601-D12-001

EPA EXTERNAL REVIEW DRAFT

Framework for Human Health Risk Assessment to Inform Decision Making

July 12, 2012

U.S. Environmental Protection Agency

Office of the Science Advisor

Risk Assessment Forum

This page is intentionally blank.

Table of Contents

Disclaimer vi

Preface vii

List of Acronyms viii

List of Text Boxes ix

Executive Summary x

1 Introduction 1

1.1 Background and History 1

1.2 Overview of the Framework 3

1.2.1 Scope and Purpose 3

1.2.2 Description of the Framework 5

2 Planning 10

2.1 Planning and Scoping 10

2.1.1 Context, Purpose and Scope 14

2.1.2 Overarching Considerations 16

2.1.3 Responsibilities and Resources 21

2.1.4 Decision Points and Scientific Peer Review 22

2.1.5 Public, Stakeholder and Community Involvement 24

2.1.6 Past Experiences and Assessments 25

2.2 Problem Formulation 26

2.2.1 Conceptual Model 27

2.2.2 Analysis Plan 31

2.3 Fit for Purpose 38

3 Risk Assessment 40

3.1 Exposure Assessment 41

3.2 Effects Assessment 42
3.2.1 Hazard Identification 43
3.2.2 Dose-Response Assessment 45
3.3 Risk Characterization 46
4 Public, Stakeholder and Community Involvement 50
4.1.1 Stakeholders 52
4.1.2 Community 53
4.2 Communication 54
5 Informing Decisions 56
5.1 Characterizing the Risks for Risk Management Options 56
5.2 Risk Management Factors Beyond the Risk Assessment and Characterization 57
6 Summary 59
References 61
Appendix I. Examples of EPA Program-Specific Resources and Guidance on Risk Assessment Activities 73

Risk Assessment Forum Technical Panel

Rita Schoeny (Co-Chair)	Office of Water (on Detail to Office of Research and Development)
Kathryn Gallagher (Co-Chair)	Office of Water
Julie Fitzpatrick (Science Coordinator)	Office of the Science Advisor/Risk Assessment Forum
Kacee Deener	Office of Research and Development
Chris Dockins	Office of Policy
Michael Firestone	Office of Children's Health Protection
William Jordan	Office of Chemical Safety and Pollution Prevention
Margaret McDonough	Region 1
Deirdre Murphy	Office of Air and Radiation
Marian Olsen	Region 2
Kathleen Raffaele	Office of Solid Waste and Emergency Response

Disclaimer

This document is a draft for peer review. It has not been adopted by the U.S. Environmental Protection Agency and should not be construed to represent agency policy. It is being circulated for comments on its technical merit and policy implications. Any mention of trade names or commercial products does not constitute endorsement or recommendation for use.

Preface

The purpose of this document is to describe a Framework for conducting human health risk assessments that are responsive to the needs of decision-making processes in the U.S. Environmental Protection Agency (EPA). This document does not present either a checklist or compendium of requirements. Rather it includes issues to consider, provides suggested questions to ask during risk assessment planning and execution, and identifies some useful practices. The intended audience for this document includes those who assess risk, those who use the information within and outside the EPA (e.g., risk managers), and those interested in the process by which EPA conducts risk assessments. This document was produced by a Technical Panel of the EPA Risk Assessment Forum.

List of Acronyms

AIEO	American Indian Environmental Office
CAA	Clean Air Act
CASAC	Clean Air Scientific Advisory Committee
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CWA	Clean Water Act
EJ	Environmental Justice
EPA	U.S. Environmental Protection Agency
FQPA	Food Quality Protection Act
HPV	High Production Volume
IRIS	Integrated Risk Information System
IRP	Integrated Review Plan
ISA	Integrated Science Assessment
MOA	Mode of Action
NAAQS	National Ambient Air Quality Standards
NAS	National Academy of Science
NRC	National Research Council
OAQPS	Office of Air Quality Planning and Standards
OMB	Office of Management and Budget
OPPT	Office of Pollution Prevention and Toxics
ORD	Office of Research and Development
PA	Policy Assessment
PCCRARM	Presidential/Congressional Commission on Risk Assessment and Risk Management
PMN	Premanufacture Notice
REA	Risk and Exposure Assessment
SAB	Science Advisory Board
SDWA	Safe Drinking Water Act
TCCR	Transparency, Clarity, Consistency and Reasonableness
TSCA	Toxic Substances Control Act

List of Text Boxes

Text Box 1-1: Examples of EPA Actions Informed by Risk Assessments 1
Text Box 1-2: Examples of Key EPA Documents Describing Risk Assessment Frameworks 3
Text Box 1-3: General Principles of Framework for Human Health Risk Assessment 4
Text Box 2-1: Key EPA References on Planning and Scoping 10
Text Box 2-2: Examples of Risk Assessment Planning and Scoping at EPA 12
Text Box 2-3: The Silver Book Statements on Utility 13
Text Box 2-4: Risk Assessment for Economic Benefits Analysis 17
Text Box 2-5: Key EPA Children's Health Guidance Documents 19
Text Box 2-6: Resources on Sustainability and Life Cycle Assessment 21
Text Box 2-7: Definitions of "Public," "Stakeholder" and "Community" 24
Text Box 2-8: EPA Resources on Conceptual Models 29
Text Box 2-9: Examples of Conceptual Models in EPA Risk Assessments 31
Text Box 2-10: Data Quality Resources 33
Text Box 2-11: EPA Exposure Assessment Resources for Human Health 33
Text Box 2-12: EPA Resources on Hazard Identification and Dose-Response Assessment 35
Text Box 2-13: Other Risk Analyses Resources 36
Text Box 2-14: Definitions of Uncertainty and Variability 37
Text Box 2-15: More Silver Book Statements on Utility 39
Text Box 3-1: Key Elements of an Exposure Characterization 43
Text Box 3-2: Example of a Consideration for Effects Characterization: Mode of Action 44
Text Box 3-3: Transparency—Clarity—Consistency—Reasonableness in the Risk Characterization Handbook (U.S. EPA 2000b) 46
Text Box 3-4: Characterizing Cancer Risk from Early Life Exposure 47
Text Box 3-5: Considerations for Risk Characterization: Cumulative Risk Assessment 49
Text Box 4-1: EPA Resources for Public Involvement Efforts, Tools and Policies 52
Text Box 6-1: The Silver Book Recommendations for a Human Health Risk Assessment Framework 59

Executive Summary

The *Framework for Human Health Risk Assessment to Inform Decision Making* (Framework) is intended to facilitate implementation of existing U.S. Environmental Protection Agency (EPA) guidance for conducting human health risk assessments and to improve the utility of risk assessment in the decision-making process. The Framework takes into account recommendations on risk assessment processes described in the National Research Council's (NRC) 2009 report, *Science and Decisions: Advancing Risk Assessment* (NRC 2009). Particular emphasis is given to recommendations on the design of risk assessment and on improving the utility of risk assessment. This Framework highlights the important roles of planning and scoping as well as problem formulation in designing a risk assessment that will serve a specific and documented purpose. In accordance with longstanding agency policy, it also emphasizes the importance of scientific review and public, stakeholder and community involvement. The Framework will strengthen the EPA's emphasis on the importance of transparency of its human health risk assessment and decision-making processes. This document is not intended to supersede existing EPA guidance; rather, by citing and discussing existing guidance in the context of the full framework, this document is intended to foster increased implementation of agency guidance.

The key elements of the process for conducting a risk assessment are as follows:

- Planning and scoping: This step ensures that the risk assessment is sound and serves its intended purpose. It also allows those interested in the risk assessment process to determine the context of the risk assessment and the intended use of its results. A broad range of technical experts working as a team may be involved in this stage.

- Problem formulation: This analytical phase identifies the major factors that must be considered in a specific assessment, thus informing the technical approach. An important outcome of problem formulation is a conceptual model that identifies the stressor(s), the exposed population(s) and the endpoint(s) that will be addressed in the risk assessment as well as the relationships among them.

- Exposure and effects assessment: Exposure assessment, a primary component of a risk assessment, will reflect the considerations identified in problem formulation. Effects assessment includes hazard identification and dose-response assessment. Susceptible or more highly exposed populations may also be identified in these assessments.

- Risk characterization: This final, integrative step provides risk managers with a useful, synthesized, set of conclusions about the risk that has been assessed. It is judged by four principles: transparency, clarity, consistency and reasonableness.

- Public, stakeholder and community involvement: Input from the public is sought and considered. Such input is essential to the agency in fulfilling its mission to protect human health and the environment.

- Informing decisions: The final step in the risk assessment process is connecting the previously defined purpose and scope with the conclusions and strengths/limitations of the risk assessment.

The Framework also reflects the NRC (2009) recommendations on assuring that risk assessments are well tailored to the problems and decisions at hand, so that they can most meaningfully inform the decision-making process. In describing these recommendations, the NRC (2009) report uses the terms "fit for purpose" and "utility of risk assessment," among others. The NRC (1983) four-step risk assessment paradigm is maintained in the current Framework, but there is increased emphasis on assuring the utility of each risk assessment. The utility of risk assessment is not something that is evaluated as a separate step in the process or as a final check that occurs once the risk assessment is completed. Rather, an emphasis on utility of the risk assessment for informing risk management decisions begins with planning and scoping and continues throughout the process. The Framework stresses the practical nature of risk assessment; it highlights the need for analysis in support of decision making and prompts the risk assessor to consider areas of overarching concern to the agency, including children's environmental health and environmental justice. The Framework encourages the consideration of innovative technology and the still-developing area of sustainability concepts in environmental decision making. This Framework supports enhanced dialogue between risk assessors and risk managers while recognizing the distinction in their roles.

1 Introduction

1.1 Background and History

Since the agency's inception, risk assessment has informed actions taken to protect public health and the environment from a range of threats. Over time, the science, approaches and methods employed for these analyses have evolved. Risk assessments performed by the agency inform a broad range of regulatory decisions (see Text Box 1-1). Thus, the design, objectives and specific outputs of risk assessments vary depending on the purpose and governing statute. Agency economic analyses also draw on risk assessments to estimate the value of health benefits associated with regulatory options and actions.

Text Box 1-1: Examples of EPA Actions Informed by Risk Assessments

- Pesticide usage restrictions.
- Hazardous waste site remediation goals and approaches.
- Regulation of hazardous materials usage.
- Ambient air quality standards.
- Emissions standards for hazardous air pollutants.

This document provides a *Framework for Human Health Risk Assessment to Inform Decision Making* (Framework) that draws on agency experience and takes into account the recommendations on risk assessment process from the 'NRC's 2009 report, *Science and Decisions: Advancing Risk Assessment* (NRC 2009)—also known as the "Silver Book." In particular, this Framework seeks to address Silver Book recommendations on the design of and improving the utility of risk assessments. This Framework also draws on a considerable body of additional expert advice, beginning with the National Academy of Sciences' (NAS) NRC 1983 report, *Risk Assessment in the Federal Government: Managing the Process* (commonly referred to as the "Red Book"), followed by the NRC's 1994 Report, *Science and Judgment in Risk Assessment* (commonly referred to as the "Blue Book") , and incorporates principles from the agency's extensive human health risk assessment guidance. Following publication of the Red Book, the agency issued Risk Assessment and Management: Framework for Decision Making (U.S. EPA 1984), which first articulated the EPA's risk assessment framework. In 1984, the agency established what is now called the Risk Assessment Forum and in 1986 added the Risk Assessment Council; in 1993, the Science Policy Council (now called the Science and Technology Policy Council) replaced the Risk Assessment Council. Shortly after publication of the Red Book, the EPA began issuing a series of guidelines for conducting risk assessments in a number of areas (e.g., cancer, chemical mixtures, developmental toxicity, exposure assessment, mutagenicity, neurotoxicity, and reproductive toxicity) (U.S. EPA 1986b, 1987, 2005a, 1986a,

2000a, 1991b, 1992a, 1986c, 1998b, 1996, respectively). Many of these original agency-wide risk assessment guidelines include frameworks that have been updated over time.

In its emphasis on the planning aspects of conducting risk assessments, this Framework builds on principles found in the EPA's 1997 *Guidance on Cumulative Risk Assessment. Part 1. Planning and Scoping*, which described an approach for integrated risk assessment and management (U.S. EPA 1997a). The 1997 guidance was designed to help risk managers and risk assessors plan and document the scope of risk assessments and consider appropriate participants (that is, technical, advisory or stakeholder) and information sources to enrich the risk assessment. Additionally, the 1997 guidance augmented the agency's February 1995 *Guidance for Risk Characterization* (U.S. EPA 1995d) by emphasizing the need for providing a transparent, clear, consistent and reasonable basis for any assessment, and strongly encouraged the undertaking of a formal problem formulation exercise for all risk assessments.

Prior to the 1997 *Guidance on Cumulative Risk Assessment. Part 1. Planning and Scoping*, the agency published the *Framework for Ecological Risk Assessment* (U.S. EPA 1992b) and subsequently released the *Guidelines for Ecological Risk Assessment* (U.S. EPA 1998a), which incorporated planning and scoping into the ecological risk assessment process. In 2003, the *Framework for Cumulative Risk Assessment* (U.S. EPA 2003a) further built on these documents in formulating a flexible structure for conducting and evaluating cumulative risk assessment (for human health or ecological risk). In 2006, the agency published *A Framework for Assessing Health Risk of Environmental Exposures to Children*, which applied this general structure (including problem formulation, analysis and risk characterization, the three critical phases in the risk assessment process) in describing risk assessments focused on evaluating potential risks arising as a result of early life exposure (U.S. EPA 2006a). In addition to these more general agency documents, individual programs and offices have implemented risk assessment frameworks specific to their missions. Examples of documents with risk assessment frameworks are provided in Text Box 1-2. Finally, the agency has developed a Risk Assessment Portal (U.S. EPA, 2012i) that provides basic information about environmental risk assessments and offers a comprehensive set of links to key EPA tools, guidance and guidelines.

Text Box 1-2: Examples of Key EPA Documents Describing Risk Assessment Frameworks

- *Risk Assessment Guidance for Superfund Part A* (U.S. EPA 1989, 1991, 1998a, 1999a, 2001d, 2004a, 2009)
- *Framework for Ecological Risk Assessment* (U.S. EPA 1992b)
- *Guidance on Cumulative Risk Assessment:. Part 1. Planning and Scoping* (U.S. EPA 1997a)
- *Guidelines for Ecological Risk Assessment* (U.S. EPA 1998a)
- *Risk Characterization Handbook* (U.S. EPA 2000b)
- *Framework for Cumulative Risk Assessment* (U.S. EPA 2003a)
- *Office of Air Quality Planning and Standards Air Toxics Risk Assessment Library – General Framework for Residual Risk Assessment* (U.S. EPA 2004e)
- *A Framework for Assessing Health Risk of Environmental Exposures to Children* (U.S. EPA 2006a)
- *Office of Pollution Prevention and Toxics Requirements for Submitting Electronic Pre-manufacture Notices (PMNs)* (U.S. EPA 2010d)

1.2 Overview of the Framework

1.2.1 Scope and Purpose

The purpose of this document is to describe a process for conducting human health risk assessments that are responsive to the decision-making needs of the EPA. It provides an organizing structure for implementing existing EPA guidance on human health risk assessment. This Framework highlights the important role of planning and scoping in designing a risk assessment so that it serves its intended purpose, as well as the importance of scientific review and public, stakeholder and community involvement. This Framework is expected to promote and increase the transparency of the human health risk assessment process at the agency. It is consistent with the EPA Scientific Integrity Policy (U.S. EPA 2012b) and follows the general principles laid out in Text Box 1-3.

In building on the basic components identified in the Red Book (NRC 1983) and on processes currently employed across the agency, this Framework takes into account key recommendations from the Silver Book (NRC 2009), which called for more interaction among risk assessors and risk managers during the course of a risk assessment while recognizing and keeping separate their different roles (NRC 2009). Thus, this Framework emphasizes the importance of early identification of risk management options so that risk assessment can most efficiently inform choices among such options. Risk management decisions are beyond the scope of the risk assessment proper; a risk assessment is one of the sources of information that informs the particular decision at hand. As discussed in Section 5 of this document, the risk assessment should not "make" the decision; it should characterize the risk, including specifying who, what or how much is at risk. The Framework describes planning to maximize the utility of the risk assessment for informing risk management decisions.

Text Box 1-3: General Principles of Framework for Human Health Risk Assessment

- Each risk assessment should be fit for its intended purpose.
- Each risk assessment should state the purpose, context and scope clearly.
- Risk assessment should be based on exposure scenarios, consistent with the purpose and context. As appropriate, it should include consideration of susceptible population groups and lifestages.
- The risk assessment should follow an acceptable, overtly logical path employing common sense and sound judgment in applying relevant guidance.
- All steps, key assumptions, limitations and decisions, along with associated rationale, should be clearly conveyed.
- There should be consideration of the role of scientific peer and public consultation and review.
- The risk assessment should be presented in a readily understandable and useful form.

The Framework reflects the often iterative nature of risk assessment; that is, as some scientific questions are answered, new ones may develop that require the generation of additional data and/or analyses that better define the distribution of risk and/or address uncertainty. Throughout the process, additional knowledge may result in further refinement of the conceptual model and analysis plan.

Finally, this Framework incorporates areas of overarching agency interest, such as the evaluation of risks to children (U.S. EPA 1995c) and environmental justice (EJ) (U.S. EPA 2012a), and promotes the consideration of the concepts of sustainability and technology innovation in risk management decision making. Executive orders that apply to these areas are Executive Order 13045 (protection of children) and Executive Order 12898 (environmental justice).

In summary, this Framework describes approaches for organizing and conducting human health risk assessments; it complements but does not replace any existing guidance or guidelines. Building from the agency's experience and NRC recommendations, the Framework is intended to identify the critical aspects of the risk assessment process within a formal albeit flexible structure. The Framework is not intended to be an exhaustive reference on all relevant guidance; rather, the Framework is intended to clearly describe the overall process, with attention to critical aspects of each component, giving relatively more attention to the description of less technical (more process-associated) components of the process, while identifying relevant references for the more technical components. It describes and discusses a series of steps and considerations important to formulating and performing a risk assessment to inform decisions. A major objective of the Framework is to improve the consistency and transparency of risk assessments while enhancing harmonization of approaches across the agency. The Framework aims to maximize the utility of the risk assessment for informing risk management decisions as well as ensuring the most efficient use of resources by aligning the nature and/or scope of the risk assessment with the decision to be made.

1.2.2 Description of the Framework

The *Framework for Human Health Risk Assessment to Inform Decision Making,* at its most basic form, is illustrated in Figure 1-1. This figure reflects the main elements of the Framework and their roles in the risk assessment process in a form that encompasses the broad range of EPA risk assessment contexts. The figure conveys a path from planning and scoping to informing decisions and illustrates that the process provides opportunities for feedback along this path, which may vary among applications.

The main elements of the Framework are discussed in the subsequent four sections of this document. The concept of "fit for purpose" is discussed in multiple sections in keeping with the need for its consideration from planning through execution, to ensure that assessments most meaningfully inform the decision-making process. Sections focused on the other elements are as shown below.

- Planning and scoping and problem formulation are detailed in Section 2 (Planning).
- Exposure and effects assessment and risk characterization are discussed in Section 3 (Risk Assessment).
- Public, stakeholder and community involvement are addressed in Section 4 (Public, Stakeholder and Community Involvement).
- Informing decisions is discussed in Section 5 (Informing Decisions).

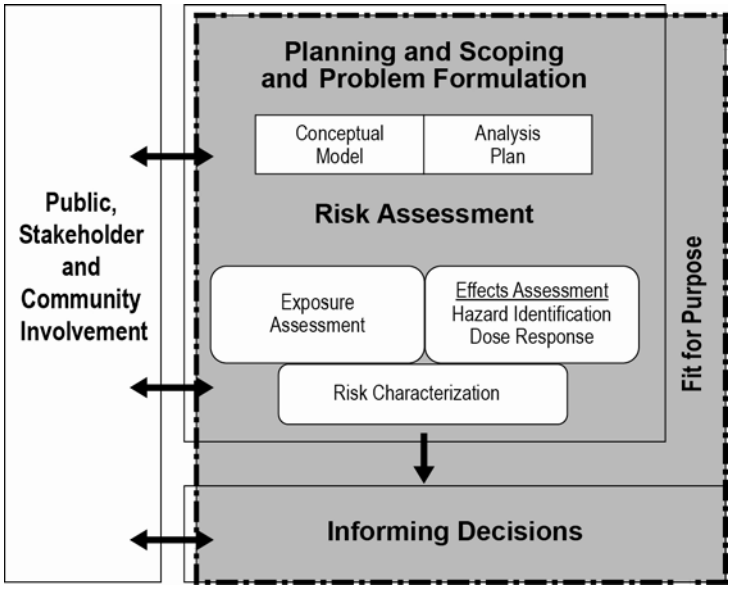

Figure 1-1. Framework for Human Health Risk Assessment to Inform Decision Making.

As described in the Silver Book (NRC 2009), the process begins with a decision to conduct a risk assessment after what is described as a "signal" of potential harm is brought to the EPA's attention. Generally, this would involve a set of existing or potential environmental conditions that appear to pose a threat to human or environmental health. The process outlined in the Framework initiates activities on the assessment of the risk potential of the environmental conditions; that is, after the signal is received.

The initial stage in conducting any EPA risk assessment focuses on carefully characterizing the task to be completed; it includes planning and scoping and problem formulation components. The planning and scoping phase involves understanding the specific environmental issue to be addressed; the legal framework under which any action will be taken; the risk management options; and the public-, stakeholder- or community-specific issues. Specific regulatory or programmatic requirements are considered throughout the planning process. An essential question in this phase is what level of complexity is required (e.g., screening, deterministic, or probabilistic risk assessment) to inform the necessary decision; this consideration is termed here as "fit for purpose." Planning and scoping also includes the identification of resources available to complete the assessment and the formation of a risk assessment team capable of performing the technical analyses that may be needed. The team members may include a project manager, risk assessor, and other staff with the appropriate expertise necessary to address the specific question. Based on the information developed during planning and scoping, the problem formulation is then conducted to develop a conceptual model and incorporate the information into an analysis plan. The analysis plan outlines how the exposure; hazard and dose-response; and risk characterization components of

the risk assessment will be conducted, with consideration of data quality; uncertainty and variability; and public, stakeholder and community involvement for each component as appropriate.

The core risk assessment then is conducted based on the analysis plan developed during problem formulation. The risk assessment phase includes developing the exposure and effects characterizations and integrating those results for presentation as part of the risk characterization. A key aspect of the Framework, "fit for purpose," is consideration of the usefulness of the assessment for its intended purpose, to ensure that the assessment produced is suitable and useful for informing the needed decisions. Attention to this concept is intended to assure, through focused planning and problem formulation and periodic reconfirmation during the process, that the informational needs of the risk managers will be met by the information being generated by the assessment. Rather than a separate step or final check in the process once the risk assessment is completed, an emphasis on the utility of the risk assessment occurs throughout the process. This begins with planning and scoping and includes evaluating the applicability of the risk assessment for informing risk management decisions; these evaluations may take place in several points of the iterative risk assessment process. Thus focus is maintained on the information needs for the risk management decisions by considering such questions as: "Is the assessment achieving its objectives for informing risk management decisions?" If the answer is negative, then the risk assessment team can make adjustments, revisit steps or develop additional information as needed.

The risk assessment may be assessed via independent peer review and/or receiving input from public, stakeholder and community involvement, recognizing that approaches for addressing these different audiences will vary among assessments. Independent peer review helps to ensure the integrity and quality of the scientific and technical aspects of the risk assessment. Where there is a need for such review, it may involve internal or external technical reviewers. Input from the public, internal and external stakeholders, and the affected community(ies) can provide insights that may not otherwise be available to risk managers but should in no way compromise the integrity or quality of the scientific and technical aspects of the risk assessment.

In the risk management phase, risk managers will use the information in the assessment report to evaluate the management options that are identified, thereby Informing Decisions as to the selection of actions appropriate under statutory authority, relevant Executive Orders (e.g., 12898, 13045) and Homeland Security Presidential Directives. Considerations in this phase of the Framework include the risk assessment results for the various options, in light of all appropriate factors. An outcome of this phase may be recognition of the need for additional assessment, leading to iteration of previous steps. This phase also may include development of

a strategy for communicating conclusions with the public, internal and external stakeholders, and affected community(ies). In addition, plans may be made for evaluation of the outcome of any actions taken.

The following case example describes the current process for conducting reviews of the National Ambient Air Quality Standards (NAAQS) (U.S. EPA 2012f). This process includes explicit phases for planning, assessment of currently available scientific evidence (including that on hazard and dose response), risk and/or exposure assessment, and policy assessment and rulemaking. In each phase there is consideration of the need for external peer review and/or public comment. Although each component or step in this example may not rely on precisely the same terms as those used in this Framework document, it illustrates one manner by which the EPA implements the key aspects of this Framework for a program in which risk assessment plays a role in informing regulatory decisions.

Case Example: Reviews of National Ambient Air Quality Standards

EPA's current process for reviewing the National Ambient Air Quality Standards (NAAQS) has four major phases:

(1) planning, (2) science assessment, (3) risk/exposure assessment and (4) policy assessment and rulemaking. The planning phase of the NAAQS review process begins with a science policy workshop to identify issues and questions to frame the review. A draft Integrated Review Plan (IRP) for the review is prepared jointly by the EPA's National Center for Environmental Assessment and the EPA's Office of Air Quality Planning and Standards (OAQPS). The draft IRP is made available for consultation with the Clean Air Scientific Advisory Committee (CASAC) and for public comment. The final IRP is prepared in consideration of CASAC and public comments, and it presents the current plan and specifies the schedule for the entire review, the process for conducting the review and the key policy-relevant science issues that will guide the review.

The second phase of the review, science assessment, involves the preparation of an Integrated Science Assessment (ISA), which provides a concise review, synthesis and evaluation of the most policy-relevant science, including key science judgments that are important to the design and scope of exposure and risk assessments. The ISA provides a comprehensive assessment of the current scientific literature pertaining to known and anticipated effects on public health and welfare associated with the presence of the pollutant in the ambient air, emphasizing information that has become available since the last air quality criteria review to reflect the current state of knowledge. The ISA forms the scientific foundation for the NAAQS review and is intended to provide information useful in forming judgments about air quality indicator(s), form(s), averaging time(s) and level(s).

In the third phase, risk/exposure assessment, staff prepares planning documents that consider the extent to which newly available scientific evidence and tools/methodologies warrant the conduct of quantitative risk and exposure assessments. If warranted, these documents outline a general plan, including scope and methods, for conducting the assessments. When an assessment is performed, one or more drafts of each risk and exposure assessment (REA) document undergoes CASAC and public review prior to completion of final REA(s). The REA provides concise presentations of methods, key results, observations, and related uncertainties.

The review process ends with a policy assessment and rulemaking phase. The Policy Assessment (PA) is a document that provides a transparent OAQPS staff analysis and staff conclusions on the adequacy of the current standards and potential alternatives that are appropriate to consider prior to the issuance of proposed and final rules. The PA integrates and interprets the information from the ISA and REA(s) to frame policy options for consideration by the Administrator. Such an evaluation of policy implications is intended to help ''bridge the gap'' between the agency's scientific assessments, presented in the ISA and REA(s), and the judgments required of the EPA Administrator in determining whether it is appropriate to retain or revise the NAAQS. The PA also is intended to facilitate the CASAC's advice to the agency and recommendations to the Administrator on the adequacy of the existing standards or revisions that may be appropriate to consider, as provided for in the Clean Air Act. In evaluating the adequacy of the current standards and (as appropriate) a range of alternative standards, the PA considers the available scientific evidence and, as available, quantitative risk-based analyses, together with related limitations and uncertainties. The PA focuses on the information that is most pertinent to evaluating the basic elements of NAAQS: indicator, averaging time, form and level. One or more drafts of a PA are released for CASAC review and public comment prior to completion of the final PA. Following issuance of the final PA and consideration of conclusions presented therein, the agency develops and publishes a notice of proposed rulemaking that communicates the Administrator's proposed decisions regarding the standards review. A draft notice undergoes interagency review involving other federal agencies prior to publication. Materials on which this decision is based, including the documents described above, are made available to the public in the regulatory docket for the review. A public comment period, during which public hearings generally are held, follows publication of the notice of proposed rulemaking. Taking into account comments received on the proposed rule, the agency develops a final rule that undergoes interagency review prior to publication to complete the rulemaking process. (Technology Transfer Network NAAQS, U.S. EPA 2012p)

2 Planning

There are multiple challenges and requirements that may arise in conducting a risk assessment. For example, an assessment conducted as part of a regulatory action may have various legal considerations, including the statute under which it is being conducted (e.g., CAA, Clean Water Act [CWA]) and the regulatory program of which it is a part (e.g., 6-Year Review of Drinking Water Contaminants under SDWA, Pesticide Registration Review, Risk and Technology Review program). Such legal considerations may result in the selection of specific aspects of the assessment.

There may also be technical challenges. For example, there may be a need to develop appropriate analytical techniques or to use fate and transport models to estimate the range of contaminant concentrations (and hence, potential exposure). An assessor also may be faced with a lack of toxicity data for specific chemicals or routes of exposure. Information on sensitive populations may be unavailable. Information on the likelihood or timing of combined exposures to multiple chemicals may be difficult to obtain or estimate. Other challenges or considerations may be related to resources, such as the need for access to specific expertise (e.g., modeling). Time constraints associated with decision making and funding—or lack thereof—also may be an issue and should be noted in the analysis plan.

2.1 Planning and Scoping

The planning and scoping phase is an element of the EPA's data quality objectives process and is critical to producing a sound risk assessment that serves its intended purpose (U.S. EPA 1997a, 1998a, 2000b, 2002a, 2003a, 2006f; Presidential/ Congressional Commission on Risk Assessment and Risk Management [PCCRARM] 1997a, 1997b; NRC 2009). EPA's guidance related to the 2001 Data Quality Act emphasizes the important role of systematic planning and attention to data quality objectives (U.S. EPA 2006f). Text Box 2-1 provides a list of EPA references on planning and scoping. This phase may involve a team of

Text Box 2-1: Key EPA References on Planning and Scoping

- *Guidance on Cumulative Risk Assessment. Part 1. Planning and Scoping* (U.S. EPA 1997a)
- *Guidelines for Ecological Risk Assessment* (U.S. EPA 1998a)
- *Science Policy Council Handbook: Risk Characterization* (U.S. EPA 2000b)
- *Lessons Learned on Planning and Scoping of Environmental Risk Assessment* (U.S. EPA 2002a)
- *Framework for Cumulative Risk Assessment* (U.S. EPA 2003a)
- *Guidance on Systematic Planning Using the Data Quality Objectives Process (U.S. EPA 2006f)*

technical experts, such as toxicologists, economists and engineers, as well as risk assessors and risk managers. In some cases, other subject matter experts may include attorneys and community outreach specialists. It also may be informed by external scientific or stakeholder input. Questions addressed in the Planning and Scoping step *(*derived from U.S. EPA 1997a), are as follows:

- What are the overall purposes and general scope of the risk assessment? Are there legal limitations or other legal considerations? If so, what are they?

- What risk assessment products are needed by management for informed decision-making? What is needed for other analyses (e.g., economic analysis)?

- What resources are required, available or pending? Resources could include data or models, funding, personnel, expertise and/or coordination with other organizations.

- Who will be involved in conducting the risk assessment, and what are their roles (e.g., technical, legal or stakeholder advisors)?

- What schedule will be followed? This will include provision for timely and adequate internal and independent external peer review where appropriate.

In general, planning and scoping provides the opportunity for the risk manager(s), risk assessor(s) and others interested in the process to consider the context in which the risk assessment is being conducted and the purpose(s) for which the results will be used. The risk assessment team, in collaboration with the risk managers, also defines what is expected to be covered, considering limitations or constraints (e.g., tools, resources or timing). Planning and scoping is an important first step to ensure that each risk assessment has a clear purpose and well-defined vision. Products from planning and scoping (e.g., the conceptual model and analysis plan) reflect a common understanding and agreement on boundaries and conduct of the assessment by those involved. Several examples of planning and scoping for EPA risk assessments are summarized in Text Box-2-2.

EPA and external advisors have repeatedly recognized that an important part of ensuring the usefulness of each risk assessment is the dialogue between the risk manager and the risk assessment team on the nature of the decision to be informed by the risk assessment (PCCRARM 1997a and b; NRC 2009; U.S. EPA 1998a, 2000b, 2002a, 2003a). This dialogue may include discussion of many topics, for example:

- Basis for the risk assessment (e.g., regulatory requirements, public concern, scientific findings).
- How the information will be used.
- Risk management options.
- Areas of interest and applicable policies.
- Overarching considerations (e.g., environmental justice, children's health, cumulative risk assessment and sustainability as presented in Section 2.1.2).
- Economics.
- Current knowledge.
- Level of effort.
- Plans for use and communication of the information.

Text Box 2-2: Examples of Risk Assessment Planning and Scoping at EPA

- In EPA's review of pesticide registrations, planning and scoping occurs for a series of risk assessments, which although focused on different pesticides are designed to address a common overarching regulatory purpose and assessment scope (Registration Review Update, U.S. EPA 2004g).
- In the planning phase for reviews of NAAQS, an integrated review plan is developed that describes all phases of the review, including the risk/exposure assessment. Additionally, a risk and exposure (REA) planning document is developed as the first step in the REA phase (for an example, planning documents for the particulate matter NAAQS review are available at: Particulate Matter Standards—Documents From Current Review—Planning Documents [U.S. EPA 2011n]).
- Planning and scoping are key components of human health risk assessments conducted under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA; also known as Superfund), and arediscussed in the following guidance documents:
  - Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (U.S. EPA 1988)
  - Human Health: Planning and Scoping (U.S. EPA 2011o)
  - Ecological: Planning and Scoping (U.S. EPA 2011p)
- In EPA's residual risk review of National Emissions Standards for Hazardous Air Pollutants, the planning and scoping step encompasses a set of emissions source categories for which risk assessments are of generally similar scope and basic design while differing in specific aspects of the sources and the chemicals emitted. A general project is described at: Risk and Technology Review (U.S. EPA 2011q), at which a case study risk assessment plan for several source categories also is available.

Figure 2-1 calls out the key elements of planning and scoping in the Framework, each of which are discussed in further detail in subsequent sections. Text Box 2-3 provides context on risk assessment from the Silver Book (NRC 2009).

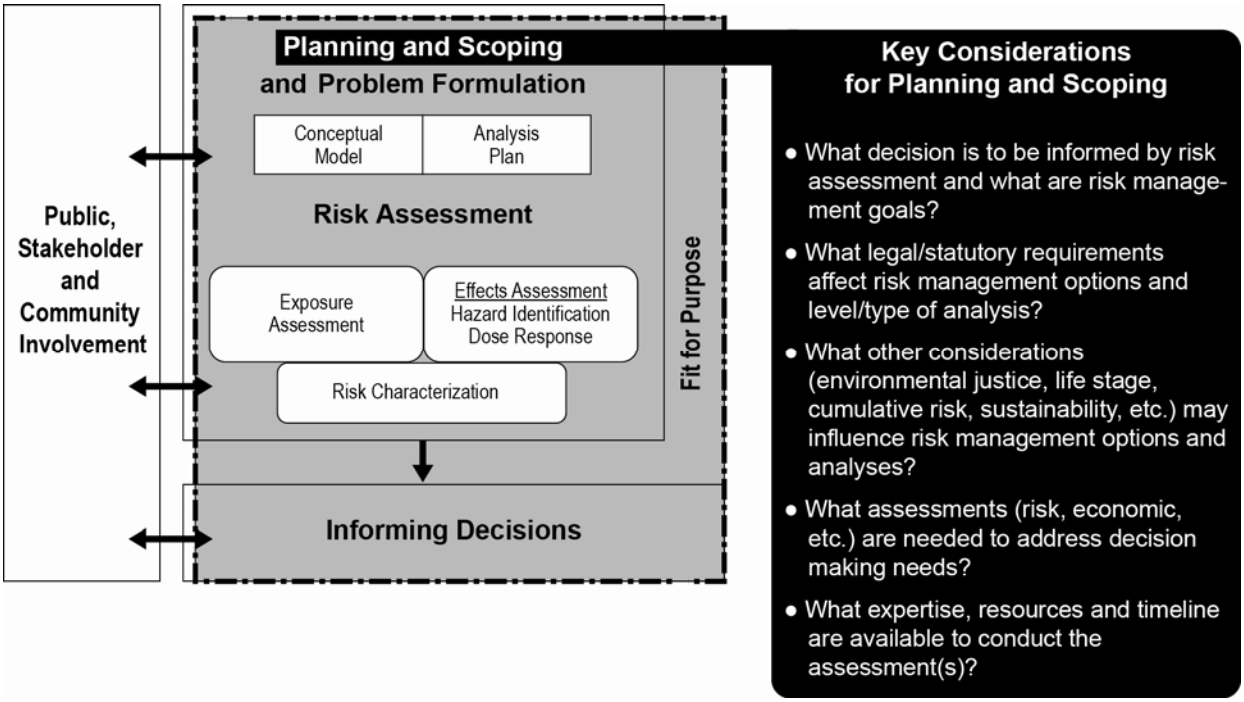

Figure 2-1. Framework for Human Health Risk Assessment to Inform Decision Making: Key considerations for *Planning and Scoping*.

Text Box 2-3: The Silver Book Statements on Utility

"Risk assessments should not be conducted unless it is clear that they are designed to answer specific questions, and that the level of technical detail and uncertainty and variability analysis is appropriate to the decision context" (NRC 2009, 247).

"The technical framework for risk assessment presented in the Red Book should remain intact but should be embedded in a broader framework in which risk assessment is used principally to help to discriminate among risk-management options" (NRC 2009, 256).

- Section 2.1.1 focuses on the need to consider the purpose and context for the risk assessment, noting that different processes may be employed depending on this context and purpose.
- Section 2.1.2 describes important overarching considerations that may affect risk management options.
- Section 2.1.3 discusses consideration of responsibilities, resources, participants and timeline.
- Section 2.1.4 addresses planning for scientific review.
- Section 2.1.5 details public involvement.
- Section 2.1.6 discusses the incorporation of lessons learned from review of previous assessments.

2.1.1 Context, Purpose and Scope

Each human health risk assessment is conducted within a particular context, which may be specific to regulatory or programmatic needs or which may be responsive to environmental events or newly identified circumstances of potential public health concern. Many EPA risk assessments are performed to inform specific decisions that guide the development of regulatory actions. For example, risk assessments commonly inform federal regulations governing the establishment and review of NAAQS; the provision of public drinking water; and the registration of pesticides for U.S. distribution, sale and use. For such risk assessments that are routine and in which the type and level of effort needed is well-established, the degree of additional planning and scoping that is warranted for each individual assessment may not be intensive. In other cases, such as a response to a newly identified environmental concern, careful planning and scoping is essential to the development of a risk assessment that provides information needed to address the concern.

For risk assessments performed within a regulatory context, statutory language or legislative history may impose requirements or restrictions that will need to be considered in scoping the risk assessment; for example, the Food Quality Protection Act (FQPA) includes directives on assessing risk that apply to pesticides in foods and water. In some regulatory contexts, a risk assessment (or some quantitative aspect of it) may be a key input into benefit-cost analyses of alternative regulatory options; these analyses may impose different or additional requirements by comparison to regulatory contexts wherein costs are not considered.

As stressed earlier, risk assessments are most useful when they are designed to answer specific questions with a level of technical evaluation that is appropriate for the decision context (“fit for purpose”). In situations that are perceived to be particularly complex, clear articulation of the overall purpose or end use of an assessment may involve extensive

interaction among the assessment team and the range of stakeholders to establish a common understanding. Explicit consideration of the purpose and decision context in the planning phase will help to ensure the most efficient use of resources in the development of a risk assessment that fulfills its purpose. That is, the utility of and risk assessment is a function of how well it informs the decision for which it is designed.

The planning phase includes explicit consideration of the nature of the assessment question or the hypothesis that the assessment seeks to address, with the goal of developing or clarifying the broad dimensions and elements of the assessment. In this step, the assessment and management objectives are defined clearly.

The particular purpose for which an assessment will be used (e.g., site-specific versus regional or national) often will have significant implications for the scope, level of detail and approach of an assessment. The risk assessment scope can be defined, in a general sense, by the scale of the environmental problem being considered (e.g., local scale vs. national scale) and the regulatory context. One example is a risk assessment intended to investigate the health risks associated with a hazardous waste site that falls under the CERCLA statute, while the scope for this risk assessment may be site-specific, considering multiple receptors, multiple chemicals and multiple pathways of exposure for on- and off-site receptors (depending on the nature of the site). This will differ from the scope for a risk assessment on uses or exposure to a particular chemical, which is conducted to inform a national regulation (such as a National Primary Drinking Water Rule).

Scoping provides a foundation for the problem formulation step. Scope, in this context, refers to the proposed boundaries of the assessment (e.g., what chemical[s] and exposure pathway[s]). The scope is considered with other items (e.g., context, purpose, participants, timeline, resources) in developing the detailed plan for the assessment. At this step, most EPA assessment projects focus on identifying and considering information available in these areas:

- Sources of contaminants.
- Stressors, associated effects, susceptible populations and life stages.
- Routes and pathways.
- Stakeholder concerns.
- Any spatial or temporal aspects of exposure (U.S. EPA 1997a, 2001b).

Consideration of these elements during scoping helps to identify missing information and potential assessment endpoints for the analysis plan. It also provides the basis for an early conceptualization of the problem being assessed and the approaches for assessment. The scoping discussion also should include regulatory context and any additional management or programmatic needs or limitations. At this stage, consideration of the needs of related, quantitative analyses (e.g., cost/benefit analysis or environmental impacts of associated policy

decisions) can contribute to improved efficiency. It also will help to ensure the compatibility of the quantitative analyses considered in the decision-making step described in Section 5. For example, Text Box 2-4 notes considerations pertaining to risk assessment for economic benefits analysis. Information considered and decisions made during the scoping step also shape the development of the conceptual model and the analysis plan (as described in Section 2.2).

In the planning and scoping phase, it also is important to identify any subprocesses that will feed into the risk assessment (e.g., Integrated Risk Information System [IRIS]). It also is important to identify larger processes (e.g., rulemaking that occurs within the agency's Action Development Process) (U.S. EPA 2011r). Furthermore, individual regulatory programs have a formalized process detailing the risk assessment process (e.g., Superfund). These processes may have specific information requirements and timelines, and these may impose additional requirements on the risk assessment process. Depending on the nature of the risk assessment and the importance of the decisions, it may be important to identify how the risk assessment team will interact with other program offices affected by the ultimate decision. Interagency coordination also may be needed.

2.1.2 Overarching Considerations

The purpose and scope of the assessment also should be considered in the context of broad EPA priorities. The extent to which these affect any given risk assessment will depend on many factors, including the risk assessment purpose, scope and regulatory context. These overarching considerations, described below, may not affect all analyses; however, early consideration and discussion of these issues can enhance the utility of the risk assessment. Further, such considerations may receive particular attention in the risk management arena, depending on the decision context. Several current examples of agency priorities that may be important overarching considerations in human health risk assessments are described below. Analysis of the following overarching considerations should involve consultation with experts and offices that focus on them.

Text Box 2-4: Risk Assessment for Economic Benefits Analysis

Although risk assessment and economic analysis often are considered very separate exercises, estimates from or inputs to risk assessment sometimes may serve as inputs into models economists use for the benefits side of benefit-cost analysis. Therefore, when benefit-cost analysis is needed to inform decisions, early communication between the risk assessment and benefits analysis teams, including consideration of the needs of both analyses, can contribute to efficiencies in the assessment designs. Key considerations in economic benefits analyses include:

- Identifying a set of human health endpoints that are economically meaningful; that is, endpoints that can be linked to human well-being and for which the risks can be monetized using economic valuation methods. This may require the risk assessment to model additional outcomes or different outcomes than it would otherwise. For example, benefits analysis incorporates changes in all health effects across the relevant range of exposure, not just the most sensitive. In this case, specific human health endpoints measured in laboratory or epidemiological studies may need to be converted in the risk assessment to additional metrics or normalized in such a manner that the effects can be valued in the economic analysis

- Estimating changes in the probabilities of human health outcomes rather than measures such as reference doses and reference concentrations that do not estimate potential risk (as noted in Chapter 5 of the Silver Book [NRC 2009]).

- Producing expected or central estimates of risk for a given population rather than conservative estimates. The *Science Advisory Board (SAB) Advisory on EPA's Superfund Benefits Analysis* highlights the issue of using conservative risk assessments in benefits analysis (U.S. EPA 2006b).

- Attempting to estimate the "cessation lag" associated with reductions in exposure. That is, the analysis should characterize the time profile of changes in exposures and resulting changes in risks. This concept is more fully described in the *Arsenic Rule Benefits Analysis: An EPA SAB Review* (U.S. EPA 2001a).

- Attempting to characterize the full uncertainty distribution associated with risk estimates. Not only does this contribute to a better understanding of potential outcomes, it also enables economists to incorporate risk assessment uncertainty into a broader analysis of uncertainty. Formal probabilistic assessment of uncertainty in benefits and costs is required by the Office of Management and Budget for some regulations.

Early communication between the teams can help to improve the analyses performed for both purposes. For example, risk assessment estimates may be informative for benefit-cost analysis and also can contribute information and insights into how behavioral changes may affect exposure and, thus, change the risk. Even in cases in which the economists' contribution to the risk characterization is not direct, communication between the teams will improve compatibility of the risk assessment and economic analysis.

Additional information on economic analysis at can be found in *Guidelines for Preparing Economic Analyses* (US EPA, 2010a).

- ***Environmental Justice***

EPA defines Environmental Justice (EJ) as the fair treatment and meaningful involvement of all people regardless of race, color, national origin or income with respect to the development, implementation and enforcement of environmental laws, regulations and policies (U.S. EPA 2012q). Achieving EJ is an agency priority that is factored into every decision (U.S. EPA 2010b). In the risk assessment process, the potential for disproportionate environmental and public health impacts to minority or low-income populations is an important consideration during the problem formulation and planning and scoping stages. There has been discussion on addressing EJ concerns in existing environmental and civil rights laws, their implementing regulations, Executive Order 12898 and the EPA's EJ policies. More information can be found at EPA's EJ website (U.S. EPA 2012a) and in the *Interim Guidance on Considering Environmental Justice During the Development of an Action* (U.S. EPA 2010b). For example, EPA priorities in this area include development of technical guidance and implementation plans. EPA has established the American Indian Environmental Office (AIEO) to coordinate the agency-wide effort to strengthen public health and environmental protection in tribal lands, with a special emphasis on helping tribes administer their own environmental programs. Information on the AIEO and related activities is available at the American Indian Environmental Office website (U.S. EPA 2012g).

- ***Children's Health Protection***

Protecting children's health from environmental pollutants has long been part of the EPA's mission. Children may be proportionately more heavily exposed to some environmental contaminants than adults based on their smaller size and increased consumption per body weight of certain foods. Furthermore, their behavior patterns, such as playing close to the ground and hand-to-mouth activity, also may increase their exposure to contaminants. In addition, they may be more vulnerable to environmental hazards because their organ systems still are developing and undergoing processes that are specifically sensitive to certain chemicals, leading to potential windows of susceptibility. Children also may be less able than adults to metabolize, detoxify and excrete some chemicals.

In 1995, the EPA established its *Policy on Evaluating Health Risk to Children* to ensure that environmental health risks to children explicitly and consistently are evaluated as part of the EPA's risk assessments and that all standards set by the EPA are protective of any heightened risks faced by children (U.S. EPA 1995c). In 1997, Executive

Order 13045 on the Protection of Children from Environmental Health Risks and Safety Risks was issued. This executive order requires all federal agencies to assign a high priority to addressing health and safety risks to children, coordinate research priorities on children's health, and ensure that their standards take into account special risks to children (EO 13045).

Some public health statutes provide for the protection of sensitive populations, population groups or subpopulations. For example, the 1996 Safe Drinking Water Act (SDWA) amendments utilize the term "subpopulation" to describe groups with unique attributes, including those defined by age or life stage. The EPA recognizes that these terms, as used in such statutes, describe groups of people with common attributes, including life stage, which may make them more sensitive or susceptible to the stressor(s) being assessed. The EPA emphasizes the importance of recognizing that childhood encompasses a sequence of life stages through which all members of a population pass. A life stage approach to risk assessment considers the relevant periods of exposure in developmental life stages and subsequent outcomes that may not be expressed until later life stages (U.S. EPA 2005a). Accordingly, EPA's risk assessments consider and take into account, using a variety of approaches, the potential for differences across life stages that may affect risk. This encompasses a statute's use of the term "subpopulation" and instead uses the term "life stage." Text Box 2-5 highlights several guidance documents available to assist in considering of children's health.

Text Box 2-5: Key EPA Children's Health Guidance Documents

- Policy on Evaluating Health Risk to Children (U.S. EPA 1995c)
- *Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens* (U.S. EPA 2005b)
- *Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants* (U.S. EPA 2005c)
- *A Framework for Assessing Health Risk of Environmental Exposures to Children* (U.S. EPA 2006a)
- *Guide to Considering Children's Health When Developing EPA Actions: Implementing Executive Order 13045 and EPA's Policy on Evaluating Health Risks to Children* (U.S. EPA 2006e)
- *Child-Specific Exposures Factors Handbook* (U.S. EPA 2008a)

- ***Cumulative Risk Assessment***

In the EPA's 2003 *Framework for Cumulative Risk Assessment* (U.S. EPA 2003a), cumulative risk is defined as the combined risks from aggregate exposures to multiple agents or stressors. Several key points are made in this definition. First, cumulative risk explicitly involves multiple agents or stressors. Second, the "agents or stressors" are not limited to chemicals; stressors may, in some cases, also include biological or physical agents as well as activities that, directly or indirectly, alter or cause the loss of a necessity (such as habitat) or adversely influence health or increase susceptibility to other stressors. Third, this definition requires that the risks from multiple agents or stressors be combined.

This does not necessarily mean that the risks should be added; rather the term "combining" may mean that some analysis is conducted to determine how the risks from the various agents or stressors interact. An assessment that covers a number of chemicals or other stressors but merely lists each chemical with a corresponding risk without consideration of the other chemicals possibly present is not an assessment of cumulative. Further, cumulative risk assessment is an analysis, characterization and possible quantification of the combined risks to health or the environment from multiple agents or stressors. One key aspect is that the specific characteristics of a given cumulative risk assessment will vary depending on scientific and regulatory needs. For example, a cumulative risk assessment need not necessarily be quantitative and is frequently used in place-based assessments. The Office of Pesticide Programs' cumulative assessments under the FQPA and those used by the Office of Water for pesticides are legally defined in the *Guidance on Cumulative Risk Assessment of Pesticide Chemicals That Have a Common Mechanism of Toxicity* as applying only to chemicals with a common mechanism of action (U.S. EPA 2002d). Other environmental statutes, such as the National Environmental Policy Act and Clean Air Act (CAA) (e.g., hazardous air pollutant aspects), also include various requirements for cumulative and multiple pollutant analyses.

- ***Sustainability***

Sustainability is defined in Executive Order 13514 as a process "to create and maintain conditions, under which humans and nature can exist in productive harmony, that permit fulfilling the social, economic, and other requirements of present and future generations" (Executive Order 13514, 74 *Federal Register* 52126 [October 8, 2009]). Sustainability is based on the simple principle that everything humans need for survival and well-being depends, either directly or indirectly, on the natural environment. The concept entails consideration of how we meet society's needs of today while ensuring

future generations can meet their own. Sustainability is important to ensure that humans have, and will continue to have, the water, materials and resources to protect human health and the environment. EPA efforts in the area of sustainability practices include approaches such as labeling green products, promoting green chemistry, and engineering and managing materials rather than creating waste. Text Box 2-6 includes EPA resources related to sustainability.

The planned risk assessment may provide the risk manager with information relevant to the sustainability of proposed risk management options. Issues to consider include the full life cycle impacts of the agent, stressor or remedy under review, as well as the potential unintended consequences of decisions. *Sustainability and the U.S. EPA* (NRC 2011) contains a detailed discussion of how a framework for sustainability relates to risk assessment and risk management.

Text Box 2-6: Resources on Sustainability and Life Cycle Assessment

- EPA/Office of Research and Development (ORD) Sustainability Program (U.S. EPA 2011e)
- EPA/ORD National Risk Management Research Laboratory Life Cycle Assessment Website (U.S. EPA 2011f)
- *Sustainability and the U.S. EPA* (NRC 2011)

Thorough analysis of the above overarching considerations involves consultation with experts and offices that focus on them. As appropriate, the risk assessment team should be expanded to include individuals with the expertise needed for their full consideration.

2.1.3 Responsibilities and Resources

The planning process includes the initial allocation of responsibilities for members for the assessment team as well as clarification of the interactions of the risk assessment team with the risk managers and stakeholders. It is important that planning be a transparent effort so that the basis for the final environmental decision (and the alternative options, limitations and approaches considered but not selected) is clearly understood early in the process by the public and regulated community. A team approach to planning risk assessments is essential (NRC 2009, U.S. EPA 2002a).

The composition of the risk assessment team is dependent on the nature of the problem. At a minimum, the team comprises individuals with the necessary scientific expertise, as well as risk managers and other personnel as appropriate. Depending on the level of complexity of a risk assessment and the context for its conduct, a multidisciplinary approach is often necessary. Some disciplines that may be pertinent include: toxicology; epidemiology; hydrogeology; fate and transport modeling (e.g., indoor and outdoor air, surface and drinking

water); computer science (including geographic information systems [GIS], data management); chemistry; biology; various engineering fields (e.g., chemical, environmental, mechanical, industrial, civil); economics; sociology; statistics and communications. Lawyers and policy makers also may be called on to contribute to risk assessment planning. Depending on the context and process in which the risk assessment is conducted, specific expertise may be needed to develop particular tools, data or analyses. Coordination with other federal, tribal and state agencies and with other stakeholders also may be appropriate, depending on the type of assessment being conducted.

Different members of the assessment team will provide expertise for specific elements of the planning discussion. For example, the risk manager may identify the regulatory needs of the assessment, time frames and quantity of funds available for the assessment. The site assessment team would focus on evaluation of the current and future concentrations of the contaminants in various media. An exposure assessor may help the team consider the nature, fate and transport of the contaminants; sources, routes, timing and pathways; the extent of contamination; and the availability of data, either at the national or local level. Other specialists may provide information on topics such as funding levels and sources, contractor requirements and relevant interagency agreements.

It also is important to describe or establish the resources in terms of staffing, budget and time for the assessment as part of the planning phase. These aspects need to be considered in the development of the analysis plan, as they can affect the scope and approach for the assessment. The timeline for the assessment is developed, taking into account critical legal and management time frames, as well as any need to meet external deadlines or coordinate with the schedules of other organizations (including critical stakeholders or external review bodies). When there is extensive stakeholder involvement, it is especially important that this be reflected in the budget and schedule and understood by all participants (U.S. EPA 2003c). When evaluating the need for human data, bioethics should be considered (see the EPA Office of the Science Advisor website on Ethics, Regulations, and Policies; U.S. EPA 2012h).

2.1.4 Decision Points and Scientific Peer Review

Various stages in the assessment process can provide decision points and opportunities for scientific review and stakeholder involvement. For example, completion of a draft conceptual model and analysis plan, or an iteration of the risk assessment, may be useful points for focused discussion between the risk assessor and risk manager and/or for scientific review and public, stakeholder and community involvement.

At such decision points, internal review and checks for quality of the assessment are important. Other types of review also may be necessary, depending on the scope and purpose

of the assessment. For example, an independent external peer review may be an important element. Also some assessments (e.g., those developed for NAAQS, pesticide registration decisions, or through the IRIS program) include a public review step, often coincident with the scientific review step.

Scientific peer review is a process used to provide a critical evaluation of a specific agency scientific and/or technical work product. The EPA has published a *Peer Review Handbook* that describes the types and extent of reviews as well as the documentation needed to fulfill EPA requirements (U.S. EPA 2006c). (The *Peer Review Handbook* incorporates the guidance provided in the Office of Management and Budget's [OMB] 2004 *Final Information Quality Bulletin for Peer Review*, [OMB 2004]). The *Peer Review Handbook* makes distinctions among peer involvement, peer consultation and peer review. Peer review is a documented process conducted to ensure that activities are technically supportable, competently performed, properly documented and consistent with established quality criteria. Peer review may be internal (to the EPA) or external. It is conducted by qualified individuals or organizations that are independent of those who performed the work and who are collectively equivalent in technical expertise (i.e., peers) to those who performed the original work. Peer review usually involves a one-time interaction, or limited number of interactions, by the independent peer reviewers with the authors of the work product. An assessment also may benefit from other types of input (such as peer involvement and public comment) that differ from peer review (U.S. EPA 2006c). Planning for the assessment includes discussion of whether and what types of reviews will be included, in light of the context and constraints for the assessment, including schedule and resources.

Consideration of the need for and timing of peer review steps is encouraged in the early stages of the project or methods selection and/or as part of the culmination of the work product, as appropriate (U.S. EPA 2006c). During the assessment planning and scoping process, the team will need to determine whether any of the analyses or products of the assessment need peer review and if so what level of peer review may be required and at what stage in the process. Evaluating peer review requirements early will help ensure that adequate resources are allocated. In addition, peer review considerations are an integral part of setting assessment milestones and schedules. EPA's *Peer Review Handbook* (U.S. EPA 2006c) provides detailed guidance for determining when peer review is required and how to plan and implement a peer review. The principle underlying the agency's peer review policy is that "all influential scientific and technical work products used in decision-making will be peer reviewed" (U.S. EPA 2006c, 30). The *Peer Review Handbook* stresses transparency in all parts of the peer review process, and EPA supports systems (e.g., Science Inventory) for documentation and disclosure of peer review plans and products (U.S. EPA 2012c).

2.1.5 Public, Stakeholder and Community Involvement

The planning phase also includes consideration of opportunities for involvement and/or review by the public and by specific stakeholders. EPA's public involvement policy (U.S. EPA 2003c), a framework for implementing it (U.S. EPA 2003d) and other references are available at the EPA's Public Involvement Policy and Related Documents website (U.S. EPA 2012d); public, stakeholder and community involvement are described at greater length in Section 4 of this Framework document. Depending on the context for the risk assessment and overarching process governing its conduct, risk assessment products also may be made available for public comment, as required or practical under specific regulatory programs. Public, stakeholder and community involvement may be initiated through a formal notice of availability of the risk assessment and opportunity for public comment, and/or there may be a formal period for public comment associated with a regulatory decision that was informed by the risk assessment. Public commenters generally include a wide range of interested parties, both experts and nonexperts, but they are not expected to provide the kind of independent, expert information and in-depth analyses obtained from the peer-review process (U.S. EPA 2006c). The involvement of public, stakeholders and communities (defined in Text Box 2-7) can help ensure that the assessment process is transparent and that risk-informed decision-making proceeds effectively, efficiently and credibly (NRC 2009). Such involvement also may facilitate development of sustainable solutions (NRC 2011).

The roles for stakeholders are considered during the planning step. Deciding how and when to involve stakeholders will depend on the context for and nature of an assessment. Depending on the project, a list of critical points for stakeholder input, such as discussions on purpose, scope and approach, may be defined (U.S. EPA 2003b).

Stakeholders may be from programs within EPA; other federal agencies; state,

Text Box 2-7: Definitions of "Public," "Stakeholder" and "Community"

- *Public Involvement* refers to the full range of activities that the EPA uses to engage the American people in the agency's decision-making process (U.S. EPA 2011g).
- *Stakeholders* are individuals or representatives from organizations or interest groups that have a strong interest in the agency's work and policies (U.S. EPA 2011g).
  - *Internal Stakeholders* include EPA program offices or regions (U.S. EPA 2007d).
  - *External Stakeholders* include the public, affected industries, public health or environmental organizations, other federal agencies, states, and local and tribal governments (U.S. EPA 2007d).
- *Community Involvement* is the process of engaging in dialogue and collaboration with community members (U.S. EPA 2011h).

local and tribal governments; regulated industries; the regulated community; community members affected by an environmental release; and members of the general public. PCCRARM (1997a and b) suggests the following questions to identify potential stakeholders:

- Who might be affected by the assessment?
- Who has information and expertise that might be helpful?
- Who has been involved in similar risk situations before?
- Who has expressed interest in being involved in similar decisions before?
- Who might reasonably think that they should be included?

Assessments that require short-term, low-budget efforts or preliminary screening assessments may not have the scope, time or resources for extensive public, stakeholder and community involvement. Community involvement, however, is important to many community-based or site-specific assessments; for a highly controversial location-specific assessment, early and extensive public, stakeholder and/or community involvement can be essential to the success of the risk assessment and the risk management options informed by the assessment.

The *Framework for Implementing EPA's Public Involvement Policy* (U.S. EPA 2003d) provides general guidance for scoping a public involvement process and identifies the following seven basic steps for conducting effective public involvement:

1. Plan and budget for public involvement activities.
2. Identify the interested and affected public.
3. Consider providing technical or financial assistance to the public to facilitate involvement.
4. Provide information and outreach to the public.
5. Conduct public consultation and involvement activities.
6. Review and use input and provide feedback to the public.
7. Evaluate public involvement activities.

2.1.6 Past Experiences and Assessments

Review of past experiences and assessments is an important part of planning and can contribute to the development of a more robust analysis plan and improve the usefulness of the assessment. For example, in the review of existing national standards, consideration of previous assessments and aspects of them where newly available information or tools may impact risk estimates can inform the planning stages for a new risk assessment, including conclusions regarding what new insights it might be able to provide. Further, such explicit

consideration of the potential value added of a new assessment may improve the efficiency of the associated risk-based decision making. Additionally, valuable lessons can be learned or information obtained from assessments performed for conceptually similar situations (e.g., previous analyses for a similar industry, analog or chemical). Assessments by other agencies (federal, state and international) also may be useful to study. Understanding past risk assessment decisions and associated risk assumptions within a specific regulatory program is important to assuring the usefulness of a given risk assessment in the decision making process. Further, notable distinctions of the current assessment from previous assessments (e.g., new health effects evidence or technical approaches) may be important to describe in the analysis plan for the current assessment, as well as in the risk characterization.

2.2 Problem Formulation

Problem formulation is the part of the risk assessment planning process that systematically identifies the major factors to be considered in a particular assessment. It draws from the regulatory, decision-making and policy context of the assessment and informs the technical approach of the assessment. EPA's *Guidelines on Ecological Risk Assessment* defines problem formulation as the analytical phase of the assessment wherein **"**the purpose for the assessment is articulated, the problem is defined, and a plan for analyzing and characterizing risk is determined" (U.S. EPA 1998a, 2). The formalization of problem formulation in the current Framework is a significant step in improving risk assessment processes.

An important outcome of the problem formulation step is a conceptual model that identifies the stressor(s), the exposed population(s) and the endpoint(s) that will be addressed in the risk assessment as well as the relationships among them. Assessment endpoints, as well as the exposed population(s), are more limited in variety in human health risk assessment than is the case in ecological risk assessment (U.S. EPA 1998a). Many agency regulatory programs have established specific human health risk assessment endpoints, often linked to statutory requirements. For example, risk assessments for the Superfund and Hazardous Air Pollutant programs, among others, include among their assessment endpoints estimates of lifetime individual cancer risk associated with the particular sources or sites assessed (U.S. EPA 1991a, 1999c). Alternatively, risk assessments performed for reviews of the NAAQS often focus on population risk metrics particular to the health effects evidence for the air pollutant being assessed. The analysis plan, the final product of problem formulation, is developed in light of the conceptual model, any programmatically established assessment endpoints and other planning considerations described in Section 2.1. Figure 2-2 highlights the problem formulation steps within the Framework.

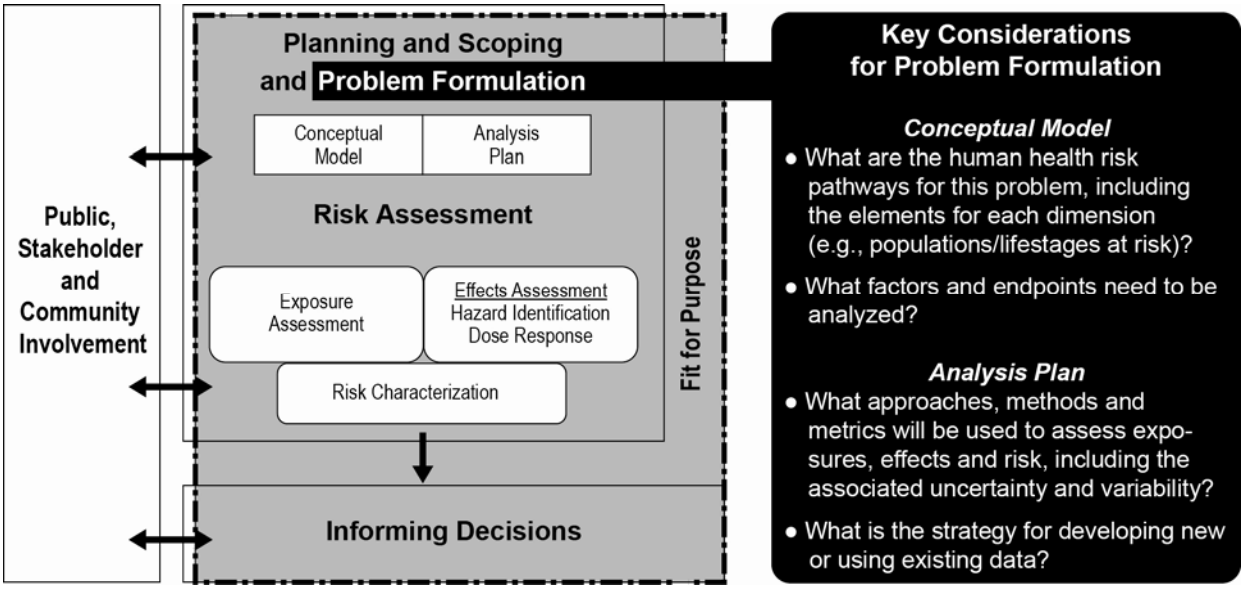

Figure 2-2. Framework for Human Health Risk Assessment to Inform Decision Making: Key Questions and Considerations for *Problem Formulation.*

2.2.1 Conceptual Model

A conceptual model includes both a written description and a visual representation of actual or predicted relationships between humans (populations or population segments) and the chemicals or other stressors to which they may be exposed. The complexity of the conceptual model depends on the complexity of the problem; this may be related to the number of stressors, exposure pathways or assessment endpoints; the nature of effects; and/or the characteristics of the exposed population(s) or life stage(s). Generally, the conceptual model identifies factors and endpoints that will be analyzed in the risk assessment. It also addresses those items that may not be analyzed in the risk assessment, the recognition of which may be important in the overall decision-making process. For example, although a risk assessment for a particular stressor may focus on exposure pathways or media relevant to the regulatory decision being faced (e.g., ingestion of drinking water), the conceptual model also will describe the role of other pathways (e.g., consumption of fish), ensuring appropriate characterization of and context for the assessment results.

The visual representation of the conceptual model and the associated narrative describe the basic rationale for pursuing a particular course of action in the assessment. It can provide documentation of decisions for future reference during risk assessment and can be useful in characterization and communication of the risk management decision. The conceptual model also is valuable as a risk communication tool both within the agency and in interactions with the public. The conceptual model is a scientific or technical work product that can include the following:

- The rationale for selecting the sources, stressors, exposure pathways, receptors, exposed populations, endpoints or risk metrics including effects.
- The basis for the model development.
- The scientific implications of additional data gathering.

A general conceptual model (visually represented in Figure 2-3) defines the key elements for the problem to be assessed and shows pathways and routes of exposure between the stressors and effects (endpoints) for human receptors. The visual representation of the conceptual model is a diagram that may include the following types of elements:

- Source(s) of stressors of interest in the environment (e.g., releases from a leaking storage tank, waste material poured on the ground).
- Types of stressor(s) that may be physical, chemical and/or biological.
- Exposure pathways, including fate and transport processes by which stressors may move from the original point of release through the environment (e.g., a chemical in soil might penetrate down into groundwater or might volatilize into air) and the interaction by which populations or individuals are exposed (e.g., ingestion of contaminated water, inhalation of chemicals in air, dermal contact with contaminated soil).
- Receptors, which may be groups of individuals or populations identified by common characteristics, including life stage (e.g., general population, infants, local residents near site of concern, adult workers, recreational visitors, populations/life stages with unique exposures and/or susceptibilities to stressors).
- Types of endpoints to be considered (e.g., cancer, asthma, IQ decrement or developmental effects).
- Risk metrics (e.g., cases of disease or disease incidence, hazard quotient, magnitude of effect or margin of exposure).

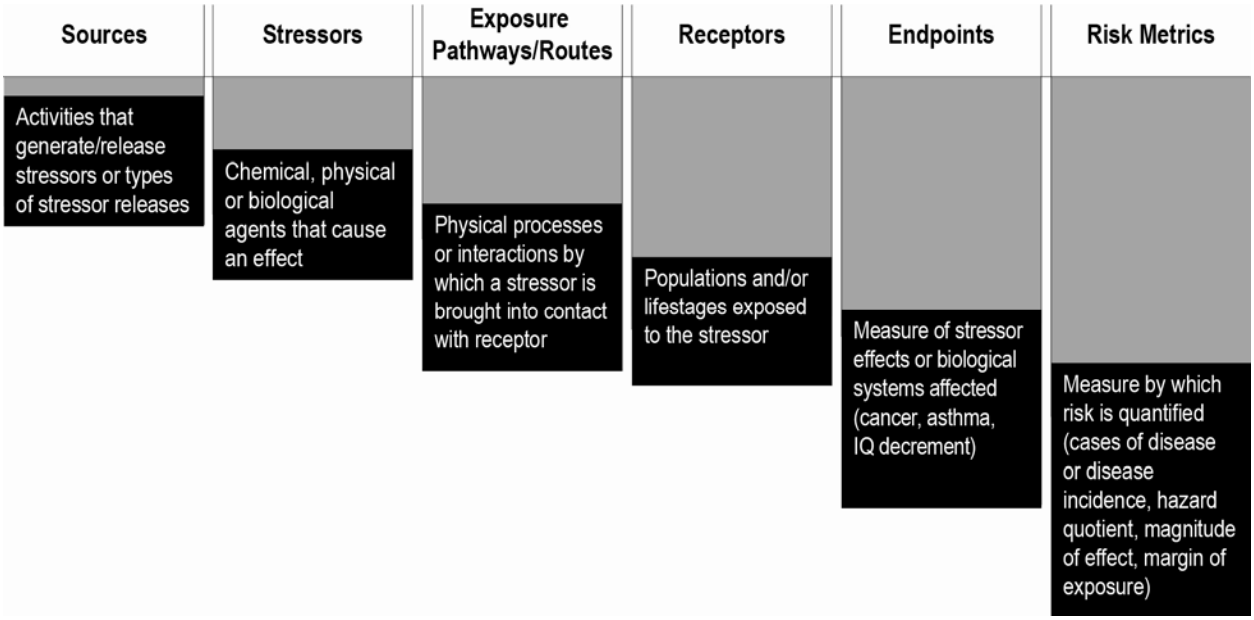

Figure 2-3. Example of a Generalized Conceptual Model With Examples of Possible Dimensions and Linkages (adapted from U.S. EPA 2002a, 2003a).

Conceptual models are used to plan the risk assessment and associated data collection activities, and they may be periodically revised as data become available. Conceptual models consist of two principal components: (1) a set of risk hypotheses that describe predicted relationships among stressor, exposure and health endpoint/response, along with the rationale for their selection; and (2) a diagram that illustrates the relationships presented in the risk hypotheses. Text Box 2-8 identifies EPA guidance documents with more information about conceptual models; references for examples of conceptual models from various EPA risk assessments are in Text Box 2-9.

Text Box 2-8: EPA Resources on Conceptual Models

- *Ecological Risk Assessment Guidelines* (U.S. EPA 1998a, 40–41)
- *Lessons Learned on Planning and Scoping for Environmental Risk Assessments* (U.S. EPA 2002a, 5–6)
- *Science Policy Council Handbook: Risk Characterization* (U.S. EPA 2000b, 29–30, B-21, B-23).
- *Cumulative Risk Assessment Framework* (U.S. EPA 2003a, 25–27)
- *Framework for Assessing Health Risk of Environmental Exposures to Children* (U.S. EPA 2006a, 3-5 to 3-9)

Figure 2-4 presents a diagram illustrating a detailed conceptual model of multiple exposure pathways and receptors potentially affected

by multiple sources of chemical stressors; this model was designed by EPA Region 8 (U.S. EPA 2012e) for the analysis of Superfund sites contaminated with PCBs.

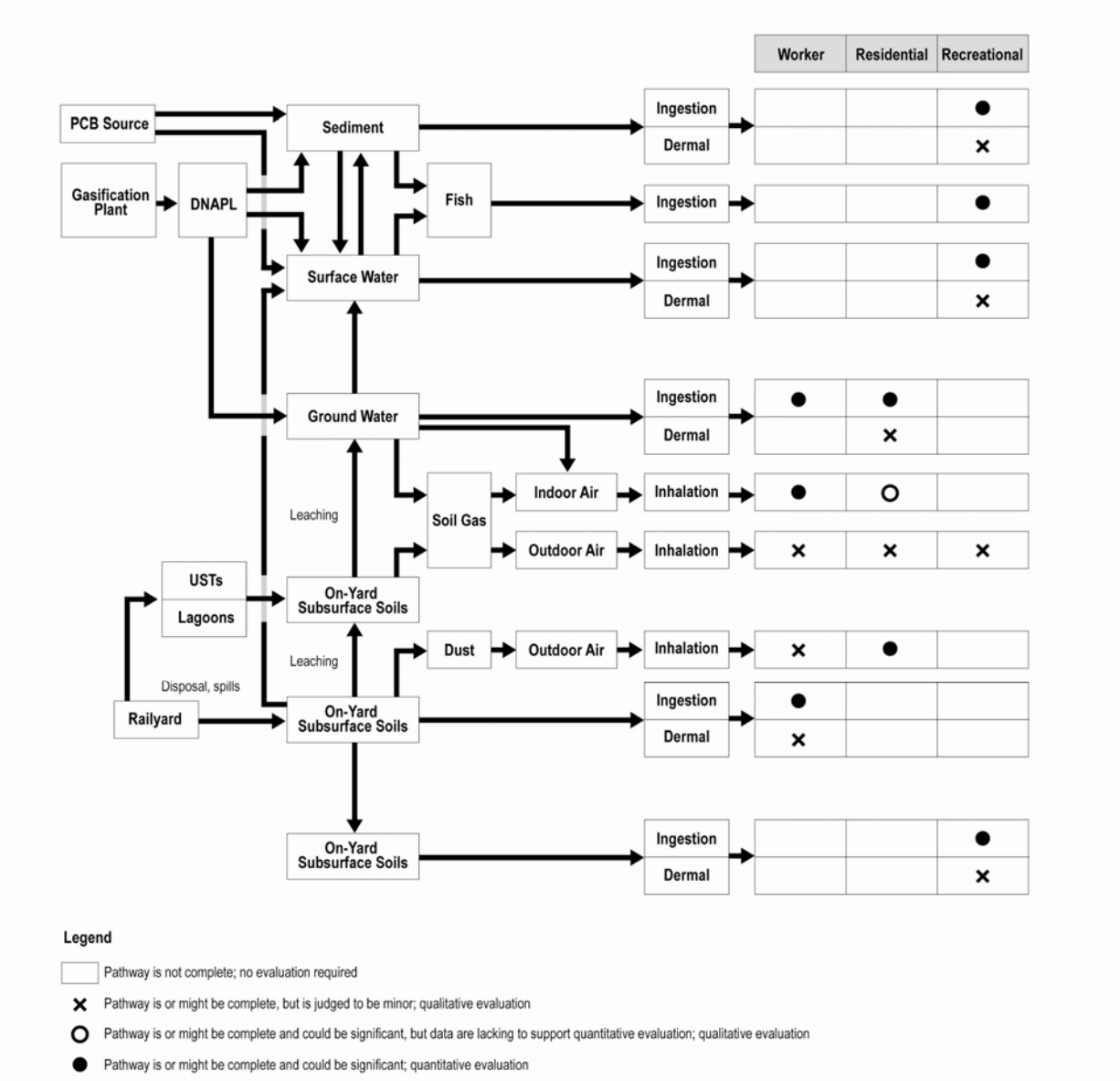

Figure 2-4. Example Conceptual Model of Exposure Pathways for Multiple Receptors to Multiple Stressors for Superfund Site Assessment (Region 8 Site Conceptual Model; U.S. EPA 2012e).

Text Box 2-9: Examples of Conceptual Models in EPA Risk Assessments

- Conceptual model to inform lead NAAQS risk assessment (U.S. EPA 2007c, 2-1 to 2-19)
- Case Study on Concentrated Animal Feeding Operations (U.S. EPA 2002b, Appendix B)
- Re-registration of Pentachlorophenol (U.S. EPA 2002c, Appendix C)

2.2.2 Analysis Plan

The analysis plan is the final stage of problem formulation (U.S. EPA 1989, 2000a, 2002a, 2003a). This is the implementation plan for performing the risk assessment and addressing the agency's needs. It describes agreements made during the planning and scoping process and provides details on technical aspects of the risk assessment, as described below. In some cases, the plan will specify a phased or tiered risk assessment approach to facilitate management consideration; scientific review; and/or public, stakeholder and community involvement.

During analysis planning, hypotheses about the relationships described in the conceptual model are evaluated to determine how they will be assessed using available and new data. Although the conceptual model may identify a larger set of pathways and relationships, the analysis plan focuses on the pathways and relationships that will be pursued during the analysis phase. The rationale for selecting or omitting pathways and relationships is incorporated into the plan, as is acknowledgement of data gaps and uncertainties. The analysis plan also may include a consideration of how the level of confidence (or precision) needed for the management decision compares with that expected from available analytical approaches; this is done to determine data needs and evaluate which analytic approach is best. When new data are needed, the feasibility of obtaining them is evaluated. The analysis plan is most useful when it contains explicit statements of how measures were selected, what the measures are intended to evaluate, and which analyses they support.

The analysis plan may include these components:

- The assessment design and rationale for which relationships are addressed.
- Description of the data and information, methods and models to be used in the analyses (including uncertainty analyses).
- The associated data gaps and limitations.

Analysis plans may be brief or extensive depending on the assessment and its level of complexity. For assessments performed for some purposes (e.g., the EPA's new chemical assessments under the Toxic Substances Control Act [TSCA]), a standard analysis plan is

established for the set of assessments to be conducted for the same purpose and regulatory context. The type or design of analyses to be conducted is influenced by statutory requirements or programmatic objectives, data availability, resources and limitations, and the purpose and scope of assessment. Thus, the risk assessment designs will vary, which will be reflected in the development of the plan. For example, the EPA performs different types of risk assessments that range from deterministic scenario-based assessments to more complex probabilistic population modeling analyses. Assessments may be screening-level or more robust, depending on various factors, including the specific resources available for the assessment. Further, the organization of the analysis plan may vary with the purpose and context for the assessment. In all cases, the plan addresses the quality of data to be used; assessments of exposure, hazard and dose-response; and risk analyses, including analyses of uncertainty and variability. These areas are described in the subsections below.

2.2.2.1 *Data Quality*

In developing and implementing the analysis plan, several aspects of the data and information to be used in the assessment are evaluated, including the following (U.S. EPA 2003a):

- **Soundness.** The extent to which the scientific and technical procedures, measures, methods or models employed to generate the information are reasonable and consistent with the intended application.
- **Applicability and utility.** The extent to which the information is relevant for the intended use.
- **Clarity and completeness.** The degree of clarity and completeness with which the data, assumptions, methods, quality assurance, sponsoring organizations and analyses employed to generate the information are documented.
- **Uncertainty and variability.** The extent to which the variability and uncertainty (quantitative and qualitative) in the information or in the procedures, measures, methods or models are evaluated and characterized.
- **Evaluation and review.** The extent of independent verification, validation, and peer review of the information or of the procedures, measures, methods or models.

Evaluation of data quality requires context. Depending on how and for what purpose the data will be used, the same data may be acceptable in one situation and unacceptable in another. EPA has established a Quality System (U.S. EPA 2011i) to ensure that environmental programs and decisions are supported by data of the type and quality needed and expected for their intended use. A critical aspect of this system involves the use of data quality objectives for the development of new data and evaluation of existing data. Aspects of a risk assessment for which data quality may be important to consider in the analysis plan include:

- The collection, evaluation and use of environmental data, including distributions of contaminants, considerations of information on sources of variability, tolerance for potential decision errors and/or precision requirements (U.S. EPA 2011i).
- Development, evaluation and use of computer or mathematical models including evaluation of uncertainty and variability.
- Use of secondary data collected for purposes other than the planned assessment.

Analysis plans also consider data quality guidance specific to the program for which the assessment is being conducted. Data quality resources are given in Text Box 2-10.

Text Box 2-10: Data Quality Resources

- EPA Requirements for Quality Assurance Project Plans (U.S. EPA 2001c)
- EPA's Quality System for Environmental Data and Technology (U.S. EPA 2011i)
- Superfund Quality Assurance/Quality Control (U.S. EPA 2011j)
- Resources for Planning New Data Collections (U.S. EPA 2011k)

2.2.2.2 *Exposure Assessment*

The analysis plan describes the approach (quantitative or qualitative) to be employed for characterizing exposure in the risk assessment. See Text Box 2-11 for EPA resources on exposure assessment. This exposure assessment plan is developed by drawing on the information, considerations and decisions represented by the conceptual model for human health (as described in Section 2.2.1 above). Accordingly, the plan describes the exposure assessment elements specified in the conceptual model, including the relevant routes and pathways, frequency and duration of exposures, populations and life stages, and assessment metrics. The plan also defines the methods, models and information or data that will be used, as well as the environmental conditions or scenarios (e.g., conditions associated with alternative standards or clean-up levels for environmental contaminants or different

Text Box 2-11: EPA Exposure Assessment Resources for Human Health

- *Guidelines for Exposure Assessment* (U.S. EPA 1992a)
- *Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants* (U.S. EPA 2005c)
- *A Framework for Assessing Health Risk of Environmental Exposures to Children* (U.S. EPA 2006a)
- *Highlights of the Child-Specific Exposure Factors Handbook* (U.S. EPA 2009)
- *Exposure Factors Handbook* (U.S. EPA 2011a)

uses for a pesticide). Key limitations, assumptions and uncertainties associated with the tools and approaches are recognized in the analysis plan.

The plan also identifies the approach for describing exposure variability. For example, the approach might specify a deterministic scenario-based assessment to provide point estimates for a particular population (e.g., long-term residents or high-end consumers of a particular food such as fish) or life stage (e.g., very young children). In contrast, a more complex probabilistic population modeling assessment might provide a distribution of estimates for the specific population assessed; an example would be children living in three specific urban areas under environmental conditions associated with a current standard or food consumption patterns for specific age groups based on dietary survey information. The rationale for the selected approach is described in the plan as well as the extent to which estimates will be developed for the central and upper percentiles of the population being assessed. Further, the plan generally delineates the approaches for assessing uncertainty and variability in the exposure estimates.

2.2.2.3 *Hazard Identification and Dose-Response*

The analysis plan specifies the strategy for characterizing hazard and dose-response relationships for the stressors being assessed. For example, the strategy may include use of publicly available hazard identification and dose-response assessments that already have been prepared (in accordance with agency guidance and methods), such as those in the EPA's IRIS database. Alternatively, the strategy may specify a different approach for characterizing the hazard of the identified stressors and describing the dose- or concentration-response relationship that will be used in the risk assessment.

The EPA has established a variety of guidance documents for all components of risk assessment (see Text Box 2-12). These documents address evaluation of particular types of toxicity, dose-response assessment and endpoint selection; the consideration of information on mode of action (MOA) or pathways of toxicity; the role of toxicokinetic information; and factors influencing sensitivity and susceptibility (e.g., nutrition, life stage, exposure characteristics and disease state). Rather than describing in detail the steps in effects assessment, the analysis plan may refer to these or other published documents.

Text Box 2-12: EPA Resources on Hazard Identification and Dose-Response Assessment

- *Guidelines for the Health Risk Assessment of Chemical Mixtures* and *Supplementary Guidance for Conducting Health Risk Assessment of Chemical Mixtures* (U.S. EPA 1986a, 2000a)
- *Guidelines for Developmental Toxicity Risk Assessment* (U.S. EPA 1991)
- *Methods for Derivation of Inhalation Reference Concentrations (RfCs) and Application of Inhalation Dosimetry* (U.S. EPA 1994)
- *Guidelines for Reproductive Toxicity Risk Assessment* (U.S. EPA 1996)
- *Guidelines for Neurotoxicity Risk Assessment* (U.S. EPA 1998b)
- *A Review of the Reference Dose and Reference Concentration Processes* (U.S. EPA 2002e)
- *Guidelines for Carcinogen Risk Assessment* (U.S. EPA 2005a)
- *Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens* (U.S. EPA 2005b)
- *A Framework for Assessing Health Risk of Environmental Exposures to Children* (U.S. EPA 2006a)

2.2.2.4 *Risk Characterization*

The analysis plan identifies and describes the strategy or approach for combining exposure information with hazard and dose-response information to generate risk estimates or other measures for characterizing health risk. The approaches may vary widely, depending on other considerations (described above for the planning phase), in the following manners: purpose and context for the assessment, the available information, and resources and timeline for the assessment. Risk analyses might range from deterministic scenario-based assessment to a probabilistic population modeling assessment. Either of these approaches may yield estimates for general population risk or for specific, defined groups within the general population. For estimates of individual risk, calculations can consider central tendency and the upper end of distribution. The upper end of the distribution used for risk characterization may vary depending on the needs of the assessment (e.g., the 90th, 95th or 99th percentiles) (U.S. EPA 1992a).

Assessments may be screening-level or more robust depending on the purpose and availability of data. Decisions on the type or design of the assessment are influenced by statutory requirements or programmatic objectives, data or resource availability and limitations, and purpose/scope of the assessment. Types of risk assessment metrics that might be considered for the assessment include:

- Incidence of specific health outcomes.
- Risk of specific health outcomes.

- Occurrences of exposures above health-based benchmarks or comparison points.
- Potential for occurrence of exposure above health-based benchmarks.
- Margins of exposure between a point of departure for an effect and a measured or estimated environmental level.
- Hazard quotients for specific exposure scenarios (hazard quotients are measured or estimated exposure levels divided by a reference value).

In defining the analyses to be performed, the plan also describes the associated limitations, assumptions and plans for assessment of uncertainty and variability. Other EPA resources for risk analysis are described in Text Box 2-13.

Text Box 2-13: Other Risk Analyses Resources

- *Guidelines for the Health Risk Assessment of Chemical Mixtures* and *Supplementary Guidance for Conducting Health Risk Assessment of Chemical Mixtures* (U.S. EPA 1986a, 2000a)
- *Risk Assessment Guidance for Superfund* (U.S. EPA 1989, 1991, 1998a, 1999a, 2001d, 2004a, 2009)
- *Science Policy Council Handbook: Risk Characterization* (U.S. EPA 2000b)
- *Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health* (U.S. EPA 2000d)
- *Framework for Cumulative Risk Assessment* (U.S. EPA 2003a)
- *Air Toxics Risk Assessment Reference Library* (U.S. EPA 2004b, 2004c, 2006d)
- *A Framework for Assessing Health Risk of Environmental Exposures to Children* (U.S. EPA 2006a)

2.2.2.5 *Uncertainty and Variability*

Drawing from EPA guidance and experience, the analysis plan describes how uncertainty and variability will be characterized in the risk assessment. The complexity of the approaches will be influenced by considerations identified earlier in the planning phase, including purpose and context for the assessment, as well as timeline and resources. Planning for this stage of the assessment also will consider how elements of an uncertainty/variability evaluation can inform different parts of the assessment approach, improving the overall plan as well as the utility of the final product. The plan may consider the value of obtaining additional data or information to reduce areas of uncertainty. More information about uncertainty and variability can be found in Text Box 2-14.

Text Box 2-14: Definitions of Uncertainty and Variability

Uncertainty refers to imperfect knowledge or lack of precise knowledge of the real world, either for specific values of interest or in the description of the system. Although numerous schemes for classifying uncertainty have been proposed, most focus on two broad categories: parameter uncertainty and model uncertainty. Descriptions of both areas are found in *Risk Assessment Principles and Practices* (U.S. EPA 2004d).

Variability refers to the inherent natural variation, diversity and heterogeneity across time and/or space or individuals within a population. Although we can better describe and understand variability in the world, or a particular system, it is unavoidable and cannot be reduced (U.S. EPA 2010c).

Resources for Characterizing Uncertainty/Variability

- *Guiding Principles for Monte Carlo Analysis* (U.S. EPA 1997c)
- *Science Policy Council Handbook: Risk Characterization* (U.S. EPA 2000b)
- *Risk Assessment Guidance for Superfund Volume III—Part A: Process for Conducting Probabilistic Risk Assessment* (U.S. EPA 2001d)
- *Risk Assessment Principles and Practices* (U.S. EPA 2004d)
- *A Framework for Assessing Health Risk of Environmental Exposures to Children* (U.S. EPA 2006a)
- *Guidance Document on Characterizing and Communicating Uncertainty in Exposure Assessment* (World Health Organization, 2008)
- Using Probabilistic Methods to Enhance the Role of Risk Analysis in Decision-Making With Case Study Examples (U.S. EPA 2010c)

2.3 Fit for Purpose

Risk assessments at the EPA are performed to inform risk management decisions. Accordingly, throughout the process of planning and performing the analyses it is important to confirm that the assessment will address the information needs of risk managers. Periodic confirmations may be part of the decision points or review steps described above or may be done as they otherwise fit within the process of the assessment. In the Silver Book (NRC 2009), the NRC recommended use of a framework that "maximizes the utility of risk assessment," with a focus on assuring that risk assessments are well-tailored to the problems and decisions at hand so that they can most meaningfully inform the decision-making process. In describing this concept, the NRC (2009) report uses the terms "fit for purpose" and "utility of risk assessment," among others. Consistent with its usage as a key principle in quality assurance programs, "fit for purpose" in this framework refers to the development of risk assessments and associated products that are suitable and useful for their intended purpose(s) particularly that of informing risk management decisions.

In the EPA's Framework described here, the utility of risk assessment is not an element that is evaluated as a separate step in the process or a final check that occurs once the risk assessment is completed. Rather, consistent with the NRC's emphasis on consideration of risk management needs early in the process, the agency's Framework emphasizes attention to utility throughout the process, beginning with planning and scoping, and including a specific focus on the applicability of the risk assessment for informing risk management decisions. Attention is given to this concept through focused planning and problem formulation and confirmation during the process to ensure that the informational needs for the assessment are being met by the information being generated by the assessment. Questions to consider in evaluating the usefulness of the assessment design and its implementation include those listed below:

- Does the assessment design meet the objectives and have the attributes identified in the problem formulation step?
- Does the assessment, as implemented, meet the initial objectives? Or, if the initial objectives have been modified (e.g., as a result of changed risk management options or issues), does the assessment meet the modified objectives?
- Does the assessment have the attributes identified in planning?
- If the assessment requires peer review, has this been done appropriately and have the issues raised during the peer review been adequately addressed?

- How will the results of the risk assessment be communicated to the risk managers and stakeholders?
- Does the assessment inform choices among risk management options? Are there any additional risk assessment needs for discriminating between or implementing risk management options?

Additional or revised analyses may be considered in the assessment, depending on the answers to these and other questions that may reflect the specific risk management decision being addressed.

The utility of the risk assessment is defined by the degree to which the assessment informs choices among risk management options. Related to this, it is critical that there be transparent dialogue between risk assessors and risk managers throughout the assessment process, beginning with the planning stage. It is important to note, however, that the EPA maintains the conceptual distinction between risk assessment and risk management, as described in the Red Book (NRC 1983); the Framework does not allow for the manipulation of the risk assessment to support predetermined policy choices. As articulated by the NRC in the Silver Book, "the conduct of risk assessments used to evaluate the risk-management options [is] in no way to be influenced by the preferences of risk managers" (NRC 2009, 244). For more information from the Silver Book see Text Box 2-15.

Text Box 2-15: More Silver Book Statements on Utility

- "Risk assessment in EPA is not an end in itself but a means to develop policies that make the best use of resources to protect the health of the public and of ecosystems"(NRC 2009, 240).
- "By focusing on early and careful problem formulation and on the options for managing the problem, implementation of the framework can do much to improve the utility of risk assessment. Indeed, without such a framework, risk assessments may be addressing the wrong questions and yielding results that fail to address the needs of risk managers"(NRC 2009, 244).

It is important to note that the uses of any risk assessment will vary with the environmental problem being assessed; statutory mandates; and the limitations of data, methods, time and resources. Further, as recognized in Section 5, risk assessments often are just one of a variety of factors that are considered in making a decision.

3 Risk Assessment

Risk assessments conducted for the EPA range from relatively simple to complex depending on needs of the risk management decision being made and the availability of relevant data. The analyses that contribute to a risk assessment may range from those based on default assumptions to more refined analyses that include site-specific information and quantitative uncertainty assessment consistent with agency policies and guidances (U.S. EPA 1992a, 2005a, 2011a). Planning and scoping identifies the level of assessment appropriate for the needs of the risk manager and the role that risk information plays in the decision. Problem formulation uses this information to develop the conceptual model and analysis plan. The assessment step builds on the conceptual model and implements the analysis plan. The steps in risk assessment often are performed together, in an integrative fashion, rather than as a linear, sequential process. As information is developed and preliminary conclusions drawn, it is not uncommon to revisit data needs or to revise the conceptual model and analysis plan. Communication among all members of the risk assessment team (and perhaps with stakeholders) is needed to ensure that the purpose of the assessment remains the major impetus for these revisions to plans and expectations.

The EPA has issued guidance on all four steps of the risk assessment paradigm (exposure assessment, hazard identification, dose response and risk characterization); note that these publications are highlighted in Section 2. This Framework document focuses on context, utility and planning for the risk assessment itself, so it does not provide detail on the conduct of the steps.

EPA risk assessments may focus on individual risk metrics or may include population-level and/or life stage-specific assessments to inform characterization of risk. Different categories of assessments may be conducted by the agency related to the specific types of regulatory or programmatic decisions they are developed to inform. The agency's Risk Assessment Portal (U.S. EPA 2012i) provides basic information about environmental risk assessments and offers a comprehensive set of links to key EPA tools, guidance and guidelines.

Figure 3-1 highlights the assessment phase in the Framework detailing several cross-cutting areas for consideration in exposure or effects characterization. The risk assessor might consider available data on metabolism; modeling; mode of action; toxicity; cumulative risk (exposure and/or effects); the susceptibility of individuals based on factors such as life stage, genetics and gender; specific population group factors including socio-economic considerations, uncertainty and variability; and other factors relevant to characterization of risk (see Text Boxes 3-2 and 3-3). The landscape of risk assessment is changing with new advances in molecular biology, computational toxicology and risk assessment methodology. The areas of consideration

noted in Figure 3-1 are meant to be illustrative of today's practices, rather than definitive or comprehensive, and they are likely to change as the science of risk assessment advances.

3.1 Exposure Assessment

Exposure characterization is one of the primary components of risk assessment. The approaches employed for this component may vary across different risk assessments and will reflect considerations described in the conceptual model and analysis plan.

Exposure is characterized, quantitatively or qualitatively, for several key aspects of the assessment: relevant routes and pathways, frequency and duration, and populations and life stages. The specific type of exposure estimation needed and the level of complexity employed for this component of the assessment will vary depending on the assessment purpose, legal authority and other factors considered in the planning and scoping step. For example, this step may involve new data collection, implementation of simple or complex fate/ transport/exposure models and/or other data analysis. A key aspect of all exposure characterizations is consideration of the potential for susceptible or more highly exposed populations, life stages or groups. Based on considerations and decisions in the conceptual model, quantitative exposure assessments may include the development of estimates specific to these populations or life stages. The available toxicokinetic information may also be characterized and internal doses calculated. The EPA's *Exposure Factors Handbooks* provide a compendium of exposure factors for a number of parameters for adults and children, including such metrics as ingestion of soil, time spent in residence, surveys of fish ingestion, ingestion of homegrown products and inhalation rates (U.S. EPA 1997b, 2008a, 2011a). Available toxicokinetic information also may be characterized and internal doses calculated. Some key elements of exposure characterizations are listed in the Text Box 3-1.

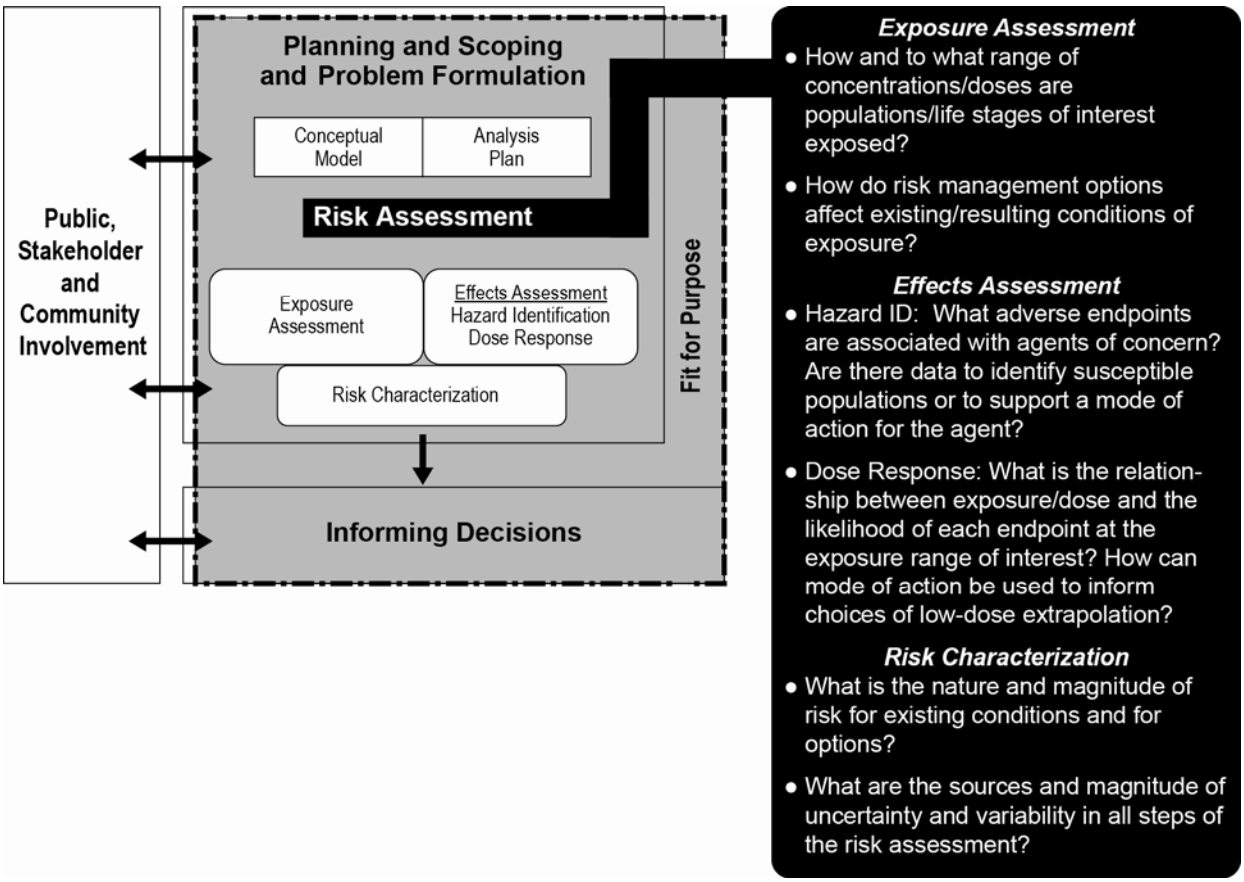

Figure 3-1. Framework for Human Health Risk Assessment to Inform Decision Making: Key Questions and Considerations for *Assessment*.

3.2 Effects Assessment

In human health risk assessment, the characterization of effects includes hazard identification and dose-response assessment. The approaches employed for these components, including, for example, the level of detail and complexity of quantitative aspects, may vary across different risk assessments and will reflect considerations described in the conceptual model and analysis plan.

Text Box 3-1: Key Elements of an Exposure Characterization

- Assess sources, pathways and routes of exposure and determine approach for consideration of multiple pathways, as relevant.
- Investigate patterns of exposure (e.g., frequency and duration).
- Assess populations and life stages (e.g., the general population, highly exposed/vulnerable groups, highly susceptible groups) and determine basis for inclusion.
- Consider the rationale for the analysis approach, including any monitoring, modeling or other analyses of exposure distributions such as Monte-Carlo or krieging.
- Establish descriptors of exposure, generally including estimates for "average" and "high-end" exposures and susceptible populations or life stages.
- Determine data and methods used in developing the exposure estimates.

Drawn from EPA's *Guidance for Risk Characterization* (U.S. EPA 1995d) and *Guidelines for Exposure Assessment* (U.S. EPA 1992a).

3.2.1 Hazard Identification

Hazard Identification is the process of identifying the type of hazard to human health (e.g., cancer, birth defects) posed by the exposure of interest for a given risk assessment. In the case of chemical stressors, the process examines the available scientific data for a given chemical (or group of chemicals) and often develops a "weight of evidence" characterization of hazard. This step requires identification, evaluation and synthesis of information to describe the health effects of individual chemicals (or chemical mixtures). Studies evaluated may include human clinical or epidemiological studies, *in vivo* or *in vitro* laboratory animal studies, or mechanistic or kinetic studies in a variety of test systems. In recent years, risk assessors have begun to consider additional types of data during hazard identification including those from computational toxicology (quantitative structure-activity relationship, high-throughput assays) and transcriptional or "omic" responses. Other data types may be identified in the future. Key aspects of hazard identification include consideration of available information on toxicokinetics (how the body absorbs, distributes, metabolizes and eliminates chemicals) and toxicodynamics (effects that chemicals have on the body) as well as potential MOAs (or toxicity pathways) related to the health effects identified. Text Box 3-2 describes some contexts in which MOA of the adverse outcome pathway is considered.

In hazard identification, the strengths and limitations of the data and information used to support the weight of evidence are described, including areas for which data may be unavailable (data gaps). In situations where a quantitative risk assessment is to be performed, a particular study or group of studies may be identified for use in dose-response assessment.

Text Box 3-2: Example of a Consideration for Effects Characterization: Mode of Action

The *Guidelines for Carcinogen Risk Assessment* (U.S. EPA 2005a) emphasizes the important contribution that understanding a chemical's MOA makes to informed risk assessment decisions. These can include:

- Relevance of data (e.g., animal, *in vitro*, *in silico*) for human health risk assessment.
- Harmonization of risk assessments for various health endpoints.
- Conditions under which an agent is likely to cause cancer (or some other health endpoint).
- Choice of low dose extrapolation (e.g., linear or nonlinear).
- In cancer assessments, applicability of default age-dependent adjustment factors for early life stage exposure.

The carcinogen guidelines and supplemental guidance (U.S. EPA 2005a, 2005b) include a framework for assessing available data to determine whether a hypothesized MOA is likely to be involved in induction of a specific tumor type. This framework also is useful for assessment of other health endpoints. For an example of application of the MOA framework to reproductive effects see the Office of Pesticide Program's work on the pesticide cacodylic acid (U.S. EPA 2012l).

Although the scientific community historically has been invested in understanding how chemicals cause biological effects, the use of detailed information on MOA in human health risk assessment has been increasing as methods are refined and more reliable information is generated. Recognizing the critical role in risk-based decision making of understanding how a chemical causes effects, *Toxicity Testing in the 21st Century* (NRC 2007) proposed that the next generation of toxicology studies be designed to focus on "toxicity pathways." These are normal biological pathways that respond to chemicals or other stressors depending on the magnitude of the insult (dose, timing, duration and frequency of perturbation). At low exposures, some systems will remain within their homeostatic limits. At higher levels of stress, other adaptive biologic responses may occur, the adversity of which may depend on physiological characteristics of those exposed; that is, groups of sensitive individuals may respond adversely, whereas others may not. At greater magnitude of stress, the adaptive capacity may be overwhelmed for all groups, increasing the likelihood of adverse effects. These and similar concepts may provide approaches for applying greater scientific understanding of what a chemical does in causing an effect. This knowledge in turn will support improved human health risk assessments.

The availability of data for these types of detailed assessments varies widely across chemicals. Accordingly the EPA and the NRC continue to support the use of default methods and procedures to complete a risk assessment when data are lacking.

Adverse Outcome Pathway: A description of plausible causal linkages that illustrates how a chemical interaction with a biological system at the molecular level causes biological effects at the subcellular, cellular, tissue, organ and whole animal levels of observation (Ankley et al. 2010).

Toxicity Pathways: Cellular response pathways that, when sufficiently perturbed, are expected to result in adverse health effects (NRC 2007).

Mode of Action: The sequence of key events and cellular and biochemical events (measurable parameters), starting with the interaction of an agent with the target cell or tissue, through functional and anatomical changes, resulting in cancer or other adverse health effects (U.S. EPA 2005a, Boobis et al. 2008). Mode of action differs from mechanism in that the latter implies a more detailed understanding of the molecular basis of the toxic effect (Seed et al. 2005).

Hazard identification may be focused on health risks of exposure to specific individual chemicals or identification of groups of chemicals with common MOAs (e.g., pesticides). In some cases, the specific chemicals for such focus are identified by statute (e.g., the CAA hazardous air pollutants). Thus the chemical exposures to be evaluated in the risk assessment may vary across programs depending on the legal authorities under which the assessment is conducted. In all cases the conceptual model and analysis plan will specify the extent, content and limits of the hazard identification.

3.2.2 Dose-Response Assessment

In this component of effects characterization, the relationship between exposure or dose of a contaminant and the occurrence of particular health effects or outcomes is assessed. Drawing from the conceptual model and analysis plan, the dose-response assessment (U.S. EPA 2012j) may be developed using a combination of data, science policy decisions and models. For example, the response assessed may be incidence of some endpoint or health outcome (e.g., cancer incidence, incidence of a critical effect, hospital admission for a specific outcome or death) or it may describe magnitude of response (e.g., magnitude of IQ loss). The assessment also may include the derivation of an established metric such as EPA's reference doses and reference concentrations (U.S. EPA 2002e).

In documentation of the dose-response assessment, aspects of the full database, particularly the key studies, are described along with their strengths and weaknesses, including the potential impact of those weaknesses on the reliability of the overall assessment. Toxicokinetic information also is described; in data-rich situations, measured or modeled target tissue dose may be used in the dose-response calculations. In some cases, multiple chemicals may be included in a single dose-response assessment, with decisions made about the grouping of chemicals, as well as the means by which the chemicals will be combined (e.g., common MOA, common toxic effect, estimation of cancer potency factors, specific data for chemical mixtures or likelihood of simultaneous exposure). Decisions on these issues are specific to the individual risk assessment and may be influenced by the information gathered during problem formulation. Details of the EPA practices and policies related to dose-response assessment can be found in the various guidance documents noted in Section 2 of this document and at EPA's Risk Assessment Guidance and Tools webpage (U.S. EPA 2012k).

3.3 Risk Characterization

Risk characterization is the final, integrative step of risk assessment. The agency's *Science Policy Council Handbook: Risk Characterization* (U.S. EPA 2000b) describes risk characterization as the step that "integrates information from the preceding components of the risk assessment and synthesizes an overall conclusion about the risk that is complete, informative, and useful for decision makers" (U.S. EPA 2000b, 10). The handbook further notes that a risk characterization is judged by the extent to which it achieves principles of transparency, clarity, consistency and reasonableness (TCCR). (See Text Box 3-3 for descriptions of TCCR.) The handbook recommends that these TCCR principles be applied in all stages of the risk assessment, from planning and scoping through the conduct of the risk assessment, and in all communication and documentation of the assessment.

Text Box 3-3: Transparency—Clarity—Consistency—Reasonableness in the Risk Characterization Handbook (U.S. EPA 2000b)

- *Transparency* "provides explicitness in the risk assessment process. It ensures that any reader understands all the steps, logic, key assumptions, limitations, and decisions in the risk assessment, and comprehends the supporting rationale that led to the outcome."
- *Clarity* "refers to the risk assessment product(s). Making the product clear makes the assessment free from obscurity and easy to understand by all readers inside and outside of the risk assessment process."
- *Consistency* "provides a context for the reader and refers to the presentation of the material in the risk assessment. For example, are the conclusions of the risk assessment characterized in harmony with relevant policy, procedural guidance, and scientific rationales and if not, why the conclusions differ. Also, does the assessment follow precedent with other EPA actions or why not. Consistency, however, should not encourage blindly following the guidance for risk assessment and characterization at the expense of stifling innovation."
- *Reasonableness* "refers to the findings of the risk assessment in the context of the state-of-the science, the default assumptions and the science policy choices made in the risk assessment. It demonstrates that the risk assessment process followed an acceptable, overt logic path and retained common sense in applying relevant guidance. The assessment is based on sound judgment."

Risks can be expressed qualitatively or quantitatively for the exposure pathways of interest. A risk characterization conveys the nature and presence or absence of risks in qualitative or quantitative terms. In addition, it describes information on how the risks were

assessed, where assumptions and uncertainties still exist and where policy choices will need to be made.

In describing the nature and magnitude of risk for the assessed condition, the risk characterization describes the universe of people who may be affected, including sensitive and/or susceptible life stages or populations. These life stages and/or populations (e.g., potentially at-risk groups) are first considered in the planning and scoping phases and may be explicitly evaluated in the risk assessment. Text Box 3-4 presents details on characterizing cancer risk from early life exposures. Additionally, in consideration of highly exposed or susceptible life stages and/or populations, risk characterizations generally present multiple risk descriptors (e.g., high end and central tendency) and may include risk descriptors (e.g., maximum exposed individual, reasonable maximum exposure and central tendency) specific to underlying legislative requirements (e.g., CERCLA, CAA, CWA) (U.S. EPA 1995d).

In risk characterization, information about uncertainty and variability (defined in Text Box 2-14) from each step of the risk assessment (e.g., use of default parameters, choice of models and data used for quantitative analysis) is integrated into an overall discussion/analysis of the impact of the uncertainty and variability on estimated risks. The EPA endeavors to ensure that risk is not underestimated when data are missing by using several techniques. The EPA may characterize uncertainty using a qualitative assessment of the overall strength and limitations of the data used in the assessment. To estimate the effect of data uncertainty on modeled pollutant impacts, various modeling tools may be employed. It should be noted that even the quantification of uncertainty and variability in probabilistic risk assessments itself includes an element of additional uncertainty. It is important that the level and type of uncertainty analysis be commensurate with

Text Box 3-4: Characterizing Cancer Risk from Early Life Exposure

When assessing cancer risk resulting from early-life exposures, the risk assessor considers life stage differences in both exposure and dose-response. The *Guidelines for Carcinogen Risk Assessment* (U.S. EPA 2005a) and EPA's *Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens* (U.S. EPA 2005b), provide guidance in this regard. The preferred approach is the calculation of life-stage specific slope factors and use of life-stage specific exposure information when this is supported by data. In the absence of sufficient data, age-dependent adjustment factors (ADAFs) in dose response (i.e., slope factors) are combined with age-specific exposure estimates when assessing cancer risks for chemicals determined to act through a mutagenic MOA. This integrative approach is used to assess total lifetime risk resulting from lifetime or less-than-lifetime exposure during a specific portion of a lifetime.

the decision to be made, in the context of the resources needed to refine such estimations. For example, highly detailed quantitative uncertainty analyses may not be warranted for some decisions while they might be useful for others.

Communicating the results of probabilistic risk assessment requires particular attention. Probabilistic risk assessments provide range and likelihood estimates for one or more aspects of hazard, exposure or risk, rather than a single point estimate (U.S. EPA 2005e, 2010c). A goal of probabilistic risk assessment is the quantitative characterization of the uncertainty and variability in estimates of hazard, exposure, or risk (U.S. EPA 1997c). Risk assessors are responsible for sharing information on probabilistic results so that risk managers have a clear understanding of quantitative assessments of uncertainty and variability and how this information will affect the risk management decision. A good dialogue between the risk assessor and risk manager is key in aiding the risk manager's understanding and use of the results from the probabilistic risk assessment.

Areas of uncertainty that may make a difference in the outcome of the assessment (and thus on informing choices among risk management options) are highlighted in the risk characterization. For example, the risk characterization document includes a discussion of any issues associated with the data quality (e.g., reliability and availability) that may impact the calculated risks or other metrics. This may include explicit discussions of the evaluation process and description of issues that may impact the reliability or utility of the endpoints identified for use. A key question addressed in the risk characterization is whether the risk assessment outcome would change significantly if data were interpreted differently or if different models were used. This kind of uncertainty is difficult or impossible to characterize probabilistically. It is essential, however, to describe uncertainty and variability so that the impact will not be overlooked or misinterpreted. It may be useful to revisit the analysis plan if it is concluded that gathering additional information will have a substantive impact on reducing uncertainty in the assessment.

The risk characterization step maintains and emphasizes the distinction between scientific conclusions and policy judgments, which may include science policy choices such as assumptions, default procedures and default values. In risk characterization, the assessor also can usefully describe other policy considerations, such as calculating monetizable health benefits under certain statutes or the lack of relevance of such calculations under other statutes. Additional details on key information is presented in the agency's *Science Policy Council Handbook: Risk Characterization* (U.S. EPA 2000b) and the *Policy for Risk Characterization* (U.S. EPA 1995a). Figure 3-1 highlights the details of risk characterization in the Framework.

Text Box 3-5 describes cumulative risk assessment (an overarching EPA interest) as a consideration for risk characterization.

Text Box 3-5: Considerations for Risk Characterization: Cumulative Risk Assessment

Cumulative risk assessments may differ in design and associated results. Examples of Cumulative risk assessment at the EPA include:

Office of Pesticide Programs' evaluation of cumulative risk (U.S. EPA 2012m) according to the Food Quality Protection Act of 1996. Some texts include:

- *Guidance for Performing Aggregate Exposure and Risk Assessments* (U.S. EPA 1999b)
- *General Principles for Performing Aggregate Exposure and Risk Assessments*. (U.S. EPA 2001b)
- *Guidance on Cumulative Risk Assessment of Pesticide Chemicals That Have a Common Mechanism of Toxicity* (U.S. EPA 2002d)

The Office of Air and Radiation's assessment of hazardous air pollutant risks remaining after implementation of technology-based emissions standards (U.S. EPA 2011l)

The Office of Environmental Justice's *Ensuring Risk Reduction in Communities with Multiple Stressors: Environmental Justice and Cumulative Risks/Impacts* (U.S. EPA 2004f)

Region 3's "Multi-criteria Integrated Resource Assessment (MIRA)" (U.S. EPA 2011m)

Additionally, two NRC publications, *Science and Decisions: Advancing Risk Assessment* (NRC 2009) and *Phthalates and Cumulative Risk Assessment: The Tasks Ahead* (NRC 2008), describe approaches to consider in the practice of cumulative risk assessment. For example, *Phthalates and Cumulative Risk Assessment* discusses the advantages of focusing on physiologic consequences rather than structural or mechanistic similarity in conducting cumulative risk assessment as this is more directly relevant to relating chemical exposures to human diseases and disorders. *Science and Decisions* discusses the importance of considering nonchemical stressors and background processes in cumulative risk assessment.

4 Public, Stakeholder and Community Involvement

As discussed in Planning and Scoping (Section 2.1), public, stakeholder and community involvement are key elements of the Framework throughout all phases of the risk assessment. Figure 4-1 highlights key questions and considerations for stakeholder involvement. As indicated in the figure, public, stakeholder and community involvement are considered early and often in the risk assessment and decision making process. Although the single term "public" could be used to include the full range of external stakeholders, including community members, this document specifically includes all three terms in recognition of differences in what they each may convey to different readers and also in recognition of roles played by internal stakeholders (see Text Box 2-7 for definitions).

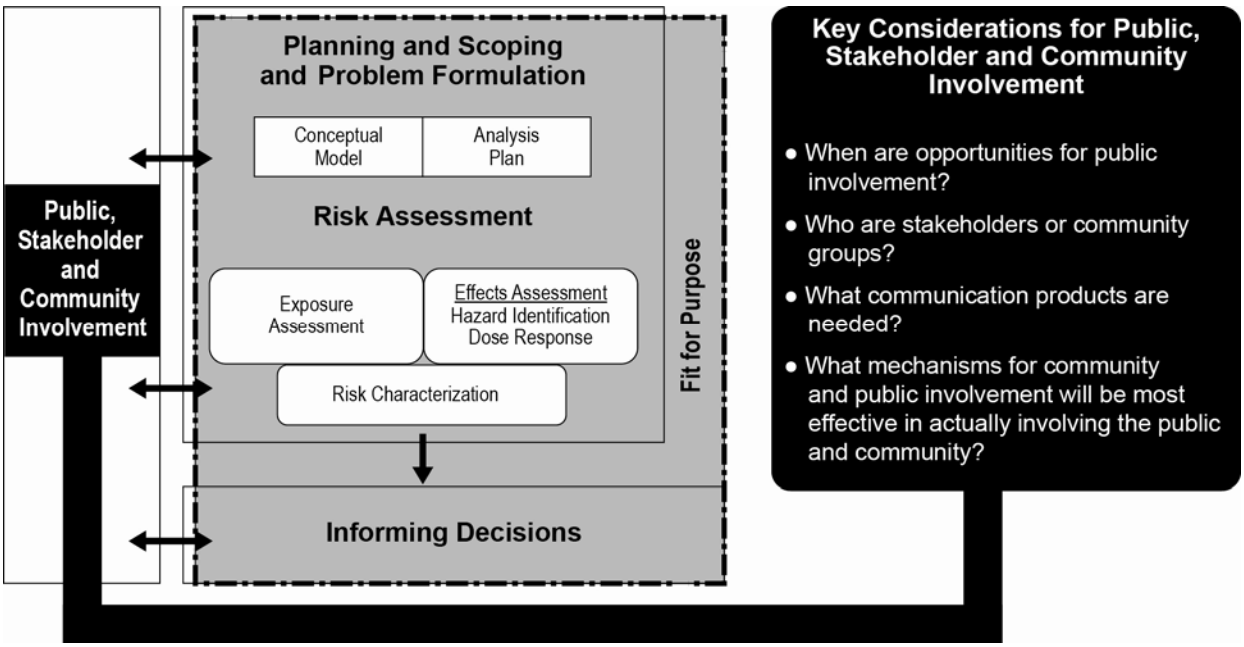

Figure 4-1. Framework for Human Health Risk Assessment to Inform Decision Making: Key Questions and Considerations for *Public, Stakeholder and Community Involvement*.

Public participation is an essential aspect of the EPA's process for making decisions to achieve the agency's mission of protecting human health and the environment. This provides the EPA with the opportunity to obtain and consider a range of views on the issue being assessed as well as on management options. Effective public involvement (including key stakeholders and/or communities) can enhance the deliberative process and improve the content of the agency's decisions (U.S. EPA 2003c), which is consistent with sustainability principles. A critical feature of the Framework is the involvement of the public, stakeholders and communities at key points in the process. The timing/frequency and level of community

involvement will depend on a number of factors, including regulatory requirements, the nature of the decision and community interest.

As discussed in Section 2.1.5, public involvement may begin when individuals and organizations seek information from the EPA about a topic or issue or when the public receives information from the EPA because the agency identifies them as a potentially affected party. The EPA's outreach activities serve and engage these individuals and organizations (U.S. EPA 2003c).

Each decision or action by the agency may call for a different level of public involvement, and certain members of the public, stakeholders or communities may need to be involved at different steps in the risk assessment process. The EPA's *Public Involvement Policy* (U.S. EPA 2003c, 1) states that, "EPA staff and managers should seek input reflecting all points of view and should carefully consider this input when making decisions." In addition, the policy (U.S. EPA 2003c, 1) states that, "EPA should not accept any recommendation or proposal without careful, critical examination."

The overall goal of public involvement is to provide opportunities for people to contribute at every point along the progression of the decision making process. Individuals and groups decide for themselves whether, when and how to participate. It is recognized that not everyone who is interested in the situation being assessed chooses to be an active participant in providing input (e.g., facts, data and opinions) to policy or regulatory decisions of the agency. The information provided through the public involvement process is considered by the agency's officials in the decision making process.

4.1 Audiences for the Risk Assessment

If properly planned and executed, the technical risk characterization itself will be consistent with the level of detail and complexity of the assessment conducted. The information presented may vary by regulatory and audience needs, however. Co-regulators such as states and tribal nations also are audiences for the risk assessments; these groups may prefer a high level of technical detail in communication of an assessment. Several statutes and executive orders affect the development of regulatory rules and other EPA decisions and may define specific activities for public, stakeholder and community involvement. In addition, several programs have developed specific guidance on public involvement (Dalton and Harter 2009) (variously termed public, stakeholder and community involvement), and these guidance documents are listed in Text Box 4-1.

Text Box 4-1: EPA Resources for Public Involvement Efforts, Tools and Policies

Public Involvement

- *The Model Plan for Public Participation* (U.S. EPA 2000c)
- EPA's Public Involvement Webpage (U.S. EPA 2011b)
- Pesticide Program Dialogue Committee: This Committee provides a forum for a diverse group of stakeholders to provide feedback to the pesticide program on various pesticide regulatory, policy and program implementation issues. (U.S. EPA 2011c)

Community Involvement

- EPA's Superfund Community Involvement Plans (U.S. EPA 2002f)
- *EPA's Superfund Community Involvement Handbook* (U.S. EPA 2005d)
- EPA's Superfund Community Involvement Publications Webpage (U.S. EPA 2011d)

Risk Communication

- *EPA's Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, Volume IV: Risk Communication* (U.S. EPA 1995b)
- Lessons Learned About Designing, Developing and Disseminating Environmental Information Products (U.S. EPA 2000e)
- *EPA's Risk Communication In Action: The Risk Communication Workbook* (U.S. EPA 2007a)
- *EPA's Risk Communication in Action: The Tools of Message Mapping* (U.S. EPA 2007b)
- *Sustainability and the U.S. EPA* (NRC 2011)

4.1.1 Stakeholders

The appropriate stakeholder involvement process will depend on the specifics of the situation. Stakeholder involvement processes are highly adaptive and can be modified to take changing circumstances into account. Additional details are found in *Better Decisions Through Consultation and Collaboration* (Dalton and Harter 2009).

Staff and management of EPA offices are important internal stakeholders in the process of drafting rules, policies, permits or plans. The planning process considers inclusion of internal

stakeholders in establishing the project. Three key considerations include involving stakeholders early, obtaining "buy-in" along the way and keeping stakeholders engaged.

Communication with stakeholders outside the agency may vary depending on regulatory requirements. For example, regulatory and non-regulatory activities in the Office of Chemical Safety and Pollution Prevention provide mechanisms to interact with stakeholders while the EPA is developing the assessments. During the review of premanufacture notices (PMNs) for new substances, the EPA Program Manager or other EPA personnel may contact the submitter for additional information if the EPA identifies concerns or needs clarification of technical information provided in the PMN. Rules issued under TSCA §5 (i.e., Significant New Use Rules) and §6 (e.g., formaldehyde) provide a notice and comment period in the *Federal Register* allowing public involvement in the Office of Pollution Prevention and Toxics' (OPPT) rulemaking actions (e.g., Proposed Significant New Use Rule for Multiwalled Carbon Nanotubes [U.S. EPA 2010e] and Formaldehyde Emissions From Pressed Wood Products [U.S. EPA 2008b). Public meetings are scheduled in different parts of the United States to increase public involvement in the rulemaking process. Under the High Production Volume (HPV) Challenge Program, OPPT posts notice of and links to data summaries and test plans for HPV chemicals (U.S. EPA 2012n) and provides a 120-day public comment period. The Office of Pesticide Programs provides multiple opportunities for public comment and involvement in its registration review program—at the opening of the process for a chemical on the Preliminary Work Plan, on the draft risk assessment and on proposed regulatory actions.

Another example of stakeholder involvement is the IRIS process (U.S. EPA 2012o), which provides multiple opportunities for stakeholder involvement. The process includes a call for nominations that allows stakeholders to nominate chemicals for assessment through the IRIS Program that includes a description why the chemical(s) should be considered for assessment. Multiple opportunities for review and comment occur during the development of the health hazard assessments. For example, the IRIS process includes a step that provides for review by other offices within the EPA (agency review) and two opportunities for interagency science consultation and discussion, which enable other federal agencies to comment on the assessment. Finally, during the period of public review and comment, any interested member of the public may comment on the assessment; there also is a public listening session in which any stakeholder or member of the public has the opportunity to speak about the assessment.

4.1.2 Community

Community involvement may be a component of the stakeholder involvement process, particularly in cases in which the issue assessed relates to a specific location (e.g., decisions regarding contaminated waste sites or facilities with environmental releases). Community involvement is the process of engaging in dialogue and collaboration with

community members who may be directly impacted by the risk assessment. For example, in the Superfund Program (U.S. EPA 2011h), the goal of community involvement is to advocate and strengthen early and meaningful community participation during the investigation, while conducting the risk assessment and during the decision making process (see EPA's Public Involvement Webpage; U.S. EPA 2011b).

4.2 Communication

Successful communication begins early in the risk assessment process during planning and scoping and problem formulation (see Section 2.1.5) and has a pivotal role throughout the process. As the Silver Book (NRC 2009, 250) points out, "communication among those involved in the policy and technical evaluations are [sic] difficult to achieve, but they are necessary for success." Communication of risk may be challenging as a result of the complexity of the information being conveyed, the inherent uncertainty in risk estimates and the varying needs of the audiences (e.g., scientists, risk managers, various stakeholders, the media and the general public). The Silver Book (NRC 2009, 66) recognized this issue, stating "... the critical final process in risk assessment is ultimately communication."

Risk communication begins with understanding the risk characterization portion of the risk assessment. Risk characterization is an integral part of a risk assessment and summarizes the key findings and the strengths and weaknesses of the assessment for risk managers and others. Although it provides information that may be useful for communicating with the public, risk characterization is not synonymous with risk communication.

Risk communication emphasizes the process of providing information to the public, including individuals, groups and other institutions, about levels of health or environmental risks. Risk communication is used for such things as information and education, behavior change and protective action, disaster warnings and emergency information, and joint problem solving. Although the final risk assessment documentation (including the risk characterization) can be used to communicate with the public, the risk communication process is probably better served by a separate set of documents designed for particular audiences.

Risk communication tools are written, verbal or visual statements containing information about risk. These tools put a particular risk in context, possibly adding comparisons with other risks, often including advice about risk reduction behavior. Risk communications also can encourage a dialogue between the sender and receiver of the message (U.S. EPA 2007a). In general, the communication tools should be concise and provide adequate information for the user but not at the level of detail provided in the risk characterization. In addition, care is required to assure that the risk information is consistent with the data provided in the risk characterization and includes risk assessment results, the strengths and limitations of the analysis, and how they will be used by risk mangers.

Risk communication documents need to consider the audience for the information. For example, risk managers generally prefer not to receive the depth of detail found in the technical risk characterization. The usual products prepared from the risk characterization for risk managers often provide a summary and can take various forms depending on specific needs (e.g., executive summary, bulleted list of key issues and conclusions, briefing packages) (U.S. EPA 2000b). Risk characterization products prepared for the public, stakeholders and communities can come in many forms. Generally, these communication pieces carry forward the key issues and describe conclusions in a lay person's context rather than a technical one written for a scientific presentation or paper; this can include plain language definitions, translations into appropriate languages, use of graphics as appropriate to convey information and so on. Communication products are developed to meet the needs of the intended audience and may include products such as fact sheets for interested public, press releases, slide shows, public relations notices, decision documents, and speeches and talks (U.S. EPA 2000b). Text Box 4-1 identifies resources helpful in developing a risk communication plan for various audiences.

5 Informing Decisions

The final step in the risk assessment process is connecting the previously defined purpose and scope with the conclusions and strengths/limitations of the risk assessment. The assessments are conducted to provide a scientific characterization of risks based on analysis of available information and knowledge that meets appropriate quality criteria. A description of the human health risks, and characterization of the confidence in the information available to describe the risks, supports risk management decisions. As discussed in Section 3.3, effective risk characterization is based on transparency in conducting and explaining the risk assessment combined with clarity, consistency and reasonableness in the preparation of the risk description (U.S. EPA 2000b).The science supporting the risk assessment conclusions, as well as consideration of important uncertainties, informs decisions among the risk management options. As noted in Section 2.3, well planned, focused and conducted risk assessments will be most useful and informative for decision making. Key questions and considerations for the informing decisions step are shown in Figure 5-1.

5.1 Characterizing the Risks for Risk Management Options

It is the role of the risk assessor to provide a transparent description of all aspects of the risk assessment (e.g., default assumptions, data selected and policy choices) to make clear the range of plausible risk associated with each risk management option. Clear communication between the risk assessors and risk managers is vital to assuring that risk information is conveyed appropriately.

Whatever approach is used to estimate risk, it is important to be clear in describing the range of possible risks (e.g., risks to highly exposed individuals, average exposed individuals or groups). For example, the extent to which the assessment may underestimate or overestimate risk for some populations should be highlighted to inform the decision making appropriately. As discussed in Section 3.3, these uncertainties may be characterized quantitatively (e.g., using probabilistic methods) or qualitatively (e.g., describing how the results would change if the data were interpreted differently). The risk assessment characterizes the nature and magnitude of risk and who is at risk under different risk management options (including a "*status quo*" option). The EPA's policy is to describe the range of the risk and highlight susceptible populations (U.S. EPA 1995a, 2000b).

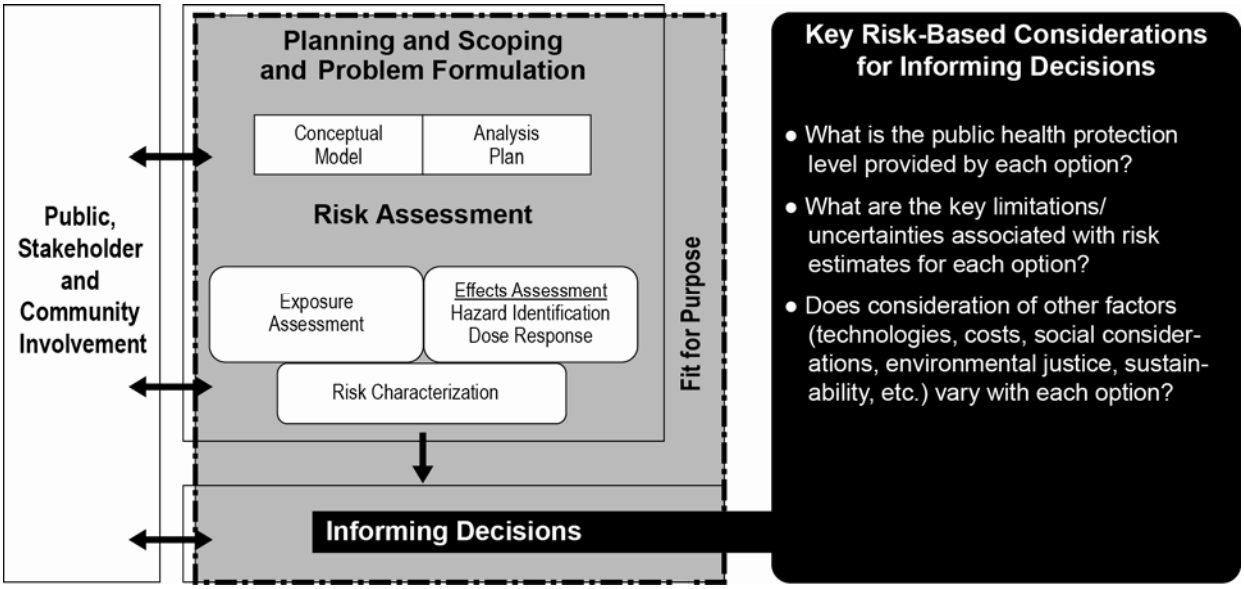

Figure 5-1. Framework for Human Health Risk Assessment to Inform Decision Making: Key Questions and Considerations for *Informing Decisions*.

The communication of the risk characterization will take different written and oral forms to meet the needs of the intended audiences, including the risk managers. The level and amount of detail in each product will vary according to the level and amount of detail of the risk assessment that is being characterized by the product; thus, being fit for purpose. In addition, it often will vary in format or detail for effective communication with the intended audience. Summaries of the risk characterization may be provided to the risk managers depending on their information needs. Key issues considered by risk managers include:

- Strengths of an assessment including the overall weight of evidence and the quality and quantity of data supporting the hazard and/or exposure.
- Level of confidence or uncertainty in the assessment and the data underlying it.
- What are the life stages and/or populations at greatest risk?
- Information that would yield changes in the risk estimates under various candidate risk management alternatives.
- Precedents that may inform the decision.

5.2 Risk Management Factors Beyond the Risk Assessment and Characterization

EPA uses risk assessment as a key source of scientific information for making sound decisions about managing risks to human health and the environment. Risk management

decisions, however, may be informed by a range of factors, evidence and policy choices, such as the following:

- Laws and Regulatory Requirements—legal mandates, flexibility and constraints.
- Economic Factors—costs, benefits and impacts of potential actions.
- Sustainability—life cycle, multimedia and long-term impacts.
- Technological Factors—feasibility, impact and range of risk management options.
- Political Factors—interactions with different branches and levels of government and the citizens that they represent.
- Public and Social Factors—susceptible population groups, nonchemical stressors and cumulative risk assessment considerations.

Statutory or regulatory requirements and restrictions, including those established by states and tribal nations, may limit decision options as the discretionary power afforded to agencies in making regulatory decisions varies greatly. The EPA faces regulatory, licensing and other decisions covering a wide range of environmental issues and pollutants. These decisions are made within a number of EPA program offices, each responding to a unique mixture of statutes, precedents and stakeholders. In statutes, Congress establishes legal requirements that generally describe the level of protectiveness that EPA regulations must achieve, and the statute may impose specific risk assessment requirements. In addition, court precedents can affect how the EPA considers assessments of risk. The statutory or regulatory requirements often also specify other kinds of factors for consideration in the risk management decision.

6 Summary

The *Framework for Human Health Risk Assessment to Inform Decision Making* is intended to foster increased implementation of existing EPA guidance for conducting human health risk assessments and to improve the utility of risk assessment in the decision making process. This document lays out a Framework for conducting human health risk assessments in support of decision making at the EPA. It draws on current EPA experience in applying both the planning and scoping and problem formulation steps as well as on the advice of the NRC (2009) and other advisory groups. For example, the Framework addresses recommendations in the Silver Book (NRC 2009) on assuring the utility of risk assessment or the assessments fit for purpose (Text Box 6-1). As indicated in the Framework diagram, Figure 6-1, the NRC 1983 four-step risk assessment paradigm is maintained, but there is increased emphasis on interaction between risk assessors and risk managers in planning the assessment to maximize utility. Emphasis on utility is maintained throughout the process, beginning with planning and scoping and during evaluation of the applicability of the risk assessment in informing risk management choices. The Framework highlights the practical nature of risk assessment. For example, although the agency is committed to advancing risk assessment science, assessments are not academic exercises. Rather, they are intended to support decision making for the protection of human health. Application of the Framework, with its emphasis on problem formulation and utility of the risk assessment, ultimately will result in better, more transparent choices among risk

Text Box 6-1: The Silver Book Recommendations for a Human Health Risk Assessment Framework

- The technical framework for risk assessment presented in the Red Book should remain intact but should be embedded in a broader framework in which risk assessment is used principally to help to discriminate among risk-management options (NRC 2009, 256).
- The framework for risk-based decision making (Figure 6-1) should have as its core elements a problem-formulation and scoping phase in which the available risk-management options are identified, a planning and assessment phase in which risk-assessment tools are used to determine risks under existing conditions and with proposed options, and a management phase in which risk and nonrisk information is integrated to inform choices among options (NRC 2009, 256).
- EPA should phase in the use of the framework with a series of demonstration projects that apply the framework and that determine the degree to which the approach meets the needs of the agency risk managers, and how risk-management conclusions differ as a result of the revised orientation (NRC 2009, 256).

management options. This Framework includes a foundation quite similar to that in *Framework for Ecological Risk Assessment* (U.S. EPA 1992b), thus illustrating conceptual similarity between the two types of risk assessment; however, it is not always advantageous to integrate human health and ecological risk assessments. This Framework builds on agency policies and guidance, and is directed at improving risk assessment products, but does not overturn or in any way change existing science policy decisions.

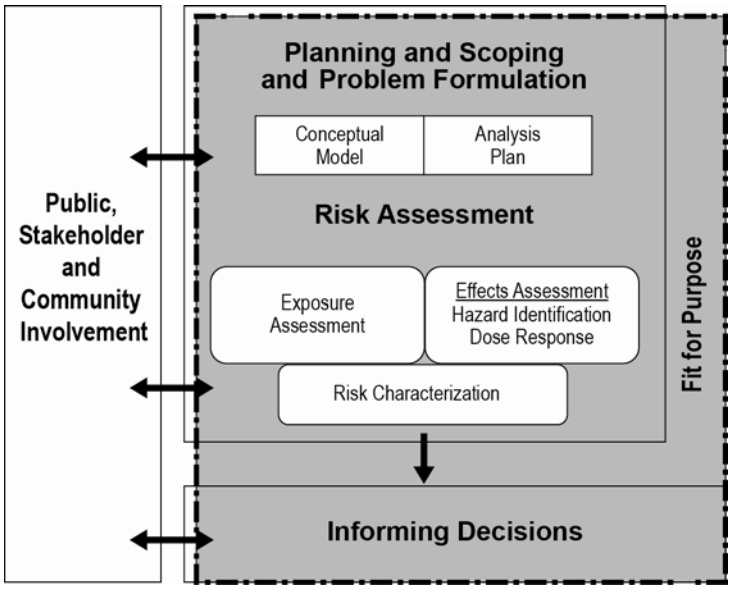

Figure 6-1. Framework for Human Health Risk Assessment to Inform Decision Making

EPA programs routinely apply components of this *Framework for Human Health Risk Assessment to Inform Decision Making* as evidenced by the examples cited in the preceding sections. It is expected, however, that this document will facilitate the formal recognition of these components in agency risk assessment activities. The Framework's explicit recognition of the roles for planning, public, stakeholder and community involvement and consideration of utility will assist in the development of risk assessments focused on informing risk management decisions. Further, "institutionalization" of this *Framework for Human Health Risk Assessment to Inform Decision Making* will contribute transparency to the agency's risk assessment process and a level of consistency across assessments, across media and programs as well as between human health and ecological outcomes.

The Framework is intended to be flexible. The structure will accommodate advances in the technology and science; for example, development of life cycle analyses and use of data from high throughput assays (those that generate data much more rapidly and for many more chemicals than the standard toxicological assays of the 20th century). The Framework structure is sufficiently adaptable to encompass needed changes in agency direction, developing needs and new or revised legislative mandates.

References

Ankley, Gerald T., Richard S. Bennett, Russell J. Erickson, Dale J. Hoff, Michael W. Hornung, Rodney D. Johnson, David R. Mount, John W. Nichols, Christine L. Russom, Patricia K. Schmieder, Jose A. Serrano, Joseph E. Tietge, and Daniel L. Villeneuve 2010. "Adverse Outcome Pathways: A Conceptual Framework to Support Ecotoxicology Research and Risk Assessment." *Environmental Toxicology and Chemistry* 29 (3): 730–741.

Boobis, Alan R., John E. Doe, Barbara Heinrich-Hirsch, M. E. (Bette) Meek, Sharon Munn, Mathuros Ruchirawat, Josef Schlatter, Jennifer Seed, and Carolyn Vickers 2008. "IPCS Framework for Analyzing the Relevance of a Noncancer Mode of Action for Humans." *Critical Reviews in Toxicology* 38 (2): 87–96.

Clay, Donald 1991. Memorandum from Donald R. Clay, Assistant Administrator. Subject: Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions. April 22. http://www.epa.gov/oswer/riskassessment/pdf/baseline.pdf

Dalton, Deborah, and Philip J. Harter 2009. *Better Decisions Through Consultation and Collaboration*. Prepared for the U.S. Environmental Protection Agency. http://www.epa.gov/publicinvolvement/pdf/betterdecisions.pdf

Exec. Order No. 12898, 59 Fed. Reg. 7629 (Feb. 16, 1994). http://www.epa.gov/lawsregs/laws/eo12898.html

Exec. Order No. 13045, 62 Fed. Reg. 19885 (Apr. 23, 1997). http://www.epa.gov/lawsregs/laws/eo13045.html

Exec. Order No. 13514, 74 Fed. Reg. 52117 (Oct. 8, 2009). http://www.epa.gov/oaintrnt/practices/eo13514.htm

National Research Council (NRC) 1983. *Risk Assessment in the Federal Government: Managing the Process.* (The "Red Book"). National Academy of Sciences, National Research Council, Committee on the Institutional Means for Assessments of Risk to Public Health, Commission on Life Sciences. Washington, DC: National Academy Press. http://www.nap.edu/openbook.php?isbn=0309033497

NRC 1994. *Science and Judgment in Risk Assessment* (The "Blue Book"). National Academy of Sciences, National Research Council, Committee on Risk Assessment of Hazardous Air Pollutants, Board on Environmental Sciences and Technology, Commission on Life Sciences. Washington, DC: National Academy Press. http://www.nap.edu/catalog.php?record_id=2125

NRC 2007. *Toxicity Testing in the 21st Century: A Vision and a Strategy*. Committee on Toxicity Testing and Assessment of Environmental Agents. Washington, DC: National Academy Press. http://www.nap.edu/catalog.php?record_id=11970

NRC 2008. *Phthalates and Cumulative Risk Assessment: The Tasks Ahead*. Committee on the Health Risks of Phthalates. Washington, DC: National Academy press. http://www.nap.edu/catalog.php?record_id=12528

NRC 2009. *Science and Decisions: Advancing Risk Assessment* (The "Silver Book"). National Academy of Sciences. Washington, DC: National Academy Press. http://www.nap.edu/catalog.php?record_id=12209

NRC 2011. *Sustainability and the U.S. EPA.* National Research Council, Committee on Incorporating Sustainability in the U.S. Environmental Protection Agency. Washington, DC: National Academy Press. http://sites.nationalacademies.org/PGA/sustainability/EPA/index.htm

Office of Management and Budget 2004. *Final Information Quality Bulletin for Peer Review*. Washington, DC. December 16. http://www.whitehouse.gov/sites/default/files/omb/memoranda/fy2005/m05-03.pdf

Presidential/Congressional Commission on Risk Assessment and Risk Management (PCCRARM) 1997a. *Framework for Environmental Health Risk Management. Final Report, Volume* 1. Washington, DC: The Presidential/Congressional Commission on Risk Assessment and Risk Management. http://www.riskworld.com/riskcommission/default.html

PCCRARM 1997b. *Risk Assessment and Risk Management in Regulatory Decision-Making. Final Report, Volume 2*. Washington, DC: The Presidential/Congressional Commission on Risk Assessment and Risk Management. http://www.riskworld.com/riskcommission/default.html

Seed, Jennifer, Edward W. Carney, Richard A. Corley, Kevin M. Crofton, John M. DeSesso, Paul M. D. Foster, Robert Kavlock, Gary Kimmel, James Klaunig, M. E. Meek, R. Julian Preston, William Slikker, Jr., Sonia Tabacova, Gary M. Williams, Jeanette Wiltse, R. Thomas Zoeller, Penelope Fenner-Crisp, and Dorothy E. Patton 2005. "Overview: Using Mode of Action and Life Stage Information to Evaluate the Human Relevance of Animal Toxicity Data." *Critical Reviews in Toxicology*. 35 (8–9): 663–672.

U.S. Environmental Protection Agency (U.S. EPA) 1984. *Risk Assessment and Management: Framework for Decision Making*. Washington, DC: Office of Policy, Planning and Evaluation. EPA/600/985/002. http://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=20008KTF.txt

U.S. EPA 1986a. *Guidelines for the Health Risk Assessment of Chemical Mixtures*. Washington, DC: Office of Research and Development. September. EPA/630/R-98/002. http://www.epa.gov/raf/publications/pdfs/CHEMMIX_1986.PDF

U.S. EPA 1986b. *Guidelines for Carcinogen Risk Assessment*. Washington, DC: Risk Assessment Forum. September. EPA/630/R-00/004. http://www.epa.gov/raf/publications/pdfs/CA%20GUIDELINES_1986.PDF

U.S. EPA 1986c. *Guidelines for Mutagenicity Risk Assessment.* Washington, DC: Risk Assessment Forum. September. EPA/630/R-98/003. http://www.epa.gov/raf/publications/pdfs/MUTAGEN2.PDF

U.S. EPA 1987. *The Risk Assessment Guidelines of 1986*. Washington, DC: Office of Health and Environmental Assessment. August. EPA/600/8-87/045. http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=29777#Download

U.S. EPA 1988. Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA. Washington, DC: Office of Solid Waste and Emergency Response, Office of Emergency and Remedial Response. October. EPA/540/G-89/004. http://www.epa.gov/superfund/policy/remedy/pdfs/540g-89004-s.pdf

U.S. EPA 1989. *Risk Assessment Guidance for Superfund: Volume 1, Human Health Evaluation Manual (Part A*). Washington, DC: Office of Emergency and Remedial Response. December. EPA/540/1-89/002. http://www.epa.gov/oswer/riskassessment/ragsa/pdf/rags_a.pdf (Also see Parts B–D.)

U.S. EPA 1991a. Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions. Memorandum from Agency Assistant Administrator for Solid Waste and Emergecny Response, Donald R. Clay, Washington, DC. April 22.

U.S. EPA 1991b. *Guidelines for Developmental Toxicity Risk Assessment.* Washington, DC: Risk Assessment Forum. EPA/600/*Federal Register*-91/001. http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=23162

U.S. EPA 1992a. *Guidelines for Exposure Assessment.* Washington, DC: Risk Assessment Forum. EPA/600/Z-92/001. http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=15263

U.S. EPA 1992b. *Framework for Ecological Risk Assessment.* Washington, DC: Risk Assessment Forum. EPA/630/R-92/001. http://www.epa.gov/raf/publications/framework-eco-risk-assessment.htm

U.S. EPA 1994. *Methods for Derivation of Inhalation Reference Concentrations (RfCs) and Application of Inhalation Dosimetry*. Washington, DC: Office of Research and

Development, Office of Health and Environmental Assessment. EPA/600/8-90/066F. http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=71993

U.S. EPA 1995a. *Policy for Risk Characterization*. Memorandum from Agency Administrator Carol M. Browner, Washington, DC. March 21. http://www.epa.gov/spc/pdfs/rccover.pdf

U.S. EPA 1995b. *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, Volume IV: Risk Communication*. Washington, DC: Office of Water. March. EPA/823/R-95/001. http://water.epa.gov/scitech/swguidance/fishshellfish/techguidance/guidance.cfm

U.S. EPA 1995c. *Policy on Evaluating Health Risks to Children*. Memorandum from Agency Administrator Carol M. Browner, Washington, DC. October 20. http://www.epa.gov/spc/2poleval.htm

U.S. EPA 1995d. *Guidance for Risk Characterization*. Washington, DC: Science Policy Council. http://www.epa.gov/spc/pdfs/rcguide.pdf

U.S. EPA 1996. *Guidelines for Reproductive Toxicity Risk Assessment.* Washington, DC: Risk Assessment Forum. EPA/630/R-96/009. http://www.epa.gov/raf/publications/guidelines-reproductive-tox-risk-assessment.htm

U.S. EPA 1997a. *Guidance on Cumulative Risk Assessment, Part 1. Planning and Scoping.* Washington, DC: Science Policy Council. Attachment to memo dated July 3, 1997 from the Administrator, Carol Browner, and Deputy Administrator, Fred Hansen, titled "Cumulative Risk Assessment Guidance—Phase I Planning and Scoping." http://www.epa.gov/OSA/spc/2cumrisk.htm

U.S. EPA 1997b. *Exposure Factors Handbook (Final Report)*. Washington, DC: Office of Research and Development, National Center for Environmental Assessment. August. EPA/600/P-95/002Fa. http://www.epa.gov/ncea/pdfs/efh/front.pdf

U.S. EPA 1997c. *Guiding Principles for Monte Carlo Analysis*. Washington, DC: Risk Assessment Forum. EPA/630/R-97/001. http://www.epa.gov/ncea/pdfs/montcarl.pdf

U.S. EPA 1998a. *Guidelines for Ecological Risk Assessment.* Washington, DC: Risk Assessment Forum. EPA/630/R-95/002F. http://www.epa.gov/raf/publications/pdfs/ECOTXTBX.PDF

U.S. EPA 1998b. *Guidelines for Neurotoxicity Risk Assessment.* Washington, DC: Risk Assessment Forum. EPA/630/R-95/001F. http://www.epa.gov/raf/publications/pdfs/NEUROTOX.PDF

U.S. EPA 1999a. *Risk Assessment Guidance for Superfund (RAGS) Volume 3—Part A: Process for Conducting Probabilistic Risk Assessment)*. Draft. Washington, DC: Office of Solid Waste

and Emergency Response. December. http://www.epa.gov/oswer/riskassessment/rags3adt/

U.S. EPA 1999b. *Guidance for Performing Aggregate Exposure and Risk Assessments*. Washington, DC: Office of Pesticide Programs. November. http://www.epa.gov/scipoly/sap/meetings/1999/february/guidance.pdf

U.S. EPA 1999c. *Residual Risk Report to Congress.* Research Triangle Park, NC: Office of Air Quality Planning and Standards. March. EPA/453/R-99/001. http://www.epa.gov/ttncaaa1/t3/reports/risk_rep.pdf

U.S. EPA 2000a. *Supplementary Guidance for Conducting Health Risk Assessment of Chemical Mixtures*. Washington, DC: Risk Assessment Forum. August. EPA/630/R-00/002. http://www.epa.gov/ncea/pdfs/chem_mix/chem_mix_08_2001.pdf

U.S. EPA 2000b. *Science Policy Council Handbook: Risk Characterization*. Washington, DC: Science Policy Council. EPA/100/B-00/002. http://www.epa.gov/spc/pdfs/rchandbk.pdf

U.S. EPA 2000c. *The Model Plan for Public Participation*. Washington, DC: Office of Enforcement and Compliance. February. EPA/300/K-00/001. http://www.epa.gov/compliance/ej/resources/publications/nejac/model-public-part-plan.pdf

U.S. EPA 2000d. *Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health*. Washington, DC: Office of Water. EPA/822/B-00/004. http://water.epa.gov/scitech/swguidance/standards/criteria/health/methodology/index.cfm

U.S. EPA 2000e. *Lessons Learned About Designing, Developing, and Disseminating Environmental Information Products*. Washington, DC: Office of Environmental Information. November. EPA/260/R-00/001. http://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P1005LPL.txt

U.S. EPA 2001a. *Arsenic Rule Benefits Analysis: An SAB Review*. EPA/SAB/EC-01/008. http://www.epa.gov/ogwdw000/arsenic/pdfs/ec01008.pdf

U.S. EPA 2001b. *General Principles for Performing Aggregate Exposure and Risk Assessments*. Washington, DC: Office of Pesticide Programs. Fax-On-Demand. Fax no. (202) 401-0527. Item no. 6043. http://www.epa.gov/oppfead1/trac/science/aggregate.pdf

U.S. EPA 2001c. *EPA Requirements for Quality Assurance Project Plans*. Washington, DC: Office of Environmental Information. March. EPA/240/B-00/003. http://www.epa.gov/quality/qs-docs/r5-final.pdf

U.S. EPA 2001d. *Risk Assessment Guidance for Superfund (RAGS) Volume III—Part A: Process for Conducting Probabilistic Risk Assessment*. Washington, DC: Office of Solid Waste and Emergency Response. December. EPA/540/R-02/002. http://www.epa.gov/oswer/riskassessment/rags3adt/pdf/rags3adt_complete.pdf

U.S. EPA 2002a. *Lessons Learned on Planning and Scoping of Environmental Risk Assessment*. Memorandum from the Science Policy Council. January. http://www.epa.gov/spc/pdfs/llmemo.pdf

U.S. EPA 2002b. "Appendix B: Case Study on Concentrated Animal Feeding Operations." B. In *Lessons Learned on Planning and Scoping for Environmental Risk Assessments.* Washington, DC: Science Policy Council. http://www.epa.gov/spc/pdfs/handbook.pdf

U.S. EPA 2002c. "Appendix C: Re-registration of Pentachlorophenol." In *Lessons Learned on Planning and Scoping for Environmental Risk Assessments.* Washington, DC: Science Policy Council. http://www.epa.gov/spc/pdfs/handbook.pdf

U.S. EPA 2002d. *Guidance on Cumulative Risk Assessment of Pesticide Chemicals That Have a Common Mechanism of Toxicity*. Washington, DC: Office of Pesticide Programs. January. http://www.epa.gov/oppfead1/trac/science/cumulative_guidance.pdf

U.S. EPA 2002e. *A Review of the Reference Dose and Reference Concentration Processes*. External review draft. Washington, DC: Risk Assessment Forum. May. EPA/630/P-02/002F. http://www.epa.gov/raf/publications/pdfs/rfdrfcextrevdrft.pdf

U.S. EPA 2002f. "Superfund Community Involvement Plans." September. http://www.epa.gov/superfund/community/pdfs/toolkit/7clplans.pdf

U.S. EPA 2002g. *Guidance on Cumulative Risk Assessment of Pesticide Chemicals That Have a Common Mechanism of Toxicity*. Washington, DC: Office of Pesticide Programs. http://www.epa.gov/scipoly/sap/meetings/2003/december11/cumulativeguidance2002.pdf

U.S. EPA 2003a. *Framework for Cumulative Risk Assessment*. Washington, DC: Risk Assessment Forum. May. EPA/630/P-02/001F. http://www.epa.gov/raf/publications/pdfs/frmwrk_cum_risk_assmnt.pdf

U.S. EPA 2003b. *Considerations in Risk Communication: A Digest of Risk Communication as a Risk Management Tool*. Cincinnati, OH: Office of Research and Development, National Risk Management Research Laboratory. March. EPA/625/R-02/004. http://www.epa.gov/nrmrl/pubs/625r02004.html

U.S. EPA 2003c. *Public Involvement Policy*. May. EPA/233/B-03/002. http://www.epa.gov/publicinvolvement/pdf/policy2003.pdf

U.S. EPA 2003d. *Framework for Implementing EPA's Public Involvement Policy*. May. EPA/233/F-03/001. http://www.epa.gov/publicinvolvement/policy2003/framework.pdf

U.S. EPA 2004a. *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment)*. Washington, DC: Office of Solid Waste and Emergency Response. EPA/540/R/99/005. http://www.epa.gov/oswer/riskassessment/ragse/

U.S. EPA 2004b. *Air Toxics Risk Assessment Reference Library, Volume 1. Technical Resource Manual*. Research Triangle Park, NC: Office of Air Quality Planning and Standards. EPA/453/K-04/001A. http://www.epa.gov/ttn/fera/risk_atra_vol1.html

U.S. EPA 2004c. *Air Toxics Risk Assessment Reference Library, Volume 2. Facility-Specific Assessment*. Research Triangle Park, NC: Office of Air Quality Planning and Standards. EPA/453/K-04/001B. http://www.epa.gov/ttn/fera/risk_atra_vol2.html

U.S. EPA 2004d. *Risk Assessment Principles and Practices*. Washington, DC: Office of the Science Advisor, Risk Assessment Task Force. March. EPA/100/B-04/001. http://www.epa.gov/osa/pdfs/ratf-final.pdf

U.S. EPA 2004e. *Air Toxics Risk Assessment Library. Volume 1 Technical Resource Manual.* Washington, DC: Office of Air and Radiation. April. Residual Risk Framework described in *Part II—Human Health Risk Assessment: Inhalation*. http://www.epa.gov/ttn/fera/data/risk/vol_1/chapter_05.pdf. All volumes available at: *http://www.epa.gov/ttn/fera/risk_atra_main.html*

U.S. EPA 2004f. *Ensuring Risk Reduction in Communities With Multiple Stressors: Environmental Justice and Cumulative Risks/Impacts*. Washington, DC: National Environmental Justice Advisory Council, Cumulative Risks/Impacts Work Group. December. http://www.epa.gov/environmentaljustice/resources/publications/nejac/nejac-cum-risk-rpt-122104.pdf

U.S. EPA 2004g. *Registration Review Update*. Washington, DC: Office of Pesticide Programs, Pesticide Program Dialogue Committee. October. http://www.epa.gov/oppfead1/cb/ppdc/regisreview/regreview-update.pdf

U.S. EPA 2005a. *Guidelines for Carcinogen Risk Assessment.* Washington, DC: Risk Assessment Forum. March. EPA/630/P-03/001B. http://www.epa.gov/raf/publications/pdfs/CANCER_GUIDELINES_FINAL_3-25-05.pdf

U.S. EPA 2005b. *Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens.* Washington, DC: Risk Assessment Forum. March. EPA/630/R-03/003F. http://www.epa.gov/ttn/atw/childrens_supplement_final.pdf

U.S. EPA 2005c. *Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants (Final)*. Washington, DC: Risk Assessment Forum. EPA/630/P-03/003F. http://www.epa.gov/raf/publications/guidance-on-selecting-age-groups.htm

U.S. EPA 2005d. *Superfund Community Involvement Handbook*. Washington, DC: Office of Solid Waste and Emergency Response. April. EPA/540/K-05/003. http://www.epa.gov/superfund/community/cag/pdfs/ci_handbook.pdf

U.S. EPA 2005e. A Probabilistic Exposure Assessment for children who Contact CCA-Treated Playsets and Decks. Washington DC: U.S. Environmental Protection Agency. February. http://www.epa.gov/heasd/sheds/CCA_all.pdf

U.S. EPA 2006a. *A Framework for Assessing Health Risk of Environmental Exposures to Children (Final)*. Washington, DC: U.S. Environmental Protection Agency. EPA/600/R-05/093F. http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=158363

U.S. EPA 2006b. *Advisory on EPA's Superfund Benefits Analysis*. January 9. http://yosemite.epa.gov/sab/sabproduct.nsf/58ADDDF28999BAC18525710100554A0F/$File/superfund_sab-adv-06-002.pdf

U.S. EPA 2006c. *Peer Review Handbook,* 3rd Edition. Washington, DC: Science Policy Council. EPA/100/B-06/002. http://www.epa.gov/peerreview/pdfs/peer_review_handbook_2006.pdf

U.S. EPA 2006d. *Air Toxics Risk Assessment Reference Library, Volume 3. Community-Scale Assessment*. Research Triangle Park, NC: Office of Air Quality Planning and Standards. EPA/452/K-06/001C. http://www.epa.gov/ttn/fera/risk_atra_vol3.html

U.S. EPA 2006e. *EPA's Action Development Process. Guide to Considering Children's Health When Developing EPA Actions: Implementing Executive Order 13045 and EPA's Policy on Evaluating Health Risks to Children*. http://yosemite.epa.gov/ochp/ochpweb.nsf/content/ADPguide.htm/$File/EPA_ADP_Guide_508.pdf

U.S. EPA 2006f. *Guidance on Systematic Planning Using the Data Quality Objectives Process*. Washington, DC: Office of Environmental Information. EPA/QA/G-4. http://www.epa.gov/quality/qs-docs/g4-final.pdf

U.S. EPA 2007a. *Risk Communication in Action: The Risk Communication Workbook*. Cincinnati, OH: Office of Research and Development, National Risk Management Research Laboratory. August. EPA/625/R-05/003. http://nepis.epa.gov/Exe/ZyNET.exe/60000I2U.TXT?ZyActionD=ZyDocument&Client=EPA&Index=2006+Thru+2010&Docs=&Query=&Time=&EndTime=&SearchMethod=1&Toc

Restrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5Czyfiles%5CIndex%20Data%5C06thru10%5CTxt%5C00000001%5C60000I2U.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=p%7Cf&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1&SeekPage=x&ZyPURL

U.S. EPA 2007b. *Risk Communication in Action: The Tools of Message Mapping*. Cincinnati, OH: Office of Research and Development, National Risk Management Research Laboratory. August. EPA/625/R-06/012. http://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=60000IOS.txt

U.S. EPA 2007c. *Lead: Human Exposure and Health Risk Assessment for Selected Case Studies. Volume 1. Human Exposure and Health Risk Assessments—Full-Scale*. Research Triangle Park, NC: Office of Air Quality Planning and Standards. July. EPA/452/R-07/014a. http://www.epa.gov/ttn/naaqs/standards/pb/data/Pb-RA-Vol-1-073007.pdf

U.S. EPA 2007d. Better Decisions through Consultation and Collaboration. Washington, DC: U.S. Environmental Protection Agency. Conflict Prevention and Resolution Center http://www.epa.gov/adr/Better_Decisions.pdf

U.S. EPA 2008a. *Child-Specific Exposure Factors Handbook (Final Report) 2008*. Washington, DC: U.S. Environmental Protection Agency. EPA/600/R-06/096F. http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=199243

U.S. EPA 2008b. "Formaldehyde Emissions From Pressed Wood Products." Proposed rulemaking. *Federal Register* 73 (233): 73620–43629. http://www.epa.gov/fedrgstr/EPA-TOX/2008/December/Day-03/t28585.htm

U.S. EPA 2009. *Highlights of the Child-Specific Exposure Factors Handbook (Final Report)*. Washington, DC: Office of Research and Development, National Center for Environmental Assessment. EPA/600/R-08/135. http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=200445

U.S. EPA 2010a. *Guidelines for Preparing Economic Analysis*. December 17. EPA/240/R-10/001. http://yosemite.epa.gov/ee/epa/eerm.nsf/vwAN/EE-0568-50.pdf/$file/EE-0568-50.pdf

U.S. EPA 2010b. *EPA's Action Development Process. Interim Guidance on Considering Environmental Justice During the Development of an Action*. Washington, DC. July. http://www.epa.gov/environmentaljustice/resources/policy/considering-ej-in-rulemaking-guide-07-2010.pdf

U.S. EPA 2010c. *Quantitative Health Risk Assessment for Particulate Matter*. Research Triangle Park, NC: Office of Air Quality Planning and Standards. EPA/452/R-10/005. http://www.epa.gov/ttn/naaqs/standards/pm/data/PM_RA_FINAL_June_2010.pdf

U.S. EPA 2010d. *Requirements for Submitting Electronic Pre-manufacture Notices (PMNs)*. Washington, DC: Office of Chemical Safety and Pollution Prevention, Office of Pollution, Prevention and Toxics. January. http://www.epa.gov/ncea/efh/pdfs/efh-complete.pdf

U.S. EPA 2010e. "Proposed Significant New Use Rule for Multi-walled Carbon Nanotubes." Proposed rulemaking. *Federal Register* 75 (22): 5546–5551. http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OPPT-2009-0686-0001

U.S. EPA 2011a. *Exposure Factors Handbook*. Washington, DC: Office of Research and Development. September. EPA/600/R-090/052F. http://www.epa.gov/ncea/efh/pdfs/efh-complete.pdf

U.S. EPA 2011b. "EPA Public Involvement." Accessed November 11. http://www.epa.gov/publicinvolvement/

U.S. EPA 2011c. "Pesticide Program Dialogue Committee." Accessed November 11. http://www.epa.gov/oppfead1/cb/ppdc/

U.S. EPA 2011d. "Superfund Community Involvement Publications." Accessed November 11. http://www.epa.gov/superfund/community/publications.htm

U.S. EPA 2011e. "Sustainability." Accessed November 11. http://www.epa.gov/sustainability/

U.S. EPA 2011f. "Life-Cycle Assessment." Accessed November 11. http://www.epa.gov/nrmrl/std/lca/lca.html

U.S. EPA 2011g. "Definitions of the Most Commonly Used Public Stakeholder Involvement Terms." Accessed November 11. http://www.epa.gov/stakeholders/definit.htm

U.S. EPA 2011h. "Superfund Community Involvement." Accessed November 11. http://www.epa.gov/superfund/community/

U.S. EPA 2011i. "EPA's Quality System for Environmental Data and Technology." Accessed November 11. http://www.epa.gov/quality/

U.S. EPA 2011j. "Superfund Quality Assurance/Quality Control." Accessed November 11. http://www.epa.gov/superfund/programs/clp/qaqc.htm

U.S. EPA 2011k. "Resources for Planning New Data Collections." Accessed November 11. http://www.epa.gov/quality/rnewdata.html

U.S. EPA 2011l. "Risk and Technology Review." Accessed November 11. http://www.epa.gov/ttn/atw/rrisk/rtrpg.html

U.S. EPA 2011m. "Multi-criteria Integrated Resource Assessment (MIRA)." Accessed November 11. http://www.epa.gov/reg3esd1/data/mira.htm

U.S. EPA 2011n. "Particulate Matter Standards—Documents From Current Review—Planning Documents." Accessed November 11. http://www.epa.gov/ttn/naaqs/standards/pm/s_pm_2007_pd.html

U.S. EPA 2011o. "Human Health: Planning and Scoping." Accessed November 11. http://www.epa.gov/oswer/riskassessment/human_health_plan.htm

U.S. EPA 2011p. "Ecological: Planning and Scoping." Accessed November 11. http://www.epa.gov/oswer/riskassessment/eco_plan.htm

U.S. EPA 2011q. "Risk and Technology Review." Accessed November 11. http://www.epa.gov/ttn/atw/rrisk/rtrpg.html

U.S. EPA 2011r. *EPA's Action Development Process. Guidance for EPA Staff on Developing Quality Actions*. Washington, DC. March. http://yosemite.epa.gov/sab/SABPRODUCT.nsf/5088B3878A90053E8525788E005EC8D8/$File/adp03-00-11.pdf

U.S. EPA 2012a. "Environmental Justice Policy and Guidance." Accessed May 24. http://www.epa.gov/environmentaljustice/resources/policy/

U.S. EPA 2012b. "U.S. Environmental Protection Agency Scientific Integrity Policy." January 15. http://www.epa.gov/research/htm/scientific-integrity.htm

U.S. EPA 2012c. "Science Inventory." Accessed May 24. http://cfpub.epa.gov/si/

U.S. EPA 2012d. "Public Involvement Policy and Related Documents." Accessed May 24. http://www.epa.gov/publicinvolvement/public/

U.S. EPA 2012e. "Region 8 Site Conceptual Model." Accessed May 24. http://www.epa.gov/region8/r8risk/hh_scm.html

U.S. EPA 2012f. "Process of Reviewing the National Ambient Air Quality Standards." Accessed May 24. http://www.epa.gov/ttn/naaqs/review.html

U.S. EPA 2012g. "American Indian Environmental Office (AIEO)." Accessed May 24. http://www.epa.gov/tribalportal/aieo/index.html

U.S. EPA 2012h. "Office of the Science Advisor: Ethics, Regulations, and Policies." Accessed May 24. http://www.epa.gov/phre/policy.htm

U.S. EPA 2012i. "Risk Assessment Portal." Accessed May 28. http://www.epa.gov/risk/

U.S. EPA 2012j. "Dose-Response Assessment." Accessed May 28. http://www.epa.gov/riskassessment/dose-response.htm

U.S. EPA 2012k. "Guidance & Tools." Accessed May 28. http://www.epa.gov/risk_assessment/guidance.htm

U.S. EPA 20121. "Cacodylic Acid." Accessed May 28. http://www.epa.gov/opp00001/reregistration/cacodylic_acid/

U.S. EPA 2012m. "Cumulative Risk Assessment Methods and Tools." Accessed May 28. http://www.epa.gov/oppsrrd1/cumulative/methods_tools.htm

U.S. EPA 2012n. "High Production Volume (HPV) Challenge: Robust Summaries and Test Plans." Accessed May 28. http://www.epa.gov/hpv/pubs/summaries/viewsrch.htm

U.S. EPA 2012o. "IRIS Process." Accessed May 28. http://www.epa.gov/iris/process.htm

U.S. EPA 2012p. "Technology Transfer Network National Ambient Air Quality Standards (NAAQS)." Accessed May 30. http://www.epa.gov/ttn/naaqs/

U.S. EPA 2012q. "Environmental Justice." Accessed May 30. http://www.epa.gov/environmentaljustice/

World Health Organization. 2008. *Guidance Document on Characterizing and Communicating Uncertainty in Exposure Assessment.* Geneva, Switzerland. http://www.who.int/ipcs/methods/harmonization/areas/uncertainty%20.pdf

Appendix I. Examples of EPA Program-Specific Resources and Guidance on Risk Assessment Activities

Air Toxics Program (Office of Air Quality Planning and Standards [OAQPS])

- Air Toxics Risk Assessment Reference Library for conducting air toxics analyses at the facility and community-scale. The library provides information on the fundamental principles of risk-based assessment for air toxics and how to apply those principles in different settings as well as strategies for reducing risk at the local level.
    - Volume 1: Technical Resource Manual (http://www.epa.gov/ttn/fera/risk_atra_vol1.html)
    - Volume 2: Facility-Specific Assessment (http://www.epa.gov/ttn/fera/risk_atra_vol2.html)
    - Volume 3: Community-Scale Assessment (http://www.epa.gov/ttn/fera/risk_atra_vol3.html)
- *Residual Risk Report to Congress* (http://www.epa.gov/ttn/oarpg/t3/reports/risk_rep.pdf)

Hazardous Waste Program (Office of Solid Waste and Emergency Response [OSWER])

- *Resource Conservation and Recovery Act Public Participation Manual* http://www.epa.gov/wastes/hazard/tsd/permit/pubpart/manual.htm

National Ambient Air Quality Standards Program (NAAQS) (OAQPS)

- Process for NAAQS reviews, including role of risk assessment (http://www.epa.gov/ttn/naaqs/review.html)
- Recent NAAQS risk assessments (http://www.epa.gov/ttn/fera/risk_criteria.html)
- Current documents for NAAQS reviews (http://www.epa.gov/ttn/naaqs/)

Pesticides Program (Office of Pesticide Programs)

- Science Policy Issues and Guidance Documents (http://www.epa.gov/oppfead1/trac/science/)
- *Public Participation in Registration Decisions*. Washington, DC: Office of Pesticide Programs, U.S .Environmental Protection Agency. 31 March 2010. - http://www.epa.gov/pesticides/regulating/public-participation-process.html
- Models and Databases (http://www.epa.gov/pesticides/science/models_db.htm)
- Public Participation Process for Registration Actions (http://www.epa.gov/pesticides/regulating/public-participation-process.html)

Safe Drinking Water Program (Office of Water)

- Public Access Information for the Safe Drinking Water Act http://water.epa.gov/lawsregs/guidance/sdwa/upload/2009_08_28_sdwa_fs_30ann_publicinvolve_web.pdf

Superfund Program (OSWER)

- Risk assessment resources and guidance (http://www.epa.gov/oswer/riskassessment/risk_superfund.htm)
- *Supplement to RAGS Part A: Community Involvement in Superfund Risk Assessments* (1999) (http://www.epa.gov/oswer/riskassessment/ragsa/pdf/ci_ra.pdf)
- Superfund Community Involvement Guidance and Publications (http://www.epa.gov/superfund/community/involvement.htm)