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INTRODUCTION TO CUMULATIVE EFFECTS ANALYSIS

Evidence is increasing that the most devastating environmental effects may result not from the direct effects of a particular action, but from the combination of individually minor effects of multiple actions over time.

Some authorities contend that most environmental effects can be seen as cumulative because almost all systems have already been modified, even degraded, by humans. According to the report of the National Performance Review (1994), the heavily modified condition of the San Francisco Bay estuary is a result of activities regulated by a wide variety of government agencies. The report notes that one mile of the delta of the San Francisco Bay may be affected by the decisions of more than 400 agencies (federal, state, and local). William Odum (1982) succinctly described environmental degradation from cumulative effects as "the tyranny of small decisions."

The Council on Environmental Quality's (CEQ) regulations for implementing the National Environmental Policy Act (NEPA) define cumulative effects as

> the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-federal) or person undertakes such other actions (40 CFR § 1508.7).

The fact that the human environment continues to change in unintended and unwanted ways in spite of improved federal decisionmaking resulting from the implementation of NEPA is largely attributable to this incremental (cumulative) impact. Although past environmental impact analyses have focused primarily on project-specific impacts, NEPA provides the context and carries the mandate to analyze the cumulative effects of federal actions.

NEPA and CEQ's regulations define the cumulative problem in the context of the action, alternatives, and effects. By definition, cumulative effects must be evaluated along with the direct effects and indirect effects (those that occur later in time or farther removed in distance) of each alternative. The range of alternatives considered must include the no-action alternative as a baseline against which to evaluate cumulative effects. The range of actions that must be considered includes not only the project proposal but all connected and similar actions that could contribute to cumulative effects. Specifically, NEPA requires that all related actions be addressed in the same analysis. For example, the expansion of an airport runway that will increase the number of passengers traveling must address not only the effects of the runway itself, but also the expansion of the terminal and the extension of roadways to provide access to the expanded terminal. If there are similar actions planned

in the area that will also add traffic or require roadway extensions (even though they are nonfederal), they must be addressed in the same analysis.

The selection of actions to include in the cumulative effects analysis, like any environmental impact assessment, depends on whether they affect the human environment. Throughout this handbook discussion of the environment will focus on resources (entities such as air quality or a trout fishery), ecosystems (local or landscape-level units where nature and humans interact), and human communities (sociocultural settings that affect the quality of life). The term resources will sometimes be used to refer to all three entities. Table 1-1 lists some of the common cumulative effects situations faced by federal agencies (see Chapter 3 for a list of common cumulative effects issues affecting various resources, ecosystems, and human communities).

PURPOSE OF CUMULATIVE EFFECTS ANALYSIS

Congressional testimony on behalf of the passage of NEPA stated that

> ...as a result of the failure to formulate a comprehensive national environmental policy... environmental problems are only dealt with when they reach crisis proportions..... Important decisions concerning the use and shape of man's environment continue to be made in small but steady increments which perpetuate requirements.

Table 1-1. Examples of cumulative effects situations faced by federal agencies including both multiple agency actions and other actions affecting the same resource

Federal Agency	Cumulative Effects Situations
Army Corps of Engineers	■ incremental loss of wetlands under the national permit to dredge and fill and from land subsidence
Bureau of Land Management	■ degradation of rangeland from multiple grazing allotments and the invasion of exotic weeds
Department of Defense	■ population declines in nesting birds from multiple training missions and commercial tree harvests within the same land unit
Department of Energy	■ increased regional acidic deposition from emissions trading policies and changing climate patterns
Federal Energy Regulatory Commission	■ blocking of fish passage by multiple hydropower dams and Corps of Engineers reservoirs in the same river basin
Federal Highway Administration	■ cumulative commercial and residential development and highway construction associated with suburban sprawl
Forest Service	■ increased soil erosion and stream sedimentation from multiple timber permits and private logging operations in the same watershed
General Services Administration	■ change in neighborhood sociocultural character resulting from ongoing local development including new federal office construction
National Park Service	■ degraded recreational experience from overcrowding and reduced visibility

Interim guidelines issued in 1970 stated that the effects of many federal decisions about a project or complex of projects can be "individually limited but cumulatively considerable" (35 *Federal Register* 7391, May 12, 1970).

The passage of time has only increased the conviction that cumulative effects analysis is essential to effectively managing the consequences of human activities on the environment. The purpose of cumulative effects analysis, therefore, is to ensure that federal decisions consider the full range of consequences of actions. Without incorporating cumulative effects into environmental planning and management, it will be impossible to move towards sustainable development, i.e., development that meets the needs of the present without compromising the ability of future generations to meet their own needs (World Commission on Environment and Development 1987; President's Council on Sustainable Development 1996). To a large extent, the goal of cumulative effects analysis, like that of NEPA itself, is to inject environmental considerations into the planning process as early as needed to improve decisions. If cumulative effects become apparent as agency programs are being planned or as larger strategies and policies are developed then potential cumulative effects should be analyzed at that time.

Cumulative effects analysis necessarily involves assumptions and uncertainties, but useful information can be put on the decision-making table now. Decisions must be supported by the best analysis based on the best data we have or are able to collect. Important research and monitoring programs can be identified that will improve analyses in the future, but their absence should not be used as a reason for not analyzing cumulative effects to the extent possible now. Where substantial uncertainties remain or multiple resource objectives exist, adaptive management provisions for flexible project implementation can be incorporated into the selected alternative.

Sustainable America

President Clinton's Council on Sustainable Development was charged with recommending a national action strategy for sustainable development at a time when Americans are confronted with new challenges that have global ramifications. The Council adopted the Brundtland Commission's definition of sustainable development and articulated the following vision:

> Our vision is of a life-sustaining Earth. We are committed to the achievement of a dignified, peaceful, and equitable existence. A sustainable United States will have a growing economy that provides equitable opportunities for satisfying livelihoods and a safe, healthy, high quality of life for current and future generations. Our nation will protect its environment, its natural resource base, and the functions and viability of natural systems on which all life depends.

The Council concluded that in order to meet the needs of the present while ensuring that future generations have the same opportunities, the United States must change by moving from conflict to collaboration and adopting stewardship and individual responsibility as tenets by which to live. This vision is similar to the first environmental policy listed in NEPA— that each generation should fulfill its responsibilities as trustee of the environment for succeeding generations. Analyzing for cumulative effects on the full range of resources, ecosystems, and human communities under NEPA provides a mechanism for addressing sustainable development.

AGENCY EXPERIENCE WITH CUMULATIVE EFFECTS ANALYSIS

Federal agencies make hundreds, perhaps thousands, of small decisions annually. Sometimes a single agency makes decisions on

similar projects; other times project decisions by many different authorities are interrelated. The Federal Energy Regulatory Commission must make licensing decisions on many individual hydropower facilities within the same river basin (Figure 1-1). The Federal Highway Administration and state transportation agencies frequently make decisions on highway projects that may not have significant direct environmental effects, but that may induce indirect and cumulative effects by permitting other development activities that have significant effects on air and water resources at a regional or national scale. The highway and the other development activities can reasonably be foreseen as "connected actions" (40 CFR § 1508.25).

Many times there is a mismatch between the scale at which environmental effects occur and the level at which decisions are made. Such mismatches present an obstacle to cumulative effects analysis. For example, while broad scale decisions are made at the program or policy level (e.g., National Energy Strategy, National Transportation Plan, Base Realignment and Closure Initiative), the environmental effects are generally assessed at the project level (e.g., coal-fired power plant, interstate highway connector, disposal of installation land). Cumulative effects analysis should be the tool for federal agencies to evaluate the implications of even project-level environmental assessments (EAs) on regional resources.

Federal agencies have struggled with preparing cumulative effects analyses since CEQ issued its regulations in 1978. They continue to find themselves in costly and time-consuming administrative proceedings and litigation over the proper scope of the analysis. Court cases throughout the years have affirmed CEQ's requirement to assess cumulative effects of projects but have added little in the way of guidance and direction. To date, there has not been a single, universally accepted conceptual approach, nor even general principles accepted by all scientists and managers. States and other countries with "little NEPA" laws have experienced similar implementation problems.

A General Accounting Office (GAO) report on coastal pollution noted that state coastal managers raised concerns about the quality of cumulative effects analysis in environmental reviews for proposed federal activities (GAO 1991). In one case study, state coastal managers told GAO that the Environmental Impact Statement (EIS) for rerouting and expanding a highway did not consider that the project as proposed would have a significant growth-inducing effect that would exceed state planning limitations by 100 percent. The Department of Commerce acknowledged the need to provide additional guidance on how to assess the indirect and cumulative effects of proposed actions in the coastal zone and recently published a cumulative impacts assessment protocol for managing cumulative coastal environmental impacts (Vestal et al. 1995).

The increased use of EAs rather than EISs in recent years could exacerbate the cumulative effects problem. Agencies today prepare substantially more EAs than EISs; in a typical year 45,000 EAs are prepared compared to 450 EISs. An agency's decision to prepare an EIS is important because an EIS tends to contain more rigorous analysis and more public involvement than an EA. EAs tend to save time and money because an EA generally takes less time to prepare. They are a cost-effective way to determine whether potentially significant effects are likely and whether a project can mitigate these effects. At the same time, because EAs focus on whether effects are significant, they tend to underestimate the cumulative effects of their projects. Given that so many more EAs are prepared than EISs, adequate consideration of cumulative effects requires that EAs address them fully. One study analyzed 89 EAs announced in the *Federal Register* between January 1, 1992, and June 30, 1992, to determine the extent to which treatment of cumulative effects met CEQ's requirements (Figure 1-2). Only 35 EAs (39%) mentioned cumulative

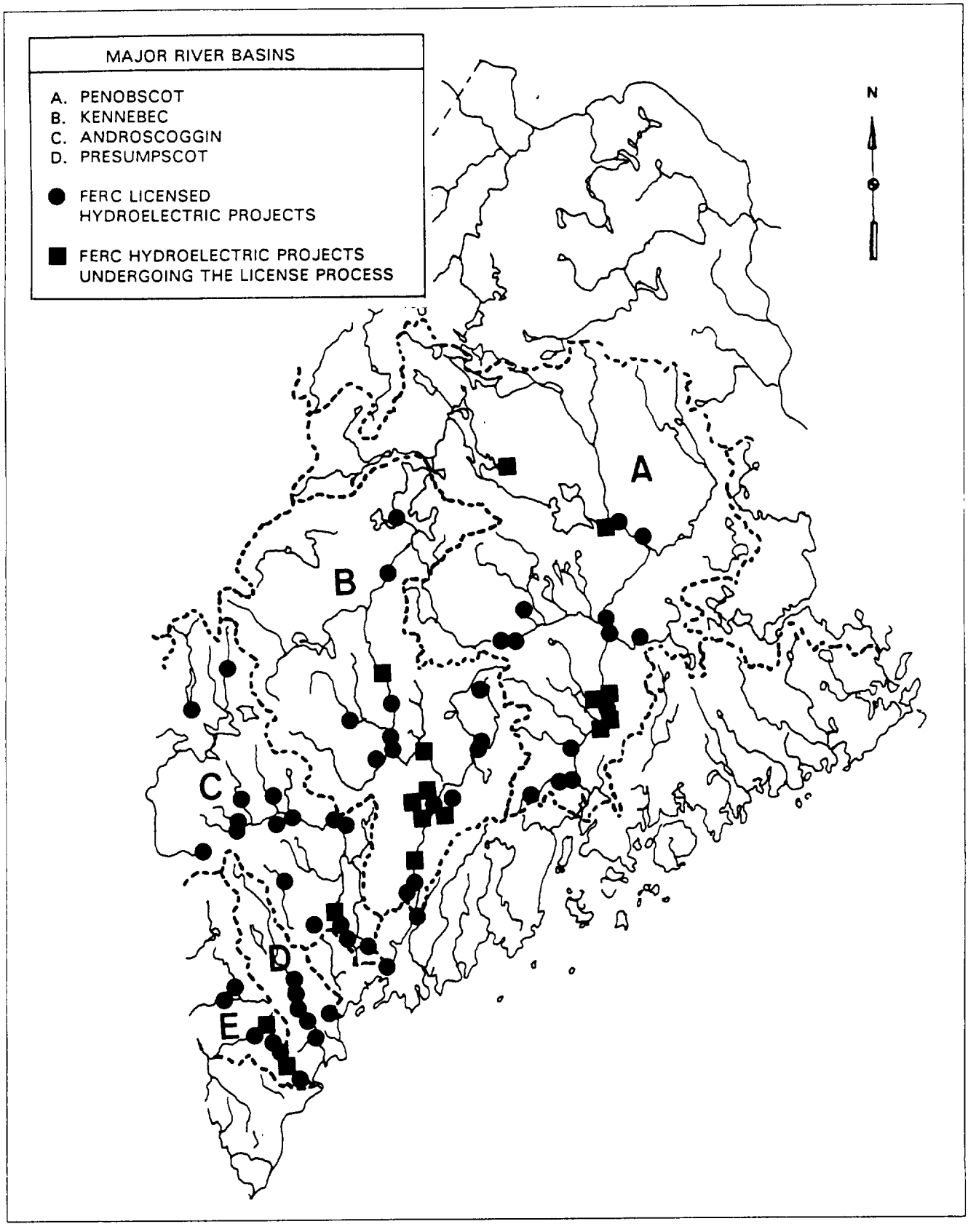
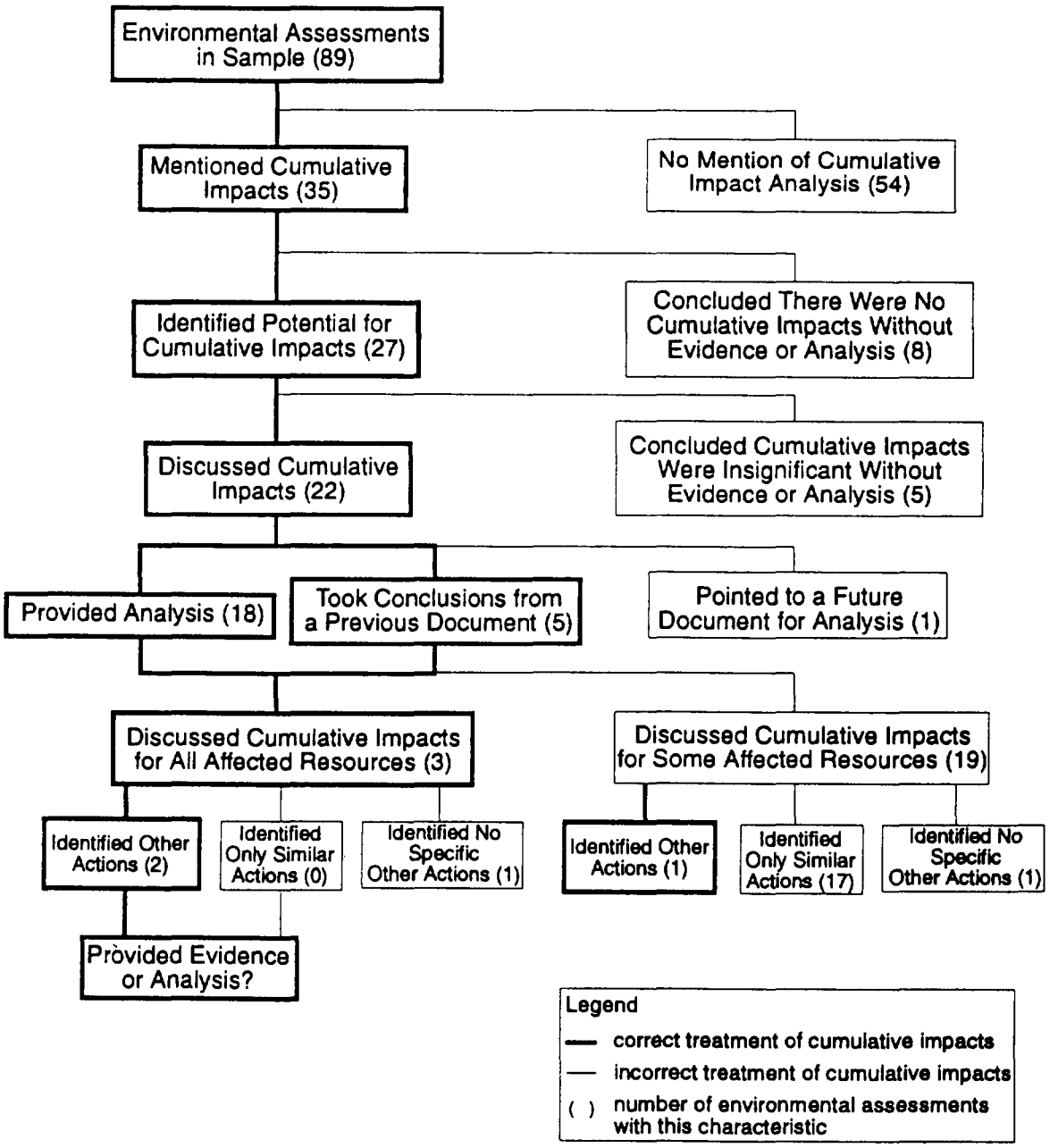


Figure 1-1. River basins and associated FERC related hydroelectric projects in Maine (undated)



For the 22 environmental assessments (EAs) that discussed cumulative impacts, the three treatments are not mutually exclusive. One EA in the sample provided analysis for some resources, took the conclusions from a previous document for one resource, and pointed to a future document for another resource. For this reason, the numbers in the boxes sum to 24 instead of 22.

Figure 1-2. Consideration of cumulative effects in environmental assessments (McCold and Holman 1995)

effects. Nearly half of those failed to present evidence to support their conclusions concerning cumulative effects (McCold and Holman 1995).

PRINCIPLES OF CUMULATIVE EFFECTS ANALYSIS

Increasingly, decisionmakers are recognizing the importance of looking at their projects in the context of other development in the community or region (i.e., of analyzing the cumulative effects). Direct effects continue to be most important to decisionmakers, in part because they are more certain. Nonetheless, the importance of acid rain, climate change, and other cumulative effects problems has resulted in many efforts to undertake and improve the analysis of cumulative effects. Although no universally accepted framework for cumulative effects analysis exists, general principles have gained acceptance (Table 1-2).

Each of these eight principles illustrates a property of cumulative effects analysis that differentiates it from traditional environmental impact assessment. By applying these principles to environmental analysis of all kinds, cumulative effects will be better considered, and the analysis will be complete. A critical principle states that cumulative effects analysis should be conducted within the context of resource, ecosystem, and human community thresholds–levels of stress beyond which the desired condition degrades. The magnitude and extent of the effect on a resource depends on whether the cumulative effects exceed the capacity of the resource to sustain itself and remain productive. Similarly, the natural ecosystem and the human community have maximum levels of cumulative effects that they can withstand before the desired conditions of ecological functioning and human quality of life deteriorate.

Determining the threshold beyond which cumulative effects significantly degrade a resource, ecosystem, and human community is often problematic. Without a definitive threshold, the NEPA practitioner should compare the cumulative effects of multiple actions with appropriate national, regional, state, or community goals to determine whether the total effect is significant. These thresholds and desired conditions can best be defined by the cooperative efforts of agency officials, project proponents, environmental analysts, nongovernmental organizations, and the public through the NEPA process. Ultimately, cumulative effects analysis under NEPA should be incorporated into the agency's overall environmental planning and the regional planning of other federal agencies and stakeholders.

HOW ENVIRONMENTAL EFFECTS ACCUMULATE

Cumulative effects result from spatial (geographic) and temporal (time) crowding of environmental perturbations. The effects of human activities will accumulate when a second perturbation occurs at a site before the ecosystem can fully rebound from the effect of the first perturbation. Many researchers have used observations or environmental change theory to categorize cumulative effects into different types. The diversity of sources, processes, and effects involved has prevented the research and assessment communities from agreeing on a standard typology. Nonetheless, it is useful to review the eight scenarios for accumulating effects shown in Table 1-3.

Table 1-2. Principles of cumulative effects analysis
1. Cumulative effects are caused by the aggregate of past, present, and reasonably foreseeable future actions. The effects of a proposed action on a given resource, ecosystem, and human community include the present and future effects added to the effects that have taken place in the past. Such cumulative effects must also be added to effects (past, present, and future) caused by all other actions that affect the same resource.
2. Cumulative effects are the total effect, including both direct and indirect effects, on a given resource, ecosystem, and human community of all actions taken, no matter who (federal, nonfederal, or private) has taken the actions. Individual effects from disparate activities may add up or interact to cause additional effects not apparent when looking at the individual effects one at a time. The additional effects contributed by actions unrelated to the proposed action must be included in the analysis of cumulative effects.
3. Cumulative effects need to be analyzed in terms of the specific resource, ecosystem, and human community being affected. Environmental effects are often evaluated from the perspective of the proposed action. Analyzing cumulative effects requires focusing on the resource, ecosystem, and human community that may be affected and developing an adequate understanding of how the resources are susceptible to effects.
4. It is not practical to analyze the cumulative effects of an action on the universe; the list of environmental effects must focus on those that are truly meaningful. For cumulative effects analysis to help the decisionmaker and inform interested parties, it must be limited through scoping to effects that can be evaluated meaningfully. The boundaries for evaluating cumulative effects should be expanded to the point at which the resource is no longer affected significantly or the effects are no longer of interest to affected parties.
5. Cumulative effects on a given resource, ecosystem, and human community are rarely aligned with political or administrative boundaries. Resources typically are demarcated according to agency responsibilities, county lines, grazing allotments, or other administrative boundaries. Because natural and sociocultural resources are not usually so aligned, each political entity actually manages only a piece of the affected resource or ecosystem. Cumulative effects analysis on natural systems must use natural ecological boundaries and analysis of human communities must use actual sociocultural boundaries to ensure including all effects.
6. Cumulative effects may result from the accumulation of similar effects or the synergistic interaction of different effects. Repeated actions may cause effects to build up through simple addition (more and more of the same type of effect), and the same or different actions may produce effects that interact to produce cumulative effects greater than the sum of the effects.
7. Cumulative effects may last for many years beyond the life of the action that caused the effects. Some actions cause damage lasting far longer than the life of the action itself (e.g., acid mine drainage, radioactive waste contamination, species extinctions). Cumulative effects analysis needs to apply the best science and forecasting techniques to assess potential catastrophic consequences in the future.
8. Each affected resource, ecosystem, and human community must be analyzed in terms of its capacity to accommodate additional effects, based on its own time and space parameters. Analysts tend to think in terms of how the resource, ecosystem, and human community will be modified given the action's development needs. The most effective cumulative effects analysis focuses on what is needed to ensure long-term productivity or sustainability of the resource.

Table 1-3. Examples of cumulative effects (modified from NRC 1986 and Spaling 1995)		
Type	**Main characteristics**	**Example**
1. Time crowding	Frequent and repetitive effects on an environmental system	Forest harvesting rate exceeds regrowth
2. Time lags	Delayed effects	Exposure to carcinogens
3. Space crowding	High spatial density of effects on an environmental system	Pollution discharges into streams from nonpoint sources
4. Cross-boundary	Effects occur away from the source	Acidic precipitation
5. Fragmentation	Change in landscape pattern	Fragmentation of historic district
6. Compounding effects	Effects arising from multiple sources or pathways	Synergism among pesticides
7. Indirect effects	Secondary effects	Commercial development following highway construction
8. Triggers and thresholds	Fundamental changes in system behavior or structure	Global climate change

In simplest terms, cumulative effects may arise from single or multiple actions and may result in additive or interactive effects. Interactive effects may be either countervailing—where the net adverse cumulative effect is less than the sum of the individual effects—or synergistic—where the net adverse cumulative effect is greater than the sum of the individual effects. This combination of two kinds of actions with two kinds of processes leads to four basic types of cumulative effects (Table 1-3; see Peterson et al. 1987 for a similar typology).

Table 1-4. Types of cumulative effects		
	Additive Process	**Interactive Process**
Single Action	**Type 1** — Repeated "additive" effects from a single proposed project. Example: Construction of a new road through a national park, resulting in continual draining of road salt onto nearby vegetation.	**Type 2** — Stressors from a single source that interact with receiving biota to have an "interactive" (nonlinear) net effect. Example: Organic compounds, including PCBs, that biomagnify up food chains and exert disproportionate toxicity on raptors and large mammals.
Multiple Actions	**Type 3** — Effects arising from multiple sources (projects, point sources, or general effects associated with development) that affect environmental resources additively. Example: Agricultural irrigation, domestic consumption, and industrial cooling activities that all contribute to drawing down a groundwater aquifer.	**Type 4** — Effects arising from multiple sources that affect environmental resources in an interactive (i.e., countervailing or synergistic) fashion. Example: Discharges of nutrients and heated water to a river that combine to cause an algal bloom and subsequent loss of dissolved oxygen that is greater than the additive effects of each pollutant.

ROADMAP TO THE HANDBOOK

The chapters that follow discuss the incorporation of cumulative effects analysis into the components of environmental impact assessment: scoping (Chapter 2), describing the affected environment (Chapter 3), and determining the environmental consequences (Chapter 4). Although cumulative effects analysis is an iterative process, basic steps that to be accomplished can be identified in each component of the NEPA process; each chapter focuses on its constituent steps (Table 1-4). The last chapter of this report discusses developing a cumulative effects analysis methodology that draws upon existing methods, techniques, and tools to analyze cumulative effects. Appendix A provides brief descriptions of 11 cumulative effects analysis methods.

Table 1-5. Steps in cumulative effects analysis (CEA) to be addressed in each component of environmental impact assessment (EIA)

EIA Components	CEA Steps
Scoping	1. Identify the significant cumulative effects issues associated with the proposed action and define the assessment goals. 2. Establish the geographic scope for the analysis. 3. Establish the time frame for the analysis. 4. Identify other actions affecting the resources, ecosystems, and human communities of concern.
Describing the Affected Environment	5. Characterize the resources, ecosystems, and human communities identified in scoping in terms of their response to change and capacity to withstand stresses. 6. Characterize the stresses affecting these resources, ecosystems, and human communities and their relation to regulatory thresholds. 7. Define a baseline condition for the resources, ecosystems, and human communities.
Determining the Environmental Consequences	8. Identify the important cause-and-effect relationships between human activities and resources, ecosystems, and human communities. 9. Determine the magnitude and significance of cumulative effects. 10. Modify or add alternatives to avoid, minimize, or mitigate significant cumulative effects. 11. Monitor the cumulative effects of the selected alternative and adapt management.