committee to the U.S. Commission on Civil Rights. 1993. *The Battle for Environmental Justice in Louisiana: Government, Industry, and the People.* Baton Rouge, La.

Lunseth, B. G. 1987. Browse Production and Utilization on a Pipeline Right-of-Way. *Proc., Fourth Symposium on Environmental Concerns in Rights-of-Way Management,* Indianapolis, Ind.

Moorhouse, S. S. 2000. *Rights-of-Way (ROW) Best Management Practices (BMPs) Literature and Regulatory Review: Phase I.* GRI Contract 5097-250-4070. URS Corporation, Colo.

O'Harrow, D. 1981. Performance Standards in Industrial Zoning. In *Dennis O'Harrow: Plan Talk and Plain Talk* (M. S. Berger, ed.), Planners Press, American Planning Association, Chicago, Ill., pp. 254-267.

OPS. 1999. *Common Ground Study of One-Call Systems and Damage Prevention Best Practices.* Washington, D.C.

Rabinow, R. A. 2004. *The Liquid Pipeline Industry in the United States: Where It's Been, Where It's Going.* Association of Oil Pipe Lines, Washington, D.C., April.

Rolf Jensen & Associates, Inc. 1982. *Urban Development Siting with Respect to Hazardous Industrial Facilities.* Office of Community Planning and Development, U.S. Department of Housing and Urban Development, Washington, D.C., April.

Rusin, M., and E. Savvides-Gellerson. 1987. *The Safety of Interstate Liquid Pipelines: An Evaluation of Present Levels and Proposals for Change.* Research Study 040. American Petroleum Institute, Washington, D.C.

Santillo, D. J. 1993. Observations on the Effects of Construction of Natural Gas Pipeline Right-of-Way on Wetland Vegetation and Birds. *Proc., Fifth Symposium on Environmental Concerns in Rights-of-Way Management,* Montreal, Quebec, Canada.

Schreiber, R. K., W. C. Johnson, J. D. Story, C. Wenzel, and J. T. Johnson. 1976. Effects of Powerline Rights-of-Way on Small Nongame Mammal Community Structure. *Proc., First Symposium on Environmental Concerns in Rights-of-Way Management,* Starkville, Miss.

Schwab, J. 1989. *Industrial Performance Standards for a New Century.* PAS Report 444. American Planning Association, Chicago, Ill.

TRB. 1988. *Special Report 219: Pipelines and Public Safety: Damage Prevention, Land Use, and Emergency Preparedness.* National Research Council, Washington, D.C.

Van Dyke, G. D., L. M. Shem, P. L. Wilkey, R. E. Zimmerman, and S. K. Alsum. 1994. *Pipeline Corridors Through Wetlands—Summary of Seventeen Plant-Community Studies at Ten Wetland Crossings.* GRI Contract 5088-252-1770. Argonne National Laboratory, Ill.

Zelenak, P., H. Haines, and J. Kiefner. 2003. *Analysis of DOT Reportable Incidents for Gas Transmission and Gathering System Pipelines, 1985 Through 2000.* PR218-0137. Kiefner and Associates, Inc., Sept. 23.

# 3

# Approach for Risk-Informed Guidance in Land Use Planning

While there is general recognition that pipelines present a potential hazard to people and property, the extent of the danger is not well understood by the public or local officials. Risk is inherent in the system; it can be reduced and managed, but it cannot be eliminated. Thus, it would be helpful to understand the risks well enough to make informed decisions to minimize the likelihood of incidents as well as the consequences of an incident if one does occur. Pipeline companies currently use risk-informed approaches (e.g., integrity management); indeed, they are required to use them.[1] However, the approach being used focuses on pipeline-related factors (e.g., pipeline diameter, internal pressure) and not on factors that are external to the pipeline and its operation (e.g., land use in the areas adjacent to the pipeline). Some local governments, at present, have plans to avert or minimize the consequences of natural and industrial disasters (see information from the American Planning Association at www.planning.org); some of these strategies might be used to identify risk management and mitigation strategies for pipelines.

In this chapter some basic issues associated with addressing pipeline safety in terms of risk are considered. A general framework is described that could serve as a basis for understanding, even by those who are not well versed in risk-informed decision making. Further background is available in work by Kaplan and Garrick (1981) and Theofanous (2003).

[1] In the mid-1990s, the Office of Pipeline Safety (OPS) began developing a risk-based approach to managing pipeline risk. The approach focuses on pipeline design and characteristics (e.g., wall thickness, type and material grade of the pipeline, internal pressure, depth of cover), construction (e.g., weld and coating inspections, hydrostatic pressure testing), and maintenance (e.g., in-line inspections) of the system. It does not, however, take into account mitigation measures (e.g., land use measures, setbacks, evacuation procedures) that can also contribute to the integrity of the system and more effectively manage overall risk.

With a risk-informed approach, it may be possible to identify and prioritize the safety and risk issues related to pipelines and use this information to make informed policy decisions at the federal, state, and local levels. Finally, the importance of risk communication is addressed. Carefully considered risk communication is critical if the risk management process is to be successful. Effective communication can increase the likelihood that the pipeline industry, the public, and other stakeholders can provide informed input into the process and can understand the results, significance, and implications of the analyses.

## BACKGROUND

An appropriately designed risk analysis could be used to aid decision makers at all levels in making choices related to pipelines (e.g., siting, burial depth, pipeline diameter, pressurization, easements, land use) and in establishing policies and guidelines to make such choices. To conduct such an analysis, one must identify the various relevant factors,[2] obtain and analyze data on the relative safety of these factors, identify the risk measures associated with each, develop a perspective that integrates the components of the pipeline system, and apply a risk management framework. The committee identified the national databases that can be used in conducting a risk assessment of transmission pipelines. (A description of the national databases is contained in Appendix B.) Pipeline operators maintain more detailed data on the pipelines they operate, which would greatly enhance the risk assessment; unfortunately, these data are not available to the public. The national databases are the only data sets that provide usable data at the national level. Even these databases, however, have limitations: they contain information only on incidents that exceed the minimum reporting threshold, they contain data that cannot

[2] The committee cannot characterize all the components of a risk assessment for transmission pipelines, but a number of factors might be included. The relevance of each of the components would vary from one location to another. Components of an assessment might include class of pipeline, pipeline diameter, pipeline pressure, commodity in the pipeline, the rate at which the product escapes from the pipeline break (i.e., the geometry of the pipeline break), existence of barriers, extent and type of corrosion, pipeline material, soil conditions, potential for natural hazards (e.g., earthquakes, frost heave), and metal fatigue from transport of the pipe before construction or the cycling of pressures during operation.

be used to generalize to the entire transmission pipeline system, and they do not include the data categories needed to conduct specific analyses that may be of interest (e.g., a specific type of pipeline transporting a specific product at a specified pressure in a particular soil type). In addition, there are definitional inconsistencies across data sets and across time for the same database, there are problems inherent in the quantity and the quality of the data (e.g., recording errors), data are missing, and the reporting thresholds may result in an inaccurate depiction of the types of transmission pipeline releases and their effects.

Although the national data are incomplete, they are sufficient to begin the risk assessment process and develop risk estimates. Because a risk assessment is iterative in nature, new data that become available should be incorporated into the assessment to provide better information to decision makers at the local level. One of the responsibilities and contributions of OPS is to collect reliable data. A consistent, comprehensive data collection effort would benefit all pipeline safety stakeholders. When the risk assessment is conducted, data needs can be identified, and appropriate efforts to improve the data should be undertaken at that time.

Risk assessments can be done in many ways—some more appropriate than others. (See Appendix D for brief descriptions of a few risk assessment techniques that are used by the pipeline industry. The committee does not endorse or recommend these approaches, but the difference between these techniques and the risk-informed approach that will be described in this chapter should be understood.) A systems approach takes into account the effect (positive or negative) that one component may have on other components in the system. Thus, while one change may reduce the risk for a particular component, it may increase the risk of failure due to another component and thus increase the overall risk (i.e., reduce the safety of the system).

Risk management offers a method of identifying risks, evaluating them on the basis of their likelihood and severity of consequences, and allocating resources to control them on the basis of their importance. This can enable decision makers to identify and evaluate effective and efficient risk mitigation options and to choose options that minimize risk commensurate with their practicality and affordability. After implementation of selected options, system performance can be monitored to determine whether risk control measures are effective. This iterative process can, over time, continue to reduce overall risk. The committee believes that such a risk assessment needs to be conducted at the national level. The issue is national in scope, with most transmission pipelines traversing multiple states. In addition, the resources, information, and expertise needed to conduct a credible assessment are of such magnitude that state and local governments may not be able to undertake such an effort on their own.

## FRAMEWORK

The principal underlying feature of the concept of risk is uncertainty. Given a system, in this case a pipeline, and its relation to (or position within) the physical world that surrounds it, one can ask what potential events could result in abnormal behaviors. In particular, events that can lead to hazardous situations for life, property, and the environment are of interest.

The only thing that is certain about the future is that it is uncertain. One way of addressing this uncertainty is by means of likelihood. Clearly, the likelihood of the initiating events is of concern, as well as the likelihood of the various potential outcomes that may result from each initiator. The latter is called "conditional" likelihood because the likelihood of the outcome is dependent on the likelihood of the occurrence of the initiating events. Likelihood can be expressed in terms of probability, and the combinations needed to yield the various outcomes can be computed by the use of logic and probability theory.

In principle, by virtue of its being systematic and comprehensive, the risk-informed approach leads to at least a qualitative treatment (and understanding) that should eliminate the possibility of surprise. Thus, at a minimum, preparations can be made to respond to a whole range of potential outcomes. This is the essence of emergency planning.

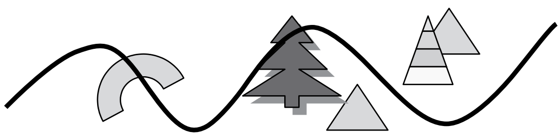
In addition, the likelihood-consequence results can be pursued quantitatively and used to inform or guide decisions, with the aim of achieving appropriate levels of prevention of such hazardous events and mitigation of their consequences. This is the essence of risk management. Appropriately conducted and implemented, risk management ensures that, *on the average,* optimal expenditures will be made to reduce or mitigate hazards, or both. "On the average" is important to understand because uncertainty, however small, cannot be dealt with in terms of a single outcome, or even a small number of outcomes. In particular, there is no guarantee that a very low-probability event will not occur tomorrow.

In practice, ideal performance is often not achieved because of the difficulty in creating the input probabilities (of initiating events) to be used in the analysis. An even larger problem is finding a common value system to measure costs and losses to optimize risk management measures. In this common value system, the perpetrator (initiator) of risk, the recipient of risk, and government must all be considered in order to define and implement a regulatory structure. Although each factor cannot be precisely quantified, a way to incorporate them into the analysis is needed.

## WHAT IS RISK?

A picture of the system and its surroundings, ranging from densely built and populated areas to rural, unincorporated areas, can be developed. The following questions are asked (see Figure 3-1): What can go wrong

Given a system



Questions to ask: ✓ What can go wrong? (Scenarios)

✓ What could be the results? (Consequences)

✓ What are respective likelihoods? (Probabilities)

$$R = \{S_i, p_i, C_i\}$$

Attributes:

- ➢ Systematic, rational, scrutable addressing of uncertainty about future events.
- ➢ Essential aid to decision making in managing potential losses.

**FIGURE 3-1** What is risk?

(scenarios)? What could be the results (consequences)? What are the respective likelihoods (probabilities)? The answers to these three questions provide a set of triplets; this is the risk.

The scenarios can be categorized as externally imposed (man-made) events, naturally occurring phenomena, and internal events (arising from influences and effects from normal operation of the system that can result in abnormal disturbances). The principal example of externally imposed events (and indeed the principal cause of pipeline failures) is human/machine intrusion (e.g., excavation, outside force). Earthquakes and floods are among the key natural phenomena because both can cause ground shifting and large-scale displacements. The major internal events include generation of defects due to corrosion/erosion and fatigue due to fluctuating pressure or temperature conditions. A separate category of potential external events recently has come to the forefront as a result of international terrorism.

In a pipeline, an initiating event is one that leads to failure of the pressure boundary, and a scenario is the specification of the failure mode and magnitude, together with all other factors that can be independently specified (e.g., location, weather, population and building distributions, environmental setting). A comprehensive risk assessment, which would identify a wide range of scenarios, would include existing and plausible future pipeline uses. Among the scenarios that should be included is a conversion of pipeline use from crude to refined petroleum products, which carry different ignition factors and spread rates for terrestrial and water movement. Another is rights-of-way that carry more than one operating pipeline (e.g., a natural gas and a refined petroleum pipeline operating simultaneously in the same right-of-way; such an arrangement would modify the risks and the spatial extent of the hazard because one pipeline failure could cause another).

The consequences are the physical/chemical/biological phenomena that follow as a natural result of the scenario. The principal distinctions and classes thereof include flammable gases, volatile flammable liquids, toxic gases, volatile toxic liquids, and environmental polluting liquids. Of course, pipeline size (diameter), pressure, and pressure control methods also are relevant because they affect quantities and rates of release. The weather determines the rate of atmospheric dispersal and the direction and size of any resulting cloud. Ignition sources define potential delays involved. In general, in the absence of strong ignition sources, the occurrence of ignition may be unpredictable.

Depending on the gas involved, flames can accelerate into explosions and perhaps even powerful detonations. Flammable liquids can burn from pools or from sprays. The consequence of fire may be a direct burn hazard to the population exposed or an indirect burn hazard through thermal radiation. Fires can propagate to nearby flammable structures and buildings. Explosions can result in health hazards and even death, depending on the magnitude of the overpressure involved and on structural failure.

All these effects are a function of the distance from the location of pipeline failure, and therefore they can be mitigated (e.g., by appropriate exclusion zones and setbacks). The approach of an exclusion zone, for example, is used to manage risks from nuclear power plants. A similar approach was developed by the National Fire Protection Association [*NFPA 59A: Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)*] to manage risks from large LNG storage tanks. An independent layer of safety is gained by requiring mitigation of consequences that result from *assumed* major failures (probability of failure is equal to 1), in addition to reducing the likelihood of major facility failures (prevention). For rare, high-consequence hazards, experience shows that such an approach is appropriate, and it is known as "defense in depth."

Naturally, a major question for the committee's task is whether such an approach (assuming, conservatively, the maximum possible failure) is appropriate here, or, if not, whether and how likelihood should be used to define various degrees of protection around pipelines.

## STRUCTURING A DECISION

A decision to do nothing is still a decision. Thus, avoidance of action because of an inability to measure uncertainty cannot be considered a sound approach to managing risk. Furthermore, a misapplication of risk analysis that could produce misleading results must be avoided. A deliberative process is needed that is well documented, and the process should include effective communication among and involvement of all stakeholders. The starting point of such a process is illustrated in Figure 3-2. The net private benefits axis is a net gain that incorporates the income from operating the pipeline as well as expenses of operation, including maintenance and accident prevention measures (inspection, maintenance of rights-of-way, etc.). The net public benefits axis includes community gains (e.g., new jobs) as well as losses due to restricted land use. The fear factor is intangible, yet it needs to be taken into consideration because pipeline safety involves local governments and millions of individuals, all with different levels of comprehension of the technical issues involved. Clearly, additional considerations (axes) may be involved.

Each point on this space represents a particular decision (for example, the setback for a particular pipeline) and is associated with a certain level of risk—the triplet defined above (i.e., scenarios, consequences, probabilities). A first step in structuring a decision process—that is, in choosing a neighborhood within this space that represents an optimally managed risk space—is to determine the various boundaries on each of

✓ Define all key ingredients (dimensions)
✓ Define scales that span extremes (measures)
✓ Choose acceptable operating space (goals and uncertainties)
✓ Determine appropriate risk management (ensure meeting goals with high enough probability)

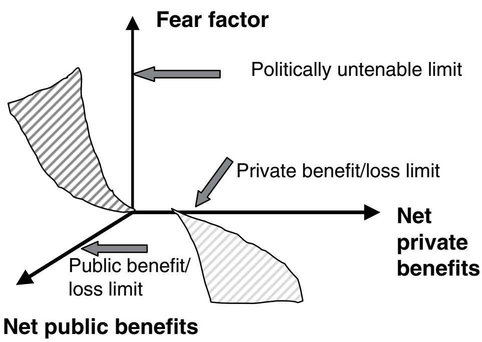



**FIGURE 3-2** Structuring a decision.

the axes that define the limits of acceptable regions. For example, one could try to define on the net public benefits axis the limit of consequences that would be deemed unacceptable, however small the possibility of initiating failure. Similarly, from an initial scoping study for various pipelines and scenarios, one could try to define a limit on the fear factor that would be considered prohibitive. The problems encountered in seeking permission to transport spent nuclear fuel to a geologic repository demonstrate the relevance of this factor in a political setting in which such decisions are made.

In assessing likelihood, a fundamental issue is the metric to be used. For example, the probability of failure per unit length of pipeline or volume transported in a pipeline is very low, and safety measured in this way exceeds, by far, that of all other modes. However, for the pipeline system as a whole, there are about 300 accidents per year, which is not negligible, especially from the point of view of those who are adversely affected.

One approach may be to use a hierarchy that is based on the magnitude of potential consequences. At the upper end of the range of consequences, practices could be consistent with those for LNG storage tanks and other chemical plant facilities, and at the lower end more effort could be placed on prevention through inspection and monitoring programs, such as those already in place (e.g., Common Ground Alliance one-call systems).

Incidentally, the common practice of obtaining a measure of risk by multiplying probabilities and consequences is, in general, not adequate. One reason for the preference for the triplet (see Figure 3-1) is that a risk number alone does not distinguish a high-consequence, low-probability event from a low-consequence, high-probability event. In contrast, applying the scenario-likelihood-consequence approach provides all the key ingredients about risk necessary to inform decisions. For example, the loss of 10 lives (consequence) every 100 years (probability) is not the same as the loss of 100 lives every 1,000 years, even though in both cases the product of the two factors gives one-tenth of a life per year. Another reason is that the triplet definition is amenable to conveying levels of confidence in such estimates. These are also crucial, especially when multiple interests are involved, as is the case here. For example, a probability estimate that is expressed with a 90 percent confidence is certainly more reliable (it means that such an estimate would turn out to be correct for 90 percent of the time histories to which it pertains) than one expressed as a "best estimate" value. A 90 percent estimate is said to be conservative, and of course a 99 percent estimate is even more conservative.

Ultimately, judgment also has to come into play to balance value systems and conflicting forces. Again, all this requires sound technical work and a deliberate, consultative process with ample input from representative stakeholders, as discussed below in the section on risk communication.

## PROBABILITY AND UNCERTAINTY

The role of logic and probability theory mentioned above is in decomposing complex, hard-to-characterize events into simpler events, to the degree deemed appropriate. This aspect of risk assessment is well founded and well developed, especially for pipeline risks, because those risks do not significantly involve complexity. "Complexity" refers to emergent system behavior—that is, behavior that is not a combination of the individually characterized behaviors of the system's presumed (superficially identifiable) parts. Thus, the success of pipeline risk assessment rests on defining the probabilities of component parts, and to a major extent this means the probabilities of initiating events.

For physical events, these probabilities can be defined with reasonable acceptability. For external events, empirical evidence is available that appears to be stable over many years and thus is acceptable for use in such assessments. Only the terrorism threat presents an intangible factor that has to be taken into account, perhaps at the upper end of the hierarchy mentioned above. The situation for internal events is mixed in that pipelines at different stages of their lifetime, under different conditions and maintenance and inspection procedures, present different kinds of challenges. Perhaps a hierarchical approach is needed here too, from well-characterized and hence more predictable cases to those so ill-defined that almost nothing can be said about them with any degree of certainty.

A robust treatment must distinguish between random and knowledge-type uncertainty (see Figure 3-3) and must express the confidence

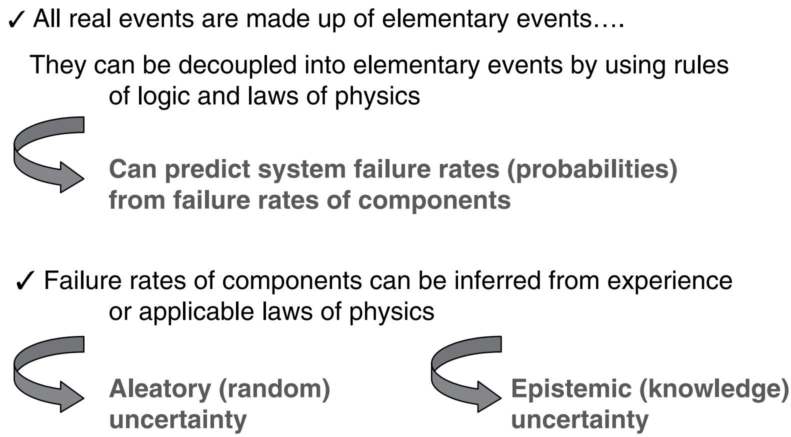



**FIGURE 3-3** Probability and uncertainty.

levels on estimates of failure probabilities accordingly. Random uncertainty is empirical (based on data) and therefore is amenable to statistical analysis. Still, care needs to be exercised in applying the results to a particular pipeline; it needs to belong to the same statistical class as the pipelines from which the data were derived. The assignment of the pipeline to a statistical class is problematic because it can only convey the expert's opinion on the matter assessed. Wide review and deliberation are then necessary to avoid the pitfalls that the opinions of any one individual might entail.

## TOWARD A PROCESS FOR RISK-INFORMED GUIDANCE

Local governments are increasingly faced with issues of land use. The availability of an easy-to-apply means for making decisions, in a manner that allows flexibility in accepting the level of risk deemed appropriate in a particular case, would be beneficial. This is possible if the decision process is structured in a risk framework as outlined above.

Most local governments have neither the resources nor the expertise to engage in developing such a structure on their own. Moreover, this approach appears inappropriate because it would involve much duplicative work done by necessity at a superficial level. Instead, a risk-informed effort is needed at the national level that results in an appropriate abstraction easily understood and used at the local government level. The necessary steps are shown in Figure 3-4. Much of the success of such an effort depends on the competence of the team engaged in the study (past performance should be a key factor in selecting the team and organizing the effort) and adherence to an open, deliberative, peer-reviewed process that iterates freely between risk assessments and decision structuring. Furthermore, the process should be open to updates and refinements as needed. Properly conducted, such an effort naturally leads to an optimal mix of prevention and mitigation measures, and this mix may be different for each class of pipelines (see Figure 3-5).

## Proposed Process

The committee believes that OPS should initiate a process, perhaps by designating an organization to convene the appropriate stakeholders, that would develop risk-informed guidance. The development of this guidance would require the commissioning of qualified and experienced analysts. In consultation with the stakeholders, the analysts would develop a methodology for a risk assessment that would—after incorporating peer review—lead to technical guidance and then a prototype set of risk guidance. The committee believes that data and methods, perhaps drawn in part from techniques described in Appendix D, are available

1. **Define classes of pipeline risks**
2. **For each class construct a decision problem**
3. **For each problem, determine the complexion of risk and its role with regard to the whole**
4. **Then carry out the work of risk assessment for representative conditions**
5. **Iterate with decision problem toward developing guidelines that are easy to understand and use**

**FIGURE 3-4** Toward a framework for risk-informed guidance.

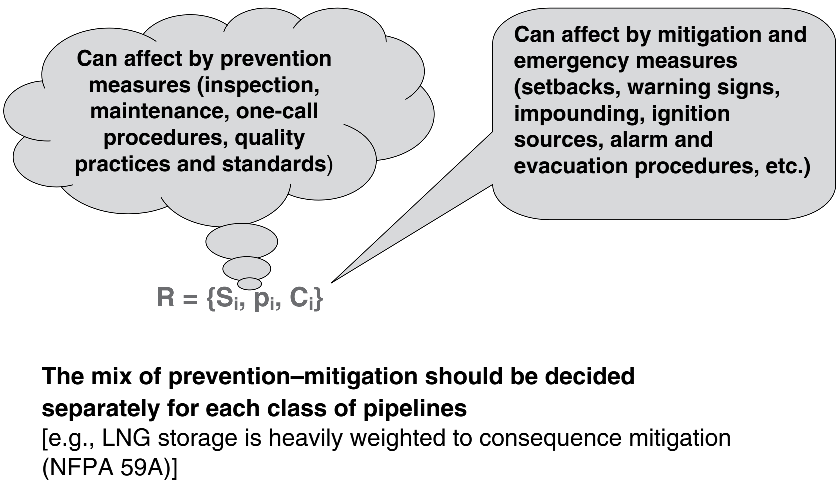



**FIGURE 3-5** Triplet definition.

for developing a set of risk estimates, which will only be approximations and will entail considerable uncertainty. The prototype guidance would be beta tested by users to determine their applicability and appropriateness. Refinements would be made on the basis of the beta testing. The stakeholder group would then share the results with federal, state, and local officials for implementation as they deem appropriate. Research would be commissioned by government and industry to improve on the initial version. Over time, the stakeholder group would refine the guidance on the basis of feedback from users and new technical information.

## Example of Guidance

The technical guidance the committee envisions might take the form of recommended practices that would allow state and local governments to select a setback, building code specification, or other mitigation strategy that could be applied to manage development and activities near a transmission pipeline. The choices would be based on the communities' decisions about an appropriate level of risk and an acceptable cost burden for both the pipeline companies and the communities. For example, the risk assessment for setbacks might be based on calculations of expected risk at various distances from transmission pipelines, which would vary by product type, pressurization, and so forth. The guidance would include procedures that could be applied to estimate the cost burden at various distances, which would significantly depend on the nature of the built environment.

## RISK COMMUNICATION

There are many stakeholders in the pipeline system who should be knowledgeable about the risks so that informed guidance can be provided. However, the subject is technical and often complex, which can lead to misunderstanding, confusion, and distrust (NRC 1989). Thus, effective risk communication, which is an interactive process of timely and credible information and opinion exchange (NRC 2003) that is used to raise the level of understanding of relevant issues and actions, is difficult. Society increasingly expects government and industry to provide new levels of protection from industrial hazards. In particular, the public increasingly demands that corporations do more than merely comply with safety regulations. And industry is realizing that it has an incentive to go beyond regulatory compliance to prevent even larger costs from litigation settlements and legal transactions and the damage to reputation and market share when bad things happen.

Risk information would allow public officials to make informed decisions about how to mediate between pipeline companies and the public, and it would allow the public to participate and feel comfortable in accepting such decisions. How this information is communicated will affect siting of new pipelines, planning for capacity expansion, development of property next to pipelines, precautions during excavation near pipelines, real estate values and assessments, and public acceptance of pipelines.

## SUMMARY AND CONCLUSIONS

A systems approach to risk management that uses quantifiable mitigation measures (such as setbacks, warning signs, and alarm and evacuation procedures) and prevention measures (such as design, inspection, and maintenance of pipelines) would likely improve pipeline safety across the nation. The committee suggests that now is an appropriate time to pursue such an approach. It suggests that the methodology should involve the following principal components, as well as a tight interaction and integration between them:

- A high-quality risk assessment, conducted at the national level, that acknowledges the various classes of pipelines and respective classes of risk profiles in a manner that encompasses the variety of conditions that exist in the field;
- Reduction and generalization of these results into simple and easy-to-use decision-guiding tools with regard to risk levels associated with various extents of setbacks, rights-of-way, and procedures involved in maintenance, inspections, and mitigation in emergencies;
- A management plan for implementation that renders help to local communities according to need and builds on the experience gained from use of the approach in the field;
- A management plan for long-term communication of risk and interplay of perceptions among all stakeholders, especially pipeline operators, local officials, and the public; and
- A management plan for integrating all the preceding components and refining them on a continuing basis by using actual experience, both in implementation and in the safety records obtained.

## REFERENCES

***Abbreviation***

NRC National Research Council

Kaplan, S., and B. J. Garrick. 1981. On the Quantitative Definition of Risk. *Risk Analysis*, Vol. 1, pp. 11-27.

NRC. 1989. *Improving Risk Communication.* National Academies Press, Washington, D.C.

NRC. 2003. *Alerting America: Effective Risk Communication—Summary of a Forum, October 31, 2002.* National Academies Press, Washington, D.C.

Theofanous, T. G. 2003. Risk Assessment and Management. In *Comprehensive Structural Integrity* (I. Milne, R. O. Ritchie, and B. Karihaloo, eds.), Vol. 1, Elsevier, Amsterdam, Netherlands, Chapter 10.

# 4

# Findings, Conclusions, and Recommendations

The United States depends on about 380,000 miles of transmission pipelines to serve a major portion of the nation's demand for energy. These lines transport virtually all natural gas, which accounts for about 28 percent of energy consumed annually, and roughly two-thirds of petroleum products and other hazardous liquids. The system includes numerous inter- and intrastate pipeline companies, which are subject to economic and safety regulation at the federal and state levels.

The transmission pipeline safety record has been improving over time. Liquids pipelines have the best safety record of any mode, where transport options exist, for moving petroleum and other hazardous liquid products. Human casualties, property loss, and environmental damage resulting from pipeline incidents are infrequent, but when they do occur the consequences can be significant. For example, a 1999 liquids pipeline incident in Bellingham, Washington, resulted in the release of 237,000 gallons of gasoline into a stream in the middle of the city. The gasoline ignited, killing three, injuring eight, and causing roughly $45 million in property damage. Such incidents, along with population growth, urbanization, a growing demand for energy, and increased public opposition to the siting of new pipelines, have combined to focus greater attention on the need for increased land use controls in the vicinity of pipelines and led to the request for this study.

The purpose of this scoping study is to consider the feasibility of developing risk-informed guidance as one means of minimizing or mitigating hazards and risk to the public, pipeline workers, property, and the environment near existing and future transmission pipelines. The study was requested by the Office of Pipeline Safety (OPS) of the U.S. Department of Transportation to assist OPS and the Federal Energy Regulatory

Commission (FERC) in developing guidance for use by state and local governments in making land use decisions near existing or proposed transmission pipelines.

## FINDINGS

### Finding 1. Pipeline incidents have potential for significant impact on life, property, and the environment.

According to OPS data, during the 3-year period 1999 through 2001, an annual average of 148 reportable hazardous liquids transmission pipeline incidents[1] occurred, resulting in 2 deaths, 11 injuries, and $97 million in property damage. During the same time period, an annual average of 73 reportable natural gas transmission pipeline incidents occurred, resulting in 6 deaths, 10 injuries, and $20 million in property damage. In the 1990s it was estimated that more than 62 million gallons of oil and other hazardous liquids have been released into the environment. Although no comprehensive studies have yet estimated the environmental damage caused by pipeline spills in the United States, there are numerous examples of the effects of individual spills on the environment. One such example is the interstate oil pipeline rupture that occurred along the Reedy River near Greenville, South Carolina, in June 1996, which spilled almost 1 million gallons of diesel fuel into the river. An estimated 34,000 fish and other wildlife were killed, and public water supplies were threatened.

There are many other examples of pipeline incidents whose impacts are wide ranging. Box 1-1 in Chapter 1 provides a brief description of seven incidents that have occurred in the recent past in the United States.

[1] A reportable pipeline incident for natural gas transmission pipelines is currently defined in 49 CFR 191 as an incident that is considered significant by the operator or that results in (*a*) a fatality; (*b*) an injury requiring hospitalization; (*c*) property damage, including cost of cleanup and recovery, value of lost product, and damage to the property of the operator or others, or both, of $50,000 or more; or (*d*) a release of gas. A reportable incident for hazardous liquids transmission pipelines is currently defined in 49 CFR 149.50 as an incident in which there is a release of the hazardous liquid or carbon dioxide transported resulting in any of the following: (*a*) explosion or fire not intentionally set by the operator; (*b*) release of 5 gallons (19 liters) or more of hazardous liquid or carbon dioxide; (*c*) death of any person; (*d*) personal injury requiring hospitalization; or (*e*) estimated property damage, including cost of cleanup and recovery, value of lost product, and damage to the property of the operator or others, or both, exceeding $50,000.

**Finding 2. Just as transmission pipelines pose a risk to their surroundings, so does human activity in the vicinity of pipelines pose a risk to pipelines. These risks increase with growth in population, urban areas, and pipeline capacity and network.**

As the U.S. population continues to grow and spread out around metropolitan areas, more development is occurring near existing transmission pipeline rights-of-way. Much suburban and exurban development is taking place in outlying jurisdictions that have been among the least active in planning for and managing growth. Many such jurisdictions contain transmission pipelines that were constructed before development began. The demand for natural gas and petroleum is projected to increase by 36 percent between 2002 and 2010. Thus, more pipelines will be required to serve growing as well as mature areas.

With increasing urbanization and land development activity near transmission pipelines as well as the addition of new facilities to serve growing populations, the probability that pipelines will be damaged by human activities in the pipeline rights-of-way may also increase. In addition, if there is an incident, more people may be affected because more people may be living and working near the pipeline who have the potential to be injured or killed. This will exacerbate the consequences of an incident.

**Finding 3. Land use decisions can affect the risks associated with increased human activity in the vicinity of transmission pipelines.**

Many different types of land use decisions can affect pipeline safety. For example, in designing and acquiring rights-of-way, pipeline operators make decisions that affect the use of land subject to their rights-of-way. Property owners make daily decisions about how they use their land that is subject to these rights-of-way. Local governments can establish rules governing structures and uses in the vicinity of pipelines. FERC prescribes the width of new natural gas transmission pipeline rights-of-way. OPS prescribes safety practices that affect the way pipeline operators use their rights-of-way. All of these actions and decisions can affect the probability of pipeline failures and the consequences arising from incidents.

**Finding 4. Pipeline safety and environmental regulation have generally focused on (*a*) the design, operation, and maintenance of pipelines**

**and (*b*) incident response. They have not directed significant attention to the manner in which land use decisions can affect public safety and the environment.**

Pipeline safety regulation is the shared responsibility of various federal and state agencies, which has resulted in a complicated regulatory system. OPS has the primary federal safety regulatory role for interstate transmission pipelines, but other federal agencies, such as the Minerals Management Service, the U.S. Environmental Protection Agency, and the Department of Homeland Security, are also involved. The states have the primary responsibility for regulating and inspecting intrastate pipelines. Federal law allows for state inspection of interstate lines as well, and Congress has provided some funding to support enhanced state efforts. Although land use regulation is vested in state police powers granted to cities and counties by their respective state legislatures, the states generally have not been active in encouraging local governments to take transmission pipelines into account in their planning and regulation of land use and development.

OPS sets all safety regulatory standards for the design, construction, operation, and maintenance of interstate pipelines and has authority to take safety enforcement action against interstate pipeline operators. The only role of states in the regulation of interstate transmission pipelines is compliance monitoring and inspections by the nine states that have been specially designated as "interstate agents" by OPS to inspect interstate natural gas pipelines and by the four states designated to inspect interstate liquids pipelines.

OPS also sets minimum standards for the design, construction, operation, and maintenance of intrastate pipelines. All 50 states regulate intrastate gas pipelines under OPS supervision. Local governments have very limited authority to regulate pipelines of any type. The only exceptions are municipalities that have the power to grant franchises or licenses to pipeline operators in order to install pipelines on public property to control the siting of new hazardous liquids pipelines. In fact, some local government proposals have gone considerably farther, often in reaction to spills and explosions, and portions of some of these proposed ordinances, which have been found to violate federal law, have been struck down under the federal preemption doctrine.

**Finding 5. For the most part, state and local governments have not systematically considered risk to the public from transmission pipeline incidents in regulating land use.**

Transmission pipelines generally are not subject to any local land use regulation. In most instances, the width, configuration, and control of pipeline rights-of-way are established without local input. Provisions with regard to the widths of rights-of-way are often established for laying and inspecting the pipeline rather than for public safety or prevention of environmental damage. For example, a catastrophic failure of a high-pressure natural gas transmission pipeline could cause injury to people 100 feet or more away. For the largest and highest-pressure natural gas pipelines, injury is possible out to 1,000 feet, but pipeline rights-of-way are rarely more than 50 feet wide.

There is no database of land use regulatory practices in the vicinity of pipelines. In a few instances where land use measures are in effect, local governments use setbacks to protect the public from pipeline incidents. Since most communities have no land use protections in place relative to transmission pipelines, schools, apartment buildings, and hospitals are sometimes built near a transmission pipeline. Individuals whose communities have experienced explosions and major leaks indicated in presentations to the committee that land use measures involving transmission pipelines that were in existence at the time of the incident were inadequate. The few local government efforts to develop more stringent restrictions have generally been in reaction to a significant incident, a proposal to route a transmission pipeline through part of a developed area, or a plan to reactivate an inactive pipeline or convert it to carry a different commodity.

**Finding 6. Risk-informed approaches are being used effectively in other domains (e.g., natural hazard mitigation, industrial hazard mitigation, nuclear reactor and waste disposal programs, tanker safety). These techniques are also being used to address other aspects of pipeline safety (e.g., pipeline integrity), but they have not been used to make informed land use decisions.**

Given the relatively small number of incidents and the geographically dispersed nature of the pipeline system, the data to predict pipeline failures at a specific location with confidence are insufficient. Risks cannot be eliminated, but a risk-informed approach can help provide guidance to minimize the probability of pipeline failures occurring and to mitigate the consequences of failures when they do occur.

The committee noted that there is a lack of risk-based technical guidance for making land use decisions near transmission pipelines, but much can be learned from hazard mitigation management techniques and strategies that have been adopted by state and local governments.

**Finding 7. Currently, decision makers lack adequate tools and information to make effective land use decisions concerning transmission pipelines.**

Guidance concerning development that incorporates the risk from transmission pipelines is not available to local government officials. As indicated previously, the few communities that have adopted setbacks have not had access to reliable data, risk analysis, or model ordinances by which they could reasonably determine appropriate separation distances between transmission pipelines and buildings. For example, after an incident involving a liquids pipeline that led to the deaths of three teenagers in Bellingham, Washington, a proposal was made that included a 1,000-foot setback using the theoretical impact radius of a major natural gas transmission line explosion. This approach, however, considers the potential consequences of an event without accounting for its probability, is based on a natural gas pipeline failure rather than a liquids pipeline failure, and does not attempt to weigh the risk-reduction benefits of such a measure against the considerable cost that such a provision would entail.

The basic informational tools needed by local governments to adopt effective local land use measures with regard to pipeline safety are missing. For example, officials often lack accurate and complete maps showing the location and dimensions of pipeline rights-of-way or where pipelines are located within such corridors. They do not have access to any reliable scientific literature that evaluates the various risk factors, such as product transported, operating pressure, age, and depth of cover, that could affect their land use decisions. There are no model ordinances for planning, zoning, setbacks, building codes, or best practices that specifically address transmission pipelines. The lack of accessible information may contribute to the apparent lack of attention to the risks by local officials.

**Finding 8. Many different forms of pipeline easements are in effect, and the terms and conditions vary widely. To the extent that an easement lacks clarity, enforcement of the right-of-way is more difficult.**

Most pipeline easements are privately negotiated agreements between a pipeline company and the owner of the land through which the pipeline passes. Many pipeline easements currently in effect were acquired many years ago, when the affected land was in agricultural use with little development. Since that time, the property may have changed hands several times, and the use of the land may have changed substantially. Provisions in these agreements depend on the time the agreement was acquired, the particular pipeline company's practices in effect at the time the easement was acquired, the land use at the time, the difficulty of the negotiation, and any special conditions or requirements involved. Some of these easements have less specificity as to uses allowed within the easement area. To the extent that an easement lacks specificity, the pipeline operator's task of preventing uses having the potential to harm the pipeline or compromise public safety is made more difficult. Furthermore, a particular landowner may not agree with the pipeline company's assessment of this potential, which leads to problems with enforcement of the easement. Appropriate land use measures utilized by local governments could bolster and complement a pipeline company's efforts to protect the right-of-way and preclude uses that could pose a public safety risk.

In addition, over time, subsequent property owners, their tenants, or the public may be unfamiliar with the terms of the agreement and may engage in activities within the easement area that are inappropriate and that could threaten the integrity of the pipeline. Inappropriate uses, such as heavy industry and landfills, buildings constructed too close to the pipeline, and the growth of mature trees on top of a pipeline, can compromise the safety of the pipeline.

**Finding 9. Encroachments and inappropriate human activity within the right-of-way can adversely affect pipeline safety. There appears to**

**be variability in the quality and extent of inspections, maintenance, and enforcement of rights-of-way.**

Pipeline operators are responsible for monitoring and inspecting their own rights-of-way. Under OPS rules, they are required to inspect all pipeline rights-of-way on a regular basis and keep them clear and visible for aerial inspection. States also have varying rules for the maintenance and inspection of intrastate pipeline rights-of-way. The committee was presented with examples of inappropriate construction by property owners within easements, such as fences and home additions, which could result in major incidents. Rules governing inspection and maintenance of rights-of-way vary across jurisdictional lines, particularly for intrastate pipelines. On the basis of anecdotal evidence shown to the committee, it appears that both the public and the private sectors need to be more vigilant in determining and enforcing easement restrictions.

## CONCLUSIONS

**Conclusion 1. Judicious land use decisions can reduce the risks associated with transmission pipelines by reducing the probabilities and the consequences of incidents.**

Pipeline safety is a shared responsibility. Land use decisions and control of activities and development near transmission pipelines may be undertaken by the pipeline operator; safety regulators; national, state, and local officials; and the property owners. Appropriate land use measures taken by local governments could bolster and complement a pipeline company's efforts to protect the right-of-way and preclude uses that could pose a public safety risk.

Rational land use decisions that provide appropriate physical separation between people and pipelines could reduce the risk associated with increasing numbers of people in proximity to transmission pipelines. Possible land use techniques include, for example, establishing setbacks, regulating or prohibiting certain types of uses and structures (such as schools, hospitals, and apartment buildings) near transmission pipelines, and encouraging other types of activities or facilities (e.g., linear parks, recreational paths) within or in the vicinity of pipeline rights-of-way. Utilization of such tools can be legitimate exercises of the local authority if they are appropriately instituted, particularly if such exercises are grounded in objective, scientifically derived data.

**Conclusion 2. It is feasible to use a risk-informed approach to establish land use guidance for application by local governments.**

Various forms of risk-informed management of pipeline safety are already in wide use within the pipeline industry. Moreover, the "integrity management" regulations governing liquids and natural gas pipelines recently promulgated by OPS require private operators to prioritize enhanced risk-reduction efforts by using risk assessment.

The probability of failure of any transmission pipeline is a function of many distinct factors including materials of construction, fabrication, exposure to corrosion, pressurization, and depth of cover. Data and models are lacking for making precise predictions about specific lines, but estimates can be developed at an aggregate level and adjusted to account for local conditions. The possible consequences of an event could be estimated on the basis of the product carried, degree of pressurization, depth of cover, surrounding development, and other considerations. The appropriateness and acceptable cost of various measures to reduce probability and consequence could be derived from local values. Although such an approach may be somewhat simplistic initially, it could be improved over time to a sufficient degree to help government officials regulate land use. The committee envisions an ongoing process that would involve risk assessment experts and stakeholders in the development, ongoing refinement, and application of such information.

**Conclusion 3. The federal government could serve a useful role by providing leadership in the development of risk-informed land use guidance for application by local, state, and federal governments.**

Pipeline safety is a national issue because 1.8 million miles of pipelines traverse the United States transporting numerous products, most of which could pose a threat to life, property, and the environment were there to be a pipeline failure. Because of the numerous stakeholders concerned about pipeline safety and their divergent interests and because of the national breadth of the concerns, the federal government may be best positioned to initiate an open process of developing risk-informed guidance. OPS played a similar role in fostering and initially supporting the Common Ground Alliance. Land use policies relevant to transmission pipelines are made at all levels of government and need to be based on an unbiased, scientific analysis of the risk posed by pipelines to their immediate surroundings. Local governments generally lack the resources and incentives to undertake such a broad-based effort on their own. The advantage of consistent guidance across jurisdictional lines also argues for federal leadership.

**Conclusion 4. There is clear evidence that guidelines can be developed that would assist in preserving habitat while maintaining rights-of-way in a state that facilitates operations and inspection.**

As an adjunct to its main charge, the committee was asked to consider the problem of habitat loss when rights-of-way are initially cleared and subsequently maintained to allow for inspection, which is required by federal law. Right-of-way maintenance facilitates such inspection, usually conducted by aerial surveillance, and reduces the potential for tree roots to interfere with pipelines, which is another possible cause of failure. Rights-of-way can provide useful and functional habitat for plants, nesting birds, small animals, and migrating animals. In developed or urban areas, the ecological function of such rights-of-way may be useful but marginal, in large part because of the narrowness of the right-of-way and the already extensive habitat fragmentation. There is an overriding environmental benefit in effective inspection of pipelines to avoid incidents with consequent releases and environmental damage.

## RECOMMENDATIONS

**Recommendation 1. OPS should develop risk-informed land use guidance for application by stakeholders. The guidance should address**

- **Land use policies affecting the siting, width, and other characteristics of new pipeline corridors;**

- **The range of appropriate land uses, structures, and human activities compatible with pipeline rights-of-way;**
- **Setbacks and other measures that could be adopted to protect structures that are built and maintained near pipelines; and**
- **Model local zoning ordinances, subdivision regulations, and planning policies and model state legislation that could be adopted for land uses near pipelines.**

**Such a risk-informed guidance system should include three interrelated components:**

1. **A decision framework informed by risk analysis,**
2. **Guidelines based on the analysis, and**
3. **Alternative actions that could be taken on the basis of the guidelines.**

**Recommendation 2. The process for developing risk-informed land use guidance should (*a*) involve the collaboration of a full range of public and private stakeholders (e.g., industry and federal, state, and local governments); (*b*) be conducted by persons with expertise in risk analysis, risk communication, land use management, and development regulation; (*c*) be transparent, independent, and peer reviewed at appropriate points along the way; and (*d*) incorporate learning and feedback to refine the guidance over time.**

**Recommendation 3. The transmission pipeline industries should develop best practices for the specification, acquisition, development, and maintenance of pipeline rights-of-way. In so doing, they should work with other stakeholders. With regard to the specific maintenance issue of clearing rights-of-way to allow for inspection, the federal government should develop guidance about appropriate vegetation and environmental management practices that would provide habitat for some species, avoid threats to pipeline integrity, and allow for aerial inspection.**

APPENDIX A

# Presentations

## FIRST COMMITTEE MEETING—SEPTEMBER 2003

### Program Development and Status; Goals for This Study

Stacey Gerard, U.S. Department of Transportation,
Office of Pipeline Safety
Mark Robinson, Federal Energy Regulatory Commission

### Trade Associations

Association of Oil Pipelines/American Petroleum Institute
Ben Cooper, Associate Director

Interstate Natural Gas Association of America
Terry Boss, Vice President for Environment,
Safety, and Operations

American Gas Association
Pam Lacey, Senior Managing Counsel

Local Government Perspective
Jim Pates, Fredericksburg City Attorney

### Stakeholder Panel

International Right-of-Way Association
Terry Mock, Pipeline Committee Chair

American Public Works Association
William Roger Buell, Right-of-Way Management Section,
Charlotte Department of Transportation

National Association of Counties
Julie Ufner, Environment and Energy

National Association of Home Builders
Debbie Bassert, Director of Land Development Services

State Government Perspective
Chuck Mosher, Council Member, City of Bellevue, Washington

Zoning/Land Use Analysis: Trends and Pressures
Jim Schwab, Senior Research Associate, American Planning Association

## SUBCOMMITTEE MEETING—NOVEMBER 2003

**Origins of Study; Agency Goals and Expectations**
Stacey Gerard, U.S. Department of Transportation, Office of Pipeline Safety
Rich Hoffmann, Federal Energy Regulatory Commission

## SECOND COMMITTEE MEETING—DECEMBER 2003

**Common Ground Alliance**
Bob Kipp

**State of Arizona Perspective on Pipeline Safety**
Commissioner Kris Mayes

**Integrity Management Program**

Federal Implementation
Jeff Wiese, Office of Pipeline Safety
Skip Brown, Cycla Corporation

Industry Implementation
Jim Wunderlin, Southwest Gas Corporation

## THIRD COMMITTEE MEETING—FEBRUARY 2004

**Local Government Perspective: Austin, Texas**
Chuck Lesniak, Austin, Texas
Bob Rackleff, Leon County, Florida

**Emergency Response to Pipeline Accidents**
Dean Sherick, Fairfax County Fire and Rescue

APPENDIX B

# Pipeline Safety Data and Trends in the United States

Pipeline safety data are compiled by the Office of Pipeline Safety (OPS) of the U.S. Department of Transportation (USDOT), the Energy Information Administration of the U.S. Department of Energy, the Bureau of Transportation Statistics, and the pipeline companies themselves. Only the national data were available to the committee. This appendix provides a brief overview of pipeline safety data and trends. It does not provide a comprehensive assessment of pipeline safety.

## DATABASES

A number of data sets could be used in reviewing various components of pipeline safety. OPS maintains the Hazardous Liquid Pipelines Accident Report database, which was established in 1970, revised in 1986, and revised again in January 2002 (when the threshold for reporting hazardous liquids pipeline accidents was reduced from 50 barrels to 5 gallons) (NTSB 2002). Irrespective of the volume spilled, any pipeline incidents in which damage exceeded $50,000 or there was an injury, fatality, fire, or explosion must be reported to OPS. The current OPS reporting requirements follow closely a voluntary industry program, the Pipeline Performance Tracking System (PPTS), which became effective January 1, 1999.

OPS maintains the Natural Gas Gathering and Transmission Systems Incident Database, which was revised in 1984 and again in 2001. Finally, OPS maintains the Natural Gas Distribution Systems Incident Database, whose reporting requirements are the same as those for gathering and transmission pipelines. This database, which was last revised in 1984, has recently been redesigned (NTSB 2002). OPS requires natural gas pipeline operators to report each failure that results in fatalities, injuries that require in-patient hospitalization, property damage (including cost of gas lost, of the operator or others, or both) of $50,000 or more, or ignition of gas (49 CFR 191.3, amended in 2001).

The numbers vary from one database to another because reporting criteria, definitions, incident causation classifications, and other categories differ from one database to another and within a database across time. For example, some pipeline product releases go undocumented because they do not meet the federal requirements for reporting. This results in an underreporting of releases and impacts. In addition, there are reporting errors, missing data, and preliminary data that are not subsequently updated. These problems make it hard to analyze the data and difficult to draw statistically significant conclusions.

## INCIDENT DATA AND TRENDS

From 1989 through 1998, 226 people died (a yearly average of 22.6 deaths) and 1,030 people were injured (a yearly average of 103 injuries) in major pipeline accidents.[1] In addition, according to GAO (2000), major pipeline accidents from 1989 through 1998 caused about $700 million in property damage. Hazardous liquids pipelines accounted for about $350 million, or 50 percent, of this property damage.[2]

In 2001, there were a total of 44,969 transportation fatalities, none of which were attributable to liquids pipeline incidents and 7 of which were attributable to natural gas pipeline incidents. In 2002, the number of transportation fatalities increased to 45,098. Of these, 1 was due to a liquids pipeline incident and 10 were related to natural gas pipeline incidents (NTSB 2003). A comparison of the accident rates for the different

[1] The figure for injuries excludes those occurring during one series of accidents caused by severe flooding near Houston, Texas, in October 1994. These injuries were excluded from General Accounting Office (GAO) analysis because the data of OPS and the National Transportation Safety Board (NTSB) differed in the number of people injured. OPS's data indicated 1,851 injuries, while NTSB reported that a total of 547 persons were treated, primarily for smoke and vapor inhalation. This accident was also excluded from GAO's analysis because the extent to which injuries were the result of explosions of petroleum and petroleum products released from the ruptured pipelines or of the controlled burn of these products could not be determined (GAO 2000).

[2] These data include spills of 50 barrels or more. Data from the U.S. Environmental Protection Agency, which maintains data on oil pipeline spills in areas where such spills could cause pollution of navigable waters, indicate that at least 16,000 spills of less than 500 barrels occurred from 1989 through 1998.

methods used to transport petroleum indicates that pipelines are the safest overall method. Only rail is safer in terms of injuries per ton-mile, and only barges are safer in terms of deaths per ton-mile. The rate of fatalities, injuries, and fires and explosions per ton-mile of oil transported for all other modes is typically at least twice—and in some cases more than 10 times—as great as the rate for pipelines. Trucks are, by far, the least safe method for transporting petroleum (see Table B-1).

From 1985 through 2001 there were 1,417 reportable natural gas pipeline safety incidents, an average of 83.4 per year; 1,159 were for natural gas transmission and gathering system incidents. Of these, 910 incidents, or 53.5 each year on average, occurred on onshore transmission and gathering systems (see Table B-2). Accidents on natural gas transmission and gathering pipelines accounted for 58 deaths in 25 incidents; 3 of the incidents accounted for 30 deaths. During the 1985–1987 period, there were 12.1 reportable injuries per year on average. For the 7-year period 1995–2001, the number of reportable injuries dropped to an average of 6.7 per year.

For the 3-year period 1985–1987, annual natural gas consumption in the United States was 16.9 trillion cubic feet (tcf), with an average of 70 reportable safety incidents per year and an average of 5.5 reportable safety incidents per year per tcf (see Table B-3). By 1999–2001, the average annual consumption had increased 29 percent to 21.8 tcf per year. For the same time period, the average annual number of safety incidents dropped to 63 and the number of reportable safety incidents per year per tcf dropped by 40 percent to 3.4. Thus, this downward trend in reportable incidents was accompanied by a 30 percent increase in natural gas consumption.

**TABLE B-1 Relative Occurrence of Transportation Accidents per Ton-Mile of Oil Transported, 1992–1997**

| Event | Pipeline[a] | Rail | Tank Ship | Barge | Truck |
|---|---|---|---|---|---|
| Fatality | 1.0 | 2.7 | 4.0 | 10.2 | 87.3 |
| Injury | 1.0 | 2.6 | 0.7 | 0.9 | 2.3 |
| Fire/explosion | 1.0 | 8.6 | 1.2 | 4.0 | 34.7 |

[a] The rates of occurrence are based on a value of 1.0 for pipeline. Values of less than 1.0 indicate a better safety record.

SOURCES: Trench 1999; GAO 2000.

**TABLE B-2 Safety Performance of Natural Gas Transmission and Gathering Systems, 1985–2001**

| | Total | Average per Year |
|---|---|---|
| Reportable safety incidents | 1,417 | 83.4 |
| Safety incidents (transmission and gathering) | 1,159 | 68.2 |
| Safety incidents (onshore transmission and gathering) | 910 | 53.5 |
| Safety incidents (offshore transmission and gathering) | 249 | 14.6 |

SOURCE: Trench and Selig 2003.

Only a small fraction of natural gas pipeline operators experience safety incidents. In 1998, 56 operators reported incidents; by 2000, this number had dropped to 33. No more than 6.5 percent of operators have had reportable incidents in any year. Furthermore, 90 percent of incidents (809 of 899) occur in unpopulated areas, and third-party damage is the single largest cause of onshore incidents at 23 percent.

Hazardous liquids pipeline summary incident statistics show a comparable downward trend (see Table B-4). From 1986 through 1989, there were an average of 201 incidents with 27 injuries and 3 fatalities per year. From 2000 through 2002, the annual average number of incidents had decreased to 140, with 5 injuries and 0.7 fatalities per year. During the same time period the annual average number of gross barrels of liquids lost decreased from 270,000 to just over 100,000 (see Table B-4).

## CAUSALITY

NTSB, the USDOT Inspector General, the New Jersey Institute of Technology, and others have reported that OPS data on pipeline incidents and infrastructure are limited and sometimes inaccurate. Until recently, OPS's

**TABLE B-3 Comparison of Consumption and Reportable Safety Incidents for Natural Gas Pipelines for Two 3-Year Periods, 1985–1987 and 1999–2001**

| | 1985–1987 | 1999–2001 |
|---|---|---|
| Consumption, tcf/year | 16.9 | 21.8 |
| Reportable safety incidents per year per tcf (all operators) | 5.5 | 3.4 |
| Safety incidents per year (transmission and gathering) | 70 | 63 |

SOURCE: Trench and Selig 2003.

**TABLE B-4 Summary Accident Statistics for Hazardous Liquids Pipeline Operators, 1986–2003**

| | Total, 1986–6/30/2003 | 1986–1989 | | 2000–2002 | |
|---|---|---|---|---|---|
| | | Total | Yearly Avg. | Total | Yearly Avg. |
| Accidents | 3,246 | 804 | 201 | 419 | 140 |
| Injuries | 249 | 109 | 27 | 14 | 5 |
| Fatalities | 37 | 12 | 3 | 2 | 0.7 |
| Gross barrels lost (in thousands) | 2,956 | 1,079 | 270 | 303 | 101 |

NOTE: Pipeline miles in 1986 totaled 153,404; pipeline miles in 2003 totaled 160,868.
SOURCE: OPS 2003.

incident report forms used only five categories of causes for incidents on natural gas distribution pipelines, four categories for those on natural gas transmission pipelines, and seven categories for those on hazardous liquids pipelines. As a result, about one-fourth of all pipeline incidents were attributed to "other causes," which limited OPS's ability to adequately identify and address causes of incidents. In addition, data on pipeline mileage in various infrastructure categories (such as age or size) are necessary for a meaningful comparison of the safety performance of individual pipeline companies. OPS did not require hazardous liquids pipeline operators to submit this type of data and did not collect complete data from natural gas pipelines. Given these limitations, in 2001 OPS revised its incident report forms for hazardous liquids and natural gas transmission incidents to include 25 categories of causes, and in early 2003 OPS revised its natural gas distribution incident form (GAO 2002, 7).

Data indicate that third-party damage is the leading cause of onshore natural gas transmission and gathering system incidents and liquid transmission system incidents, accounting for 28 percent and 41 percent of all such incidents, respectively (see Tables B-5 and B-6). External corrosion is the second leading cause, accounting for 17 percent of natural gas pipeline incidents and 21 percent of liquids pipeline incidents. Of those causes listed on the reporting form, vandalism and malfunction are the least likely to result in pipeline incidents. Vandalism accounts for fewer than 1 percent of incidents.

On the basis of voluntarily reported liquids pipeline data in PPTS Advisories 8, 9, and 10, 7 percent of 1,882 total spills were caused by

**TABLE B-5** Natural Gas Transmission/Gathering Systems—Cause of Onshore Incidents, 1985–2001

| Cause | Pipelines (%) | Nonpipeline Facilities (%) | Total (%) |
|---|---|---|---|
| Third-party damage | 28 | 9 | 23 |
| External corrosion | 17 | 0 | 13 |
| Internal corrosion | 11 | 7 | 10 |
| Natural forces | 10 | 8 | 9 |
| Miscellaneous | 2 | 30 | 9 |
| Incorrect operation | 3 | 19 | 7 |
| Unknown | 7 | 5 | 6 |
| Other failure | 4 | 8 | 5 |
| Construction/installation | 6 | 1 | 5 |
| Manufacturer | 6 | – | 4 |
| Previously damaged pipe | 4 | 0 | 3 |
| Malfunction | 1 | 11 | 3 |
| Stress corrosion cracking | 2 | – | 2 |
| Vandalism | – | 1 | 1 |
| Total | 100 | 100 | 100 |

NOTE: These data are based on 662 incidents.
SOURCE: Trench and Selig 2003.

**TABLE B-6** Liquids Pipelines—Cause of Incidents, 1996–2000

| Cause | Line Pipe (%) | Tank/Pump (%) |
|---|---|---|
| Third-party damage | 41 | 5 |
| Corrosion | 21 | 22 |
| Equipment | 4 | 45 |
| Unknown | 11 | 0 |
| Incorrect operation | 6 | 8 |
| Miscellaneous | 1 | 17 |
| Manufacturer | 6 | 0 |
| Construction/repair | 4 | 1 |
| Weather | 3 | 1 |
| Previously damaged pipe | 3 | – |
| Vandalism | 0 | – |
| Total | 100 | 100 |

SOURCE: Trench 2002.

third-party damage. These spills accounted for 100 percent of incidents causing death, 52 percent of incidents involving an injury, 28 percent of incidents involving fire or explosion, 35 percent of incidents affecting public safety, 56 percent of all volumes released from onshore pipelines, and 54 percent of the largest 2 percent of spills (more than 5,575 barrels). For 75 percent of liquids pipeline incidents caused by third-party damage, the failure occurred at the time of the incident. The failure was due to a prior incident in 17 percent of the cases, and the failure was due to "other" damage (e.g., vehicle accident) in 8 percent of the cases. A breakdown of liquids pipeline incidents involving failure at the time of the incident is presented in Table B-7. Finally, the primary cause of third-party damage reported by the operator was failure to use one-call.

Kiefner and Trench (2001) examined oil pipeline characteristics and risk factors for pipelines constructed from before the 1930s to the present. Twenty-three percent of existing liquids pipelines (measured in terms of mileage) were constructed in the 1960s, only 2 percent before 1930, 7 percent in the 1940s, and another 7 percent in the 1990s. For the pre-1930s pipelines, the incident rates were more than four times higher than for all pipelines combined, whereas for all periods thereafter, the incident rates were approximately equal to the representation (i.e., average) rate. There has been a small downward trend in incident rates for pipelines constructed in the 1930s and more recent periods (see Table B-8). In addition, the greatest percentage (more than 4.0 percent) of third-party damage occurs to pre-1930s liquids pipelines. The smallest percentage of third-party damage (0.3 percent) affects pipelines constructed in the

**TABLE B-7 Liquids Pipeline Incidents Involving Failure at Time of Incident**

| | Incidents | | Barrels Released | |
|---|---|---|---|---|
| | Number | Percentage | Total | Percentage |
| Landowner (subtotal) | 25 | 37 | 37,711 | 44 |
| Landowner—farming | 19 | 28 | 18,717 | 22 |
| Landowner—homeowner | 6 | 9 | 18,994 | 22 |
| One-call partners | 18 | 26 | 19,008 | 22 |
| Additional industrial/commercial activity | 17 | 25 | 24,312 | 28 |
| Road construction/maintenance | 9 | 13 | 5,534 | 6 |
| Total | 69 | 100 | 86,565 | 100 |

**TABLE B-8** Pipeline Mileage and Incidents for Liquids Pipelines Constructed Each Decade from the Pre-1930s to the Present

| Decade of Pipeline Construction | Percentage of Existing Pipelines (in miles) | Percentage of All Reportable Incidents[a] | Percentage of Reportable Incidents due to Third-Party Damage[a] |
|---|---|---|---|
| Pre-1930s | 2 | > 4 | 4.0 |
| 1930s | 7 | 1.2 | 1.0 |
| 1940s | 13 | 1.1 | 1.5 |
| 1950s | 22 | 0.9 | 1.0 |
| 1960s | 23 | 1.0 | 1.0 |
| 1970s | 17 | 0.7 | 0.7 |
| 1980s | 9 | 0.8 | 0.6 |
| 1990s | 7 | 0.5 | 0.3 |
| 2000+ | < 1 | Incomplete | Incomplete |

[a] Data are the percentage of all reportable incidents divided by the percentage of existing mileage. 1.0 indicates that the incident data are directly proportional to the amount of pipeline in that age category.

1990s (see Table B-8). In comparison with past years, recent experience with third-party damage includes the following: steel is now less brittle, encroachments are more frequent, farming techniques are more invasive, and depth of cover is greater. Thus, pre-1930s transmission pipelines have a higher likelihood of problems, whereas the difference from one decade to the next since then is not very significant.

According to FERC (2003), older natural gas pipelines (i.e., those installed in 1950 or earlier) exhibit a significantly higher rate of incidents compared with those installed since 1950. This may be partially due to a higher frequency of corrosion, which is a time-dependent process. However, since July 1971 pipelines have been required to have external protective coatings and cathodic protection to reduce corrosion potential.

The changes in the reporting forms, which have been adopted recently, should enable OPS and others to better understand the causes of incidents so that efforts to improve pipeline safety will be more likely to reduce the number and severity of incidents and failures. In addition, a comprehensive, detailed, viable database on pipeline incidents and an inventory of the pipeline infrastructure can be used to establish quantifiable performance measures by which the effectiveness of the integrity management and other risk management programs may be evaluated (GAO 2002).

## REFERENCES

***Abbreviations***

| | |
|---|---|
| FERC | Federal Energy Regulatory Commission |
| GAO | General Accounting Office |
| NTSB | National Transportation Safety Board |
| OPS | Office of Pipeline Safety |

FERC. 2003. *Grasslands Pipeline Project.* Final Environmental Impact Statement. FERC/EIS-0154F. Washington, D.C.

GAO. 2000. *Pipeline Safety: The Office of Pipeline Safety Is Changing How It Oversees the Pipeline Industry.* GAO/RCED-00-128. Washington, D.C.

GAO. 2002. Status of Improving Oversight of the Pipeline Industry. Testimony before the Subcommittee on Energy and Air Quality, Committee on Energy and Commerce, House of Representatives. GAO-02-517T. Washington, D.C., March 19.

Kiefner, J. F., and C. J. Trench. 2001. *Oil Pipeline Characteristics and Risk Factors: Illustrations from the Decade of Construction.* Report prepared for API. Washington, D.C.

NTSB. 2002. *Safety Report: Transportation Safety Databases.* NTSB/SR-02/02. Washington, D.C.

NTSB. 2003. National Transportation Safety Board 2001–2002 U.S. Transportation Fatalities. Washington, D.C., Oct. 2. www.ntsb.gov/Pressrel/2003/trans_fatalities_2001-2002.htm.

OPS. 2003. *Hazardous Liquid Pipeline Operators Accident Summary Statistics by Year, 1/1/1986–6/30/2003.* Washington, D.C., Sept. 17. ops.dot.gov/stats/lq_sum.htm.

Trench, C. J. 1999. *The U.S. Oil Pipeline Industry's Safety Performance.* Allegro Energy Group, New York, May.

Trench, C. J. 2002. *The U.S. Oil Pipeline Industry's Safety Performance.* Allegro Energy Group, New York, March.

Trench, C. J., and B. J. Selig. 2003. *The Safety Performance of Natural Gas Transmission and Gathering Systems.* Allegro Energy Group, New York, April.

APPENDIX C

# Overview of the Transmission Pipeline Industry and Its Regulation

Pipelines to transport crude oil were constructed as early as 1874. The network of crude transmission pipelines grew during the first half of the 20th century as crude was discovered and produced throughout the United States, especially in Texas, Louisiana, and Oklahoma. During World War II, the first large transmission pipelines for refined products were constructed, primarily from the Gulf Coast to the Mid-Atlantic states. Construction was motivated by the vulnerability of coastal tankers to German U-boats. Growth of the products pipeline network was aided by development of methods to segregate and move multiple petroleum products in sequential batches. According to 2001 estimates, pipelines now transport 66 percent of the petroleum consumed in the United States, while waterborne vessels transport 28 percent, trucks 4 percent, and rail 2 percent (Rabinow 2004).

The long-distance transport of natural gas was more difficult and was not technologically possible until 1925. Thus its commercial use did not develop as rapidly as did that of refined petroleum. Major expansion of the natural gas transmission pipeline system began after World War II when large crude oil trunk lines were converted for natural gas (Congressional Research Service 1986), and pipelines now transport nearly all of the nation's natural gas.

This appendix provides a description of the economic structure and regulation of the natural gas and liquids pipeline industry, including an overview of the size and diversity of the industry, the way in which tariffs are set, and financial incentives. Many agencies have a role in pipeline regulation, and various new safety-related programs and regulations have been or are in the process of being implemented. The programs, however, stop short of managing land use to increase safety because the national agencies do not have regulatory authority in these areas. The roles these various agencies, as well as state and local jurisdictions, have in pipeline regulation are described. The reader is referred to Chapter 2 for an overview of approaches that state and local governments have taken to address land use near pipelines.

## ECONOMIC STRUCTURE AND REGULATION

### Hazardous Liquids Pipeline Industry

#### *Structure of the Industry*

The structure of the pipeline industry is diverse and reflects the various needs for transporting natural gas and liquids. Liquids pipelines may be independent entities or may be owned, in whole or in part, by integrated energy companies, by other companies in or out of the energy industry, and by investors. In many instances, they are owned jointly by a combination of entities. A particular pipeline may be organized as a stock corporation, a partnership, a particular form of partnership known as a master limited partnership, or as a limited liability company. Furthermore, the owner may not be the operator of a pipeline. While it is most common for an owner or one of the owners, in the case of a joint venture, to act as the operator, in some instances an independent third party operates the line on behalf of the owners. The way in which a pipeline is owned and structured is a function of many factors, including the purpose of the pipeline, the complexity of the task, historical considerations, legislative and regulatory constraints, the ability to raise capital, and the necessity to manage a wide variety of risks.

The way a liquids pipeline company is structured must take into consideration the purpose of the system. In its simplest form, a pipeline may move a single material from one source to one destination over a distance that may be less than 1 mile or more than 1,000 miles, it might operate in a single state or cross numerous state boundaries, or it might be located in federal waters and not in any state. Examples include pipelines carrying crude oil from one production platform to another in the Gulf of Mexico, crude oil from one marine terminal to one refinery, jet fuel from one refinery or terminal to one airport, fuel oil from one terminal to one power plant, and petrochemicals from one plant to another. Beyond those simplest forms, the complexity can become considerable. There can be many sources and a single destination (such as crude gathering), a single source and many destinations (such as a products line serving a single refinery and a number of end markets), and networks that include many sources and many destinations. Whatever the physical layout of the pipeline, it may carry a single product or many discrete products and grades, and it may carry material for one or for many shippers.

Although natural gas and hazardous liquids transmission pipelines have similar construction and safety standards, pipeline parameters vary considerably. Hazardous liquids transmission pipelines span approximately 200,000 miles and range from a few inches up to 48 inches in diameter. Interstate oil pipeline systems, operated by 220 companies, account for about 80 percent of total liquids pipeline mileage and volume transported (Trench 2001). Liquids pipelines in the United States deliver more than 600 billion gallons (or 14 billion barrels) of petroleum each year (Trench 2001).[1] Many volumes are shipped more than once (e.g., as crude oil and then again as refined product), so these pipelines transport more than twice the U.S. consumption of oil (Trench 2001, 2). Liquids that are transported by pipeline fall into three broad categories: (*a*) crude oil and refined petroleum products such as gasoline, diesel and jet fuel, and home heating oil; (*b*) toxic materials, usually chemicals such as benzene, toluene, xylene, and butadiene; and (*c*) highly volatile liquids (e.g., butane, ethane), which are gases at atmospheric temperature and pressure but liquids at the operating pressures in pipelines.

More complete descriptions of the liquids pipeline industry are given by Rabinow (2004) and Kennedy (1993).

### *Economic Regulation*

With few exceptions, liquids pipelines are common carriers, and the rates charged and the terms and conditions of the services are regulated by the Federal Energy Regulatory Commission (FERC) for interstate lines and similar state agencies for intrastate lines. The Office of Pipeline Safety (OPS) provides most operational oversight, although other federal agencies, such as the Environmental Protection Agency (EPA) and the

[1] There are 42 gallons in a barrel.

Minerals Management Service (MMS), play important roles. State agencies regulate intrastate lines, and local jurisdictions become involved in a variety of matters, including siting and emergency response in the event of an incident.

The economic (i.e., rate) regulation of liquids pipelines has evolved over a long period. For the past decade, pipeline rates have been set on the basis of one of four approved methodologies. The most common method has been to adjust historical cost-based rates according to a FERC-set index that uses an inflation factor to establish a ceiling for any rate. Alternatively, pipeline companies may (*a*) negotiate rates if all shippers using the service concur, (*b*) use the market-clearing price if FERC has found that the pipeline lacks market power in the affected origin and destination markets, or (*c*) apply for traditional cost-of-service treatment. Shippers may also request a cost-of-service review of rates. Under the rules of common carriage applicable to most pipelines, the same rate must be charged to all similarly situated shippers. Of the various available methods, the least used since the inception of indexation has been traditional cost-of-service rate making. However, as pipeline assets change hands, more rates are being challenged, which leads to more cost-of-service reviews being conducted by FERC. Pipeline companies do not have pricing freedom to recoup costs imposed on them by local governments. The companies have to work through state and federal regulators to recover their costs.

Interstate rate making applies to about 80 percent of U.S. oil pipeline mileage and volumes transported. Intrastate movements may be regulated by the respective states (often by a public utility commission, but sometimes with a different name, such as the Railroad Commission in Texas and the Regulatory Commission of Alaska), and most state statutes provide for generally similar approaches to economic regulation. An issue that sometimes arises involves decisions as to whether a pipeline is in interstate or intrastate service, because this is not always clear.

In addition to interstate and intrastate issues, there can be some local economic regulatory issues, an example of which is franchise fees. In most cities, utilities that have easements under the streets to distribute water, telecommunications, electricity, and natural gas to consumers pay franchise fees to the city for the right to use those easements. Normally the fees are paid annually and can be substantial, perhaps a percentage of the value of the service being distributed. With few exceptions, liquids pipelines do not use city streets as rights-of-way, although there may be numerous crossings of streets, especially as urban sprawl increases. In most places, liquids pipeline companies pay a fee that bears some relationship to the costs incurred by the city to grant an initial permit and then to administer it. However, in recent years, some cities have tried to impose franchise fees. Litigation has ensued, and for the most part the liquids pipeline companies have prevailed in opposing such fees. The situation in California is different in that a system of franchise fees imposed on oil pipelines has been in place for many years.

***Incentives***

Pipeline company revenues and profitability are closely tied to the volumes transported; the costs to operate, maintain, and upgrade existing lines; and the costs to build new lines. In today's competitive transportation market, shippers (even in integrated energy companies) apply considerable pressure on the pipeline companies to keep their tariffs low. Shippers back up their demands by using other transportation options and by challenging tariffs. The result is that pipeline companies are driven to maximize efficiencies in the short term. A continuous trade-off is made between short-term profits and investment to meet a variety of needs, some arising from shippers, others from legislative and regulatory requirements, and still others from public demands (Rabinow 2004). Regardless of the methodology used to establish the tariffs, the cost of transportation represents only a small portion of the total cost of petroleum to a consumer. For example, the cost to move a gallon of gasoline from Houston to New Jersey is about 3 cents (Trench 2001).

The distribution of expenses associated with capital projects is largely influenced by the cost of the pipe and equipment and the cost of constructing the facilities. During the 1990s the single largest capital cost category was pipeline construction (35 percent), followed by the cost of line pipe (20 percent), other station equipment (12 percent), oil tanks (5 percent), pumping equipment (4 percent), and line pipe fittings (3 percent). The category "all other" accounted for the remaining 21 percent and was made up of a large number of smaller categories (Rabinow 2004).

Unlike the postwar period of the 1950s through the 1970s, when some 62 percent of the presently existing pipeline infrastructure was put in place, the 1980s and 1990s saw relatively small additions—9 and

7 percent, respectively. The reasons included the decline of inland crude production, which made considerable pipeline mileage available for other purposes; the ability to reduce bottlenecks in existing capacity; and the limited growth of refining capacity. Today factors are emerging that may alter the situation and increase the industry's need to invest. These include a growing, shifting population, especially in some areas of the country; the limited remaining ability to achieve incremental capacity growth by redeploying existing infrastructure; and the capital-intensive development of new regions, whether to gather and transport large crude reserves in very deep water (5,000 to 10,000 feet) in the Gulf of Mexico or to build large-diameter pipelines in congested, urban areas. Other factors concern the maintenance of older pipelines and the need to replace some portion of those systems, as well as the need to respond to the heightened public expectations of the industry that are reflected in legislative and regulatory requirements, including the development and implementation of expensive, cutting-edge technology (Rabinow 2004).

## Natural Gas Pipeline Industry

### *Structure of the Industry*

Natural gas is transported in about 180,000 miles of transmission lines ranging from 20 to 42 inches in diameter. These pipelines are designed to operate at high pressures that generally range from 500 to 1,000 pounds per square inch. Natural gas transmission pipelines are primarily interstate, larger-diameter pipes constructed of carbon steel, engineered and constructed to meet standards established by the American Petroleum Institute and adopted by the U.S. Department of Transportation (USDOT). Most of the natural gas transmission network is owned and operated by large interstate pipeline companies. Natural gas transmission pipeline systems are operated by about 785 companies, which transport most of the 23 trillion cubic feet of natural gas that is currently consumed annually in the United States (EIA 2004).

If a relatively small quantity of natural gas leaks from a crack, flaw, or damaged section of the pipeline, a serious incident may not result if repairs are made in a timely manner. However, if a natural gas transmission line fails catastrophically, there is usually an initial explosion that can injure or kill people in the vicinity and cause extensive property damage. The escaping product continues to burn until the supply is shut off. Because the product is lighter than air, it rises and tends to dissipate quickly, usually posing few environmental risks. In contrast, many of the liquid hydrocarbons transported by transmission pipelines are heavier than air. When a pipeline containing such liquid ruptures, the hazardous liquid often flows along the ground and can enter streams and rivers, contaminating public water supplies and killing fish and other wildlife.

A more complete description of the natural gas pipeline industry is given by Kennedy (1993).

### *Economic Regulation*

Under the Natural Gas Act of 1938, the Federal Power Commission (now known as FERC) regulates the construction of new natural gas pipelines and related facilities and oversees the rates, terms, and conditions of sales for resale and transportation of natural gas in interstate commerce. Traditionally, FERC determined the rates transmission companies could charge purchasers, governed the financial structure of the companies (including profit ranges), and regulated other aspects of pipeline operation. The traditional method of setting natural gas rates was cost-of-service rate regulation, but this approach provided few incentives for regulated companies to lower costs, provide better service, or remove barriers to open commodity trading (FERC 2003a).

According to Kennedy (1993, 308), "Gas price regulation is considered by most energy analysts to have had a negative influence on the search for new gas supplies because the price was held below that needed to make exploration and development profitable." One of the purposes of the Natural Gas Policy Act of 1978 was to provide more incentives for producers to search for new reserves. The act also created several categories of natural gas—some of which were still to be regulated, some to be deregulated in 1985, and still others to be immediately deregulated. The deregulation of natural gas wellhead prices in 1989 resulted in complete deregulation.

The natural gas industry developed a rate-setting approach using indices created and published by the trade press. This practice followed the more established practice in oil markets. Soon thereafter, certain orders and tariffs proposed by natural gas companies and approved by FERC contained references to these price indices. According to FERC, many negotiated rate transportation contracts establish transportation rates using the basis differentials between two or more price index trading points (FERC 2003b).

Restructuring of the natural gas industry has resulted in a change in contracting as well. During the 1980s, pipeline companies and their customers were burdened with costs resulting from take-or-pay[2] provisions in gas procurement contracts that were put in place prior to the new approach to regulation. A producer sold natural gas under a long-term contract, usually lasting 20 years or more, to a pipeline company.

> The contract required the pipeline company to purchase the gas at a specified rate, or "take." Even if the pipeline company did not accept delivery of that amount of natural gas from the producer, the pipeline company had to pay the producer for the agreed amount. The producer insisted on a take-or-pay provision because it ensured a constant market for the gas. . . . Under most contracts, the pipeline company could recover the gas paid for, but not taken, by taking more than the contract volume over a specified period. (Kennedy 1993, 309)

As a result of regulatory changes in the 1980s, the effects of take-or-pay provisions were significantly reduced.

Under FERC Order 636, which went into effect November 1, 1993, interstate pipeline companies were required to unbundle or separate the sales and transportation services of natural gas. Consequently, the way in which rates were determined for transportation services was revised. While Order 636 resulted in reduced pipeline revenues (although not necessarily profitability), the new method of setting rates allowed pipeline companies to collect most of their costs in fixed demand charges, which reduced the risk of recovering these costs.

> These measures, among others, fostered competition in the natural gas commodity market, paved the way for the gradual introduction of competition into the retail purchase of natural gas, and permitted the creation of new transportation and marketing services that have improved the efficiency of the overall natural gas transportation process. Consequently, the

[2] "Take-or-pay provisions require the pipeline companies to pay for specified gas quantities (typically a percentage of well deliverability) even if the gas is not delivered" (EIA 1998).

> interstate pipeline segment of the natural gas industry in the United States has instituted a number of major changes in its operational and business practices over the past decade. In particular, the pipeline industry has significantly changed the transaction processes and mechanisms for transportation services. (Johnson et al. 1999, 1)

While rates are not regulated directly, FERC reviews the filed tariffs of pipeline companies to ensure that they are just and reasonable and nondiscriminating. In instances where a pipeline system has no competition, FERC may set rates by using a traditional public utility accounting regulatory format (Kumins 2001).

### *Incentives*

Since deregulation, incentives in the natural gas pipeline industry are comparable with those in the hazardous liquids pipeline industry. Because of Order 636, in the late 1980s and early 1990s interstate natural gas pipeline companies went from being sellers to primarily transporters of natural gas. Revenues fell dramatically as pipeline services no longer included revenues from the sale of natural gas, but only transportation revenues.

New transmission lines are continuing to be built to meet projected demand. Pipeline construction data indicate that material accounts for 37 percent, labor for 39 percent, right-of-way and damages for 4 percent, and miscellaneous costs for 20 percent of total construction costs. Miscellaneous expenses include engineering, supervision, administration and overhead, interest, contingencies, and filing fees (Kennedy 1993). In 1990, data indicated that natural gas pipeline construction cost ranged from about $200,000 per mile for an 8-inch-diameter pipeline to $1.2 million per mile for a 42-inch-diameter pipeline.

## PIPELINE REGULATORY ENVIRONMENT

Jurisdiction over pipeline safety is distributed among government agencies at the federal, state, and local levels. Federal agencies (USDOT and MMS) regulate interstate natural gas and liquids pipelines; state agencies may assume responsibility for enforcing intrastate pipeline regulations and may inspect interstate pipelines, legislate damage prevention laws, legislate land use controls, and sponsor emergency preparedness planning and training. Local (i.e., city, county, town, and village) governments may impose land use controls, contribute to damage prevention through construction permits, and develop emergency preparedness plans (TRB 1988).

## Office of Pipeline Safety

The distribution of pipeline regulatory responsibility has evolved since the enactment of the Natural Gas Pipeline Safety Act of 1968, which was the first legislation to require OPS to establish minimum federal safety standards for interstate natural gas transmission and distribution pipelines. The interstate commerce clause was broadly interpreted in this act so that federal regulations extended to intrastate as well as interstate natural gas pipelines. Section 5(a) of the Natural Gas Pipeline Safety Act provides for a state agency to assume all aspects of the safety program for intrastate facilities by adopting and enforcing the federal standards, while Section 5(b) permits a state agency that does not qualify under Section 5(a) to perform certain inspection and monitoring functions. The majority of the states have either 5(a) certifications or 5(b) agreements, while nine states act as interstate agents (FERC 2003c).

A cost-reimbursement formula is used that enables states to recover up to 50 percent of their costs from the federal government. As of 1999, 49 states were certified to implement the intrastate natural gas program, 9 states served as agents to administer the interstate natural gas program, 4 states were permitted to inspect intrastate natural gas or liquids facilities but had no enforcement authority, 12 states were certified to implement the intrastate liquids program, and 4 states served as agents to administer the interstate liquids program (Pates 2000). However, OPS is now in the process of phasing out the interstate agent program because it believes that additional congressional appropriations for OPS preclude the need for interstate agents.

Although federal safety regulations for liquids pipelines were promulgated in 1967, many of the regulations were general in nature and limited to interstate pipelines (TRB 1988). The Federal Railroad Administration of USDOT had regulatory authority for liquids pipeline safety until this authority was transferred to OPS of USDOT in 1972 (Congressional Research Service 1986, 118).

The Hazardous Liquid Pipeline Safety Act of 1979 allows for shared governmental responsibility for pipeline safety. Although regulation of the design, construction, maintenance, and operation of natural gas and hazardous liquids pipelines is primarily a federal responsibility, a federal–state partnership is encouraged in which the federal government sets and enforces national safety standards for interstate pipelines but states may perform day-to-day inspection and administrative duties. A state can be certified by OPS to assume jurisdiction over interstate liquids pipelines if it has adopted federal standards and does not impose more stringent standards (except for siting new pipelines) that are incompatible with federal standards (Pates 2000).

OPS is currently mandated to develop safety regulations and other approaches to ensure the safe transportation of natural gas and other hazardous materials by pipeline. OPS carries out this directive by regulating the design, construction, testing, operations, maintenance, and emergency response of pipeline facilities. Many of the regulations are written as performance standards, which set the minimum level of safety and allow the pipeline operator to use various technologies to achieve it.

In addition to regulating pipeline safety, OPS is tasked to ensure that people and the environment are protected from the risk of pipeline incidents. Thus, OPS's responsibilities include improving and expanding regulations, assessing risks, mandating the repair of defects in a timely manner, communicating information, developing performance measures, providing assistance to local communities, supporting state partners, and promoting damage prevention and the advancement of technology.

Traditionally, OPS has carried out its oversight responsibility by requiring all pipeline operators to comply with uniform minimum standards. Because pipeline operators face different risks depending on such factors as location and product being transported in the pipeline, OPS began exploring the concept of a risk-based approach to pipeline safety in the mid-1990s. The Accountable Pipeline Safety and Partnership Act of 1996 directed OPS to establish a demonstration program to test a risk management approach to pipeline safety, which involved identifying and addressing specific risks faced by individual pipeline operators rather than applying uniform standards regardless of the risks. This "act, together with a presidential memorandum to the Secretary of Transportation, requires OPS to evaluate . . . whether a risk management approach to pipeline safety can achieve a level of safety and environmental protection that is greater than the level achievable through compliance with the current pipeline safety regulations" (GAO 2000, 17). The Risk Management Demonstration Program allowed individual companies to identify and focus on risks unique to their pipelines. Since the program's initiation in 1997, OPS has approved six demonstration programs.

OPS has moved forward with the Integrity Management Program. The program for hazardous liquids pipelines allows pipeline operators flexibility to design and implement the program on the basis of pipeline-specific conditions and risks. By December 31, 2001, operators of long-distance hazardous liquids pipelines (i.e., pipeline systems of at least 500 miles) were required to have identified pipeline segments that can affect high-consequence areas. By March 31, 2002, they were required to have developed a framework for their company's integrity management program and a plan for conducting baseline assessments. Similar rules were issued for operators of small hazardous liquids pipelines (i.e., those less than 500 miles long) with later deadlines. For hazardous liquids pipelines, a high-consequence area is defined as a populated area, an area unusually sensitive to environmental damage, or a commercially navigable waterway.

The final rule for integrity management of natural gas transmission pipelines in high-consequence areas [published on December 15, 2003 (68 *Federal Register* 69778)] went into effect in February 2004. This rule requires operators of natural gas transmission pipelines to develop integrity management programs for pipelines located where a leak or rupture could do the most harm (i.e., could affect high-consequence areas). The rule requires gas transmission pipeline operators to perform ongoing assessments of pipeline integrity; to improve data collection, integration, and analysis; to repair and remediate the pipeline as necessary; and to implement preventive and mitigative actions. For natural gas transmission pipelines, OPS is developing a definition that focuses on populated areas (GAO 2002; Cycla Corporation 2004). The definition of a high-consequence area may require additional protection for people with limited mobility such as inhabitants of day care centers, old age homes, and prisons (C-FER Technologies 2000).

## Federal Energy Regulatory Commission

Although federal regulations promulgated by OPS deal with pipeline safety issues, they do not address such issues as pipeline siting and financing. These issues are often a matter of negotiation between pipeline companies, landowners, and local government zoning boards. FERC is responsible for authorizing the construction and operation of interstate natural gas pipelines and issues certificates of public convenience and necessity for such pipelines. It is also responsible for addressing issues concerning environmental impacts of interstate natural gas pipelines, which often affect siting and routing, financing, and tariffs.

For natural gas transmission lines, FERC's Office of Energy Projects addresses landowner and environmental concerns by encouraging collaboration among parties, addressing stakeholder concerns before the certification process, incorporating environmental conditions into certificates, and ensuring compliance with conditions. However, USDOT and FERC signed a Memorandum of Understanding on Natural Gas Transportation Facilities, dated January 15, 1993, giving USDOT exclusive authority to promulgate federal safety standards used in the transportation of natural gas. An applicant must certify that it will design, install, inspect, test, construct, operate, replace, maintain, and inspect the facility for which a certificate is requested in accordance with federal safety standards [Section 157.14(a)(9)(vi) of FERC's regulations] unless it has been granted a waiver of the USDOT requirements in accordance with Section 3(e) of the Natural Gas Pipeline Safety Act. FERC accepts this certification and does not impose additional safety standards (FERC 2003c, 3.12-2).

When a natural gas pipeline company is planning to build an interstate pipeline, a notice of intent to prepare an environmental assessment or an environmental impact statement (EIS) is prepared and sent to federal, state, and local agencies; environmental groups; and landowners of the properties that might be affected. The notice requests comments from interested parties, after which FERC prepares an environmental assessment or an EIS outlining its findings and recommendations. An EIS describes the positive and negative effects of the proposed undertaking and cites possible alternative actions. This is followed by another comment period. Comments received are addressed in the final EIS or the final order granting or denying the pipeline a certificate. In the case of liquids pipelines, if there is a need for any major federal permits, the issuing agency would serve a role similar to that of FERC for natural gas projects.

## Other Federal Agencies

### *U.S. Environmental Protection Agency*

EPA, whose mission is to protect human health and to safeguard the natural environment (air, water, and land), develops and enforces regulations (i.e., sets national standards and issues sanctions and takes other actions when the standards are not met). When FERC is required to prepare an EIS for a proposed pipeline, EPA reviews and responds to the filed impact statement.

EPA is a regulatory agency. As such, it enforces many regulations that affect the transport of natural gas and liquids via pipelines. For example, under the Clean Water Act (33 U.S.C. § 1251) as amended by the Oil Pollution Act of 1990 (33 U.S.C. § 2701), EPA can seek injunctions and civil penalties against oil pipeline companies for discharge of oil into navigable waters of the United States and adjoining shorelines.

### *Bureau of Land Management*

The Bureau of Land Management within the Department of the Interior is responsible for the management of public lands and is principally responsible for issuing right-of-way permits authorizing pipelines to cross federal lands (FERC 2002).

### *Bureau of Reclamation*

The Bureau of Reclamation within the Department of the Interior is responsible for managing, developing, and protecting water and related resources in an environmentally and economically sound manner. It may grant rights-of-way for pipelines (FERC 2002).

### *Bureau of Indian Affairs*

The Bureau of Indian Affairs within the Department of the Interior is responsible for approving rights-of-way for pipelines across lands held in trust for an Indian or an Indian tribe (FERC 2002).

### *Fish and Wildlife Service*

The Fish and Wildlife Service within the Department of the Interior is responsible for the conservation, protection, and enhancement of fish, wildlife, plants, and their habitats. Applicants for pipeline construction projects are required to consult with the Fish and Wildlife Service on projects that could affect any of these resources. The Fish and Wildlife Service may also authorize use by permit for areas within the National Wildlife Refuge System (FERC 2002).

### *National Transportation Safety Board*

The National Transportation Safety Board (NTSB) investigates significant accidents in all transportation modes, including pipelines, and issues safety recommendations aimed at preventing future accidents. NTSB attempts to determine the probable cause of pipeline accidents involving a fatality or substantial property damage or releases of hazardous materials, as well as selected transportation accidents that involve recurring problems. NTSB identifies major safety issues that are provided to the Research and Special Programs Administration's OPS as action items, but NTSB does not regulate equipment, personnel, or operations, and it does not initiate enforcement action.

## REFERENCES

*Abbreviations*

| | |
|---|---|
| EIA | Energy Information Administration |
| FERC | Federal Energy Regulatory Commission |
| GAO | General Accounting Office |
| TRB | Transportation Research Board |

C-FER Technologies. 2000. *A Model for Sizing High Consequence Areas Associated with Natural Gas Pipelines.* Report 99068. Gas Research Institute, Edmonton, Alberta, Canada.

Congressional Research Service. 1986. *Pipeline Safety—The Rise of the Federal Role.* Committee Print 99-Y. 99th Congress, 2d Session, March.

Cycla Corporation. 2004. ops.cycla.com/pipelineInfo/glossary.htm.

EIA. 1998. Natural Gas 1998 Issues and Trends. www.eia.doe.gov/pub/oil_gas/natural_gas/analysis_publications/natural_gas_1998_issues_trends/pdf/chapter1.pdf. Washington, D.C.

EIA. 2004. www.eia.doe.gov/neic/quickfacts/quickgas.htm. Washington, D.C.

FERC. 2002. *Interagency Agreement on Early Coordination of Required Environmental and Historic Preservation Reviews Conducted in Conjunction with the Issuance of Authorizations to Construct and Operate Interstate Natural Gas Pipelines Certificated by the Federal Energy Regulatory Commission.* Washington, D.C., May.

FERC. 2003a. Detailed Strategic Plan. www.ferc.gov/about/strat-docs/09-29-03-detail-strategic-plan.pdf.

FERC 2003b. Discussion on Commission Use of Natural Gas Price Indices. www.ferc.gov/legal/ferc-regs/land-docs/Harvey-01-15-03-CommissionPresentation-A-5.pdf.

FERC. 2003c. *Grasslands Pipeline Project.* Final Environmental Impact Statement. FERC/EIS-0154F. Washington, D.C.

GAO. 2000. *Pipeline Safety: The Office of Pipeline Safety Is Changing How It Oversees the Pipeline Industry.* GAO/RCED-00-128. Washington, D.C., May.

GAO. 2002. Status of Improving Oversight of the Pipeline Industry. Testimony before the Subcommittee on Energy and Air Quality, Committee on Energy and Commerce, House of Representatives. GAO-02-517T. Washington, D.C., March 19.

Johnson, S., J. Rasmussen, and J. Tobin. 1999. Corporate Realignments and Investments in the Interstate Natural Gas Transmission System. *Natural Gas Monthly,* Oct. www.eia.doe.gov/emeu/finance/sptopics/ng_realign&invest/.

Kennedy, J. L. 1993. *Oil and Gas Pipeline Fundamentals.* Penn Well Books, Okla.

Kumins, L. 2001. *Natural Gas Prices: Overview of Market Factors and Policy Options.* RL30815. Congressional Research Service, Washington, D.C.

Pates, J. M. 2000. Testimony on behalf of the National Pipeline Reform Coalition before the U.S. Senate Committee on Commerce, Science, and Transportation. May 11.

Rabinow, R. 2004. *The Liquid Pipeline Industry in the United States: Where It's Been, Where It's Going.* Association of Oil Pipe Lines, Washington, D.C., April.

TRB. 1988. *Special Report 219: Pipelines and Public Safety: Damage Prevention, Land Use, and Emergency Preparedness.* National Research Council, Washington, D.C.

Trench, C. J. 2001. *How Pipelines Make the Oil Market Work—Their Networks, Operation and Regulation.* Allegro Energy Group, New York, Dec.

APPENDIX D

# Risk Assessment Techniques in the Pipeline Industry

During the past two decades, emphasis on pipeline safety has shifted from response to prevention of accidents. Preventive actions have included greater levels of inspection, involvement of the public through communications, and prospective analysis of the dangers presented by pipelines. Pipeline companies also began to use various risk assessment techniques, including hazard and operability (HAZOP) analysis, fault tree analysis, scenario-based analysis, and indexing methods. Most analyses focus on specific factors affecting the probability of pipeline failure (e.g., internal corrosion, external corrosion, pipeline loading) or on the consequences of rupture (such as heat intensity, thermal impact radius, depth of cover). Some of these analyses focus on specific pipeline system components, while a few attempt to take component interdependencies into account. Some of the more commonly used techniques are described below.

The pipeline risk assessment and management approaches that have been published to date, regardless of the methodology used to obtain the probabilities and consequences of processes and events leading to risk, emphasize the calculation of a risk number (i.e., a mathematical product of probability and consequence). Although this calculation allows a quantitative comparison of the effect of different factors on pipeline safety, it is not adequate to define risk to the public. As outlined in Chapter 3, such a risk is better characterized in terms of the three questions posed (known in risk assessment as the risk triplet).

Recently, the U.S. Department of Transportation's Office of Pipeline Safety (OPS) implemented a new regulatory approach—the Integrity Management Program—that establishes new testing, repair, and mitigation requirements for transmission pipelines and requires pipeline companies to use a risk-based approach for pipeline safety. Under the program, liquid and natural gas pipeline operators, as a first step, will be required to perform risk assessments on each of their pipeline segments in high-consequence areas. Inspections will be performed by the use of in-line inspection tools, analysis of operating and maintenance records, and direct examination of pipe in selected areas. Risk criteria have been considered in other countries, including societal risk due to land use near pipelines (IGE 2001; Committee for the Prevention of Disasters 1999).

## CURRENT APPROACH TO RISK ASSESSMENT IN THE PIPELINE INDUSTRY

Risk assessment is the process of identifying, describing, and analyzing risk with the following elements:

- Recognition or *identification* of a hazard or potential adverse event, perhaps with definition of accident scenarios in which the hazards are realized or experienced;
- Analysis of the *mechanisms* by which an event can occur and the mechanisms by which the event can create loss;
- Analysis of the *consequences* of an adverse event as a function of various factors of design or circumstance; and
- Estimation of the *likelihood* of the sequences of events that lead to the consequences.

According to Muhlbauer (1999), because the risk of pipeline failure is sensitive to unmeasurable or unknowable initial conditions, risk efforts are often not attempts to predict how many failures will occur or where the next failure will occur. Instead, efforts are designed to systematically and objectively capture everything that is known and use the information to make better decisions.

Risk assessments can guide pipeline operators to make decisions and take precautions that allow the risks to be minimized or avoided entirely. *Risk management* is a systematic focusing of limited resources on those activities and conditions with the greatest potential for reducing risk. In risk management, decision makers take the results from risk assessments and use them to prioritize risk reduction actions. Risk controls can involve measures both to prevent adverse events and to mitigate their magnitude. One reduces the likelihood; the other reduces the severity of impact. Another step in risk management is the monitoring of performance to determine whether risk control measures are effective. The process can be repeated to further address and reduce overall risk.

The first step in defining risk is to identify a potential hazard or dangerous situation and describe the mechanisms by which the hazard can cause harm to people, property, and the environment. Risk is then analyzed for *each* hazard or hazard scenario. In terms that can be analyzed, risk is defined as the product of (*a*) severity of impact and (*b*) the likelihood of impact from an adverse event. The severity of impact, often called consequences, can be expressed in human terms such as fatalities or injuries or some other metric such as dollars lost. The likelihood of occurrence of an adverse event can be estimated with a variety of methods, ranging from prior experience with the frequency of occurrence, perhaps using statistical data of similar events, to computations based on mathematical models. Likelihood can also be determined by examining the probability of the adverse event occurring in a Bayesian sense, a prior perception of probability.

The example of automobile travel can clarify the concepts. The consequences of an automobile crash can be damage to the car and injury or death to the driver or passengers. More than 40,000 Americans are killed in automobile crashes each year, and several hundred thousand more are injured. Fender benders and other minor crashes are even more frequent. From these data, the risk for large automobiles or small, local streets or Interstate highways, fender bender or serious crashes can be quantified. If a person never rides in an automobile, the risk of death, injury, or damage to one's personal property is zero, except as a nonmotorist (e.g., pedestrian, bicyclist). By similar reasoning, a person who makes a living traveling in automobiles is more likely to experience harm than a person who rides occasionally, even given the differences in driving skill. The difference in the likelihood of experiencing harm is a concept known as *exposure.* The greater the exposure, the higher the risk.

Data on pipeline incidents are collected and analyzed by OPS for each reportable safety incident. These data provide the number of incidents that result in death, injury, or significant property damage. They also provide the general causes of these incidents, including damage by outside force, corrosion, construction defects, operator error, natural forces such as ground movement, and many other categories. At some level of aggregation, the data can be used to determine, or quantify, the risk from various types and sizes of pipelines. On the basis of this experience, one can begin to identify factors that determine risk.

The principle of exposure can be applied to pipelines as well. For an individual who seldom crosses or comes near a pipeline right-of-way—a person who has little exposure—the risk is minimal, while people who live, work, or congregate near pipelines have greater exposure. Exposure is a function of time near a pipeline and effective distance. Exposure to the potential dangers of a pipeline leak or rupture is the result of proximity to the pipeline, natural or man-made barriers, and the mobility of people near the pipeline. People pursuing activities on or near the pipeline that can cause damage to the pipeline have the greatest exposure.

## SCENARIO-BASED RISK ASSESSMENT

This category of risk assessment includes a number of methods: HAZOP studies, scenario-based fault tree/event tree analysis, and so forth. These techniques are useful for examining specific situations, and often they are used with other techniques.

### HAZOP Technique

In the HAZOP study approach, all possible failure modes are examined, but it is very time-consuming and costly. HAZOP analysis is used in the preliminary safety assessment of new systems or modifications of existing systems. A HAZOP analysis involves a detailed examination of pipeline system components to determine the outcome if a specific component does not function as it is designed to (within its normal parameters). Each parameter (e.g., pressure or flow rate) is examined to identify potential changes in the system that are based on changes in the component parameter.

### Fault Tree Analysis

In scenario-based fault tree analysis, the sequence of events is traced backwards from a failure. This technique uses most probable or most severe pipeline failure scenarios, and then resulting damage is estimated and mitigation responses and prevention strategies are developed.

Fault tree analysis is a method of risk identification and scenario building in which the outcome of an event is traced backward to all possible causes (Mc$^2$ Management Consulting 2004). It is a probabilistic top-down analysis that is used to assess the likelihood of occurrence of an undesired system-level event (e.g., a release of product, an explosion), and it can be used to quantify the risk associated with resulting safety hazards. Factors or combinations of factors that could cause the event are put in a structured logic diagram (which takes interdependencies in components into account). The network branches from the outcome event to individual factors (e.g., failure of pump, failure of switch, no response from operator) in a treelike structure. [Additional information is given by Mc$^2$ Management Consulting (2004), IsographDirect (2004), and Sandia National Laboratories (2004).]

Fault tree analysis can include such factors as natural disasters, human activity, and other externally induced causes. The method can also be used to establish cost-effective troubleshooting procedures based on the factors that are most likely to cause a failure.

### Other Probabilistic Risk Assessment Techniques

While fault tree analyses are better suited to examine systems in which the failures of components or processes can be described in terms of pass/fail outcomes (a binary description), they are not ideal for systems in which the processes are not discrete and the outcomes cannot be described simply as pass or fail. (Typically, these are natural events.) Other probabilistic risk assessment techniques have been developed that can consider a range of outcomes of individual processes in a scenario.

An example of scenario-based risk assessment models is the PIPESAFE model (Acton et al. 1998).

## INDEX MODELS

Index models use customized algorithms to conduct pipeline risk assessment. There are a variety of index models, including Muhlbauer's

Risk Assessment Methodology, Consequence Modeling (the C-FER method), and the PipeView Risk Model.

## Muhlbauer's Risk Assessment Methodology

Muhlbauer (1996, *x*) believes that "data on pipeline failures are still insufficient to perform a thorough risk assessment using purely statistical concepts" and that an assessment using probabilistic theory is not required because the probabilities used in the assessment are of questionable benefit.

A hazard, according to Muhlbauer, is a characteristic that provides the potential for loss; it cannot be changed. Risk is the probability of an event that causes a loss and the magnitude of that loss, and therefore actions can be taken to affect the risk. Thus, when risk changes, the hazard may remain unchanged. Risk can change continuously; conditions along a pipeline are usually changing, and as they change, the risk also changes.

Risk is defined by answering three questions:

- What can go wrong (every possible failure must be identified)?
- How likely is it to go wrong?
- What are the consequences?

In this technique, numerical values are assigned to conditions on the pipeline system that contribute to risk. The score, which reflects the importance of an item relative to other items, is determined from a combination of statistical failure data and operator experience. As do all techniques, this model has a number of assumptions:

- All hazards are independent and additive.
- The worst-case condition is assigned for the pipeline section.
- All point values are relative, not absolute.
- The relative importance of each item is based on expert judgment; it is subjective.
- Only risks to the public are considered, not risks to pipeline operators or contractors.

In Muhlbauer's basic risk assessment model, data gathered from records and operator interviews are used to establish an index for each category of pipeline failure initiator (i.e., what can go wrong and the associated likelihood): (*a*) third-party damage, (*b*) corrosion, (*c*) design, and (*d*) incorrect operations. These four indexes score the probability and importance of all factors that increase or decrease the risk of a pipeline failure. The indexes are summed. The last portion of the assessment addresses the potential hazards, their probabilities of occurring, and their consequences. The consequence factor begins at the point of pipeline failure, called the leak impact factor. The leak impact factor is the sum of the product hazards divided by the dispersion factor.

This basic model can be expanded to include other modules such as the cost of service interruption, distribution systems, offshore pipelines, environment, failure adjustment, leak history adjustment, sabotage, and stress.

## Consequence Model (C-FER Model)

C-FER Technologies developed a model that examines isometric thermal radiation distances to determine a burn radius and a 1 percent fatality radius from a natural gas pipeline break. An assumption of this model is that risk can be expressed as the product of failure probability and failure consequences, and reliability is the complement of failure probability. Probability of failure and consequence calculations are conducted by using two C-FER software programs—PIRAMID, which is used to optimize maintenance and inspection decisions, and PRISM, which is used to conduct pipeline reliability analyses (Zimmerman et al. 2002). The model incorporates three factors: a fire model that relates the gas release to the intensity of the heat, a model that provides an estimate of the amount of gas being released as a function of time, and a heat intensity threshold. The model can be used to determine a zone of impact for a pipeline fire. The equation used in the model relates the diameter and operating pressure of a pipeline to the size of the affected areas, assuming a worst-case failure event (Stephens 2000). The model can also be used to determine how the intensity of heat changes with the distance from the fire. From the model, "circles" around a pipeline fire that have equal levels of thermal radiation can be calculated. (In fact, the distance of equal thermal radiation from a pipeline fire may not be circular, depending on the nature of the gas discharge, obstructions of the jet of flowing gas, and delays in ignition. For example, the gas coming out of a ruptured pipe may be discharged in a particular direction or upward from the surface depending on the direction of the jet of flowing gas.)

C-FER calculates the degree of harm to people due to thermal radiation by using a model that relates the potential for burn injury or fatality to the thermal load received. A 30-second exposure time is assumed for people exposed to the fire in the open. In this interval, it is assumed that an exposed person will remain in fixed position for between 1 and 5 seconds (presumably to understand what is happening and react) and then run at 5 miles per hour in the direction of shelter. It is further assumed that a person would find a sheltered location within 200 feet of his or her initial position. It is offered that the heat flux that will cause burn injury is between 1,000 and 2,000 Btu/h/ft$^2$ (3.2 and 6.3 kW/m$^2$), depending on the burn injury criterion (e.g., time to blister). The threshold level of heat flux for fatal injury is determined when the chance of mortality is 1 percent; that is, 1 in 100 people directly exposed to this thermal load would not be expected to survive. This heat flux is calculated to be 5,000 Btu/h/ft$^2$ (15.8 kW/m$^2$).

C-FER also calculates a lower bound reliability curve based on the probability of a fatality or injury of an individual standing on the centerline of a pipeline. The third calculation is the cumulative frequency of casualties along the length of a pipeline system, called the FN curve. [See Harris and Acton (2001) for more information on these calculations.]

C-FER models the thermal load on wooden structures leading to ignition and fire. One calculation shows that 5,000 Btu/h/ft$^2$ (15.8 kW/m$^2$) would correspond to ignition in the presence of a flame source in approximately 20 minutes. It calculates that spontaneous ignition at this level of thermal radiation would not occur.

On the basis of these thermal radiation levels, C-FER calculates the radius of a hazard area as a function of pipeline size (diameter) and operating pressure. The graph of hazard area radius versus maximum operating pressure is shown in Figure D-1. A 36-inch-diameter pipeline operating at a maximum pressure of 1,000 pounds per square inch would have a hazard area radius of 750 to 800 feet. A 6-inch-diameter pipeline operating at less than 500 pounds per square inch would have a hazard area radius of less than 100 feet.

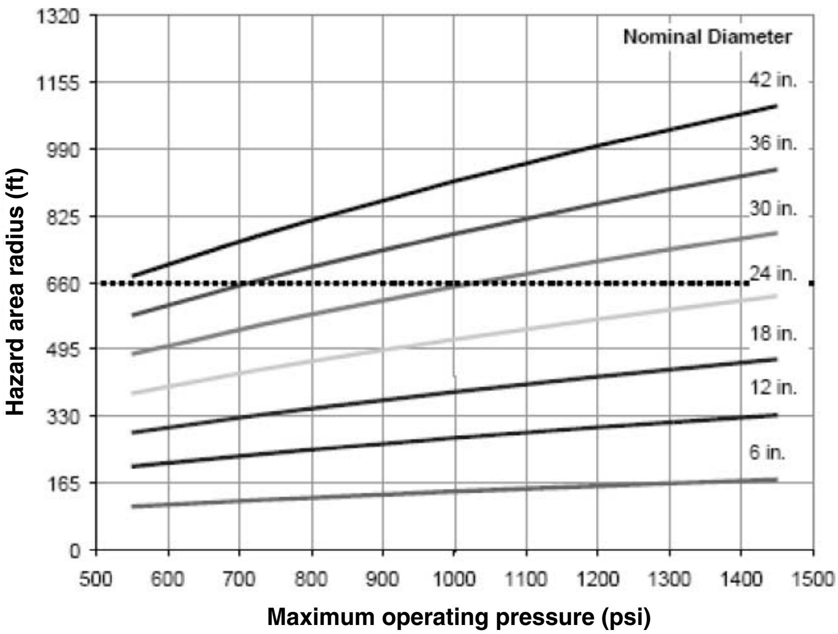



**FIGURE D-1 Proposed hazard area radius as a function of line diameter and pressure.** (SOURCE: Stephens 2000.)

By using the approach in C-FER's report, it would be possible to calculate hazard area distances for a variety of hazard scenarios involving more hardened structures and different accident scenarios.

## PipeView Risk

PipeView Risk is a pipeline risk assessment program that assists pipeline operators in evaluating the current condition of their pipelines and identifying sections of higher risk in order to prioritize maintenance programs (Kiefner & Associates and M. J. Harden Associates 2004). PipeView Risk uses a relative risk ranking model. The analyses are performed by evaluating the physical pipeline attributes (e.g., diameter, grade, and wall thickness) in an algorithm that models the relationship between them. PipeView Risk is designed to be geographic information system (GIS) compatible by starting with an Integrated Spatial Analysis Techniques

(ISAT) database—a family of applications that integrate information from many sources including GIS; the Global Positioning System; pipeline maps; and other operating, monitoring, and maintenance data. The ISAT project was begun at the Gas Research Institute in the mid-1990s.

## SUMMARY

A number of risk assessment methods are being used by the pipeline industry to prioritize risk mitigation actions. Regulatory agencies in the United States and abroad have developed risk-based regulations and criteria for safe operation of pipelines. While the risk assessment methodologies in use allow scarce resources to be focused on mitigation of the highest-risk items by emphasizing a single risk number, they do not adequately characterize all the dimensions of risk. A broader characterization of risk, as outlined in Chapter 3, will enable state and local policy makers, with input from stakeholders, to make land use decisions in a systematic manner.

## REFERENCES

Acton, M. R., P. J. Baldwin, T. R. Baldwin, and E. E. R. Jager. 1998. The Development of the PIPESAFE Risk Assessment Package for Gas Transmission Pipelines. *Proceedings of the International Pipeline Conference,* American Society of Mechanical Engineers, Calgary, Alberta, Canada.

Committee for the Prevention of Disasters. 1999. *Guidelines for Quantitative Risk Assessment.* CPR18E. The Hague, Netherlands.

Harris, R. J., and M. R. Acton. 2001. Development and Implementation of Risk Assessment Methods for Natural Gas Pipelines. *Proceedings of the China Gas 2001 International Conference with Special Focus on Gas Safety,* Chongqing, China, Nov. 20-21.

IGE. 2001. *Steel Pipelines for High Pressure Gas Transmission.* IGE Code TD/1 Edition 4, Communication 1670.

IsographDirect. 2004. www.faulttree.org.

Kiefner & Associates and M. J. Harden Associates. 2004. www.mjharden.com/pipeline/products/pipeviewrisk.html.

$Mc^2$ Management Consulting. 2004. www.mc2consulting.com.

Muhlbauer, W. K. 1996. *Pipeline Risk Management Manual,* 2nd ed. Gulf Publishing Co., Houston, Tex.

Muhlbauer, W. K. 1999. Lessons Learned in Pipeline Risk Assessment. Presented at Minerals Management Service Alaskan Arctic Pipeline Workshop, Anchorage, Alaska, Nov. 8-9. www.pipelinerisk.com/WKMConsultancy/RALessonsPaper.pdf.

Sandia National Laboratories. 2004. reliability.sandia.gov/Reliability/Fault_Tree_Analysis/fault_tree_analysis.html.

Stephens, M. J. 2000. *A Model for Sizing High Consequence Areas Associated with Natural Gas Pipelines.* GRI-00/0189. Gas Research Institute, Oct.

Zimmerman, T., M. Nessim, M. McLamb, B. Rothwell, J. Zhou, and A. Glover. 2002. Target Reliability Levels for Onshore Gas Pipelines. *Proceedings of the International Pipeline Conference,* American Society of Mechanical Engineers, Calgary, Alberta, Canada, Sept. 29-Oct. 3.

# Study Committee Biographical Information

**Don E. Kash,** *Chair,* is Hazel Professor of Public Policy in the Department of Public Affairs at George Mason University. He is also guest professor at the Research Academy for 21st Century Development, Tsinghua University, Beijing. He received B.A., M.A., and Ph.D. degrees in political science at the University of Iowa. He was professor of political science at the University of Oklahoma from 1970 to 1991. From 1978 to 1981, Dr. Kash was Chief of the Conservation Division at the U.S. Geological Survey, which was responsible for regulating energy and mineral development on the Outer Continental Shelf (OCS), federal, and Indian lands. The division's responsibilities ranged from economic evaluations of minerals before leasing through establishing the standards for and regulating all of the steps from exploration through development and production to royalty collection. While he was division chief, the organization launched a new centralized royalty collection system, was reorganized, and implemented the regulations for OCS oil and gas operations required by the 1978 Outer Continental Shelf Lands Act Amendments. Dr. Kash has chaired numerous committees including the Marine Board Committee on Lightering; the 1995–1996 Advisory Panel on Technologies to Protect Fish at Dams, the 1994–1995 Advisory Panel on Advanced Automotive Technologies Project, the 1994 Workshop on Global Communications, and the 1991 Workshop on Alaska–California Subsea Water Pipeline for the Office of Technology Assessment; and the Cross-Disciplinary Engineering Research Committee of the National Research Council from 1986 through 1988. In addition, he has served as a member of numerous committees including the Selection Committee, Critical Technologies Institute Science and Engineering Fellows Program, American Association for the Advancement of Science, 1993–1994; the Committee on Transportation Research Centers, Transportation Research Board, National Research Council, 1992–1993; the Committee on New Technology and Innovation in Building, National Research Council, 1990–1992; the Panel on Oil and Gas Development in Hostile Offshore Environments for the Office of Technology Assessment, 1983–1985; and the Marine Board, 1974–1977 and 1985–1988. A Fellow of the American Association for the Advancement of Science, Dr. Kash has also published extensively in the fields of science technology and public policy, energy policy, and policy analysis.

**Bruce G. Boncke** is President of BME Associates. He holds a B.S. degree in civil engineering from Clarkson College, Potsdam, New York. He has provided consulting services for more than 30 years and has done extensive work on land development projects. He has prepared and conducts training programs for the Monroe County Planning Council, the New York Planning Federation, the New York State Bar Association, and the Home Builders Association. He is past president of both the Rochester Home Builders Association and the New York State Builders Association, and he is the 2003 chairman of the National Home Builders Association Land Development Committee. He is the current president of the New York Planning Federation, a past president of the Rochester Section of the American Society of Civil Engineers, and a member of the New York State Quality Communities Task Force Committee. In New York State, Mr. Boncke has been involved in writing state and local incentive zoning regulations, State Environmental Quality Review Act revisions, wetland delineation and mitigation guidelines, clustering provisions, and conservation easement statutes.

**Raymond J. Burby** is the Director of the Ph.D. Program in the Department of City and Regional Planning at the University of North Carolina at Chapel Hill. Dr. Burby teaches courses in land use and environmental planning, development impact assessment, development management, sustainable cities, hazard mitigation, and research methods. He is a fellow of American Institute of Certified Planners and is a member of numerous professional organizations. Dr. Burby is a former coeditor of the *Journal of the American Planning Association,* has authored or edited 14 books, and has published extensively in planning and policy journals including *Journal of the American Planning Association, Journal of Planning Education and Research, Journal of Policy Analysis and Management, Land Economics,* *Environmental Management*, and *Journal of Environmental Planning and Management*. He is currently principal investigator on a study of urban growth boundaries funded by the National Science Foundation. Dr. Burby received an A.B. degree from the George Washington University and M.R.P. and Ph.D. degrees from the University of North Carolina.

**Cynthia Jensen Claus,** attorney-at-law, lives and works in Lawrence, Kansas. By appointment of Governor Bill Graves, Ms. Claus served from 1997 to 2003 on the Kansas Corporation Commission, the agency having state regulatory oversight of public utilities (including telecommunications, electricity, natural gas, and water), pipeline safety, transportation, and the production of crude oil and natural gas. During her tenure as Commissioner, she served as the official representative of Kansas to the Interstate Oil and Gas Compact Commission, where she was a member of the Legal and Regulatory Affairs Committee and served on the Steering Committee, the Resolutions Committee, and the Finance Committee. She was also a member of the National Association of Regulatory Utility Commissioners, serving on the Finance and Technology Committee and the Telecommunications Committee. Before her service on the Kansas Corporation Commission, she provided in-house legal services for 16 years (including 5 years as chief counsel) to ARCO Pipe Line Company, a regulated cross-country oil pipeline company. She served as a member of the State Affairs Committee of the Association of Oil Pipe Lines from 1989 to 1995 and as Chairman of the Pipeline Committee of the Texas Mid-Continent Oil and Gas Association from 1994 to 1995. Ms. Claus has an undergraduate degree from the University of Kansas and a law degree from the University of Kansas School of Law, where she was elected to Order of the Coif. She served as a member of the Board of Governors for the Law Society for the University of Kansas School of Law from 1983 to 1985. She also served as the Municipal Judge for the cities of Independence and Cherryvale, Kansas, from 1978 to 1979. In 2003, she was appointed to the American Arbitration Association's panel of neutrals.

**Geraldine E. Edens** is Office Counsel at McKenna, Long & Aldridge, LLP. Before taking this position, she was Special Litigation Counsel to Cadwalader, Wickersham & Taft's Environmental Law Group. Dr. Edens practices in areas involving environmental litigation, regulatory matters, and issues concerning law and science, and she has performed environmental audits and reviews for a variety of corporate clients in the chemical manufacturing and mining industries. She counsels clients on environmental compliance, the law and science of chemical regulation, toxic tort health claims [asbestos, boron, polychlorinated biphenyls, lead, benzene, methyl tertiary butyl ether (MTBE), etc.], and a wide variety of Clean Air Act issues. Dr. Edens has a broad base of litigation experience, including service as lead counsel on behalf of an intervenor-defendant in a National Environmental Policy Act case challenging a federal grant of a right-of-way for an interstate pipeline and challenging the authority of the Department of Transportation to ban the transport of MTBE in an interstate pipeline. Dr. Edens graduated from the University of Miami School of Law magna cum laude and Order of the Coif, where she was a member of the *University of Miami Law Review.* She has a Ph.D. in education from the University of Florida and M.S. and B.S. degrees from the University of Miami. Dr. Edens is a member of the District of Columbia and Maryland Bars. She is coauthor of two chapters, "Federal Environmental Liability" and "Indoor Air Quality," in *Environmental Aspects of Real Estate Transactions,* and the chapter "Indoor Air Quality" in *Environmental Law Practice Guide: State and Federal Law.* Before joining Cadwalader, Dr. Edens was a professor at the University of Miami, where she was a member of the graduate school faculty.

**William L. Halvorson** is a research ecologist with the U.S. Geological Survey at the Sonoran Desert Research Station and a professor in the School of Natural Resources, both at the University of Arizona. His research interests include vegetation ecology of arid and semiarid regions, species distribution and diversity, community structure, restoration and management of natural ecosystems, and landscape ecology. He has a bachelor's degree from Arizona State University, a master's degree from the University of Illinois, and a Ph.D. from Arizona State University. He is a member of the California Botanical Society and the Ecological Society of America and serves on the Board of Directors of the Society for Ecological Restoration.

**Robert L. Malecki** is principal owner of Malecki Consulting, LLC. He provides consulting services to energy-sector clients in the northeastern United States, with an emphasis on environmental assessment and permitting, government and community cooperation, approval acquisition, and design and implementation of environmental protection techniques. He recently retired from the New York State Electric and Gas Company. During the last 10 of his 33 years there he was responsible for environmental planning, regulatory approvals, licensing, construction and operational impact mitigation, compliance, and hazardous waste disposal. Mr. Malecki holds a B.S. in forest science from Pennsylvania State University and has undertaken graduate studies on environmental impact assessment at the College of Environmental Science and Forestry at the State University of New York, Syracuse. He also has taken graduate studies in the management development program at the University of Michigan.

**James M. Pates** has served since 1986 as the City Attorney of the City of Fredericksburg, Virginia, in which capacity he is responsible for all of the civil legal affairs of the city, including litigation, legislation, and a wide variety of commercial, real estate, land use, and environmental transactions. Since 1990, he has helped lead a national effort by a coalition of environmental, state and local government, and public interest groups to improve pipeline safety. He is one of the founders and currently serves as Vice President of the National Pipeline Reform Coalition. He has testified before Congress on various pipeline safety bills and has authored local, state, and federal legislation aimed at increasing the role of state and local governments in pipeline safety. Mr. Pates is the author of two papers on pipeline safety and the producer of a 1996 public service video, "Out of Sight, Out of Mind: What Every Local Government Should Know About Pipeline Safety." Before taking his current position, he served as legislative counsel to the Subcommittee on Commerce, Consumer, and Monetary Affairs of the Committee on Government Operations, U.S. House of Representatives, and later as government relations counsel for a national trade association in Washington, D.C. Mr. Pates is a magna cum laude graduate of Amherst College and a graduate of the University of Virginia Law School.

**Richard A. Rabinow** became President of The Rabinow Consortium, LLC, following his retirement from ExxonMobil in 2002 after 34 years of service. At the time of his retirement, Mr. Rabinow was the president of

ExxonMobil Pipeline Company (EMPCo), a position he had held at EMPCo and its predecessor, Exxon Pipeline Company, since 1996. Before that, Mr. Rabinow held the position of Vice President and Lower 48 Manager of Exxon Pipeline Company. He received a B.S. degree in engineering mechanics from Lehigh University and M.S. degrees in mechanical engineering and management, both from the Massachusetts Institute of Technology. During 1994 and 1995, Mr. Rabinow held the position of Senior Vice President, Integrity and Compliance Projects, while on loan to the Alyeska Pipeline Service Company in Anchorage, Alaska. He serves as Vice President of the Board of Trustees of the Houston Arboretum and Nature Center. He is a former member of the American Petroleum Institute and the Association of Oil Pipe Lines and has been a member of the Trans Alaska Pipeline System Owners Committee.

**Narasi Sridhar** is a Program Director in the Mechanical and Materials Engineering Division at Southwest Research Institute, where he has worked since 1989. At Southwest Research Institute, he has been managing projects related to the licensing of engineered barrier system designs for high-level nuclear waste disposal, safety evaluation of processes to remediate liquid radioactive wastes at Hanford, corrosion mitigation pertaining to gas pipelines, corrosion prediction for chemical process industries, marine corrosion, and aircraft corrosion. Before joining Southwest Research Institute, he was active in the chemical process, pulp and paper, and oil and gas industries. He has more than 20 years of experience in materials development, electrochemistry, and corrosion, and he has been involved in the development of nickel-, cobalt-, copper-, and iron-base alloys for more than 15 years. Dr. Sridhar received a B.S. degree in metallurgy from the Indian Institute of Technology in 1975, an M.S. degree in materials engineering from Virginia Polytechnic Institute and State University in 1977, and a Ph.D. in metallurgical engineering from the University of Notre Dame in 1980. He has published more than 70 papers and has contributed chapters to several handbooks on corrosion and corrosion-resistant alloys. He is a member of the Electrochemical Society, NACE International, ASM International, American Society for Testing and Materials, and the Board of Editors of the journal *Corrosion.* In recognition of his outstanding contributions to corrosion in several industries, he received a NACE Technical Achievement award.

**Theofanis G. Theofanous,** NAE, is Professor and Director of the Center for Risk Studies and Safety at the University of California, Santa Barbara. He received a Ph.D. from the University of Minnesota and a B.S. degree from the National Technical University, Athens, Greece, both in chemical engineering. From 1974 through 1985, he was a professor and founding director of the Nuclear Reactor Safety Laboratory at Purdue University. Dr. Theofanous is a member of the National Academy of Engineering, a fellow of the American Nuclear Society, and a foreign member of the Ufa Branch of the Russian Academy of Sciences. Among his other honors are the E. O. Lawrence Presidential Medal and an Honorary Doctorate from the University of Laapeenrantaa, Finland. He has published extensively and has received numerous best paper awards. His technical interests focus on multiphase transport phenomena and risk assessment and management in complex technological and environmental systems. He studies methodological issues in treating uncertainty in risk assessments and basic multiphase flow physics, and he works to integrate these basic aspects toward understanding and optimizing system behavior, assessing risks, and improving safety.

**Theodore L. Willke** is President of TLW Solutions, Inc., a consulting firm specializing in risk management and the application of new and emerging oil and gas pipeline technology. He is a lecturer and faculty advisor in the H. John Heinz III School of Public Policy and Management at Carnegie Mellon University. Dr. Willke received B.S. degrees in astronautical engineering and engineering science from the U.S. Air Force Academy, an S.M. in nuclear engineering from the Massachusetts Institute of Technology, an M.B.A. from the University of Dayton, and a Ph.D. in industrial and systems engineering from the Ohio State University. From 1997 to 2001, he was Director and Chief Executive Officer of Carnegie Mellon Research Institute. Dr. Willke is a member and has served as chair of a pipeline safety advisory committee for the U.S. Secretary of Transportation, Technical Pipeline Safety Standards Committee, Office of Pipeline Safety. He also served as chair of the International Committee on Pipeline Repair and Rehabilitation representing 22 countries for the International Gas Union. Dr. Willke served as Vice President in charge of pipeline, distribution, and environment and safety technology research and development at the Gas Research Institute, where he worked in various capacities from 1984 through 1997. He managed the design and construction of two major pipeline test facilities—the Metering Research Facility in San Antonio and the Pipeline Simulation Facility in Columbus, Ohio. He developed and obtained regulatory approval for a new pipeline repair technology and introduced a van-mounted natural gas leak detector to the market. Dr. Willke was chair of the Pittsburgh International Science and Technology Festival and of the technology committee of the New Idea Factory for County Executive Jim Roddy. He is a previous board member of the Ben Franklin Technology Center of Western Pennsylvania and a former board member of PRC International, a pipeline technology research organization. He has published extensively and holds one patent.

# Transmission Pipelines and Land Use
## *A Risk-Informed Approach*

Transmission pipelines make up 20 percent of the 1.8 million total miles of pipelines in the United States and transport virtually all of the nation's natural gas and two-thirds of its petroleum products. In the absence of land use policies, development often may proceed adjacent to pipeline rights-of-way or in the vicinity of active pipelines. Pipeline incidents occur almost daily; most are minor, but a few are not. This report calls on the Office of Pipeline Safety in the U.S. Department of Transportation's Research and Special Programs Administration to work with stakeholders to draft guidance on risk-informed land use for policy makers, planners, local officials, and the public.

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