Introduction to Environmental Impact Assessment

A Guide to Principles and Practice

Bram F. Noble

Third Edition

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Cumulative Environmental Effects

Describing the loss of coastal wetlands along the east coast of the United States between 1950 and 1970, Odum (1982, 728) explains:

> No one purposely planned to destroy almost 50% of the existing marshland along the coasts of Connecticut and Massachusetts . . . However, through hundreds of little decisions and the conversion of hundreds of small tracts of marshland, a major decision in favour of extensive wetlands conversion was made without ever addressing the issue directly.

It is not possible to determine the true significance of a project's effects without the consideration of cumulative environmental effects. Each additional disturbance or impact, regardless of its magnitude, can represent a high marginal cost to the environment. Cumulative effects can be characterized as "progressive nibbling," "death by a thousand cuts," or the "tyranny of small decisions." In other words, cumulative effects are the culmination of effects—many of which can be individually small and seemingly insignificant, such as seismic lines, pipelines, water withdrawals, or the incremental filling of wetlands. Such characterizations are based on the notion that a significant adverse effect can result over space or over time because of the culmination of seemingly small and insignificant actions. For each action, the effects are deemed marginal or relatively insignificant when compared to other types or scales of change or disturbances. But over time, such seemingly insignificant effects can result in significant cumulative environmental change (Gunn and Noble 2012).

Definition of Cumulative Effects

The terms "cumulative environmental change," "cumulative effects," and "cumulative impacts" are often used interchangeably. Generally speaking, these terms all refer to effects of an additive, interactive, synergistic, or irregular (surprise) nature, caused by individually minor but collectively significant actions that accumulate over space and time (Canter 1999). There is no universally accepted definition of cumulative effects, and various definitions have been proposed in the literature, for example:

- the accumulation of human-induced changes in VECs across space and over time that occur in an additive or interactive manner (Spaling 1997);
- the impact on the environment [that] results from the incremental impact of the action [under review] when added to other past, present, and reasonably foreseeable future actions (US Council on Environmental Quality 1978);
- changes to the environment caused by an action in combination with other past, present, and future actions (Hegmann et al. 1999).

Perhaps the most commonly used definition of "cumulative environmental effect" is the one provided by the US Council on Environmental Quality (1997), which characterizes cumulative environmental effects as:

- the total effect, including direct and indirect, on a given resource, ecosystem, or human community of all actions taken;
- effects that may result from the accumulation of similar effects or the synergistic interaction of different effects;
- effects that may last for many years beyond the life of the action that caused them;
- effects that must be analyzed in terms of the specific resource, ecosystem, or human community affected and not from the perspective of the specific action that may cause them;
- effects that must be approached from the perspective of carrying capacity, thresholds, and total sustainable effects levels.

Gunn and Noble (2014), in a report commissioned by the Canadian Council of Ministers of the Environment, indicate that jurisdictional interpretations of a "cumulative effect" vary in scope—some being inclusive of social, cultural, and economic aspects and others more restrictive in scope and focused only on biophysical aspects. They argue that ensuring a standard definition of "cumulative effect" requires that the term be defined independently of the focus of concern, be it biophysical, social, or economic or any combination thereof. In other words, whether a social or cultural effect is included in the definition of a cumulative effect is a matter of jurisdictional preference. Adding or removing any one or more of these components does not change the core definition of what constitutes a "cumulative effect"—it changes only what must be considered within the scope of assessment in that particular jurisdiction. Based on a review of Canadian and international legislation, policies, regulations, and guidelines, Gunn and Noble (2014) suggest a set of mutually supportive definitions for cumulative effects concepts, with each definition nested within the context of the previous:

- **Cumulative effect**: a change in the environment caused by multiple interactions among human activities and natural processes that accumulate across space and time.

- **Cumulative effects assessment**: a systematic process of identifying, analyzing, and evaluating cumulative effects.
- **Cumulative effects management**: the identification and implementation of measures to control, minimize, or prevent the adverse consequences of *cumulative effects*.

Sources of Cumulative Effects

The Canadian Environmental Assessment Research Council (1988) suggests that cumulative effects can occur when impacts on the biophysical or human environments take place frequently in time or densely in space to such an extent that they cannot be assimilated or when the impacts of one activity combine with the activities of another in a synergistic manner. This suggests that a variety of different *sources* of change contribute to cumulative environmental effects (Table 11.1). Consider, for example, the total downstream effects on water quality and fish resulting from upstream **point-source** and **non-point-source stress** in a watershed (Figure 11.1), including:

Table 11.1 Sources of Change That Contribute to Cumulative Environmental Effects

Source of change	Characteristics	Example
Space crowding	High spatial density of activities or effects	Multiple mine sites in a single watershed
Time crowding	Events frequent or repetitive in time	Forest harvesting rates exceeding regeneration and reforestation
Time lags	Activities generating delayed effects	Human exposure to pesticides
Fragmentation	Changes or interruptions in patterns and cycles	Multiple forest access roads cutting across wildlife habitat
Cross-boundary movement	Effects occurring away from the initial source	Acid mine drainage moving downstream to community water supply systems
Compounding	Multiple effects from multiple sources	Heavy metals, chemical contamination, and changes in dissolved oxygen content resulting from multiple riverside industries
Indirect	Second-order effects	Decline in recreational fishery caused by decline in fish populations due to heavy-metal contamination from industry
Triggers and thresholds	Sudden changes or surprises in system behaviour or system structure	Collapse of a fish stock when persistent pressures from harvesting and environmental stress result in a sudden change in population structure

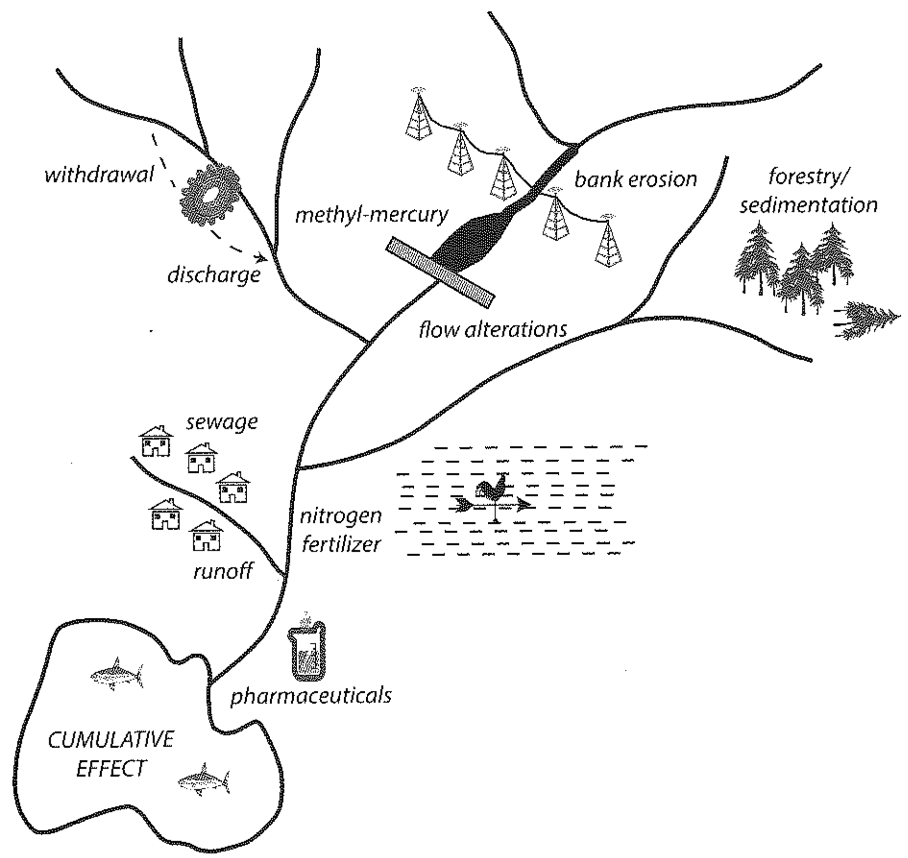


Figure 11.1 ◉ Sources of Cumulative Environmental Effects in a Watershed

- increased sedimentation due to forestry activity;
- alterations in flow at a hydroelectric facility;
- increased methyl-mercury concentrations caused by reservoir flooding;
- bank erosion at a transmission line crossing;
- water withdrawal and discharge from heavy industry;
- septic leakage from residential areas;
- urban storm water runoff as a result of surface imperviousness;
- nutrient loadings from agricultural runoff;
- pharmaceuticals and other chemicals from industry and manufacturing.

The total environmental effect of all of these activities, combined with larger-scale stress caused by climate change and transboundary effects acting on a single VEC, such as fish or water quality, is a cumulative environmental effect. The problem is that not all of these point and non-point sources would be subject to EIA, and certainly few assessments ever would consider non-point sources of stress or capture the point sources from headwater to mouth.

Types of Cumulative Effects

While multiple types of activities and impacts can lead to cumulative environmental change, it is often useful to characterize the different types of cumulative effects. Such characterizations can help in the communication of cumulative effects issues and in identifying cumulative effects management measures—such as setting limits or maximum levels of allowable change. Based on Peterson et al. (1987), Sonntag et al. (1987), and Hegmann et al. (1999), four broad types of cumulative effects can be identified:

1. **Linear additive effects.** Incremental additions to, or deletions from, a fixed storage where each increment or deletion has the same individual effect.
2. **Amplifying effects.** Incremental additions to, or deletions from, an apparently limitless storage or resource base where each increment or deletion has a larger effect than the one preceding.
3. **Discontinuous effects.** Incremental additions that have no apparent effect until a certain threshold is reached, at which time components change rapidly with very different types of behaviour and responses.
4. **Structural surprises.** Changes that occur as a result of multiple developments or activities in a defined region. They are often the least understood and most difficult to assess.

Pathways of Cumulative Effects

Cumulative environmental effects result from different combinations of actions or pathways that consist of both additive and interactive processes. Peterson et al. (1987) present a classification of functional pathways that lead to cumulative environmental effects (Figure 11.2); each pathway is identified and differentiated according to the sources of change and type of impact accumulation. An example of pathways that lead to cumulative effects is illustrated by the Cold Lake oil sands project in Alberta (Box 11.1).

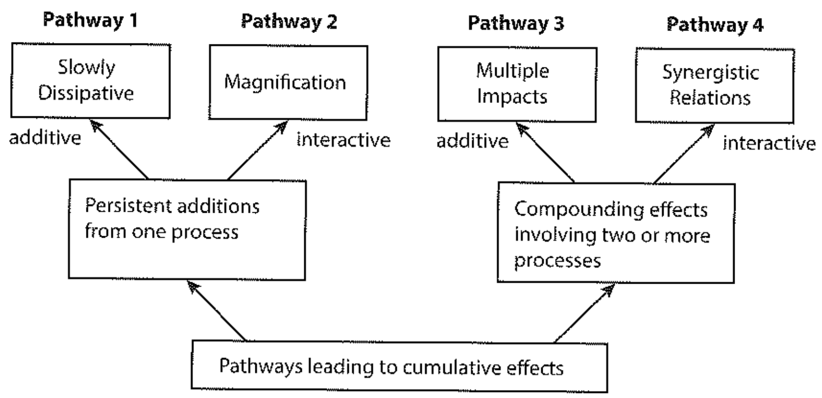


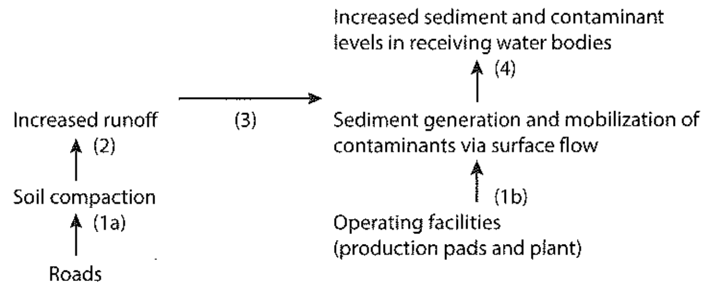
Figure 11.2 ◉ Pathways Leading to Cumulative Effects

Box 11.1 Cold Lake Oil Sands Project Cumulative Effects Pathways

The Cold Lake oil sands project is a heavy oil facility in northern Alberta. Approximately 2500 wells are currently operating in the region. The Cold Lake facility is at present the second largest producer of oil in Canada. In 2003, the Cold Lake operations accounted for 10 per cent of Canada's crude oil production. Oil deposits are located in sand deposits approximately 400 metres below the surface and are extracted by a steam recovery process that injects high-pressure steam into the reservoir to separate the sand and oil. Wells are drilled and steam injected via clusters of vertical and directional-drilled wells, organized onto large surface pads. In 1997, the proponent, Imperial Oil Resources Limited, proposed to expand its operation in the Cold Lake area with the development of a central plant and additional production wells. A total of 35 impact models were contained in the EIA to assess the cumulative effects of the project on surface water quality, including the additive effects of roads and facilities (well pads) on sediment and contaminant levels in nearby water bodies.

Cumulative impact statement:

- Operation and maintenance of roads and facilities will result in the generation of sediment and transport of contaminants to receiving waters.



Pathways:

1a. The operation and maintenance of roads will lead to compaction of the roadbed.
1b. Operation and maintenance of pads and plant facilities will result in the generation of sediment and mobilization of contaminants via overland flow from these facilities.
2. Compaction will cause an increase in surface runoff from the road.
3. Increased runoff from roads will result in erosion of exposed soils, resulting in an increase in sediment generation and transport. Soluble contaminants from the road and the roadbed will be transported along with the sediment.
4. Increased sediment and contaminant transport will result in higher levels of these parameters in receiving waters, which will result in a decline in surface water quality.

Sources: Based on Hegmann et al. 1999; Imperial Oil Resources Ltd. 1997.

Single-Source Perturbations

Pathway one results from the persistent effects of a single project on a particular environmental component, such as repeated changes in water temperature resulting from a reservoir development. When any single activity has multiple effects, potential interactions between them may create cumulative effects. Pathway two is characterized by a single activity, but the effects accumulate synergistically. For example, the creation of a reservoir can change water temperature, lower dissolved oxygen content, and lead to heavy-metal contamination. While each of these effects can individually affect aquatic life, they can also accumulate in such a way that the toxicity of certain contaminants is multiplied because of high water temperatures and low dissolved oxygen content (Bonnell 1997).

Accumulation of Effects from Two or More Projects

Pathway three occurs when the environmental effects of multiple actions accumulate in an additive manner, as would be the case with the development of multiple reservoirs in a river basin. Although no interaction occurs between the effects of individual projects, they collectively result in significant impacts on aquatic resources. Pathway four occurs when these multiple effects do interact in a synergistic manner. For example, each project may alter water temperature, change dissolved oxygen content, and introduce heavy metals, thereby contaminating aquatic life, but the impacts from the interaction of these effects across all projects would be greater than the sum of the individual project impacts (Bonnell 1997).

Models of Cumulative Effects Assessment

Cumulative effects assessment (CEA) refers to the systematic process of identifying, analyzing, and evaluating cumulative effects—that is, identifying environmental effects and pathways in order to avoid, wherever possible, the potential triggers or sources that lead to cumulative environmental change (see Spaling and Smit 1994). Good CEA is focused on the condition of environmental receptors and whether the total effects via all stressors in a project's regional environment are acceptable, including the potential additional stress caused by the proposed project. There are, however, two broad and often competing models of how this should be achieved: effects-based and stressor-based models.

Effects-Based CEA

Effects-based CEA is focused on assessing existing environmental conditions relative to a reference condition and is typically retrospective in design—*what has happened.* Examples include environmental effects monitoring programs (see Environment Canada 2010; 2011) and ecological modelling and baseline studies (see Culp, Cash, and Wrona 2000; Munkittrick et al. 2000; Dubé et al. 2006; RAMP 2010). The strength of effects-based approaches is in measuring the accumulated environmental state of a system and identifying whether performance indicators are at or below an acceptable level (Dubé and Munkittrick 2001). Doing so can inform the identification of thresholds

and help to inform risk assessment processes that, in principle, support decision-making about the impacts of development. Emphasis is on understanding the total effects on a particular VEC from all sources of stress (point, non-point, direct, indirect) and comparing these effects to some reference condition in order to determine an actual measure of cumulative change, irrespective of the number and nature of the impacts causing that change. Under this model, the focus of cumulative effects shifts away from the individual project and its localized stressors to allow for questions of a broader nature related to ecological thresholds and synergistic effects. The underlying premise of this approach is that cause–effect relationships can be established through long-term monitoring, which can then be used to predict cumulative impacts. According to Spaling et al. (2000), however, rarely under this sort of framework is there authority to implement recommendations or to carry forward CEA findings to specific project-based assessments. Many effects-based CEA studies are "one-offs," disconnected from regulatory-based development decision-making (see Sheelanere, Noble, and Patrick 2013).

Stressor-Based CEA

Stressor-based CEA is prospective in design—*what might or could happen.* The focus is typically on quantifying current (and, in some cases, past) levels, types, and distributions of human disturbance in the project's environment (e.g., industrial footprint, road densities, habitat fragmentation) and then projecting disturbances, caused by the project and other sources of human actions, into the future under different scenarios of resource use or development. Attention is placed on predicting the cumulative stress associated with particular agents of change—such as different projects or types of disturbances. This involves an analysis of the distribution and rates of change in disturbance in the baseline and predictive modelling of future disturbance patterns. The assumption is that stressors and VEC response can be correlated or that stressors are a good proxy for threats to VEC sustainability.

Good CEA

Both the effects-based and the stressor-based approaches are useful, but each offers a different type of understanding of cumulative effects—the first from the perspective of change in the receiving environment, the second from the perspective of change in human disturbance or stress to the environment. If the role of CEA is solely to understand the accumulated state and set thresholds through monitoring, then further development of effects-based models is required. If the role of CEA is to guide decisions about the potential implications of proposed land and resource use, then further development of stressor-based models is required. Arguably, good CEA requires both effects- and stressor-based approaches. As Duinker and Greig (2006) report, dwelling on the past is useful but only in the sense of possible learning about interactions, knowledge that can be used to sharpen predictive analysis for the future. At the same time, focusing solely on the future is useful only if we are able to understand the implications of future environmental change, which is often based on learning from the past and understanding thresholds or limits of change.

Good CEA must focus on understanding the accumulated environmental state and human stressors—past, present, and future.

Framework for the Application of CEA

The notion of cumulative environmental effects is not new to EIA, and the terms "cumulative impacts" and "cumulative effects" actually appeared in many national EIA guidelines and laws during the early 1970s. The US Council on Environmental Quality (1978), for example, suggested that project impacts on the environment could interact with other past, present, and reasonably foreseeable actions to generate collectively significant environmental change. It was not until the late 1980s, however, that cumulative effects started to receive any real attention in EIA. In Canada, CEA emerged on the scene in the early to mid-1980s as a priority of the Canadian Environmental Assessment Research Council (CEARC). Federally and provincially, CEA is now an accepted part of most assessment systems and is mandatory at the federal level for all EIAs conducted under the Canadian Environmental Assessment Act, 2012.

Section 19(1)(a) of the Canadian Environmental Assessment Act, 2012 requires that an EIA under the act take into account the environmental effects, including cumulative environmental effects, that are likely to result from the project in combination with other physical activities that have been or will be carried out. Cumulative environmental effects must be considered when determining the significance of a project's impacts and in the design of mitigation and follow-up programs. The Canadian Environmental Assessment Agency's (2013) *Operational Policy Statement* outlines the general requirements and approach to CEA under the Canadian Environmental Assessment Act, 2012 and suggests that CEA include an initial scoping, analysis, identification of mitigation measures, determination of significance, and follow-up.

There are a variety of frameworks that present steps or phases for CEA (e.g. Ross 1998; Hegmann et al. 1999; European Commission 1999; Canter and Ross 2010; Gunn and Noble 2012), including the Canadian Environmental Assessment Agency's (2013) *Operational Policy Statement*. Regardless of the number of steps identified or their labels, a review of standards and practices for CEA by Gunn and Noble (2012) suggests that good CEA can be distilled to four necessary components. These four components are scoping, retrospective analysis of cumulative effects, prospective or futures analysis of cumulative effects, and the management of cumulative effects (Figure 11.3). In the absence of any one of these components, CEA is incomplete.

Scoping

Scoping, or context setting, establishes all that will be included and all that will be excluded when evaluating cumulative effects and subsequent impacts to VECs. When conducting CEA as part of the regulatory EIA process, the Canadian Environmental Assessment Agency's (2013) *Operational Policy Statement* recommends that the CEA consider those VECs for which residual environmental effects are predicted after consideration of project mitigation measures, *regardless of whether those residual environmental effects are predicted to be significant*. Good CEA thus adopts ecosystem

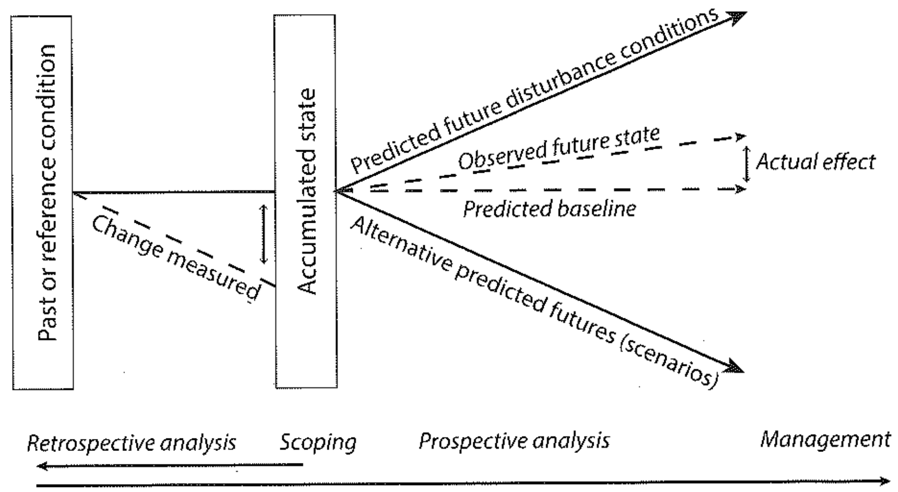


Figure 11.3 ◉ Conceptualization of Cumulative Effects Assessment

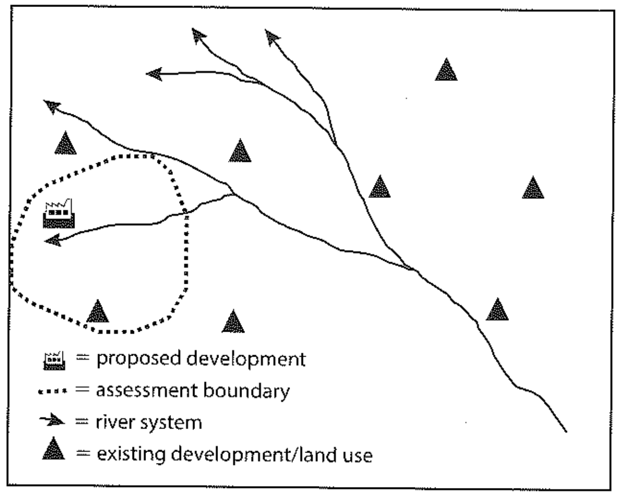
Source: Adapted from Gunn and Noble 2012. Developed originally based on Dubé et al., "Developing cumulative impacts assessment and management strategies" project, funded by the Canada Water Network and depicted in the Lower Athabasca Water Quality Monitoring Program Phase I (Environment Canada, Catalogue no. En14-42/2011E-PDF.)

health and functioning as a core determinant of VEC selection; thus, effective CEA must be spatially and temporally bound based on the distribution of the VECs affected by both the project(s) in question and the effects of other projects and disturbances—past, present, and future.

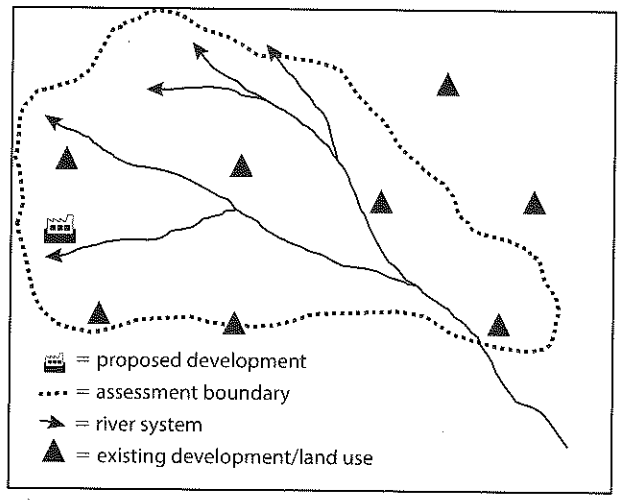
Spatial Boundaries

The spatial boundaries for CEA vary considerably and are defined by a combination of factors, including: (i) the specific land uses or industrial activity of interest; (ii) planning or management jurisdictions; and (iii) the characteristics or distribution of the VECs or indicators of concern (Noble 2013). Cumulative effects occur over a large spatial scale and over a long time period. Determining the spatial boundaries for a CEA is thus critical to its success in effectively managing the cumulative impacts associated with development. Boundaries in CEA delimit the spatial extent of the assessment and thus the environments and VECs that are considered.

It is generally acknowledged that in order to assess cumulative effects effectively, the spatial boundaries of assessment must be extended well beyond the project site. The Canadian Environmental Assessment Agency's (2013) *Operational Policy Statement*, for example, indicates that the spatial boundaries for CEA need to encompass the potential environmental effects on VECs of the project being assessed in combination with other physical activities that have been or will be carried out. However, if the boundaries identified are too large, only a superficial assessment may be possible, and uncertainty will increase. Moreover, the incremental addition of a single project may seem less and less significant—only a small drop in a large bucket. If the boundaries are too small, a more detailed examination may be feasible, but an understanding of the broad context may be sacrificed. In addition, the incremental impacts of a single project may be exaggerated—a large drop in just a small bucket (Figure 11.3). This, of course, depends on the nature of the project and the impacts.



Restrictive bounding may result in the project's additive effects on water quality being perceived as quite *significant* when considered together with the surrounding development and land-use activities.



Ambitious bounding may result in the project's additive effects on water quality being perceived as quite *insignificant* when considered in light of the total effects of all development and land-use activities on the watershed.

Figure 11.4 ◉ Restrictive and Ambitious Spatial Bounding

For example, by selecting a relatively small spatial boundary, the impacts of emissions from a proposed smelting operation might seem quite insignificant, especially if emission stacks are relatively high. The choice of spatial boundaries for CEA, then, can be to the proponent's advantage or disadvantage.

Establishing the appropriate boundaries for CEA requires consideration of three types of scale.

Spatial scale refers to the actual geographic extent of the assessment and is typically based on one or both of natural boundaries, such as watersheds, or administrative boundaries, such as townships or landownership. This is usually the most common interpretation of "scale" in CEA; however, it is certainly not the most functional with regard to the actual analysis of cumulative effects.

Analysis scale is used to examine VECs and impacts across space and is represented by such ideas as data resolution, detail, and granularity. In the Cold Lake oil sands project discussed in Box 11.1, for example, the geographic boundaries for wildlife and vegetation were restricted to local township areas, based on the availability of historical and current information on vegetation composition and wildlife habitat as well as on the extent of available aerial photo coverage. Spatial boundaries were determined on the basis of data availability and desired analysis scale.

Phenomenon scale is perhaps the most important type of scale in CEA, since it refers to the spatial units within which various processes operate or function. Thus, in any single assessment, different spatial boundaries may be appropriate for different cumulative effects and for different VECs. The boundaries selected for cumulative effects on air quality might be quite different from those chosen for cumulative effects on soil quality or sedentary versus migratory wildlife.

While there is no best method for determining the spatial boundaries for any particular CEA, the CEA literature offers a number of guiding principles to assist the practitioner:

- *Adequate scope.* Boundaries must be large enough to include relationships between the proposed project, other existing projects, and the VECs. This means crossing jurisdictional boundaries if necessary to account for interconnections across systems.
- *Natural boundaries.* Natural boundaries such as watersheds, airsheds, or ecosystems are perhaps the best reflection of the natural components of a system and should be respected.
- *VEC differentiation.* Different VECs and VEC processes operate at different spatial scales, and boundaries must therefore reflect spatial variations in the VECs considered.
- *Maximum zones of detectable influence.* Impacts related to project activities typically decrease with increasing distances; thus, boundaries should be established where impacts are no longer detectable.
- *Multi-scaled approach.* Multiple spatial scales, such as local and regional boundaries, should be assessed to allow for a more in-depth understanding of the scales at which VEC processes and impacts operate.
- *Flexibility.* CEA boundaries must be flexible enough to accommodate changing natural and human-induced environmental conditions.

In principle, CEA should focus on ecological units, such as watersheds or ecoregions (Seitz, Westbrook, and Noble 2011). In practice, administrative boundaries play an important role in the success of CEA programs. Ambitious ecological boundaries often need to be tempered by institutional arrangements and the administrative authority to implement CEA, including mitigation and monitoring programs. Squires and Dubé (2012) suggest that the spatial scale of CEA be determined by the spatial scale of the processes (i.e., industry, land uses) that most affect or control the resources of concern in a region.

Temporal Boundaries

The Canadian Environmental Assessment Agency's (2013) *Operational Policy Statement* indicates that the spatial boundaries for CEA should take into account future activities and the degree to which the environmental effects of these activities will overlap those predicted from the proposed project. However, good-practice temporal bounding for CEA also requires asking "how far into the past" should cumulative environmental change resulting from other actions and activities be considered in the assessment. The extent of temporal boundaries depends on the amount of information desired, the amount of information available, and what the assessment is trying to accomplish. Examining past conditions may be as simple as examining land-use maps, and in certain cases it may be feasible to incorporate 50 years of historical data if deemed necessary.

The Canadian Environmental Assessment Agency's *Cumulative Effects Assessment Practitioners' Guide* (Hegmann et al. 1999), developed under the former act, outlines several options for establishing how far into the past a CEA should extend. The first two options have limited historical perspective and are based on the temporal characteristics of the proposed project itself:

- temporal bounds established only on the basis of existing environmental conditions; or
- when impacts associated with the proposed action first occurred.

Other options are based on more historical perspectives of land use and conditions of environmental change and include:

- the time when a certain land-use designation was made (for example, the establishment of a park or the lease of land for development);
- the time when effects similar to those of concern first occurred; or
- a time in the past representative of desired environmental conditions or pre-disturbance conditions, especially if the assessment includes determining to what degree later actions have affected the environment.

Identifying which potential future actions and activities to include in CEA can be much more uncertain. The Canadian Environmental Assessment Agency's (2013) *Operational Policy Statement* recommends that CEA for future actions include those that are certain and reasonably foreseeable. Actions that are certain are those that will proceed or for which there is a high probability that they will proceed (e.g., the proponent has received the necessary authorizations or is in the process of obtaining those authorizations). Actions that are reasonably foreseeable are those that are expected to proceed (e.g., the proponent has publicly disclosed its intention to seek the necessary EIA or other authorizations to proceed). Arguably, good CEA is not limited to certain and reasonably foreseeable actions but also gives some consideration to hypothetical actions—those for which there is considerable uncertainty as to whether they will proceed but that are of potential concern for cumulative environmental effects should they proceed. These may include actions or activities discussed only on a conceptual basis or speculated to proceed, based on current information. **Scenario analysis** is a common tool used to identify such hypothetical actions.

These actions lie on a continuum from most likely to least likely to occur. For each assessment, the practitioner or the regulatory agency will have to decide how far into the future the assessment should reach. Often, a major criterion is whether the future action or actions are likely to affect the same VECs as the proposal under consideration. While practical, this criterion may detract from these projects, creating "nibbling" effects that, while they may not directly affect the same VECs, contribute to overall decline in environmental quality.

Retrospective Analysis

Regardless of the temporal boundary selected, it is important to consider the significance of past changes to the VECs of concern—and not treat past changes in, or effects to, VEC conditions simply as the "new normal." The latter approach, whereby the magnitude of the cumulative effects of past projects is discounted and treated as part of the current baseline condition, misses important opportunities for impact management—particularly for those VECs that might be nearing, or already beyond, a critical sustainability threshold (see Chapter 5, Box 5.4).

The concept of retrospective analysis, as part of baseline assessments, was introduced in Chapter 5. Retrospective analysis involves assessing past VEC conditions and analyzing trends and changes in conditions over time and against thresholds. Good CEA requires an understanding of how VEC conditions have changed over time and whether that change is significant in terms of the sustainability of the VEC. An attempt should be made to identify relationships between indicators of change in VEC conditions (e.g., caribou population, water quality indices) and measures of human or natural disturbance so as to determine trends and associations that can be used to predict and monitor VEC conditions or responses to future cumulative change (Gunn and Noble 2012).

Examples of disturbance measures of interest in cumulative effects analysis may include the density of linear features per unit area on the landscape (e.g., road or trail density—km / km^2), percentage disturbed landscape (e.g., cleared area), edge density or perimeter area ratio, the rate of land conversion (e.g., rate and area of change from forested to non-forested), the number or density of river crossings (e.g., number of crossings per river kilometre in a river reach), the density of impervious or hard surfaces in a watershed (e.g., road surfaces and parking lots have been linked to contaminant transfer and measurable responses in water quality [see Brydon et al. 2009]), and broader natural processes of change such as flood or fire frequency (Gunn and Noble 2012). In many cases, cause-and-effect relationships between disturbances and VEC responses may not be known, but correlations or qualitative associations can be relied upon. The objective is to identify measures of the drivers of change in the region, characterize VEC or indicator responses over space and time, and identify—when and where appropriate—thresholds, management targets, or maximum allowable limits of change.

Prospective Analysis

Using knowledge gained and models developed from the scoping phase and retrospective analysis, prospective analysis is about predicting and evaluating how VECs or their indicators (e.g., caribou population, water quality index) might respond to additional stress in the future—stress caused by the project and by other projects and actions in the regional environment (e.g., fragmentation, river crossings). The focus of analysis is on the VEC conditions and understanding potential VEC response to cumulative disturbance. Gunn and Noble (2012) explain that prospective analysis for CEA might involve "summing up" individual effects such that the total effects on VECs are evaluated and summarized into trend information, focusing on regional environmental issues and whether they will grow worse or better, and assessing the effects on VECs of broad regional change agents such as "surface disturbance" that are, by definition, cumulative and provide a measure of ecosystem health.

Predicting such future conditions is often uncertain, and data are often incomplete. Greig and Duinker (2007) suggest the use of scenario analysis, particularly for large projects, to address the range of possible future VEC conditions under different development/disturbance regimes. Other methods that support CEA, many of which are discussed in Chapter 3, include landscape metrics, correlation and statistical modelling, and more complex simulation tools such as ALCES and MARXAN. The Canadian Environmental Assessment Agency's (2013) *Operational Policy Statement* also recommends that scientific data can often be supplemented with knowledge from other areas with comparable conditions, from community knowledge, and from Aboriginal traditional knowledge.

Management

The best way to manage cumulative effects is to avoid them. However, this not always feasible—most projects are proposed in areas that have already been subject to some level of human disturbance. The management phase of CEA involves the identification of potentially significant cumulative effects, identifying impact management measures, and developing follow-up and monitoring programs for cumulative effects. Of particular importance is determining whether the incremental or cumulative effects caused by the project under consideration are significant. This requires an evaluation of the total effects on each VEC of concern, including the effects of the project plus the effects caused by other sources. Gunn and Noble (2012) suggest that

important to this determination is assessing how much more change in VEC conditions is acceptable. This requires some assessment against thresholds, management targets, or maximum allowable limits of change identified during the retrospective or scoping stages of the assessment or set out in regulations or broader environmental policy objectives. Viable management measures are then proposed, considering the range of possible future outcomes or VEC conditions. The objective is to minimize, if not eliminate, the cumulative contribution of the project to an adverse effect on VEC conditions. In those cases where a VEC is already unhealthy or unsustainable, or nearing such levels, the only acceptable management action may be rectification or restoration of VEC conditions—i.e., no additional cumulative effect caused by the project is acceptable.

State of CEA in Canada

Notwithstanding the recognized need for CEA and the implications of not doing it, there are constant and consistent messages that CEA is either not being done or not being done well when it is done. In a 1998 report of the Auditor General of Canada, the auditor noted that on a sample of 159 environmental assessments conducted by federal authorities, excluding Parks Canada, only 48 indicated that cumulative effects had been considered. In Canada's western prairie watersheds, Schindler and Donahue (2006) suggest an impending water crisis, arguing that policy decision-makers and planners have seldom, if ever, considered the cumulative effects of climate warming, drought, and human activity. Rather, the focus of attention has been on project-by-project decision-making, while cumulative environmental change and broader regional and non-point sources of stress have been ignored. In a more recent panel review process for the Manitoba Hydro's Bipole III transmission line project, witnesses for the Consumers' Association of Canada (Manitoba) reported that the project's CEA largely ignored cumulative effects on VECs of other, past projects, including the proponent's own past projects. For most VECs, impacts were measured against, rather than in addition to, the effects of other future disturbances (see Environmental Assessment in Action: Review of the Bipole III Transmission Line Project Cumulative Effects Assessment).

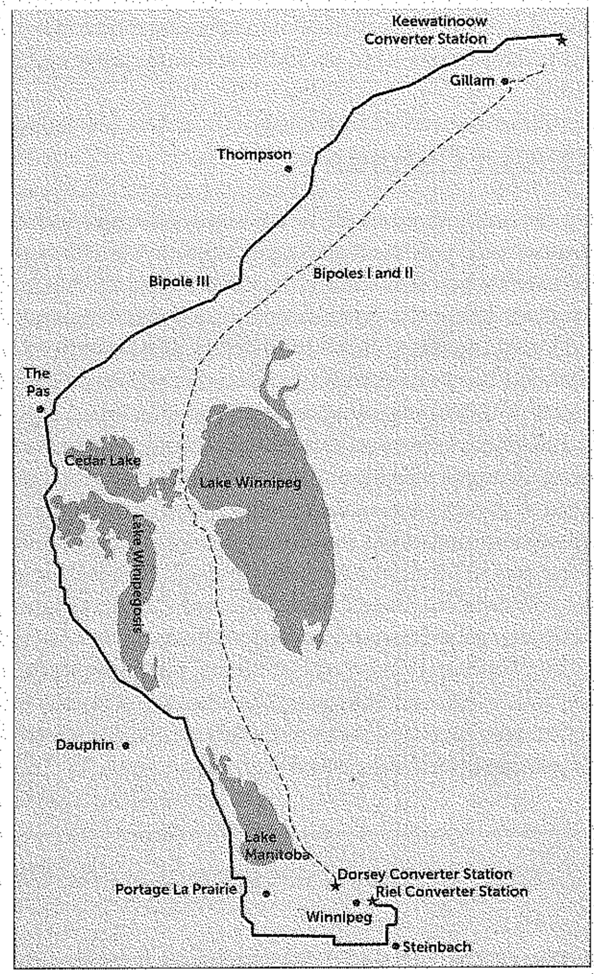
Environmental Assessment in Action

Review of the Bipole III Transmission Line Project Cumulative Effects Assessment

The Bipole III Transmission Line project was introduced in Chapter 5, Box 5.4. The project, proposed by Manitoba Hydro, involves the construction of an approximately 1400-kilometre transmission line from northern Manitoba, near Gillam, south to Winnipeg. The transmission line will traverse boreal forest and

continued

caribou habitat in the north and agricultural land in the south, including several river and stream crossings along the route. The project is to help improve the reliability of electricity supply to Manitoba and reduce the risk of supply interruptions due to ice storms, fires, and other events. Currently, more than 70 per cent of the province's electricity is transmitted via a single corridor on the Bipole I and II transmission lines. Construction is planned for 2013, with a project operation date set for 2017.



The project was subject to EIA under the Environment Act of Manitoba. As part of its EIA, the proponent submitted a CEA of its project. In section 9.1 of the EIS, the proponent noted that its CEA was conducted based on guidance from the project's scoping document, the Canadian Environmental Assessment Act, and review of other guidance documents for cumulative

effects assessment. In 2005, the minister of Manitoba Conservation and Water Stewardship requested that the Manitoba Clean Environment Commission (CEC) conduct a public hearing into the proposal. The CEC is an arms-length provincial agency mandated to provide advice to the minister and ensure public participation in environmental matters. The CEC held its public hearings between October and November 2012 and in March 2013. Several interveners participated in the hearing process, including the Consumers' Association of Canada (Manitoba), which focused on, among other issues, the nature and quality of the proponent's CEA.

An analysis of the quality of the proponent's CEA was undertaken by Gunn and Noble (2012) on behalf of the Consumers' Association of Canada. Gunn and Noble applied several criteria to guide their analysis of the CEA, as follows:

A. Scoping practices:

i. Is the CEA methodology distinct from the project impact assessment?
ii. Does the CEA consider all types of activities and stresses that may interact with the project's effects?
iii. Does the CEA adopt "ambitious," ecologically based scoping?
iv. Is an explicit rationale for VEC selection documented?
v. Do the spatial boundaries reflect the natural distribution patterns (present and historical) of VECs selected for the cumulative effects assessment?
vi. Does the CEA adopt "pre-disturbance" conditions as the historic temporal limit and capture other certain and reasonably foreseeable future projects and activities?

B. Retrospective analysis:

i. Does the baseline analysis delineate past and present cumulative effects in the study area?
ii. Does the baseline analysis establish trends in VEC conditions and known or suspected relationships between changes in VEC conditions and the primary drivers of change?
iii. Are thresholds specified against which cumulative change and the significance of effects can be assessed?

C. Prospective analysis:

i. Is the time scale of cumulative effects predictions/analysis sufficient to capture the scope of impacts associated with the project's life cycle?
ii. Is there sufficient analysis/evidence to support conclusions about potential cumulative effects?
iii. Are the tools and techniques used capable of capturing the complexities of cumulative effects pathways and the uncertainties of future developments?
iv. Are trends and linkages established between VEC conditions and disturbances in the baseline analysis used to inform predictions about cumulative impacts?
v. Is the analysis centred on the total effects on VECs in the project's regional environment?

continued

D. Cumulative effects management:

i. Is the significance of the project's cumulative effects measured against a past reference condition and not simply the current, cumulative, or disturbed condition?
ii. Is the significance of cumulative effects adequately described and justified and based on VEC sustainability, defined by a desired or healthy condition or threshold as opposed to the magnitude of the individual project stress on that VEC?
iii. Are the incremental impacts of the proposed initiative "traded off" against the significance of all other disturbances of activities in the region (i.e., minimized or masked)?
iv. Are mitigation measures identified that help offset significant cumulative environmental effects, and if so, is consideration is given to multi-stakeholder collaboration to develop joint management measures?
v. Is adaptive management identified for significant cumulative effects contingent upon future and uncertain developments and impact interactions?

Gunn and Noble concluded that the Bipole III CEA fell short of good practice and significantly short of the standard identified in the EIS scoping document, which commits to a cumulative effects assessment based on best and current practices. Several significant deficiencies were identified in the report, including:

- The baseline against which cumulative effects are assessed largely ignored the cumulative effects on VECs of past actions and changing VEC conditions over time.
- There was a lack of supporting analysis of cumulative effects to support many of the conclusions.
- The baseline was descriptive; few trends or condition changes were identified and analyzed, and thus there was little means of predicting or modelling cumulative effects into the future.
- The temporal scope of analysis was insufficient and inconsistent with the lifetime of the project. For example, the CEA adopted only a five-year horizon for what is one of the VECs of most concern, caribou.
- The majority of VEC conditions were not examined within the context of regional ecological health but rather from the perspective of absorbing the project's stress.
- Much of the effects analysis was restricted to the transmission line right-of-way, ignoring the effects of the Bipole I and II projects.
- The CEA often assessed the magnitude of the project's impacts against or "compared to" the effects of other actions, versus "in addition to" past changes in VEC conditions and "in addition to" the effects of other current and future actions. As a result, the total or cumulative effects were rarely addressed or analyzed.

Among the recommendations of their report was that the project not proceed until the government of Manitoba undertakes a regional and strategic environmental assessment of the cumulative effects of current and future land uses, particularly in the northern portion of the Bipole III study area.

The Manitoba Clean Environment Commission issued its final panel report on the public hearings in July 2013. In its report, the CEC noted that "The cumulative effects analysis should be the most important section of an environmental assessment report" (p. 11), but the CEC also indicated that "The Commission has a long history of being less than satisfied with the nature of cumulative effects assessments conducted by proponents in Manitoba" (p. 11). The CEC reported that it was "simply inconceivable—given the 50-plus-year history of Manitoba Hydro development in northern Manitoba and given that at least 35 Manitoba Hydro projects have been constructed in the north in that time—that there are few, if any, cumulative effects identified in this EIS" (p. 112). The CEC recommended, as a non-licensing requirement, that Manitoba Hydro implement a CEA approach that would go beyond the minimal standard and would be more in line with current "best practices" (p. 129). The panel also recommended that Manitoba Hydro, in cooperation with the Manitoba government, conduct a regional CEA for all Manitoba Hydro projects and associated infrastructure in the Nelson River sub-watershed and that this be undertaken prior to the licensing of any additional projects in the region after the Bipole III project. The CEC concluded, however, that it was prepared to concede that the proponent had met the minimum standards and that the project be approved.

The Bipole III CEA was a significant step forward in publicly recognizing the limits of CEA as currently practised and established the need for a better standard. It was also a significant step forward in recognizing that effective CEA requires a regional approach and that a regional CEA be undertaken in northern Manitoba prior to approving further development proposals. The Bipole III CEA was a also a step backward in advancing the practice of CEA, sending a message via project approval that the current practice of CEA is still "good enough" to secure EIA approval.

Enduring Challenges and Concerns

Parkins (2011) suggests that "thinking cumulatively and regionally does not emerge naturally from a project-based perspective." In a review of the state of cumulative effects assessment in Canada, Duinker and Greig (2006) conclude that "continuing the kinds and qualities of CEA currently undertaken may be doing more harm than good." Baxter, Ross, and Spaling (2001), Duinker and Greig (2006), Canter and Ross (2010), Noble (2010), and Seitz, Westbrook, and Noble (2011) point to several enduring challenges and concerns with the current practice of CEA in Canada. Some of the main ones are synthesized below.

The first problem concerns the context of CEA as currently required in Canada—situated within project-based EIA. As explained at the outset of this chapter, cumulative environmental effects concern the total effects of human activities on a VEC. Project EIA, in contrast, is concerned about project-induced stress and making sure that the impacts of a project are acceptably small rather than understanding the total effects of all stressors, project and non-project, on any single VEC. Parkins (2011) reports that cumulative effects simply as additive impacts from multiple projects on indicators such as water use or pollution does not facilitate broader discussions about regional limits to development and change and the ways in which specific projects and impacts are aligned or misaligned with regional development goals and objectives.

Second, and closely related, is that project EIA is concerned primarily with minimizing project stress to a level of acceptability. The objective of proponents is to ensure that their project meets regulatory and public approval—this usually means minimizing any efforts regarding CEA and paying little attention to understanding VEC quality and longer-term sustainability. The result is often findings of "non-significance" when, in reality, the project is contributing to incremental, if not synergistic, cumulative environmental change (Box 11.2)

A third concern relates to thresholds. Understanding the cumulative effects of human activity on a VEC, and the implications of such effects, requires some understanding of thresholds and carrying capacities. The challenge, however, is that thresholds are not easily determined, particularly within the spatial and temporal confines of a project assessment. There is often reluctance to set thresholds or to limit development when our understanding of natural variability and adaptability within the system is poor. However, in general, for any assessment it is useful to have a management target or benchmark against which to assess condition change (either

effects-based change or stressor-based change); otherwise, it is difficult to determine when to take action and what action to take when undesirable change occurs. When thresholds are addressed, they are usually defined within the context of the project as opposed to the total effects on a VEC and, further, typically defined on the basis of public acceptability as opposed to ecological knowledge.

Fourth, CEA and management are ultimately about the future and demand, looking far enough into the future to capture the full array of human activities and natural changes that may affect the sustainability of VECs of concern. This is a highly uncertain environment and one that is about possible futures and outcomes—a view that stands in sharp contrast to the shorter-term perspective of project approval and predicting the "most likely," versus the most desirable, effects of development. Greater attention needs to be given to exploring alternative futures in CEA; this includes the consideration of hypothetical development scenarios.

Fifth, our assumptions about cumulative effects, as evidenced by practice, are not always consistent with the nature of how environmental systems function. Advancing CEA will require that we rethink our assumptions and, thus, our approach to CEA (Table 11.2). As Ross (1994, 6) points out, "the environmental effects of concern to thinking people are . . . not the effects of a particular project; they are the cumulative effects of everything." In particular, there is a need to think about limits of environmental systems in terms of the types, amounts, and rates of development that can be accommodated.

Box 11.2 Individually Insignificant Actions

In southwest Saskatchewan, a 1940 km^2 ecologically rich land base, consisting of active sand dunes, rare and endangered species, and plants of Aboriginal cultural importance is subject to the pressures of approximately 1500 natural gas wells, cattle grazing, and more than 3000 kilometres of access roads and trails. The landscape is significantly fragmented, and biodiversity, in a once native grassland ecosystem, is at risk. Cattle grazing and roads and trails in the region have not been subject to EIA. Of the 1500 wells in the area, only five proposals were subject to assessment—none of which was deemed to have significant environmental effects (GSH SAC 2007). Nasen, Noble, and Johnstone (2011), however, found that the ecological footprint of petroleum and natural gas wells in southwest Saskatchewan grasslands has an effect on soils and range health up to 25 metres from the well head—well beyond the physical footprint of the infrastructure and with a duration of at least 50 years (see Chapter 4, Environmental Assessment in Action).

The Athabasca River basin, Alberta, is exposed to a wide range of land-use activities, including agriculture, forestry, pulp and paper operations, and petroleum extraction. Roads, power lines, pipelines, and other disturbances have fragmented forests, and the amount of old-growth forest has been significantly reduced. Between 1966–76 and 1996–2006, the number of pulp mills discharging into the Athabasca basin increased from one to five; total farm area increased from 47.2 million acres to 52.1 million acres; the number of operating oil sands leases increased from 2 to 3360; water withdrawals increased from approximately 12 million m^3/yr to 595 million m^3/yr, of which more than 70 per cent can be attributed to oil sands operations. Between these two time periods, the cumulative annual flow in the Athabasca River decreased by more than 500 m^3/s, and temperature increased by 1.4°C; conductivity, turbidity, and phosphorous levels also increased (Squires, Westbrook, and Dubé 2010). Many of these disturbances, such as urban growth and agricultural expansion, have not been subject to assessment. For others, the effects of each project have been deemed unlikely to cause significance adverse environmental effects.

Part of what leads to scenarios like these is that cumulative effects are often ignored or diminished in project assessment, sometimes deliberately and sometimes because the project in question is considered too small to warrant attention. Quite often, individual developments are evaluated independently of other activities and thus deemed "unlikely" to cause significant adverse environmental effects. In other cases, the magnitude of a project's impacts are sometimes erroneously "measured against" or "compared to" the effects of other projects, versus focusing on the overall effects on VEC conditions. When the significance of a project's effects, no matter how small the effect, is evaluated from the perspective of the additional stress placed on VECs that are already stressed by other sources, it is far more likely to be deemed unacceptable, particularly in regions of concentrated development where environmental thresholds may already be exceeded (Gunn and Noble 2012).

Table 11.2 Characteristics of Status Quo CEA versus Requirements for Effective CEA

	Status quo CEA	Required CEA
Assumptions	abundance	limits
Receptors	single media	environmental systems
Spatial context	project	multiple scales
Temporal context	present	past, present, future
Scope	regulated activities	all disturbances
Assessment	stressors *or* effects	stressors *and* effects
Futures	predicted impacts	possible outcomes
Management	mitigation	avoidance
Monitoring	regulatory compliance	thresholds and capacity
Responsibility	individual proponents	multi-stakeholder
Performance	increased efficiency	increased efficacy

A final concern relates to governance, specifically roles and responsibilities for carrying out CEA and ensuring its influence when CEA is conducted outside the scope of the regulatory EIA process—such as regional CEAs or cumulative effects studies. There is a requirement under the Canadian Environmental Assessment Act, 2012, section 19(1), that the EIA of a designated project take into account the results of any relevant regional study conducted by a committee established under the act. However, regional CEAs and cumulative effects studies have had a tradition of being short-term bursts of activity with no long-term support (Kristensen, Noble, and Patrick 2013; Parkins 2011). Notwithstanding considerable advances in the science to support CEA beyond the regulatory and spatial constraints of project EIA, there has been limited attention to the institutional arrangements necessary for implementing and sustaining it. In an analysis of CEA practices in western Canadian watersheds, Sheelanere, Noble, and Patrick (2013) and Kristensen, Noble, and Patrick (2013) argue that among the requirements for implementing, sustaining, and ensuring influential CEA beyond the project scale are:

- an agency with the authority and mandate for CEA, including the means to direct monitoring programs and influence decisions about land use and project development in the region;
- clearly defined stakeholder roles and responsibilities for undertaking the CEA, implementing the results, and monitoring and following-up for continual learning and improvement;
- sharing of monitoring data, both spatial and aspatial and in common data formats, among all stakeholders;
- a means of implementing CEA initiatives, enforcing monitoring programs and compliance, and ensuring influence over development decisions taken at the individual project level;

- sufficient financial and human resources to implement and sustain, over the long term, CEA programs and requirements (e.g., monitoring programs, landscape modelling, reporting, communication and data management, and co-ordination).

The above challenges are not to say that project-based CEAs are not useful; rather, something more is needed to address and manage cumulative environmental change in an effective manner (Cooper 2003; Creasey 2002). CEA should go beyond the evaluation of site-specific direct and indirect project impacts to address broader regional environmental impacts and concerns. Cocklin, Parker, and Hay (1992) identify three main objectives in advancing CEA beyond EIA:

- to develop a broader understanding of the current state of the environment vis-à-vis cumulative change processes;
- to identify, insofar as possible, the extent to which cumulative effects in the past have conditioned the existing environment;
- to consider priorities for future environmental management with respect to general policy objectives and with regard to potential development options.

The underlying notion is that cumulative environmental change is the product of multiple, interacting development actions and that the multiplicity of development decisions in a particular region, while often individually insignificant, cumulatively lead to significant environmental change. Some significant progress has been made in CEA; however, most of this progress has been outside the constraints of the regulatory EIA process.

Key Terms

amplifying effects
analysis scale
cumulative effect
cumulative effects assessment
cumulative effects management
discontinuous effects
effects-based CEA
linear additive effects
non-point-source stress
phenomenon scale
point-source stress
scenario analysis
spatial scale
stressor-based CEA
structural surprises

Review Questions and Exercises

1. Do provisions exist under your provincial, territorial, or state EIA system for cumulative effects assessment?
2. Using the example of multiple reservoir developments in a single watershed, sketch a diagram similar to Figure 11.2, and identify and classify the different

types of cumulative impacts that might result. State the impact "pathways" as illustrated by the example in Box 11.1.

3. What is the difference between effects-based and stressor-based approaches to cumulative effects assessment?
4. Using an example, explain how a proponent might use spatial bounding to its advantage. Given this, should the proponent be solely responsible for determining the spatial boundaries for cumulative effects assessment?
5. It has been said that cumulative effects assessment is simply EIA done right. Do you agree? Given the challenges to and the constraints of EIA in assessing and understanding cumulative effects, should CEA be part of EIA or a separate, independent process? Identify the benefits and limitations of a more integrated versus a more separated CEA process.
6. Cumulative effects often result from multiple and often unrelated project developments in a single region. Should regional cumulative effects assessment be the responsibility of the project proponent?
7. When a project creates environmental damage, it is often the responsibility of the proponent to rectify or compensate for such damage. Assume a region where there are multiple projects and activities, including oil and gas, forestry, highways, recreation, and hydroelectric developments. Individually, each project was approved for development based on the fact that it would not generate significant environmental effects. Cumulatively, however, all of these activities are contributing to overall environmental decline.
   a) Who should be responsible for managing overall cumulative environmental change resulting from the many, unrelated project developments and activities?
   b) How does one determine how much each development or activity is contributing to cumulative change?
   c) Given that each project is "individually insignificant" but that together they are cumulatively damaging, should an additional development be permitted in the region if it too is determined to be individually insignificant? What are the implications of such a decision with regard to equity versus environmental protection?

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