CUMULATIVE EFFECTS ASSESSMENT:
A CONTEXT FOR FURTHER RESEARCH AND DEVELOPMENT

N.C. Sonntag, R.R. Everitt, L.P. Rattie, and D.L. Colnett
ESSA Environmental and Social Systems Analysts Ltd.
Vancouver, British Columbia

C.P. Wolf
Social Impact Assessment Center
New York, New York

J.C. Truett
LGL Ecological Research Associates Inc.
Bryan, Texas

A.H.J. Dorcey
Westwater Research Centre
University of British Columbia
Vancouver, British Columbia

C.S. Holling
University of British Columbia
Vancouver, British Columbia

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FOREWORD

The Canadian Environmental Assessment Research Council (CEARC) was established on January 30, 1984 by the federal Minister of the Environment to advise government, industry and universities on ways to improve the scientific, technical and procedural basis for environmental impact assessment (EIA) in Canada.

CEARC is currently in the process of establishing research programmes related to improving the practice of environmental assessment. The Council has identified cumulative effects assessment as an area of research interest and plans to pursue this topic over the longer term.

The purpose of CEARC-sponsored background documents is to provide relevant information and to stimulate discussion on the topics of interest to the EIA community. The opinions expressed, however, are strictly the authors' own and do not necessarily reflect the view of the members of the Council or its Secretariat.

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For more information pertaining to the Council's general activities and its publications, please contact:

Dr. Elisabeth Marsollier
Manager, CEARC
13th Floor, Fontaine Building
200 Sacré-Coeur Blvd.
Hull, Quebec
K1A OH3

Tel.: (819) 997-1000

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EXECUTIVE SUMMARY

The purpose of this study is to review current practices for identifying and assessing cumulative effects in order to formulate recommendations that the Canadian Environmental Assessment Research Council (CEARC) may use in drafting a research prospectus. This report presents a prelimiriary analytical framework for cumulative effects assessment (CEA), which provides some common ground in the analysis of the case studies, and brings together, in one model, the spatial, temporal, and system dimensions of cumulative effects. Three case studies documenting some Canadian experience with assessing and managing cumulative effects are presented in the context of the framework. Finally, knowledge of various researchers and practitioners in environmental impact assessment (EIA) and CEA are incorporated in the recommendations.

As experience with "comprehensive planning" over the year? demonstrates, the jurisdictional fragmentation characteristic of public institutions is scarcely conducive to co-ordinated, much less to integrated, efforts to evaluate broader societal issues. Recognition of cumulative effects situations, such as acid precipitation, signals the beginning of a willingness by both decision makers and scientists to recognize the full range of environmental problems that attend modern industrialism and to exercise the analytical and institutional capabilities necessary for their resolution. In this sense, CEA may represent an advance in the direction of comprehensive and integrated environmental assessment.

The report begins, in Chapter 1, with brief summaries of conclusions from other studies on the evidence of cumulative effects on the national and global scales. Next, some studies at the regional scale are described, indicating the range of topics that reflect current definitions of CEA. Finally, lessons from U.S. and Canadian experience are noted. The negative factors influencing this experience, such as confusing legislative mandates and the constraints of narrowly defined assessment studies, are outlined.

The review of current practice in Chapter 1 leads to a definition of cumulative effects in Chapter 2. The definition is based on a systems framework for categorizing the effects, focusing on the processes by which they occur, rather than their sources. After reviewing various methodologies that have been used or proposed for CEA, an analytical framework incorporating the spatial, temporal, and systems elements is described. It uses a systems view, based on an input-output model with development activity as the causes or inputs, inducing a perturbation on existing systems, whose output takes the form of cumulative effects.

The framework for categorizing effects is applied to the Canadian case studies presented in Chapter 3. Although cumulative effects were not explicitly addressed in these studies, it was clear that the issue of the accumulation of actions over space and time was being considered. The three case studies summarized are the Fraser River Estuary, New Brunswick forest management, and the impact of northern development on resource harvesting. The summary of each case study outlines the context, the cumulative effects analysed, how the cumulative effects were dealt with, and what appeared to work. The lessons learned from these experiences are generalized and presented in Chapter 4 under the topics of ecological analysis, social analysis, and institutional analysis.

Finally, in Chapter 5, a number of observations and recommendations are made for improving the assessment of cumulative effects in Canada. In estimating the present state of the art 'and indicating steps for its improvement, the recommendations are organized under four main areas of field development: theoretical, methodological, institutional, and professional. The first two areas correspond to the analytical dimension of CEA and the latter two to the instutional dimension. Each is related to the others; that is, assessment practices and procedures should be theoretically based, empirically grounded, and policy-relevant.

These recommendations are summarized as follows:

RECOMMENDATION 1
Establish a research program to identify the key processes that determine the response of environmental systems to stress and their recovery from it, e.g., rate of system recovery, threshold of resiliency.

RECOMMENDATION 2
Establish a research program to synthesize, extend, evaluate, and apply recent developments that attempt to better understand cumulative effects and respond to the possibility of structural change in the physical, social, and ecological sciences.

RECOMMENDATION 3
Establish a research program to further develop and refine our ability to map the causal basis of cumulative effects situations and trace the network of causative factors.

RECOMMENDATION 4
Develop computer simulation models for specific case studies to further evaluate models as appropriate tools for CEA and to contribute to further characterization of cumulative effects.

RECOMMENDATION 5
Establish a research program to review, appraise, and refine current methods of analysis of institutional response to cumulative effects issues.

RECOMMENDATION 6
Develop guidelines for the assessment of cumulative effects and incorporate them into existing EIA legislation and terms of reference.

RECOMMENDATION 7
Design and implement area-wide and long-term monitoring programs to support the comprehensive assessment framework contained within CEA.

RECOMMENDATION 8
Carry out a systematic survey to codify and compare existing cumulative effects situations in Canada, other developed nations, and the developing world.

RECOMMENDATION 9
Broaden the institutional and methodological context for EIA to fully incorporate the planning community and the concepts of regional and environmental planning.

RECOMMENDATION 10
Broaden the consideration of social issues in EIA through evaluation and incorporation of recent advances in goals-based planning.

RECOMMENDATION 11
Implement a pilot study application of the concepts of comprehensive environmental management and planning within an identified cumulative effects problem.

ACRONYMS

AEAM	Adapative Environmental Assessment and Management
ALC	Agricultural Land Commission (B.C.)
ALR	Agricultural Land Reserve (B.C.)
BOD	Biological oxygen demand
CEA	Cumulative effects assessment
CEARC	Canadian Environmental Assessment Research Council
CEQ	Council on Environmental Quality
DDT	Dichloro-diphenyl-t-richloroethane
DIAND	Department of Indian Affairs and Northern Development
DNR	Department of Natural Resources (New Brunswick)
DREE	Federal Department of Regional Economic Expansion
EARP	Environmental Assessment and Review Process (Canada)
EIA	Environmental impact assessment
EIS	Environmental impact statement
EPA	Environmental Protection Agency (U.S.)
FEAR0	Federal Environmental Assessment Review Office
FREMP	Fraser River Estuary Management Plan
FRES	Fraser River Estuary Study (B.C.)
FWS	Fish and Wildlife Service (U.S.)
GNWT	Government of the Northwest Territories
GVRD	Greater Vancouver Regional District
HUD	Housing and Urban Development (U.S.)
LMP	Lower Mainland Plan
LMRPB	Lower Mainland Regional Planning Branch
LRPP	Livable Region Planning Program
MEMP	Mackenzie Environmental Monitoring Program
NEPA	National Environmental Protection Act (U.S.)
NRC	National Research Council
NYSERDA	New York State Energy Research and Development Agency
ORBES	Ohio River Basin Energy Study
ORP	Official Regional Plan
PCB	Polychlorinated biphenol
SIA	Social impact assessment
USFWS	United States Fish and Wildlife Service

CHAPTER 1: INTRODUCTION AND BACKGROUND

In an initial attempt to define the scientific and management dimensions of cumulative effects assessment (CEA), the Canadian Environmental Assessment Review Council (CEARC), in co-operation with the U.S. National Research Council (NRC), sponsored a Workshop in Toronto, Ontario in February 1985. At this workshop, researchers and managers described their perspective on CEA and proposed directions for both research and planning. Recommendations on research needs that would improve the assessment and management of cumulative effects were not definitive, however. Therefore, CEARC decided to commission a provocative analysis of guiding research in CEA techniques over the next 10 years. This document is the final report of one of two studies funded by CEARC for that purpose.

The focus of this study is to review current practices for identifying and assessing cumulative effects in order to formulate recommendations that CEARC may use in drafting a research prospectus. These recommendations were reached in consultation with researchers and managers, in Canada and the United States, who were involved with environmental assessment procedures. A series of regional workshops was held in Vancouver, Montreal, and Winnipeg (see lists of participants in Appendix 4) at which issues about CEA were identified and analysed. In conjunction with the workshops, three case studies documenting some Canadian experience with assessing and managing cumulative effects were prepared and presented. A synopsis of the U.S. experience with CEA is also included to provide a larger set of examples from which generalizations are drawn.

STATEMENT OF THE PROBLEM

The rationale for convening the 1985 Toronto workshop was the "...increasing concern that neither scientists nor institutions work at the temporal and spatial scales needed for the assessment of cumulative effects" (CEARC and U.S. NRC 1986: ix). Traditional environmental impact assessment (EIA) tends to:

- *ignore the additive effects of repeated developments in the same ecological systems; for example, the effects of the loss of wetlands and disposal of toxic chemicals on fish habitats and productivity;*
- *deal inadequately with precedent-setting developments that stimulate other activities, which would not otherwise have been given approval by government;*
- *ignore changes in the behaviour of ecological systems in response to increasing levels of perturbation; for example, nonlinear functional relationships; and*
- *discourage the development of comprehensive environmental objectives that reflect the broad goals of society.*

It is this last point which is perhaps most indicative of the current interest in CEA. As experience with "comprehensive planning" over the years demonstrates, the jurisdictional fragmentation characteristics of public institutions is scarcely conducive to co-ordinated, much less integrated, efforts to evaluate the broader societal issues that the public is raising. Recognition of cumulative effects situations, such as acid precipitation, signals the beginning of a willingness by both decision makers and scientists to recognize the full range of environmental problems that attend modern industrialism and to exercise the analytical and institutional capabilities necessary for their resolution. In this sense, CEA may represent an advance in the direction of comprehensive and integrated environmental assessment. To date, it represents the most rigorous attempt at comprehensive rationality.

BACKGROUND

What is different about cumulative effects assessment? From our review of the available literature and discussions we had with EIA practitioners, it is a matter of emphasis and approach. Cumulative effects assessments tend to:

- be oriented beyond the project level to program and policy level concerns;
- have an expanded spatial assessment scale:
- have an extended planning horizon;
- be comprehensive in the range of systems assessed;
- be interdisciplinary in approach and interorganizational in context; and
- be coupled with impact monitoring and management systems.

This section will cite some situations identified as exhibiting cumulative effects and some studies that were initiated in response to them. First, the global and national situations are briefly described to provide a context for the description of the regional and project-specific studies that follow. Together, the situations and studies provide a set of operational issues that form the groundwork for the operational framework presented in Chapter 2.

Cumulative Effects at the Global Scale

Assessments at the international scale have tended to focus on the expected outcomes of current development trends rather than evaluating the systems that created the situations. Their conclusions are useful, however, to indicate which local effects are also manifest at the global level.

The most comprehensive and systematic effort to date was consulted for this inquiry: the Global 2000 Report to the President (U.S. Council on Environmental Quality 1980). The main conclusions of this report are that cumulative effects at the global scale may be observed in all media. Perhaps most conspicuous are atmospheric conditions of carbon dioxide build-up, ozone depletion, and acid rain deposition. Also marked are terrestrial impacts, deforestation and desertification, and aquatic impacts, both freshwater and marine. Overpopulation and overurbanization are pervasive in human environments of the less developed countries.

Although the study focused on world environmental futures, its relevance for Canada is tangible and substantial. Against the rather pessimistic global projections, Canada stands as a bright exception with relatively few environmental, problems compared with many other countries (Barney *et a/.* 1982; Voyer and Murphy 1984). These few problems are severe, however: acid rain and some potentially difficult agricultural soil and water problems. Additional vulnerabilities and comparative disadvantages are increasing pressures from immigration; limitations on grain export potential before the end of the century, due to increasing demand from domestic consumers and the impending impact of a continual decline in soil fertility; vulnerability to climatic changes; and probable continuation of internal tensions related to resource development policies.

On balance, as Voyer and Murphy (1984: 3) point out:

> *The biggest threat to Canada may be the disturbance of its economy because of dislocations in the global economy.. . . e.g., balance of payments problems, protectionalism, financial and other economic calamities.*

Conversely, "Canada's greatest vulnerability-its resource exporting economy-also constitutes its most fundamental strength" (Barney *et a/.* 1982: 37). In any case, the message of *Global* 2000 is that Canada cannot isolate itself from the global situation when considering what cumulative effects will become important in the future.

Cumulative Effects at the National and Regional Scales

A study of the national environment in' the United States completed a year after *Global* 2000, also focused on identifying effects, rather than the contributing factors. The conclusions are similar and emphasize the magnitude of particular issues, such as atmospheric pollution.

In 1981, the U.S. Council on Environmental Quality (CEQ) stated that U.S. environmental trends do *not* support a general conclusion of worsening trend impacts; if anything, the reverse is true (U.S. Council on Environmental Quality 1981: iv). They point out the great progress made in controlling pollution, with concentrations of many pollutants showing measurable decline: total suspended particulates and sulphur dioxide concentrations in urban air; concentrations of suspended solids and biological oxygen demand in many waterways; and the flow of DDT and other persistent organochlorine pesticides, PCBs, vinyl chloride, benzene, asbestos, and heavy metals into the environment.

On the other side of the equation, the CEQ does note increased photochemical oxidents and nitrogen oxides in urban air, respirable particulates in indoor atmospheres, and toxic substances in water; anthropogenic effects on natural areas such as wetlands, virgin forests, native grasslands, estuarine, and other unique habitats; and continual loss of biological diversity within ecosystems "as a result of greater standardization of agricultural, forestry, and fishery practices and of other intensive uses of land and water" (U.S. Council on Environmental Quality 198 1: v).

Some examples of cumulative effects assessment at the regional scale are given in Table 1. The issues selected for evaluation in these studies tended to focus on river basin development, large scale oil and gas developments, effects of urban sprawl, and the aggregation of effects from multiple sources on a specific resource such as wildlife.

Recent work funded by the U.S. Fish and Wildlife Service (Horak *et al.* 1983a, b; Cline *et a/.* 1983) provides a comprehensive review of the state of the art of CEA, particularly as it relates to fish and wildlife issues. These authors concluded that two basic approaches have traditionally been used in CEA. One involved "mapping" the distribution of the major components in the study area and superimposing proposed activities and related impacts. In the second approach, the emphasis was on an additive procedure, implicitly based on a causal, sequential model. The point at which impacts reached an "unbearable" point could be judged against some articulated "threshold" denoting the arrival at a condition of tolerance or carrying capacity. Both these practices have similar assumptions and procedures. Their common concepts are carrying capacity and tolerance of the surrounding environment either conceived in advance (sensitivity maps) or arrived at in an additive manner (threshold emphasis).

These authors viewed current methods to be uniformly inadequate for assessing cumulative effects operating over large temporal or spatial scales. Horak *et a/.* (1983a) suggest reasons why:

> *. ..lack of time, absence of a systematic database, limited theoretical and methodological know/edge of the topic and last, but not least, little commitment to cumulative impact utilization. No agency is given the responsibility to view questions at such a far-reaching scale and scope.*

EMERGING CEA ISSUES

A few important patterns appear when reviews (Horak *et a/.* 1983a; Cline *et al.* 1983), and the recent CEARC workshop papers (CEARC and U.S. NRC 1986) are considered together. These are as follows:

Table 1
Some Examples of Cumulative Effects Studies and Research Programs in Canada and the United States.

Canada
Consultative Task Force on Industrial and Regional Benefits from Major Canadian Projects (198 1)
Cumulative Socioeconomic Monitoring: Issues and Indicators for Canada's Beaufort Region (Carley 1984)
Fraser Thompson Corridor Review (FEAR0 1986)
Great Lakes Water Quality (Regier 1986)
United States
The *Costs of Sprawl* (Real Estate Research Corporation 1974)
Secondary Impacts of Transportation and Wastewater Investments (USEPA 1975)
Cumulative Impact Studies in the Louisiana Coastal Zone (Center for Wetland Resources 1977)
Denver Metropolitan Areawide Environmental Impact Statement (U.S. HUD 1978)
Cumulative Effects of Management on California Watersheds (Staniford and Ramacher 1980)
Cumulative Environmental Impacts of Coal Conversion (NYSERDA 1981)
Energy from the West (Science and Public Policy Program 1981)
Ohio River *Basin Energy Study* (ORBES Core Group 1981)
Permit Activities Regulated by the U.S. Army Corps of Engineers (Dames and Moore 1981)
Santa Maria Urban Impact Assessment (Grigsby 1981)
Cumulative Effects Task Force (California State Board of Forestry 1982)
Southern Regional Environmental Assessment (Science and Public Policy Program 1982)
Cumulative Hydrologic Impact Assessment (New Mexcio Hydrology Task Force 1984)
Alaskan North Slope Oil and Gas Development (Meehan and Webber 1985)
Hydro Power Projects Clustered in River Basins (Federal Energy Regulatory Commission 1985)
U.S. Fish and Wildlife Service Cumulative Impact Program (Williamson *et a/.* 1985)

- Cumulative effects assessment of physio-chemical changes is much more advanced than that of biological/ecological phenomena because there is greater concensus about which physical and chemical parameters are appropriate as measures of cumulative impact.
- None of the cumulative effects case histories reviewed dealt with very large dimensions in space or time.
- Evaluation of ecological impacts was problematic because lack of information often hampered prediction.
- Socio-cultural values invariably determined the focus of biophysical impact assessments but the recognition of this influence varied greatly among assessment documents.

These patterns form the basis of a number of very basic problems in both theory and practice which appear to have hindered cumulative effects assessment practices in Canada and the United States. The three sections that follow describe those problems.

Theory: A Confusing Legislative Mandate

Legal mandates are often ambiguous in wording and conflict with other government policies. A consensus is needed on what constitutes environmental quality, particularly in biological systems, and what the relative values of various biological components should be in impact assessments. Unless this is done, guidelines will remain ambiguous and thus impossible to address effectively.

In addition to these ambiguities, environmental assessment guidelines (e.g., NEPA, CEQ, EARP) promoting environmental protection and mitigation, conflict with other government policies that, at the same time, promote human population growth and increased per capita consumption. At the current rate of population growth and demand for ever higher standards of living, it will become impossible to maintain the diversity 'and abundance of species that constitute environmental quality in the view of most people. True mitigation under these circumstances becomes a pipe dream.

The consequences of these points are obvious. First, the ambiguity about what constitutes environmental quality must be dealt with before science can be productively applied. Selected environmental attributes important to society must be identified and assigned values so that research can be sufficiently focused to allow for defensible studies and consequent predictions of effects. Second, reductions in the abundances of species and in the biological diversity of systems are inevitable given the current growth of human population. Therefore, many "adverse" impacts to plant and animal populations cannot be mitigated in any way.

Practice: The Constraints of Tradition

Attempts at broad-scale CEA in the ecological realm have almost invariably bogged down in unworkable complexity because of assessment traditions set in motion in the 1970s. Even assessments of single projects have frequently proven too complex for practical application. Some of the most stultifying traditions might be called "study everything," "rigour of science," "multiple-use," "no change," and "juggle-the-pieces." As a consequence of these traditions, assessments have been unfocused, time-consuming, unduly complex due to multiple demands, at times misguided in objectives, and narrowly defined rather than holistic.

Institutions: Perpetrators of Tradition

Reluctance to change at all levels of public and private institutions hinders their ability to accommodate the changes necessary for effective CEA. The following are examples of these problems.

- Educational institutions offer relatively few courses with the interdisciplinary approach needed for environmental assessment and particularly CEA.
- Because it is very difficult to change the status quo in government, drastic changes in assessment approaches may require the creation of a new, independent agency or agencies.
- Individual development-oriented industries, and the impact assessment practitioners who assist them, approach problems on a project-by-project basis and are not anxious to perform studies beyond what is required by law or custom. Consequently, industry will probably only change if there is a major change in government regulatory attitudes.

CHAPTER 2: FRAMEWORK OF THE STUDY

Rather than attempt to provide a single definition for all possible cumulative effects situations, we decided instead to bring together common attributes from several definitions. These attributes are then categorized to provide an overall characterization of cumulative effects. We chose this approach because, in our opinion, there is no one definition; each situation has its unique character. Therefore, each attempt in the literature to define cumulative effects is valid in the context in which it was established. We concluded that ultimately all resource development situations experience an accumulation of impacts. Further, practitioners have been successfully assessing, in many respects, some of these impacts within the methodological and institutional frameworks currently available. There are, however, potential cumulative effects situations that, until recently, were not even considered and for which current methods and institutions are inadequate to assess or manage. Therefore, in this section, we propose a more comprehensive framework for the assessment of cumulative effects.

REVIEW OF CUMULATIVE EFFECTS DEFINITIONS AND TYPOLOGIES

For our purposes, the definition provided by CEARC for this study is a good starting point for identifying the attributes of cumulative effects:

Cumulative effects can be characterized as impacts on the natural and social environments which:

> 1) occur so frequently in time or so densely in space that they cannot be "assimilated," or
>
> 2) combine with effects of other activities in a synergistic manner.

Other definitions of cumulative effects, listed in Table 2, have common themes of overlapping or sequential impacts occurring in the same geographic space, within a specific time frame. At the 1985 Toronto workshop on cumulative effects, these attributes were categorized according to the type of assessment issue, the processes associated with the issues, and examples of the effects (Table 3). This approach, like others suggested by Clark (1986: 114) and Fox (1986: 67) for example, focuses on sources of cumulative impact. Baskerville (1986: 11-12), on the other hand, identifies these same features from the perspective of the impacted system and the character of the resulting impacts.

CUMULATIVE EFFECTS TYPOLOGY

As a consequence of the above review, a characterization scheme was developed based on a systems view of the processes that generate a cumulative effect, taking into

Table 2
Key Phrases and Concepts from Various Definitions of Cumulative Effects.

U.S. Council on Environmental Quality (40 CFR Parts 1508.7 and 1508.8, 29 November 1978): . *..the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions.. ..Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time.*

Schwitzer *(198 1: 295): . . .impacts resulting from the interaction of the proposed project with other significant projects in the same area during the same time period.. ..*

Gris by (198 1: 5): *... mu/tip/e projects occurring within a relatively similar time frame and ... we//-defined geographic area whose implementation is likely to bring about or accelerate changes in existing conditions.*

SOM *et al.* (198 1: *18): . ..significant net effects of urban growth... which occur in an areawide geographical context, over an established time period.*

Vlachos (1982: 6 1, 64): *...integration of effects of a// current and reasonably foreseeable actions over time and space.. .* and *... three interrelated conceptual dimensions ...aggregative... interactive ... diachronic.. .*

California Environmental Quality Act (14 Cal. Admin. Code 15023.5; 5 Cal. Pub. Res. Code 21083): . *..two* or *more individual effects which, when considered together, are considerable or which compound or increase other environmental impacts.*

Beaufort Sea Environmental Assessment Panel (1984: 138): *. ..activities occurring either simultaneously or sequentially.*

Table 3
Types of Difficult Project Assessment Issues Developed at the CEARC Workshop on Cumulative Environmental Effects, February 1985, Toronto

ISSUE TYPES	MAIN CHARACTERISTICS	EXAMPLES
Time Crowding	Frequent and repetitive impacts on a single environmental medium	Wastes sequentially discharged into lakes, rivers, or watersheds
Space Crowding	High density of impacts on a single environmental medium	Habitat fragmentation in forests, estuaries
Compounding Effects	Synergistic effects due to multiple sources on a single environmental medium	Gaseous emissions into the atmosphere
Time Lags	Long delays in experiencing impacts	Carcinogenic effects
Space Lags	impacts resulting some distance from source	Major dams; gaseous emissions into the atmosphere
Triggers and Thresholds	Impacts to biological systems that fundamentally change system behavior	Effects of changes in forest age on forest fauna
Indirect	Secondary impacts resulting from a primary activity	New road developments opening frontier areas

account spatial, temporal, and system dimensions. This scheme encompasses four distinct outcomes forming a hierarchy of cumulative effects significance with structural surprise at the apex.

Type 1 Linear Additive Effects

Incremental, small additions are made to or deleted from a fixed large storage. Each addition has the same effect whether it is made early or late in a regional development sequence. An example is the addition to a lake of a toxic substance with a linear dose/effect relation.

Type 2 Amplifying or Exponential Effects

Incremental additions are made to an apparently limitless storage (e.g., global atmosphere). Unlike the previous category, each addition has a larger effect than the one preceding it so that the effect gradually becomes more detectable.

Type 3 Discontinuous Effects

In the case of discontinuous effects, incremental additions have no obvious consequences until a threshold (in static representations or a stability boundary (in dynamic representations) is crossed; then variables begin to change rapidly and/or move into a distinctly different regime of behaviour. A simple example would be eutrophication accompanied by anaerobic episodes triggered after sufficient accumulation of inputs of phosphates into a lake. These situations are considered to be naturally recoverable surprises.

Type 4 Structural surprises

Structural surprises are effects having the following characteristics:

- They are caused by multiple developments within regions and affect a number of ecosystems through terrestrial, aquatic, and atmospheric connections.
- Two features of time and space behaviour occur. First, the effects appear locally and abruptly (e.g., localized episodes of pollution, species or population collapse, and population blooms and booms). Second, slow changes gradually exaggerate the intensity of the sudden episodes and spread their effects over larger regions. The latter changes tend to be hidden (e.g., loss of soil fertility, loss of regulation of atmospheric constituents). Gradually, they define a coherent syndrome of effects on structure that ‘result in decreasing resilience of the ecosystems. The syndrome is measured by

spatial homogenization of key variables, by loss of key ecosystem functions of release and renewal, and by reduction of variability and loss of regulatory control.

- The surprises can be described ecologically but they emerge from a growing interdependence and interaction among ecological, economic, social, and government regulatory forces. This interdependence among subsystems is matched by a growing interdependence over geographical space. The coupling mechanisms are maintained principally through trade (regionally, nationally and internationally) and through large-scale biophysical processes of the atmosphere and oceans.

As discussed later in this report, it is this last category that is least understood and represents the biggest challenge to the understanding and management of cumulative effects.

SOME EXISTING METHODOLOGIES FOR CEA

Recent reviews of potential cumulative effects methodologies (Horak et *a/.* 1983a; Witmar et *a/.* 1985), quoted in Bain et *a/.* (1985a: 2) state that "there are no existing methods to effectively address multiple projects, multiple resources, and impact interactions." They go on to point out that "the most likely reason for the lack of any real progress toward cumulative impact analysis appears to be the absence of suitable assessment methods."

Adapting existing impact methods to assess cumulative effects has had some success for effects fitting into Types 1, 2, and 3 of the typology, primarily because the scale of analysis required is local to regional in extent. The cumulative effects occurring on a larger spatial scale and over considerably longer time frames (Type 4) require the development of new assessment methods. In our own review of the literature, and through previous reviews (Horak et *a/.* 1983a), several candidate methodologies were identified and a number of innovations were uncovered. Most innovations fell into three distinct categories: matrix methods, causal analysis, and adaptive management. These will now be briefly described.

Matrix Methods

Bain et *al.* (1985b: 4) propose a methodology for cumulative effects assessment based on a matrix analysis "considerably modified and expanded" by the addition of interaction matrices:

> *The cumulative impact of a configuration (combination of projects) is computed as the sum of a/l project-specific impacts adjusted for interactions among projects. This analytic approach is applied to all possible configurations of the projects under study.*

The logic of this approach appears to follow the reductionist strategy outlined by Clark (1986: 113):

> *One of the most useful roles for science in environmental impact assessment is,.. to reduce as many apparently cumulative problems as possible to simple cases of single cause and single effect. Residual cases of cumulative impacts will exist, and must be addressed. However, our goal should be to minimize, not maximize, such cases.*

The general matrix model advanced by Clark (1986) to assess residual cases of atmospheric impacts is also based on summation, thereby reducing multiple impacts to a single value. Row summation assessments determine the impact of a single source of cumulative impact on several valued ecosystem components and column summation assessments "focus on perturbations of a single valued ecosystem component by a number of different natural events or human activities."

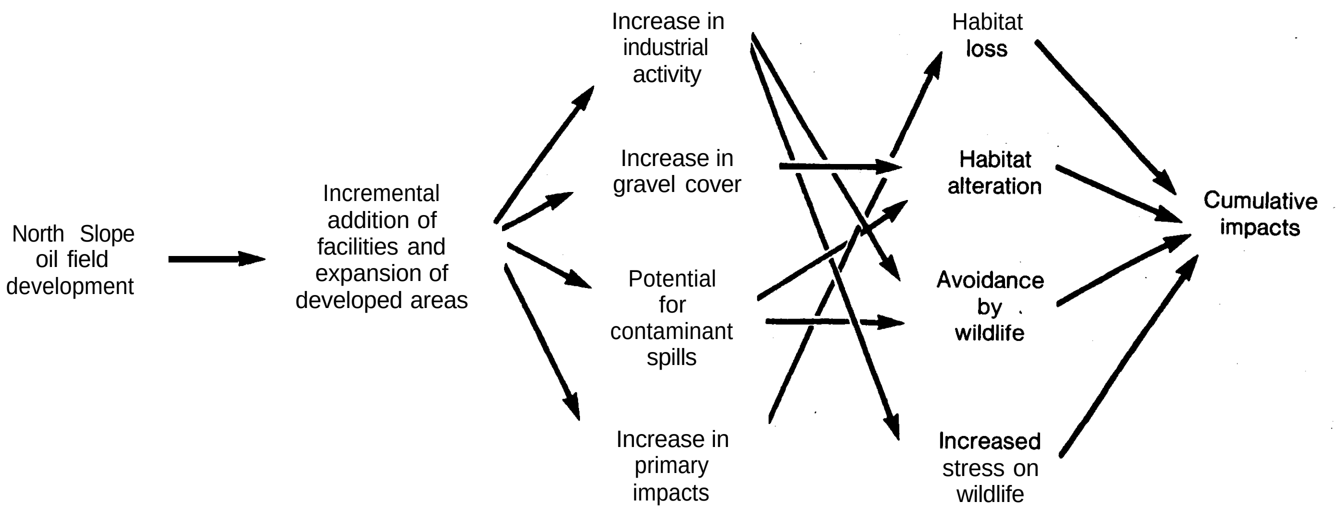
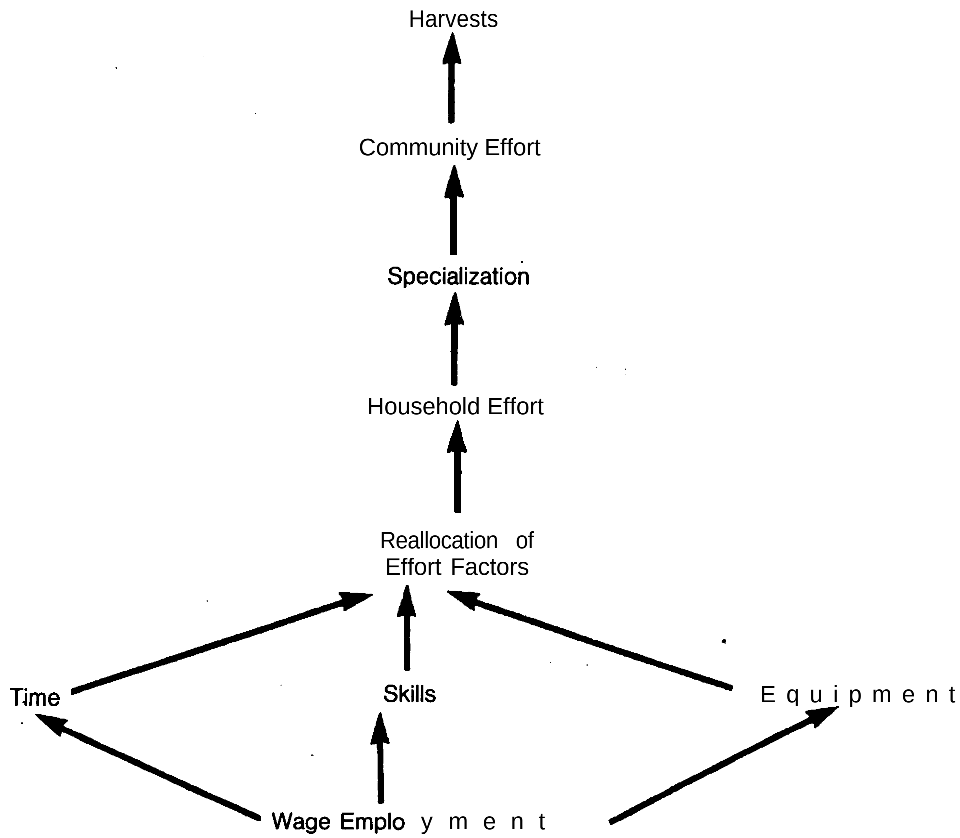


Figure 1. A simple illustration of the sequential effect of North Slope oil field development on fish and wildlife (Meehan and Webber 1985: 31).



Hypothesis 23: The effects of wage employment on harvesting.

Increased levels of wage employment have little effect on total annual community harvest, provided that the following conditions are met:

1. wage employment is flexible, especially with respect to timing, location, and duration;
2. income is sufficient to enable appropriate levels of capitalization for harvesting;
3. the system of mutual aid and sharing is maintained at a level appropriate to ensure effective substitution of labor and capital within and among units of production; and
4. adequate levels of appropriate skills are maintained within the available pool of labour.

Figure 2. Example Impact Hypothesis Taken from Resource Harvesting Case Study. (LGL Ltd., ESSA Ltd., and ESL Ltd. 1985)

There has been some criticism recorded that matrix methods do not account well for component and project interactions (e.g., Beaufort Sea Environmental Assessment Panel); in other words, they do not account for the processes causing the impacts, and are therefore ill-suited to CEA. For example, Brown (1986: 16) contends "the inadequacy of this approach has been revealed by recent theoretical and empirical studies." Despite these criticisms, however, it is clear that such matrix methods are useful in CEA and deserve further development and evaluation.

Causal Analysis

The causal analysis approach employs a "backstep analysis" to reduce causal complexity by identifying and isolating relatively discrete effects resulting from a proposed activity (Meehan and Webber 1985). These effects are then resynthesized into a causal network (Figure 1) similar to those applied in other CEA contexts such as areawide environmental assessment. The formalization of a causal analysis affords a basis for systematic 'development of a quantitative model.

A good example of this procedure is the approach taken to native resource harvesting in the Mackenzie Environmental Monitoring Program (MEMP) (LGL Ltd. et *al.* 1985). In MEMP, the effects on the resource harvesting systems are represented by a set of impact hypotheses composed of the causal relationships that link oil and gas activities with valued ecosystem components (Beanlands and Duinker 1983). Taken together, this set of hypotheses represents a systematic view of the potential cumulative impact of oil and gas development on resource harvesting (Figure 2).

The formulation of impact hypotheses can be viewed as part of the scoping process; testing theirsystematic relations is the work of assessment itself. At their present state of development, however, these hypotheses do not allow for structural changes in the resource harvesting system and hence the community. In terms of the cumulative effects processes described previously, this represents the category of discontinuous impacts or perhaps structural suprises. Because these effects, which are probably the most significant, are not taken into account, causal analysis cannot address all the issues. It does, however, offer a consistent framework to initiate a CEA analysis.

Adaptive Management

Horak et *al.* (1983a: 30, 34-35) evaluated 64 candidate CEA methodologies with eight criteria: 1) emphasis of multiple projects and actions; 2) consideration of off-site impacts and effects; 3) interaction and synergism among actions, impacts, and effects; 4) ability to aggregate effects; 5) consideration of ecological functional aspects; 6) consideration of ecological structural aspects; 7) ability to predict; and 8) adaptability. From this screening they selected three methods especially relevant to CEA: Erikson's framework based on the requirements of NEPA (Erickson 1979), KSIM (Kane et *al.* 1973), and the procedure of adaptive environmental assessment and management (AEAM) developed by Holling and his colleagues (Holling 1978). AEAM has been recognized elsewhere (Cline *et al.* 1983: 33; ESSA 1982) for its adaptability to "promote understanding and integration of environmental, economic, and social issues into policy-level decisions concerning design and implementation of natural resource developments or research programs." Its utility was considered to be greatest "when used continuously from pre-design through implementation." It combines both technical analysis, by means of simulation modelling, and interactive, multidisciplinary workshops, with well-structured monitoring procedures in order to develop a process of continuous refinement and learning (Walters 1986).

The AEAM procedure has now evolved to the point where it is being used as a base for developing a new model for predicting cumulative impacts at local, regional, and global scales. Recent work carried out on "the analysis of suprise" (Ralf Yorque Inc. 1986) at the University of British Columbia provides some new insights and approaches to this problem. Using a "meta-model" framework that incorporates a range of spatial (local to global), temporal (fast to slow), and system dimensions (ecological, social, and economic), their preliminary proposition is:

> *We have ended up with the perspective that forecasting is potentially powerful if the goal is to predict changes in structure, not changes in events. That is, it seems possible to predict vulnerabilities but not possible to predict. the specific events that will expose vulnerabilities.*

The concept of a "meta-model" is intended to integrate an assortment of models representing more traditional forms of analysis, at particular spatial and temporal scales, into an overall analysis that explicitly considers the linkage between actions and processes operating at each of the relevant scales. A unique challenge posed by this model is the need to consider explicitly the potential sources of surprise (at any scale) and integrate these into the analysis. The framework proposed later is an attempt to do just that.

A SYSTEMS MODEL FOR CEA

A simple systems model for CEA is found in Figure 3 (see also Horak *et al.* 1983a: 45). It suggests that cumulative effects situations can be both identified and analysed, as a first approximation, in a single input-output format. In this model, the input is the set of causative factors, including proposed actions of immediate concern as well as other "reasonably foreseeable" actions and trend impacts (i.e., activities). The implementation of occurrence of these activities could induce a perturbation on the existing systems and conditions (i.e., system structure and processes) whose output then takes the form of cumulative effects. A methodology for predicting or assessing cumulative effects requires resolution of all these elements.

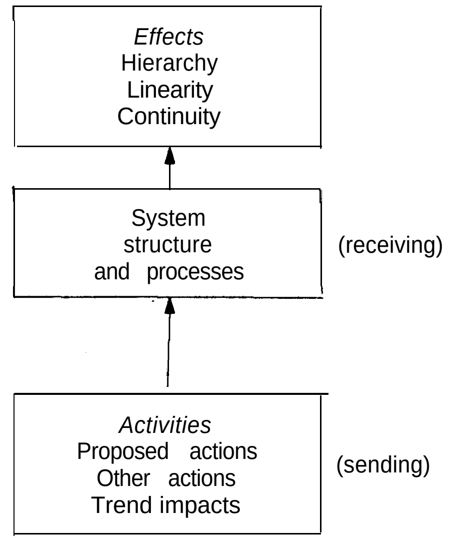


Figure 3. A System Model of Cumulative Effects Assessment.

In consideration of an *activity,* cumulative effects situations and their assessment are distinctive because they take a greater breadth of causative factors into account. CEA also emphasizes trend impact analysis with respect to both the "normal change" occurring in existing systems and conditions apart from the "induced change" peculiar to a specific proposed action.

Systems analysis involves the evaluation of structures and their dynamics and linkages. Structures are repetitive patterns of behaviour that are characteristic of a particular system type. Structures may also be considered as a cross-sectional or static view of system processes, the function of which is to maintain the system in its setting. System dynamics include properties such as response and recovery rates. Systemic linkages occur within levels, in subsystem relations, and across systems (ecological-economic).

With regard to system conditions, the cumulative effect situation is assumed to be comprised of systems in their normal settings. Together, the settings constitute the "total environment," although specific features such as 'valued ecosystem components" may be selected for special attention. The conditions and how they contribute to a cumulative effects situation may, however, be more direct and important in conditioning system response to perturbations. In the limiting case, the relationship between input and output may be one of simple determinism. Usually in CEA, however, we would expect a situation of complex causality, where the impact is a joint effect of characteristics of the perturbation and the existing systems and conditions.

Finally, the impact of the interaction between sending and receiving sides can be broadly classed in terms of hierarchy, linearity, and continuity. "Hierarchy" describes the ordering of impacts in a causal network as to priority (secondary and higher-order) and immediacy (direct /indirect). Linearity as a cumulative effect dimension is developed in the effects typology described at the beginning of this chapter; continuity intersects with linearity by recognizing spatial (proximate/ remote) and temporal (prompt /delayed) aspects. It should be noted that the substantive, content categories of cumulative effects are those reflecting alterations in system structures and their states; impact dimensions indicate what is changing about that content.

PROPOSED ANALYTIC FRAMEWORK FOR CEA

For this study, this simple systems model approach has been integrated with the "meta-model" framework to provide a preliminary analytic framework for CEA. Although speculative, it is presented here to provide some structure to the problem of CEA with the understanding that further development must follow from this modest beginning.

Activity

Activities are those actions associated with a particular development. Development is used here in a broad sense to cover any perturbation to the biophysical, social, or economic system. The key characteristic of concern is the system change or trend. Specific actions can take place locally and in the short term, such as forest clearcut, or can be aggregated over large geographic extents and long time-horizons, such as long-range transport of sulphur emissions. Activities generally fit into four major types:

- *single activity:* a single project or event usually completed in a short time-period and spatially fairly well contained; e.g., constructing a hydro-electric dam; single point source release of effluent;
- *multi-component activity:* a single project or event with a number of components being developed in sequence or simultaneously; e.g., developing a hydro-electric project comprised of a dam, transmission corridor, and access roads; developing an oilfield with associated transportation facilities;
- *multiple activity:* a regional development involving construction of several facility types of a varied nature over an extended period of time; e.g., developing an entire river basin; considering all forms of development (mining, transportation, hydro-electric, and oil and gas) over a large area; multiple point source emissions for region; and
- *global activity:* an activity that is dispersed over space and time with characteristics that make it of global concern; e.g., emissions of pollutants to the atmosphere from worldwide sources; changes in commodity prices,

Having decided the type of activity, the next step is to consider its spatial and temporal characteristics explicitly. Usually this could be thought of as a layer in a 3x3x4 matrix (activity matrix; see Figure 4). To accomplish this, two questions need to be asked:

- What is the longest period of time over which the activities are to be considered? This should include construction, start-up, operation, shut-down, and decomissioning where appropriate.
- What is the largest geographic extent over which these activities will occur?

Some examples are shown in Table 3. Note that each of the activity types will probably include specific actions that occur locally and in the short term.

After classifying an activity in space and time, the next step is to develop an explicit definition of each action that collectively makes up the activity. The objective is to ensure that the essential "output" characteristics are identified; e.g., regulation of water flow, discharge of toxic wastes, emissions of sulphur oxides. Each of these specific actions should be classified as to their magnitude and temporal characteristics; e.g., one time, continuous, intermittent, probabilistic. Upon completion, each box in the "activity matrix" should have been considered as a potential source of "action" on the system.

Systems Structure and Processes

The next step in the framework is to characterize the "receiving" system. For the purposes of simplicity, the receiving

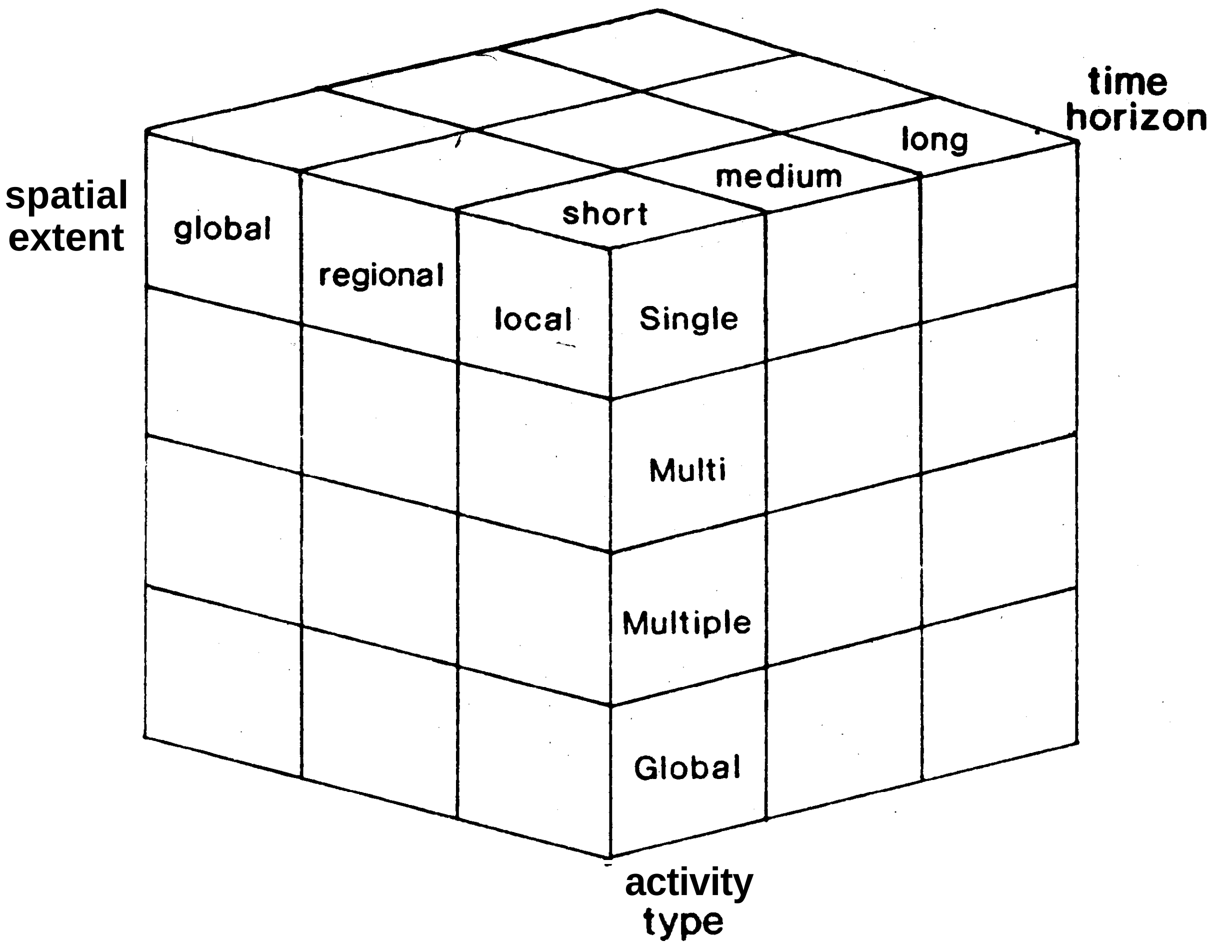


Figure 4. Activity Matrix: Identification of Activities in Spatial and Temporal Context

system is divided into three primary subsystems: social, economic, and ecological. Then, by associating the spatial and temporal dimensions with the subsystems, we have the "system matrix" (Figure 5); a 3x3x3 representation of space, time, and subsystem.

To use the matrix approach most effectively, a set of "indicators" (Holling 1978) or "valued ecosystem components" (Beanlands and Duinker 1983) relevant to each subsystem are selected as part of a scoping exercise. Then, a separate matrix can be formulated for each indicator. Matrix formulation involves identifying processes operating at each space and time scale which could possibly link the actions identified in the "activity matrix" to the indicator variable in each subsystem (e.g., causal analysis). Of principal interest are processes that relate to the ability of the indicator to recover over time. These need to be stressed to focus the analysis on the dynamics of the system; in other words, how the system will respond and recover over time. Examples of the kinds of processes to look for are:

- ecological systems — recovery and renewal processes;
- economic systems — scarcity and productive processes; and
- social systems — processes for the maintenance of society and culture.

The challenge in this stage of the analysis is to not isolate the analysis to one particular time or spatial scale but,' rather, to explore the possibility that actions on one scale may combine with processes on another scale to generate a possible impact. For example, a number of local, point source emissions operating on a fast time-scale could interact with an atmospheric distribution process operating on a regional space-scale and intermediate time-scale.

The intent of this exercise is to force the analyst to be creative and to broaden the scope of the analysis especially in the area of spatial and temporal contexts. This exercise will require

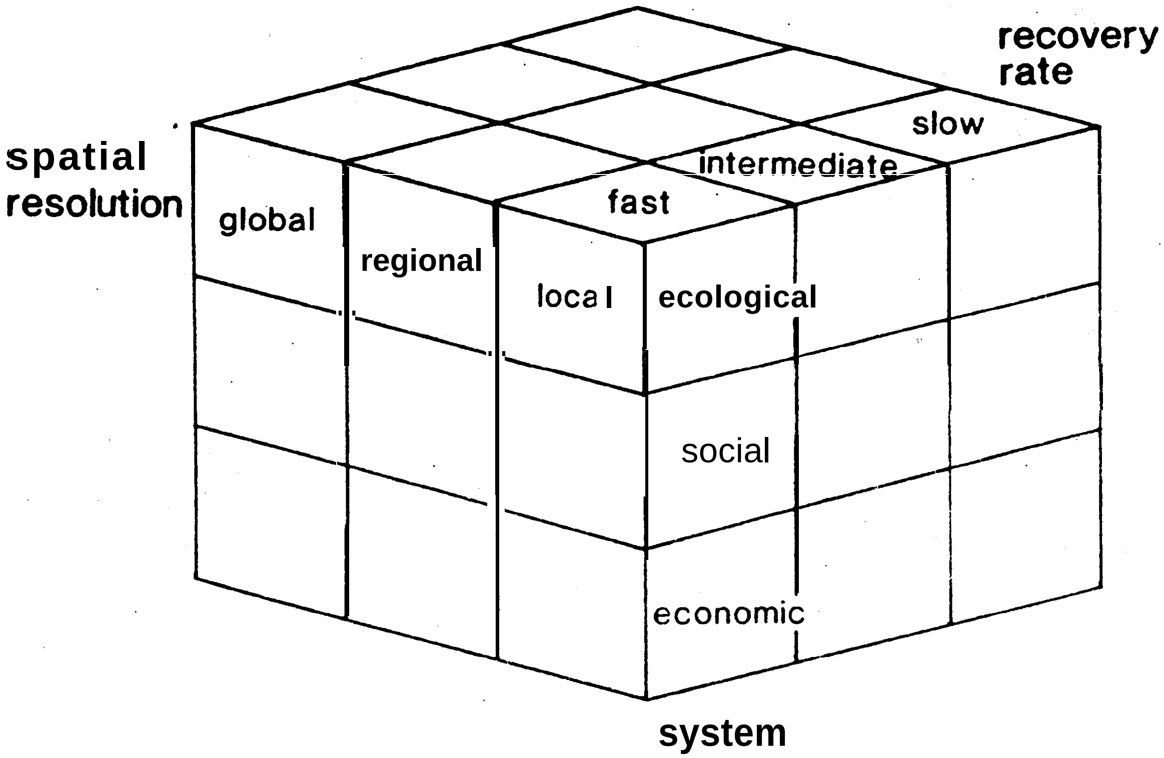


Figure 5. System Matrix: Identification of System Processes/Structure in Spatial and Temporal Context

some hard and often presumptive thinking but is necessary to better identify and assess cumulative impacts.

Effects

Development of the "systems matrix" is a first step in scoping the. potential for cumulative effects. Ultimately, however, a more detailed characterization of the effects is needed to facilitate assessment and design of mitigation and monitoring schemes in support of management and project redesign. It is at this juncture that the analyst must be cautious and yet expansive; cautious in that resources must be used efficiently and effectively; expansive in the methods of integration considered for predicting cumulative effects or the vulnerability of the systems to cumulative effects, as suggested by Holling (Ralf Yorque Inc. 1986). The procedural requirement is to integrate the "activity matrix" and the "systems matrix" to generate a picture of the possible spatial and temporal dynamics of each of the selected "indicators," assess the cumulative effects, and attempt to identify the possible sources of surprise.

A number of methods are available for accomplishing this integration (see the beginning of this section) and research is underway on some new approaches (Toth 1985; Ralf Yorque Inc. 1986). Ultimately, the selected "tool" for analysis is a function of the skills and experience of the analyst(s). Some points, however, should be kept in mind:

- Where possible, more than one method should be applied to assess effects. Given the level of uncertainty present in environmental and social systems, every possible avenue for improving one's insight into the problem should be explored.
- In most cases it would be foolish to attempt to capture all the spatial, temporal, and systems scales within one analytic tool. The past history of simulation models that tried to capture detail on the "local and fast" scales in a 'global context offer numerous lessons on how not to do things. Rather, the analysis is better directed to first take "slices" of the matrix and carry out an analysis on the selected scale in the slice. For example, management and policy questions might focus on the regional or global space scales while research might focus on a more local scale. These slices often represent more traditional kinds of analyses already being carried out.
- The analysis should focus on identifying and characterizing three basic system properties that can generate cumulative effects:

- secondary and higher order processes that lead to direct or indirect impacts or impacts across systems;
- linear and non-linear processes that generate additive, amplifying, threshold, or structural surprise impacts (see beginning of this section) within or between systems; and
- processes that operate over space and time in such a way so as to generate discontinuities in system behaviour (i.e., indicator response or system response). Examples are the delayed health impacts associated with the accumulation of toxic wastes, or the long-range transport of air pollutants.

Following analysis of each of the relevant slices of the "systerns matrix," some form of integration across the scales should take place. to ensure that all possible linkages are explored. At this time, how to accomplish this task is not clear. Possibly a computer model could be structured to use output from each analytic "slice" as input into an overall "integrator" model. Another option is to take the results of the more traditional analyses (i.e., the slices) into a workshop of selected experts and facilitate a set of structured exercises designed to explore various future scenarios under a number of system and management assumptions. Work along these lines is currently being pursued at the International Institute for Applied Systems Analysis (Toth 1985) and the University of British Columbia (Ralf Yorque Inc. 1986).

CHAPTER 3: CASE STUDIES

A major task in this project was to select a number of case studies in which the study team felt that aspects of cumulative effects were specifically addressed. Although in all three studies the term “cumulative effects” was never found, either in the literature or the interviews, it was clear that the issue of the accumulation of actions and their effects over space and time were being considered. Measures are now being taken to deal with cumulative effects; although some very useful insights can be gained now, the results of these measures will be unknown for some time. Therefore, many of the ultimate lessons that will assist CEARC and others in developing a final procedure for CEA are as yet unknown.

The three case studies summarized in the following pages concern:

- the Fraser River Estuary;
- New Brunswick forest management; and
- the impact of northern development on resource harvesting.

In preparing each of these case studies an attempt was made to incorporate the concept of cumulative effects and their assessment throughout the analysis. The complete description of the three case studies can be found in Appendix 1 of this report, The summary of each case study outlines the context, the cumulative effects analysed, how the cumulative effects were dealt with, and what appeared to work.

FRASER RIVER ESTUARY

Context

The Fraser Estuary is part of many major ecological systems: the Fraser River is renowned for its salmon runs, the estuary is home for the largest population of wintering waterfowl in Canada, and it is an important stopping point on the Pacific flyway for migrating birds. Thus, there are strong linkages far inland (e.g., salmon spawning in the streams of the Rockies), far out to sea (e.g., North Pacific feeding grounds), and to environments on other continents (e.g., bird habitats from Peru to Siberia).

Human settlement has radically changed the Lower Fraser Valley in the last 50 years: dyking has channelled the river, two-thirds of the original wetlands have been drained, and forests on the valley floor have been replaced by agriculture and urbanization. Commercial fishing fleets operating coast-wide are increasingly sharing moorage with port facilities associated with international trade (i.e., forestry) and recreationists. Industrial effluents, sewage, and run-off are discharged throughout the estuary. Thus, the evolving socio-economic systems have strong linkages to the ecological systems as well as to the international markets far removed from the sources of the natural resources (e.g., salmon, lumber, and coal sold in European and Pacific Rim countries; cars imported from Japan).

Applying the Typology of Cumulative Effects

The cumulative consequences of developments on the Fraser Estuary have been numerous and major. To better understand at What levels these effects are occurring, the four-level typology, presented in Chapter 2 can be applied to the activity classification. One example in each of the four categories is given.

Single activity — Linear additive: The Iona Island Sewage Treatment Plant, at the western edge of the estuary, which gives only primary treatment to the combined storm and sanitary sewage from the City of Vancouver, continues to discharge effluent onto the banks of the estuary. This has resulted in a degraded environment and accumulations of a variety of toxic materials in sediments and biota.

Multi-component activity — Amplifying: Development of the Roberts Bank Superport involved construction of a causeway out over Roberts Bank and an island at the end for coal storage and loading berths. The island was later expanded. As a consequence, wetland habitat has been directly lost by infill and, in adjacent areas, continuing processes of erosion and accretions have resulted in the loss and creation, respectively, of fish habitat.

Areal activity — Discontinuous: The accumulation of pollutant discharges and losses of shoreline habitat are a result of a diversity of developments, as small as marinas in Ladner Slough or as large as the industrial development on the North Arm.

Global change — Structural surprise: If scenarios of climatic change, resulting from increasing concentrations of carbon dioxide caused by development worldwide, come to pass, sea levels are likely to rise as a result of melting ice caps. These levels will, in turn, increasingly threaten to overtop the dykes in the estuary, causing massive damage to the extensive urban development on the floodplains.

Evaluating Cumulative Effects in the Estuary

Four major cumulative effects in the Fraser River Estuary were identified, based on the framework established above. Although each issue was previously used as an example of a particular type of effect, in various ways each issue has also either evidenced, or is suspected of causing, all four types of cumulative effects.

Agriculture: The accumulating losses of highly productive agricultural land became an increasing concern because of the province's growing dependence on imported products which may not be as economically available in the longer term.

Floods: Even though dyke protection is now adequate for the 1-in-200-year flood, the expected value of damages from the bigger flood that will inevitably occur in the future continues to accumulate through continuing urban expansion into the floodplain.

Toxics: Beginning in the early 1970s, general concern for the effects of toxic discharges led specifically to an increasingly intensive search for those materials in the estuary. Evidence of the accumulation of toxic materials has been found (see detailed case study in Appendix 1), particularly in the sediments and biota adjacent to outfalls where there is poor flushing.

Wetlands: In the early 1970s, the increasing appreciation of wetland environments was reinforced by the discovery that juvenile salmon are resident in these areas during a critical period of growth and adaptation prior to migrating out to sea. A study also showed that about 70% of the original wetlands of the estuary and floodplain have been lost, mainly as a result of dyking before the turn of the century. This gave rise to concerns about the cumulative effects on wildlife from continuing loss of remaining wetlands to various forms of development.

Responses to Possible Cumulative Effects

These cumulative issues have been identified and responded to in a variety of ways. Five planning and impact assessment initiatives have been significant.

Lower Mainland Regional Planning Board (LMRPB): The experience with floods in 1948 and the loss of farmland to urban development led to the establishment, in 1949, of the LMRPB. The Board, consisting of representatives from all municipalities and a small staff of planners, was responsible for regional planning. Through studies and negotiations between the government agencies, a Long Range Land Use Plan for the Lower Mainland was finally adopted in 1966.

Agricultural Land Commission (ALC): In spite of the Lower Mainland Plan, the accumulating losses of farmland led to a "land freeze" in 1972 and to the creation in 1973 of the B.C. Agricultural Land Commission (ALC) which was to establish and administer Agricultural Land Reserves (ALR). The members, appointed by the provincial government and aided by a small staff, have been continually "fine-tuning" the reserves, with inclusions and deletions, and progressively working towards closer relationships with other governmental planning processes.

Livable Region Planning Program (LRPP): The regional planning responsibilities of the LMRPB, after its abolition in 1968, were given to four regional districts, one of which was the Greater Vancouver Regional District (GVRD). Responding to the perception that the cumulative consequences of urban development were making the region less "livable," the GVRD launched the LRPP in the early 1970s. Of the 70 "livability objectives" of the LRPP, defined through studies and intensive 'discussions between the public, politicians, and planning staff, many directly related to the cumulative issues previously defined. A five point strategy, adopted in 1975, for implementing these objectives was voluntary, however, and has been successful in only a few areas. Nonetheless, binding land use designations, contained in the 1980 update of the earlier Lower Mainland Plan, clearly reflect the influence of the LRPP.

Impact Assessments in the Fraser Estuary: In the early 1970s, the proposal to expand Vancouver International Airport onto Sturgeon Banks stimulated public concern for the cumulative consequences of developments in the estuary specifically. As one of the first projects submitted to the federal Environmental Assessment and Review Process (EARP), the proposal led to an intensive questioning of both the biophysical and socio-economic consequences. It also stimulated similar questions about other developments in the estuary, particularly the need for more advanced treatment processes at the major municipal sewage plant on Annacis Island. In 1977, two, responses to the concern expressed at the public hearings were the provincial cabinet approved Order-in-Council 908 that required all proponents of developments outside the dykes to prepare an environmental impact assessment and, the signing of a federal-provincial agreement to undertake the Fraser River Estuary Study (FRES).

Fraser River Estuary Management Program (FREMP): The first two phases of FRES (1977- 1978; 1979-1982) defined the nature of the estuary management problem, began to formulate management strategies, and evaluated alternative institutional arrangements for ongoing management. These phases were conducted by a small study staff, under the direction of a management committee, and usually employed interagency task forces and public involvement processes. An implementation strategy began in the third phase in 1985 and will continue for five years. The strategy has three major components: a series of goals and general policies for balancing economic development and environmental protection in the estuary; a Management Committee to co-ordinate the management program,- resolve conflicts, and ensure achievement of the goals; and a co-ordinated set of activities to develop and implement the program (i.e., an information system, a co-ordinated project review process, area planning work groups, and activity program work groups).

Evaluating the Responses

A criterion for evaluating the success of these initiatives in assessing and managing cumulative effects could be "no unpleasant surprises." This implies a desire to avoid what will be considered unpleasant, as well as an ability to anticipate it. Success, therefore, depends on the institutional arrangements having the capacity to predict future consequences of development, to evaluate those consequences, and to act to avoid the undesirable.

Success So Far

There has been substantial success in avoiding unpleasant surprises in the Fraser but there are significant uncertalnties about the future.

Agriculture: Although controversy continues about "fine-tuning" the ALRs, their introduction greatly reduced the rate of loss of agricultural land. This cumulative issue had long been a concern but was not acted upon until a change in government took place. Its future success depends on the continuing desire to maintain the ALRs, as well as to improve agricultural productivity and the economic viability of farming.

Floods: The dykes have provided adequate protection against all freshets since 1948. The public, however, does not appreciate that a flood with potential for high damage costs due to increasing development in the floodplain will eventually occur. Future success depends on extreme physical events (including combinations of high freshets, storms, and earthquakes) not occurring and on improved public understanding of the risk and opportunities for reducing that risk.

Toxics: Serious toxicity problems have not yet been found in the estuary but accumulations of toxic materials have been found in proximity to outfalls, particularly in backwater areas. Future success depends first on discovering problems that have not yet been searched for or recognized, and second, on being able to recognize and avoid new threats from the increasing diversity and quantity of toxic materials that could potentially reach the estuary.

Wetlands: Since the realization that much of the original wetlands have been lost to dyking and that juvenile salmon are resident in the estuarine marshes, a large proportion of the remaining wetlands have been designated conservation areas, the incremental loss of the remainder has been greatly reduced, and attempts at restoration and enhancement have begun. In the future, success will depend on not discovering undesirable consequences of the losses to date, being able to maintain conservation areas, and the development and application of marsh restoration and enhancement techniques.

Contribution of Planning and Impact Assessment

Although both planning and impact assessment have been frequently controversial, it can be argued that the early application and later refinement of these methodologies have contributed to the substantial success in controlling the cumulative effects of development in the Fraser River Estuary:

- The early introduction of regionally based planning by the LMRPB began a questioning of the cumulative consequences of development in the region and led to the adoption of broad goals and general strategies for achieving them (i.e., controlling floodplain development).
- Over time, planning has become more detailed and specific in response to the growing pressures of development: the ALR program dealt with agricultural land losses and FRES specifically responded to environmental degradation in the estuary.
- In planning, there has been a major shift from emphasizing the final "plan" or product to emphasizing the ongoing "planning" process. This shift has been accompanied by expanded involvement of bureaucrats, politicians, and the public, which has facilitated increased consideration of science and essential values.
- With the creation of impact assessment procedures in the early 1970s, a more specific consideration of the environmental issues in the estuary began. Assessments for both waste management 'permits and foreshore leases, in addition to EARP, have become progressively more comprehensive and detailed. FRES is developing planning processes that would give them a more specific context in the estuary and link them to planning activities.

Challenge to FREMP

While the success and potential of the planning and impact assessment initiatives taken so far have been emphasized, it is clear that FREMP faces major challenges in the future. The absence of unpleasant surprises (e.g., a major flood) until now has, in part, been good fortune, although, in the future, surprises from past practices might emerge (e.g., new knowledge about the effects of toxic discharges). Other difficulties to overcome include lack of knowledge of the estuarine ecosystem, long gestation periods for developing institutional responses, ongoing political controversy, and lack of political commitment to regional planning. In addition, cumulative issues are becoming more numerous and difficult to predict as the development of the socio-economic system creates greater interdependencies and uncertainties with other systems (e.g., climate change effects on flooding). Success will therefore depend on FREMP continuing to learn how planning and impact assessment techniques and processes can be better integrated and employed to provide a timely basis for action.

Opportunities for Immediate Improvement

Currently, there are three major opportunities for initiating improvements to CEA in the Fraser River Estuary. These are to:

- make better use of existing knowledge and techniques of analysis;
- develop processes for setting research 'priorities; and
- increase the effectiveness and productivity of existing institutional arrangements.

NEW BRUNSWICK FOREST MANAGEMENT

Context

New Brunswick has the largest proportion of forested land of any province (approximately 86% of the land base or 6.2 million hectares), most of which is accessible and capable of growing repeated crops. Economic development has traditionally involved exploitation of the forest resource to promote local and regional economic growth. Simultaneously, however, undesirable local ecological impacts on wood supply have cumulated to the level of regional degradation, threatening the future of New Brunswick's forest industry. As with the previous case study, a structural change in one system causes structural changes in the other two systems.

In the context of this study, the ecological system undergoing change is a forest comprised of a mix of predominantly spruce and fir (60 %), other softwoods (10%), and hardwoods (30%). In terms of the socio-economic systems, primary and secondary forest industries directly employ 16,000 (5%) of the New Brunswick work force and indirectly account for an additional 20,000 (5.5%) jobs. Forty percent of the province's manufacturing and 38% of exports are derived from forestry. More specifically, the economic system can be broken down into three major components: wood supply, management practices, and land ownership and tenure patterns.

Cumulative Effects

Shortfall in Wood Supply

The cumulative issue in this case study is the accumulation over space and time of the consequences of many small-scale, 4-80 hectares (lo-200 acres) interventions by man and natural agents, in the form of harvesting and budworm infestations, respectively, occurring over approximately 70 years. The historical high-grading harvest policy for pulp and saw logs, in combination with economic and institutional pressure to supply an overcapacity of mills, has resulted in the cumulative effect of a product mix of poor quality and unusable species with a projected shortfall in the volume of raw materials. Referring back to the typology from Chapter 2, this is a Type 1 activity that manifested itself as a Type 4 effect (i.e., the incremental harvesting of trees became a surprise change in forest structure).

Responses to Cumulative Effects

Many changes in the structure of stands and forests have accompanied the development of the forest industry in New Brunswick. Consideration of the cumulative effects of the methods and scheduling of harvests, have become increasingly important because all these activities have long-term implications on the development of a new stand and, ultimately, the forest upon which the industry depends. For example, saw mill closures have been due not to a lack of logs but to the inability of the saw mills to adapt technologically to smaller tree sizes.

Local industry realized that it was losing competitiveness in world trade, due to the high cost of raw materials resulting from the overharvesting of certain species and potential socio-economic consequences to local communities of saw-mill closures. This, in turn, forced recognition of resource degradation and the need for a new perspective. Recognition by decision makers in industry and government occurred between 1975 and 1980. Once it was agreed that maintaining the flow of quality material was the real problem, emphasis on designing and implementing long-term corrective measures soon followed (Regier and Baskerville 1986).

Changes in Management Perspective

The first accomplishment was a change in the operational paradigm for forest management. The new approach focuses on controlling the way the whole forest develops, both temporally and spatially, so that the pattern of stands over the forest is continously suitable for the purposes of management. Regulating the timing of available harvest as well as the location of stands available for harvesting is essential to reduce the risk of losing all of one stage of development to a natural disaster, causing a break in the future flow of stands available for harvest. The long lag-times between action and system response of the forest structure means that management must anticipate problems and the need for action 30 years in advance.

Any management plan must include the following four elements at the stand level:

- harvest schedule — determining when and how each stand will be harvested;
- product mix — determining what distribution of materials will be taken in each harvest to provide consistent quality supply;
- silviculture — altering stand development away from natural patterns or accelerating natural trends by means of pre-commercial thinning and planting; and
- protection — protecting stands from unscheduled harvest caused by insects, disease, or fire.

Forest Resources Study (1974)

The projected gap in the forest age structure under historical management led the province in 1974 to commission a forest resources study to gather data, analyse present use, develop a comprehensive policy, and recommend new marketing strategies. The report set the tone for establishing a new forest management program and producing comprehensive guidelines for forest resource development. Moreover, it paved the way for new legislation, bringing the control of timber licences to one agency, the Department of Natural Resources.

Crown Lands and Forests Act (1982)

This Act reallocated access to Crown timber, based on the needs of mills and the ability of Crown forests to supply those needs. Saw mills and pulp mills were provided equal access to the productivity of the forest and the management units in the forest were altered to make it possible for the provincial government to rigorously design and control forest management.

The Act also provided incentives for silviculture that will improve the wood supply situation in the gap period. The arrangement establishes mechanisms for reimbursement to the licensees for costs associated with forest management actions, such as thinning and pest control, and establishes a penalty for failure to meet minimum management standards.

Evaluating the Responses

In general, the shift in the management paradigm has had considerable success, especially considering that it began only 10 years ago. The public (woodlot owners), saw mill and paper mill industry, and government have become aware of the complexity of the wood supply problem and the measures that can be taken to rectify it. The role of the major government player, the Department of Natural Resources, has changed from one of providing silvicultural and protection services to one of designing management strategies and monitoring their outcome. A good rapport between industry and government has proven to be an important step in advancing the need for integrated management.

The 1982 legislation has worked for the industrial freeholds of saw mills and paper mills in that it has altered the way harvested areas are treated. Further, both small and large mills must share the costs of management so the available supply is more equitably divided among the industrial users.

For the nonindustrial freeholds of private woodlot owners the legislation has, however, failed. An attempt in the Act to improve the market for the freeholds and thereby stimulate better management has instead resulted in increased sales with no reinvestment. The reason for this reaction is that the majority of freehold property owners do not depend on the wood supply for their livelihood and do not live on the land. Therefore, they do not wish to invest money in forest management. In fact, they expect the government to pay for forest management while they reap the financial benefits.

IMPACT OF NORTHERN DEVELOPMENT ON RESOURCE HARVESTING

The resource harvesting case study focuses on the assessment of social and economic effects of resource development that have potential, in the long term,. to become cumulative effects.

Context

Since the 1920s, northern Societies, based now, as traditionally, on the harvesting of renewable resources, have been subject to industrial and governmental interests that wish to exploit the land and resources for southern use. Struggles by these societies to protect their social structures and livelihoods have led to legal and political conflicts over claims to land and resources. One of the most visible aspects of this struggle has been the frequency and bitterness of environmental protection battles, which have provided one of the few forums for raising native concerns about the long-term cumulative effects of nonrenewable resource exploitation.

In the traditional lifestyle of northern native communities, the people and their environment are one; in other words, the ecological, social, and economic systems are inseparable. The integration of these three systems is most evident in the native resource harvesting system. Resource harvesting (the northern people do not call their lifestyle by this name) encompasses the activities of hunting, fishing, or trapping and the subsequent processing of fish and wildlife for food, clothing, and sale. The ecological system comprises populations of animals and the physical environment that supports them. The social system is, of course, the set of mores and norms that govern the relationships in the community. The economic system in a small northern community revolves around four sources of income: wage employment, transfer payments, sale of commodities (e.g., furs and handicrafts), and domestic production (e.g., meat, fish, wood).

Applying the Typology of Cumulative Effects

The impact of development on resource harvesting gives rise to many types of cumulative effects. It is useful to consider these effects in the context of the typology that was developed in Chapter 2. Examples of each of the four types of cumulative effects are given in Table 4. Some effects are already evident in northern communities (Types 1 and 2), while other effects have not yet occurred (Types 3 and 4), although the potential is there. The current practice of EIA can evaluate, to some extent, Type 1 and 2 effects; it is inadequate, however, for the assessment of Type 3 and 4 effects. The latter effects indicate structural changes in the social, cultural, and economic systems. Some responses to these effects from native communities and institutions are outlined in the next section.

Responses to Cumulative Effects

Native Communities

Northern communities have generally resisted development, voicing a desire to have a say in how it proceeds. The people have adopted the attitude that the resource development process is essentially, a boom-or-bust phenomena and they wish to return to more traditional ways of life when it is over; therefore, a strong environmental protection feeling is prevalent. They wish to ensure that the fish and wildlife, upon which they depend, will not be depleted by development. These factors mitigate against the cumulative effects.

More specifically, the native people recognized early, and often reiterated, the potential for cumulative effects, especially from large-scale resource development. The focus of native presentations to the Berger Inquiry into the Mackenzie Valley Pipeline is reflected in the evocative title of the report of the inquiry, Northern Home/and, *Northern Frontier.* The title suggests that the social impacts of the Mackenzie Valley Pipeline Project were going to be far more significant than the ecological effects on a northern biome. Consequently, the Berger Inquiry recommended a IO-year moratorium on development in the Mackenzie Valley pending the settlement of native claims.

For the most part, the response to the problem has been bound up in the political development of native communities and accompanying land claim negotiations and settlements. Thus, the response of the native community to the potential for cumulative effects is to acquire more power over the management of the land and its resources. The major government agencies, namely the Department of Indian and Northern Affairs and the Government of the Northwest Territories, are responding to these pressures by decentralizing decision making and increasing native participation.

Government Institutions

The scientific and technical communities inside and outside government have neglected the cumulative effects of development on renewable resource harvesting. The failures of the

Table 4
Applying the Cumulative Effects Typology to Resource Harvesting.

Type 1: Linear Additive	Small-scale industrial projects that incrementally reduce wildlife habitat, thus changing the amount and location of the hunting effort.
Type 2: Amplifying or Exponential	With more people living in the North as a result of new development projects there is increased competition on local wildlife resources.
Type 3: Discontinuous	With the introduction of a wage economy, increasing numbers of native people are employed outside the home. Consequently, the processing of fish and wildlife is done by other family members or imported items are purchased as compensation for those items no longer produced at home. This change means there is greater reliance on outside sources for products and the wages for purchasing those products.
Type 4: Structural Surprise	There is potential for a major structural change in the resource harvesting system if the Type 3 issue, described above, continues until most people lose their traditional skills and are totally dependent on outside sources for food, clothing, and shelter. At this point, a viable resource economy will no longer exist. It would likely be replaced by government assistance. For example, the recent decline in the price of oil and the consequent drop in northern oil exploration appears to have had substantial effect on some communities. The degree and extent of effect is yet to be determined.

Beaufort Environmental Assessment Panel to address the cumulative effects issues are well documented (see the detailed case history in Appendix 1). For the most part, these effects lay well outside the Panel's mandate.

The Northern Land Use Planning Program may be a positive response by the Department of Indian Affairs and Northern Development (DIAND) and the territorial governments to the need to manage cumulative effects. The program began formally in January 1986; therefore, it is too early to tell whether the pace of development can be regulated to mitigate the negative impacts on the resource harvesting economy in small communities. The strong desire of native peoples for more say in the disposition and management of the land has forced the early phases of the land use planning process to concentrate on maximizing the role and rights of native peoples. As a result, Northern Land Use Planning has dealt thus far with very few of the substantive land use issues.

Another DIAND program involving native peoples as partners in discussions about renewable resource harvesting is the Mackenzie Environmental Monitoring Program (MEMP). DIAND co-sponsors MEMP along with the Department of Fisheries and Oceans, Environment Canada, the Government of the Northwest Territories, and the Yukon Territorial Government. What began as an ecological monitoring project expanded to include social effects; almost serendipitously, MEMP began to define cumulative effects of oil and gas development on renewable resource harvesting. Although, like Northern Land Use Planning, MEMP is in its formative stages, it may provide a mechanism for better understanding of cumulative effects.

Evaluating the Responses

Thus far in the history of northern development, three actions have helped to manage cumulative effects: Berger's Inquiry and recommended moratorium, resistance, and apathy by native communities toward development, and increasing political involvement by native people. Contrasted against these marginal successes is the inadequacy of existing environmental assessment techniques to assess cumulative effects. Constrained by its mandate, the federal environmental assessment panel on the Beaufort Sea did not adequately address the issues surrounding resource harvesting or cumulative effects in general. In terms of designing and conducting impact assessments, most attention by regulatory agencies has been given to compiling databases on physical aspects, such as wildlife habitat; rather than on the social and economic structures of northern communities. Lack of a suitable database only compounds the problems of predicting how these impacts will manifest themselves in each of the communities.

Northern Land Use Planning and programs like MEMP may be steps toward better processes and methods. Northern Land Use Planning has only been operational for less than a year, so it is difficult to judge its effectiveness. Due to an explicit linking of the scale of projects to a corresponding level in the planning hierarchy, decentralized decision making, and the representation of northern residents at all levels in the process, this program may succeed where other attempts have failed.

CHAPTER 4: CASE STUDY SYNTHESIS

The usefulness of the case analyses depends on whether these experiences can be generalized to other cumulative effects situations. To attain and exercise that ability to generalize, we next review the materials summarized in Chapter 3 to identify the elements that may be more broadly applicable.

ECOLOGICAL ANALYSIS

In the three case studies analysed for this project, some major aspects of cumulative effects were manifested in the ecological system. In the Fraser example, the discussion focused on the continual loss of agricultural land, the synchronicity of hydrologic events generating a flood event, the accumulation of toxics in the ecosystem, and the increasing rate of wetlands loss in the estuary. In the resource harvesting case study, one focus was the potential alterations in animal populations, and therefore harvest levels, due to the accumulating effects of oil and gas development in the North. Finally, the New Brunswick forest case study focused on the cumulative effect, over a 70-year period, of a large number of small-scale harvesting events on the long-term sustainability of forest production.

Scientific Uncertainty

Various levels of uncertainty are associated with the cumulative effects situations in each of the case studies (see the Fraser River Estuary case study in Appendix 1). They range, in the case of northern resource harvesting, from the very uncertain situation which is a function of expert opinion with limited supporting data, to a more certain situation, with the New Brunswick forests, where available analyses and data were ultimately applied to the problem. The Fraser River study lies in the middle, characterized by considerable uncertainty with regard to the impacts of toxics and losses of wetlands but enough analyses and data to establish the likelihood and impacts of an extreme flooding event. Notwithstanding these uncertainties, an apparent consensus on the need to act developed, culminating in the institutional reponses outlined.

Structured Analysis

An exciting feature of the resource harvesting case is the evolving definition and provision of a set of hypotheses describing the potential pathways of impact. During the Berger Inquiry, and the Beaufort Sea Environmental Monitoring Project and, more recently, the Mackenzie Environmental Monitoring Program, increasingly successful efforts were made to structure scientific thinking on the ecological system to guide impact prediction, research, and monitoring. This approach greatly aided these studies and has resulted in a "paper trail" of thought and research upon which to build. What is needed now is a comprehensive monitoring program to evaluate the hypotheses and evaluate management options.

Time Frames for Analysis

In the New Brunswick forest management case study, the initial difficulty was poor problem definition. The spatial context of analyses carried out prior to the late 1970s was not sensitive to the longer-term forest inventory problem. The myopic bias of the 1950s was maintained, almost without question, until evidence from new inventories in the mid-1970s supported predictions made by earlier budworm modelling studies (early 1970s) of shortfalls in future supplies. As a consequence, a second inventory was carried out in 1979 with a different set of guidelines and rapid transition in the paradigm took place. It seems reasonable to presume that if an analysis of the type carried out in the 1970s had instead been done in the 1950s, the problem of cumulative loss of volume and species supply due to overharvesting would have been identified earlier, notwithstanding the more limited computing tools available at that time.

On the other hand, the Fraser River system has been under scrutiny for some 60-70 years. As part of various institutions' efforts to better understand the impacts of certain alterations in the system, specific research efforts were implemented (e.g., the relationship of wetlands habitat to salmon rearing). Through various aspects of this research some effects we classified as cumulative were assessed. What is not in place at this time, however, is an established analytic procedure for assessment of future development issues. Although FREMP provides a process to assess new developments, it has not been tested and uncertainties about ecological processes will become increasingly important as we push closer to the established policy thresholds. The need for a comprehensive monitoring program and established procedures for adapting management and mitigation strategies is a pressing issue; FREMP has been the institutional response to these concerns.

SOCIAL ANALYSIS

In each of the case studies analysed, anthropogenic action was the major cause of changes to the ecological and economic systems, and, through feedback mechanisms, to the social system itself. The value-based nature of social planning and plan implementation is pronounced at the areawide and regional scales; it is a distinctive property of social systems, intersecting with ecological systems in the concept of "valued ecosystem components" applied in environmental assessment and planning criteria. In some instances, however, such as northern development, it is very difficult to separate ecological from social analysis because they are practically synonymous. Another problem arising from the analyses of social effects is the lack of suitable assessment methodologies. Because most effects are seen as being qualitative, rather than quantitative, analysis is not a simple matter of transferring ecological assessment techniques to social conditions.

Scale of Social Actions

In all three cases, the socio-economic causes of cumulative effects occur on a continuum from local to global. The global dimension is pronounced in terms of the influence that international trade and export markets have on regional and local actions, indicating the emerging worldwide interdependency on trade. Local actions can also create regional, if not global, effects. The experience with toxic chemicals in the Fraser Estuary is common to most industrialized areas.

Problems of assessment

The difficulty of measuring change in socio-economic systems is captured in the description of northern development pressures by Carley (1983: 2). In this case, which effects can be directly attributable to oil and gas development and which effects are part of an irreversible social trend that may have occurred in the absence of that development?

> *Cumulative regional impacts will be intensified by various developments, both oil- and gas-related and independently. . . the landscape will change from a few communities in the wilderness to one of numerous interspaced resource extractive and suppotting industries, with attendant growth in existing or new towns, linked by roads, pipelines, and new shipping and air routes.*
>
> *Of course, there is also a great amount of social and cultural change occurring in the region that has little to do with oil and gas, and that really began about the 1950s: increasing urbaniza tion, increasing enrolment in the formal educational system, exposure to mass media and especially TV, a welfare system, the provision of housing, increased health care, roads, snowmobiles, and many others.*

As this makes plain, hydrocarbon development is only one edge of the advancing northern frontier. Its temporary retreat, or the end of the "mega-project" era generally, will moderate, but not basically alter, the civilirational impact.

Involvement in the Assessment Process

Social analysis in the case of New Brunswick forest management is notable for its absence — it is as if no community or society existed, only an industry, its management, and work force. But even on these terms the social conflict of interest and the breakdown of social consensus are apparent. One may very well question in whose interest forest policies are formulated and implemented when by far the largest group of stakeholders, the 40,000 private freeholders, exempt themselves from its provisions. Their attachment to the land may equally well be questioned, if the 85% absentee landowner figure is borne out. Of course, forest management is not simply a matter of "jobs at any cost." The spraying policy raised potent fears and doubts about public health and safety concerns. The larger question of the dimensions and proportion of "quality of life" concerns, and the balance of economic well-being and environmental quality factors, is no less at issue in this case than the others.

INSTITUTIONAL ANALYSIS

Our analysis thus far has already shown that the term "cumulative effects assessment" was not used historically; thus, some care has to be taken in interpreting.specific events and activities. For each case study the cumulative effects were defined in relatively specific terms. In this section we look at how those effects were identified, how the institutions responded, and whether or not there was a client who could use the results of a cumulative effects assessment.

Identification of Cumulative Effects

It is difficult to generalize about how cumulative effects are identified. In New Brunswick, analyses by the government and academia pointed out the potential shortfall in wood supply. In the renewable resource harvesting case it is the native people that clearly articulate the potential threat to the renewable resource economy. In the Fraser case it appears to be a combination of government initiatives, public awareness, and scientific research that help identify the potential for cumulative effects.

Institutional Response

Examining the case studies, we can see that governmental institutions' responses to the potential for cumulative effects can be classified into two main categories:

- prohibition or curtailment of the development activity; and
- comprehensive environmental management or planning.

Both responses imply greater control over the forces that are responsible for the effects.

Prohibition or curtailment appears to be the most common strategy when a cumulative effect clearly exists but there is no basis for the rigorous assessment of what the significance of the effect might be. This could be construed to be the case for the Agricultural Land Reserve in the Fraser case and Berger's recommendation for a moratorium on development in the Mackenzie Valley.

Comprehensive environmental management and planning may also appear to be recommended where there is no clear cumulative effect present, where the effect is not perceived to be significant, or where curtailment of an activity would seriously disrupt the economy. Examples of this are the toxic materials issue in the Fraser case and the forest management case in New Brunswick.

In some cases, comprehensive environmental management and planning could be viewed as a replacement for prohibition and curtailment. Examples of this are found in the land use planning process recently initiated in the Canadian North and the Habitat Management Activity for the Fraser Estuary Study.

In most of the case studies, actions taken were not based on clear evidence of the cumulative effects. The exception may be the New Brunswick case. This implies that we lack the methods to assess cumulative effects in any predictive sense.

This shortcoming may explain the need for prohibition and curtailment in some cases.

Who is the Client for Cumulative Effects Assessment?

For some classes of cumulative problems, it has been hypothesized that there is no client for a cumulative effects assessment. This was not the-case in each of three Canadian case studies; in fact, it was relatively easy to identify the clients. In New Brunswick; it was clearly the Department of Natural Resources. In the resource harvesting case it is DIAND and GNWT. In the Fraser case it was less clear who should take the lead, but it is clear who jointly has responsibility and therefore who is the client for a cumulative effects assessment. In all cases, the client was an agency with some mandate large enough to encompass the spatial scale of the effect.

CHAPTER 5: OBSERVATIONS AND RECOMMENDATIONS

The preceding chapters have presented a preliminary review of the state of the art of cumulative effects assessment. On the basis of this review, and the input provided by participants at the workshops, seven observations were evident (Table 5). Before these observations can become conclusions, more evidence will be required; however, they help to lead the analysis toward the recommendations. Participants at the workshops associated with this project made suggestions that were in close agreement with those from the 1985 Toronto workshop (CEARC and U.S. NRC 1986: 165-166), generally appealing for improved scientific understanding and new institutional processes that would be interdisciplinary and accountable.

The concluding section of this report indicates a number of generic and specific recommendations for advancing the state of the art in CEA, with the emphasis on action. Table 6 is an overview of these recommendations classified by area of field development. In estimating the present state of the art and indicating steps for its improvement, we can identify four main areas of field development: theoretical, methodological, institutional, and professional. The first two areas correspond to the analytical dimension of CEA and the latter two to the institutional dimension. Each is related to the others; that is, assessment practices and procedures should be theoretically based, empirically grounded, and policy-relevant. Because a close relationship exists among categories, placement of one or another of the recommendations may, at times, seem arbitrary.

OBSERVATIONS

Theoretical Development

Observation 1: Increased Potential for Cumulative Effects

The linkages between technological, ecological, and social systems are a major determinant in considering the potential for cumulative effects. Increased spatial and temporal scales of development, combined with narrowly focused management strategies, are creating situations where previously independent systems are becoming more tightly coupled and therefore interdependent. As a result, not dealing with cumulative effects is resulting in the amplification of consequences leading to system homogenization, such as single species forestry, and pointing out the fragility of the systems involved. A good example of this is the New Brunswick forest case. Other examples are the issue of declining soil fertility in the Prairies, and the extensive use of hatchery production for Pacific salmon, especially on the Columbia River.

Observation 2: Science and Values

Planning and assessment involve the analysis and synthesis of scientific and value information about relevant resource systems, To the extent that there is uncertainty about the science and values, both planning and impact assessment become more difficult. Cumulative effects issues are characterized by high uncertainty about values, science, or both. What is required is an agreed upon framework within which the concepts and concerns of science and public values can both be accommodated.

Table 5
Observations on the Needs and Directions of CEA According to the Main Areas of Concern.

Theoretical Development
There is an increased potential for cumulative effects.
A framework is needed to integrate scientific concerns and public values.
Methodological Development
Available techniques for addressing cumulative effects are underutilized.
New methods must be developed that explicitly incorporate linkages and interdependencies across space, time, and subsystems.
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In Canada, there has been a lack of explicit consideration of cumulative effects in past assessments.
It is not clear who will take responsibility for the assessment of cumulative effects.
Planning and project assessment have been evolving towards a common context for consideration of cumulative effects.

Table 6
CEA Recommendations Organized According to Main Areas of Field Development.

Theoretical Development
Theoretical basis of CEA: systems structure and processes
The prediction of future environments and environmental problems
Methodological Development
Causal analysis
Modelling approach
Methods of institutional analysis
Institutional Development
Guidelines formulation
Coupling with monitoring
Professional Development
Meta-analysis
Planner involvement
General
Social aspects of cumulative effects assessment
Pilot studies

Methods Development

Observation 3: Utilization of Available Techniques

For some classes of cumulative effects, trained professionals find it relatively easy to make a good assessment using tested techniques. The record for cumulative effects assessment is spotty, however. The techniques available for assessing cumulative effects of single projects and multi-component projects are either not being used effectively or are not being used at all. Examples of techniques with proven utility are simulation modelling, group problem solving (i.e., consultative processes), area assessment, cross-impact analysis, and threshold analysis. Often, even straightforward use of an interaction matrix can help identify the possible occurrence of cumulative effects.

Why these techniques are not being applied is unclear. Lack of appropriate training was suggested by one workshop participant. Another suggestion was the lack of an institutional will to identify cumulative effects; proponents rarely attempt to do more than is required by legislation. The attitude is: "If it works (in other words, if you get project approval), why mess with it?"

Observation 4: Need for New Methods

Not all classes of cumulative effects can be identified and assessed with existing techniques. Structural surprises emerge from accumulating changes in those hidden or unperceived parts of systems that determine the structural surprise. These system parts concern the number and intensity of linkages and interdependencies across space and time and across subsystems (ecological, economic, social, and governmental). Standard EIA and regional planning approaches are inadequate and often counterproductive. New and improved methods to deal with the complexities of multidisciplinary systems operating at a number of spatial and temporal scales are needed.

Institutional Development

Observation 5: Lack of Explicit Consideration of CEA

In most of the Canadian experiences there has been little explicit consideration of cumulative effects. While the planning and project assessment approaches have undoubtedly been concerned with cumulative consequences of development, and increasingly included environmental consequences, these approaches have not been based on the explicit recognition of the need to assess and manage cumulative effects.

The need to consider cumulative effects must be recognized by the practitioners working in the fields of planning or EIA. Further, the need to assess cumulative effects must be institutionalized by explicitly questioning and investigating the possible impacts and interactions of a new development with past experience and with what might occur in the future.

The Fraser case is a good example of a situation in which planning has been carried out but the need for assessment of cumulative effects has not yet been institutionalized. A specific set of procedures is needed, describing a method of assessment that will blend with the planning framework currently in place.

Observation 6: Responsibility for CEA

Currently, no one has accepted the responsibility for assessment of cumulative effects except in narrow, well-defined contexts. In the context of established environmental assessment procedures, there are often informal and formal negotiations on the content of the environmental impact assessment between the proponent and the regulatory agencies responsible for project approval. This negotiation extends to the determination of which activities are to be included in the assessment. In practice, this discretion effectively constrains the degree to which cumulative effects can be assessed in project-based assessment processes.

Formal institutions with the mandate to assess and/or manage environmental impacts do not match the scales of most cumulative effects situations. If a project affects aspects across ecological, social, and economic systems, a high degree of co-operation between institutions is required to resolve the issues that arise. Few good precedents exist; it is difficult enough getting scientists to agree among themselves on key process issues, let alone adding social and economic concerns. Further, many oumulative effects situations require broader spatial and temporal bounds than afforded by traditional EIA procedures to incorporate potential processes and impacts. Jurisdictional problems very quickly become overwhelming in these situations and more time is spent establishing who is responsible for the effect than in improving our understanding of the effects and designihg appropriate mitigation and monitoring strategies. A good example of this situation is the acid rain issue in North America and Europe.

Observation 7: Coevolution of Planning and Project Assessment

Through planning there has been progressively more detailed consideration given to the cumulative consequences of development and how to manage them. Planning implicitly incorporates assessment of some types of cumulative effects, additive and amplifying in particular, through execution of the following major steps: identifying broad goals, specifying policy objectives, designing strategies, monitoring system response, and revising goals, objectives, and strategies as needed.

Because many planning initiatives have been characterized by technical difficulties, long gestation periods, and political controversy, the partial success of planning procedures at accommodating cumulative effects in their analyses is not widely recognized. Further, myopic preoccupation with continuing problems has slowed recognition of the need for an ongoing process to deal with cumulative effects issues. Two major changes, however, have evolved over time:

- planning has become more comprehensive as it has shifted from a relatively narrow focus on the orderly and efficient development of resources to the broader concern of balancing conflicting demands for limited resources; and
- there has been a shift from the early emphasis on the "plan" produced to emphasizing the ongoing process of "planning."

Over the last 15 years, development of progressively more refined project assessment procedures has improved the consideration of project impacts, including those that are cumulative. EIA, as practiced in Canada, has evolved, with many worthy attempts to better accommodate aspects of the cumulative effects problem (e.g., Beaufort EIS, CN Twin Tracking application of EARP). This attention to cumulative effects, however, is still constrained by current legislation and is institutionally restricted in the spatial and temporal bounds of the assessment, which are, as was pointed out earlier, crucial dimensions in a more complete assessment of cumulative effects.

The practitioners in planning and environmental assessment have approached the cumulative effects question from different perspectives, and as a consequence, it would appear there has been little cross-fertilization of ideas or methods. A consensus, however, appeared to emerge within the subset of the environmental planning and assessment community that participated in this study; EIA should be viewed as an integral part of planning. Further, the environmental impact statement (EIS) itself is not the most important product; rather, the consultative process is the most significant product. It is used to develop the statement and the procedures put in place to monitor the impacts of developments; provide feedback to management and project design; and ensure that learning is transferred within and between institutions.

RECOMMENDATIONS

Theoretical Development

Recommendation *1*: Establish a research program to identify the key processes that determine the response of environmental systems to stress and their recovery from it, e.g., rate of system recovery, threshold of resiliency.

Many workshop participants, this year and last, have stated that cumulative effects assessment, especially the methods for predicting impacts, would be improved by increasing the fundamental knowledge of system responses; for example, rates of recovery to perturbations and thresholds of resiliency. Certainly, a great deal is known about natural system processes that could be useful to CEA if placed in a suitable context and framework; for example, "generalized biological response patterns to increased levels of environmental stress" (see Horak et *al.* 1983a: 52). Much remains to be learned, however, and preparation and presentation of this knowledge for field use is not a simple matter. The requisite degree of precision for different assessment purposes and policy decisions is likewise open to question. In general, the formula for policy research is: "the optimum amount of analysis is the minimum that will distinguish between policy alternatives" (Lee Jr. 1974: 35). Nevertheless, rigorous scientific quality criteria have been advanced even at the risk of jeopardizing a necessarily interdisciplinary enterprise.

The theoretical basis of CEA has previously been reviewed from the standpoint of wildlife interests (Cline et *al.* 1983: 50). Suggested research topics emerging from that review include:

— *Additional studies of ecological relationships between and among plant and animal species. Concurrently, knowledge of how plants and animals interact, competition relationships, and predator-prey interactions, for the most part, are not well known. Further analyses of community ecology would be useful in cumulative impact assessment.*

— *A study of various ecosystems' sensitivity to disturbance, particularly related to their resiliency, stability, etc. An understanding of how ecosystems respond as a unit to disturbances is foreseen as being an integral part of cumulative impact assessment.*

— *A study of life history and behavior of a variety of animal species particularly those about which little information is known. Such data are important in determining impacts on wildlife populations.*

— *A study of basic impact relationships;' e.g., urbanization and minimal road kills. Such relationships are usually assumed to be linear; this premise needs to be tested.*

— *A study of synergism among impacts. Greater insight into how environmental changes interact with one another to produce an impact on a species, and then how species' responses interact is required to develop a method to assess cumulative impacts.*

Similar items for different systems, for example the socio-cultural system, could doubtless be compiled. One immediate need is to codify systems characterizations and descriptions across all systems of interest. Field research will be required to verify and refine these procedures and categories.

Recommendation 2: Establish a research program to synthesize, extend, evaluate, and apply recent developments that attempt to better understand cumulative effects and respond to the possibility of structural changes in the physical, social, and ecological systems.

The question of emerging cumulative effects situations has been considered at length in this report (Chapter 1), along with the problem of predicting impact discontinuities, particularly "suprises" (Chapter 2). For discontinuous impacts, Holling (1978) and Walters (1986) prescribe a program of research, monitoring, adaptive management experimentation, and regulation. Structural surprises, on the other hand, require fundamentally different conceptual, procedural, and methodological approaches.

In AEAM, the expectation of and adaptation to surprises is a salient concern. Holling and his colleagues have recently developed "An Analysis of Surprise" — a set of procedures and methods "designed to allow a group, or an individual, to evaluate the vulnerabilities of existing trends and policies, or of proposed policies, in a resource sector" (Ralf Yorque Inc. 1986: 2). The venture is speculative but imaginative, and presents itself as a candidate for "breathrough research."

The issue of "structural surprises" (see Chapter 2) is generically similar to that faced by economies and societies experiencing structural change. Since we have now increased interdependence among social, economic, and ecological forces, the issue of cumulative effects in the environmental arena has to be seen within the context of the potential consequences on sustainable development. It also has to be seen as a part of present national economic and social priorities.

No one knows how to address these issues; no one has solutions. We need a theory dealing with non-linear structural change that can lead to operationally useful definitions of change and sustainability. That theory needs to be substantiated with an exceptionally wide array of empirical examples. In addition to identifying variables that reflect structural change, we need to develop designs that retain flexibility and adaptive capability. We need, moreover, methods that are not space- or time-specific, that are not subsystem-specific, and that are neither "top-down" or "bottom-up." Those are the features that characterize good EIA and other state-of-the-art analyses, but they assume structural stability and thereby ignore the causes of structural change.

The ultimate goals of the recommended research are to:

- develop an adequate theory and context for evaluating structural change;
- analyse examples and case studies that can provide empirical breadth;
- develop procedures and methods to make the analysis of structural surprise feasible; and
- establish the requirements needed to implement the results in a practical setting.

Methodological Development

Recommendation 3: Establish a research program to further develop and refine our ability to map the causal basis of cumulative effects situations and trace the network of causative factors.

The analysis of causative factors in cumulative effects situations are particularly difficult to analyse for the following reasons. Due to the scope of CEA, multiple, rather than single, cause/effect relationships are investigated between and across systems and their components. Moreover, because these systems are dynamic and adaptive, the causal relationships are pervasive, which further complicates the analysis. Finally, the attribution of causes to effects becomes problematic when both the "with and without" scenarios of proposed actions are assessed. In the Beaufort Sea EIA, considerable difficulty arose in predicting cumulative effects on ringed seals because a number of uncertainties stem from two perspectives — hydrocarbon development and ecological implications. For example, can a change in the population of ringed seals be attributed to a cyclical population, ice conditions, disease, overhunting, hydrocarbon development activity, or from some combination of these causes?

Despite these difficulties, it is possible to propose and pursue means by which the analytic situation can be made more determinate and tractable. The discussion in Chapter 2 centered on these problems, as did Recommendation 2. In the future, CEA practitioners can expect to benefit from the development of causal models, an active area of methodological development.

Recommendation 4: Develop computer simulation models for specific case studies to further evaluate models as appropriate tools for CEA and to contribute to further characterizatioh of cumulative effects.

A modelling approach that might be effective for CEA draws on the intellectual and research traditions of AEAM (Holling 1978; ESSA 1982). One suggestion for extending this research line would be to construct simulation models for the case studies reported here, although New Brunswick forest management already has several model versions (Holling 1978). In addition, several hydrology models have been applied in the Fraser River Estuary Study. Linking these models with land use models might prove a worthwhile exercise.

The Fraser-Thompson Corridor Panel (FEAR0 1986: 24), which was involved in what O'Riordan (1986: 61) has described as "perhaps the first example of a public inquiry into cumulative assessment in Canada," has proposed that:

> . ..a river *system* model could be developed to stimulate the cumulative effects of river encroachments on *fish, and efforts to develop such a model could serve to identify and focus data collection monitoring programs.*

Model linkage between the Fraser Estuary and Fraser-Thompson Corridor might also be considered (see Recommendation 11). Comparison across these cases might itself become the focus of research activity.

Cline *et al.* (1983: 50) also endorse the development of ecosystem models, which could be used in simulations of disturbances, especially for those ecosystems expected to be impacted. Increasingly more detailed and sensitive ecosystem models could be used as tools to predict cumulative effects by manipulating various levels and types of impacts.

Recommendation 5: Establish a research program to review, appraise, and refine current methods of analysis of institutional responses to cumulative effects issues.

The 1985 Toronto workshop (CEARC and U.S. NRC 1986: 3) repeatedly cautioned that "neither scientists nor institutions work at the temporal and spatial scales needed for the assessment of cumulative effects." This condition was labelled "mismatch"; its cause was commonly ascribed to the "jurisdictional fragmentation" said to characterize the institutional system, at least in the public sector. Nevertheless, only Chagnon, Jr. (1986: 130) moved the discussion closer to operational definition by comparing cumulative effects and institutional controls in several areas of atmospheric impact assessment. His tentative finding contradicts the common view of "mismatch" that other participants espoused; where cumulative effects are well characterized and assessed, institutional controls have evolved rapidly and effectively. Clearly what is required is a thordugh appraisal of the methodology of institutional analysis, complementing other CEARC-sponsored work on the topic, particularly in the context of social impact assessment. Work along this line would also strengthen the institutional component of AEAM.

Institutional Development

Recommendation 6: Develop guidelines for the assessment of cumulative effects and incorporate them into existing EIA legislation and terms of reference.

Along with practical directives for scoping and performing CEA, terms of reference should include a statement of policy in support of this effort and some broad guidelines for carrying it out. Their proper emphasis and placement are matters for institutional analysis and, where needed, for institutional development.

Processes for project-specific environmental impact assessment should incorporate the assessment of cumulative effects through guidelines. At present, there are no definite requirements to assess cumulative effects in any formal project-specific EIA processes. For example, there are no formal provisions that cumulative effects must be assessed under the existing Order-in-Council that governs the federal Environmental Assessment and Review Process. Cumulative effects are defined and discussed in Appendix 1 of the new EARP *Initial Assessment Guide,* however. A different situation exists in the United States in regard to compliance with the Council on Environmental Quality regulations on CEA.

A guideline stating that cumulative effects should be assessed should be included in a proponent's terms of reference for preparation of an EIA. The present EARP arrangement implies that there is some discretion as to whether or not cumulative effects will be assessed. This is easily remedied through EARP, whose terms of reference can direct panels to insist on the assessment of cumulative effects. A recent example of how this works in practice was the request by the Minister of Transport to the environmental assessment panel responsible for the public review of CN Rail's twin tracking proposal. Subsequently, the Minister requested that the panel further provide him with observations and recommendations concerning long-term environmental effects along the entire Fraser-Thompson Corridor, in other salient categories besides transportation.

Recommendation 7: Design and implement areawide and long-term monitoring programs to support the comprehensive assessment framework contained within CEA.

CEA must be a continuing exercise over longer time intervals and wider areas than provided for by traditional EIA processes. This is the second of Root's definitions of "cumulative assessment of effects" (CEARC and U.S. NRC 1986: 151). "To undertake such monitoring requires an overviewing group with a mandate to take a regional, longer-term perspective" (Carley and Bustelo 1984: 65). Satisfying that requirement calls for institutional design and development. The design of the monitoring systems themselves must be conceived with a comprehensive assessment framework in mind (Carley 1983: 8).

> *Unlike project impact monitoring the focus is not confined or limited to project-related or indirect impacts. Rather, the focus is on monitoring all critical social, economic, cultural, or political issues or changing patterns in a region, whether they are related to a project, or occur independent/y of a project. Cumulative monitoring examines the interrelated and additive effects caused by a variety of industrializing projects and government interventions over time.*

Carley (1983: 9) concludes, "It should be apparent that such monitoring would be an essential component of a regional planning process.'' In its absence, there can be no reasonable expectation that cumulative impacts will be anticipated, detected, or in the case of adverse impacts, averted or mitigated.

Professional Development

Recommendation 8: Carry out a systematic survey to codify and compare existing cumulative effects situations in Canada, other developed nations, and the developing world.

The generic term for cumulative research findings across impact situations and studies is "meta-analysis" (e.g., Hunter *et a/. 1982).* Among other things, this might involve a systematic literature search and synthesis, a retrieval of cumulative effects history, and an impact data inventory and integration.

In his closing remarks to the Toronto workshop participants, Roots (1986: 139) observed:

> *Cumulative impact assessment was said by some to be equivalent to the assessment of cumulative impacts. Others thought it included cumulative assessments of impacts which, although related, are quite different problems. I did not hear anyone equate it to be the cumulative impact of assessments, although that may well be what we will have to deal with if we cannot get the assessment house in order.*

In fields of knowledge and application such as impact assessment, which depend on amassing a weight of evidence to support their findings, rather than performing a crucial experiment, this last version matters as much as the other two. In social impact assessment (SIA), for instance, the house is in considerable disarray. As Freudenburg and Keating (1985: 583) note:

> *The accumulation of evidence in SIA has been slow to date. While the lack of adequate empirical research may result from the time and money constraints that may exist for any single study, the net result across many studies is a surprising lack of cumulation in SIA work, with few studies going very far beyond the ones that preceded them, and with some not going as far.*

Documentation of field development and codification of its experience are necessary to promote cumulative knowledge and its effective transmission to practitioners. This requires a survey to identify the frequency of occurrence in the different categories of impacts at various stages of historical development in Canada and other developed nations, as well as in developing ones.

Bain *et a/.* (1985b: 5) have argued, "The most critical and difficult aspect of a cumulative impact assessment is obtaining the necessary data." While this may be overstating the problem, certainly it is true that, as they continue:

> *The preparation of a data overview document, which synthesizes historical information in the study area, would provide a useful background document to complete the scoping exercise.*

The kind of document indicated is referred to as an "ecological characterization" (Environment Canada *et al.* 1985: 5):

> *The purpose of an ecological characterization is to describe the major ecological elements and processes in a specific area by syn thesizing and integrating existing biological, physical, and socio-economic information to guide resource management and coastal planning and to aid in the evaluation of human impacts on the ecosystem.*

The Environment Canada Atlantic Region (1983: 5) further asserts the need for a data collection program to "determine the adequacy of an existing database (or bases) to perform an areawide assessment," to "prepare historical summaries and overviews involving a compilation of relevant field studies," and to "ensure that the ecological principles which govern the functions of the area under investigation are well understood."

Recommendation 9: Broaden the institutional and methodological context for EIA to fully incorporate the planning community and the concepts of regional and environmental planning.

The goal of comprehensive and integrated environmental planning and management cannot be achieved without the full participation and partnership of the planning profession. Planner involvement is indispensable in broadening the planning context of EIA toward better institutionalization at all levels of government and greater attention, at the planning level, to environmental quality concerns. The ultimate success of CEA, as all forms of impact assessment, depends on this broadening and embedding in the operational contexts of planning. Yet, with few exceptions, professional planners are unaware of and unskilled in assessment methods and techniques. Unless those are perceived in the relation of solutions to planning problems, there is but little prospect of this changing. A similar case might be made in reference to resource managers. Fortunately the field of impact assessment can assert and validate its claim, but to receive a hearing it must create professional opportunities for education, experience, and eventually roles and rewards. Better institutionalization of regional and strategic planning will facilitate this transformation.

General

Recommendation 10: Broaden the consideration of social issues in EIA through evaluation and incorporation of recent advances in goals-based planning.

To keep the scope and size of the 1985 Toronto workshop "manageable," social scientists were, for the most part, excluded. It was acknowledged, however, that, "the solution of the problems caused by cumulative effects...will require the participation of social scientists" (CEARC and U.S. NRC 1986: ix). Reservations were also expressed concerning the adequacy and scientific quality of present work in this area; and modalities for more effective incorporation of social concerns into environmental assessments (Roots 1986: 154).

> Almost everyone agreed on the desirability *of including more reliable information of predictions on socio-economic consequences and responses into environmental assessment, but workshop participants were unable to identify how this could be done other than in the present* ad hoc *manner.*

These were the circumstances leading to the suggestion that social aspects of CEA be made the focus of special attention.

The workshop itself pointed to a number of areas requiring further research and development. Several participants (e.g., Robilliard 1986: 107) recognized that institutional issues are central to discussions of CEA. Another major topic is that of a social values/goals orientation and approach to policy decision making and the formulation of planning objectives; e.g., "...when cumulative effects from several activities, each of which has different and sometimes conflicting social values, had to be considered" (Roots 1986: 155). There is now a substantial body of research and application on such multivalent decision situations and multi-objective planning approaches, directly relevant to CEA. A review of these materials would be appropriate, along with a review of those on efforts to implement goals-based planning. Community and public involvement is a related topic of similar relevance, particularly in regard to the implementation of policy decisions and program plans at local levels.

Recommendation 71: Implement a pilot study application of the concepts of comprehensive environmental management and planning within an identified cumulative effects problem.

To evaluate the effectiveness of CEA methodologies and procedures developed in connection with this program of focused research, applications to a variety of cumulative effects situations will be required. A plausible strategy would be to begin with a relatively small-scale, well-bonded system, e.g., at the watershed scale, but the full range of assessment scales from local to global should receive coverage. Indeed, those at regional and global scales, such as acid rain deposition, are among the most important and urgent. Re-analysis of ongoing studies, such as the Great Lakes Water Quality, is an option.

No doubt case selection will be dictated by the willingness of interested parties to accept a comprehensive environmental planning and management approach. Candidate cases include the three found in this report. For example, Sadler (1986: 74) has commented regarding the Fraser River estuary study: "It could...prove worthwhile to monitor and follow this 'experiment'" because of its involvement with cumulative effects previously. A natural extension of this study would be the inclusion of upstream conditions and plans throughout the Fraser-Thompson Corridor. Since both upstream and downstream stretches and interests are relatively well characterized, this might fit O'Riordan's (1986: 61) description of "cumulative assessments between watersheds." This aggregate method of proceeding would seem to hold promise as a practical approach to enlarging the scale of CEAs to regional proportions and beyond.

SUMMARY

The Toronto workshop was described as "very conceptual." CEARC's charge to the present study was to push CEA beyond the conceptual level into a plan of action for cumulative effects research, on a research planning horizon of 5 - 10 years. Further, we were asked to consider which specific methods could be immediately implemented and which could be implemented later. By way of summary, an overview of our response is presented in Table 7.

Table 7
Cumulative Effects Assessment Recommendations, immediate and Longer Term.

Recommendation	Immediate Action (1-5 Years)	Longer Term (5-10 Years)
1. Systems structure and processes	Codify systems characterization and description categories and procedures: design field research	Initiate field research
2. Prediction of future environments and environmental problems	Trend inventory and extrapolation, e.g., Global 2000 Canada	Analysis of "surprises"; prediction of discontinuities
3. Causal analysis	Review causal model construction and calibration	Causal model validation
4. Modelling approach	Fraser-Thompson Corridor application	Integrated systems model applications at global scale
5. Methods of institutional analysis	Develop capability, constraint, implementation analysis met hods	Institutional design applications for comprehensive environmental planning
6. Guideline formulation	Draft model terms-of-reference	Evaluate regional planning co-ordination effectiveness
7. Coupling with monitoring	BEMP/MEMP modification and testing	Implement comprehensive regional environmental monitoring systems
8. Meta-analysis	Literature synthesis; revise and refine analytic frameworks; impact data inventory	Data integration; devise "expert system"
9. Planner involvement	Design program for professional education and experience opportunities	Redesign professional roles and rewards
IO. Social aspects	Review values-based planning approaches, e.g., TECHCOM; social indicator models	Apply social criteria for project select ion
11. Pilot studies	Linkage of cumulative assessments between watersheds, e.g., Churchill-Nelson	Regional and transboundary applications, e.g., Great Lakes

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APPENDIX A

DETAILED CASE STUDIES

CEA AND MANAGEMENT IN THE FRASER ESTUARY

Anthony H.J. Dorcey

INTRODUCTION

The objectives of this case study are to:

- illustrate the type and significance of cumulative effects of development in the Fraser Estuary;
- identify whether and how cumulative effects have been assessed and managed in terms of the analytical techniques and administrative processes utilized;
- evaluate how well cumulative effects have been assessed and managed;
- suggest how cumulative effects assessment can be improved in the short term in both the Fraser and elsewhere, based on the case; and
- suggest priorities for research on CEA in the Fraser and elsewhere.

For present purposes, the definition of cumulative effects provided by CEARC has been adopted. The spatial boundary for this case study is the same as that of the Fraser River Estuary Study and is referred to as the Fraser Estuary (Figure A-l). The Fraser Estuary will also be considered within the context of the Lower Fraser Valley because of the strong linkages between ecological and socio-economic systems within this region.

GENESIS OF THE NEED FOR CEA

The history of European settlement in the Fraser Estuary began in earnest with the discovery of gold in the Interior in 1857.[1] Large numbers of European settlers arrived at what is now New Westminster and made their way up the river through the lower valley, to the goldfields. After the gold rush, many miners returned to settle in the lower valley; trees were cleared and dykes were built to begin draining the land for agriculture.

The following years saw the completion of the transcontinental railway, and the growth of a commercial salmon fishing industry. The expansion of port facilities at Vancouver shifted the focus of development away from the Fraser River and New Westminster. The "big flood" of 1894 stimulated a major dyking program which, by the turn of the century, gave protection to most flood-prone lands and laid the basis for extensive development. During the interwar years when settlement consolidated around Vancouver, agricultural land uses predominated in the valley. Since 1945, economic growth has fuelled the expansion of the metropolitan area; service centers have expanded throughout the valley, replacing early dependence on the metropolitan area. This growth continues today.

The changes that accompany development in the Fraser River Estuary have progressively necessitated consideration of the accumulating consequences of development. These changes are generated both by endogenous and exogenous events. Examples of the events causing these changes are:

- increasing extent, density, and duration of developments — contrast the extent, density, and duration of current development with the pre-European settlement of native Indian villages;
- increasing diversity of systems involved — population and economic growth have led to the evolution of many systems, i.e., fisheries, ports serving various industries, recreation, and waste disposal;
- alteration of major natural systems — the hydrology of the Fraser River has been greatly changed by development and dyking, drainage of lands has destroyed extensive wetlands, and air movement patterns have been changed by the warming effects of a major metropolitan area astride the estuary;
- expanding spatial bounds of the systems — formerly bounded by ecological events such as salmon migrating from headwaters far inland to feeding grounds in the North Pacific, the spatial bounds of the estuary are now extended by economic systems such as ports and export-import development;
- increasing interdependence within and between systems — the fortunes of the fishery and forestry industries are strongly dependent on world markets; however, their fortunes are also strongly linked within the estuary because they are competing users of water areas that provide habitat for fish and storage for log booms;
- fluctuating rates of change — contrast the high rates of new development in the estuary in the 1970s, including institutional innovations, with the much slower rate of development in the 1980s;

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[1] Information in this section is based on Dorcey (1986) and papers in Siemens (1968), in particular Howell Jones (1968), and Parker (1968).

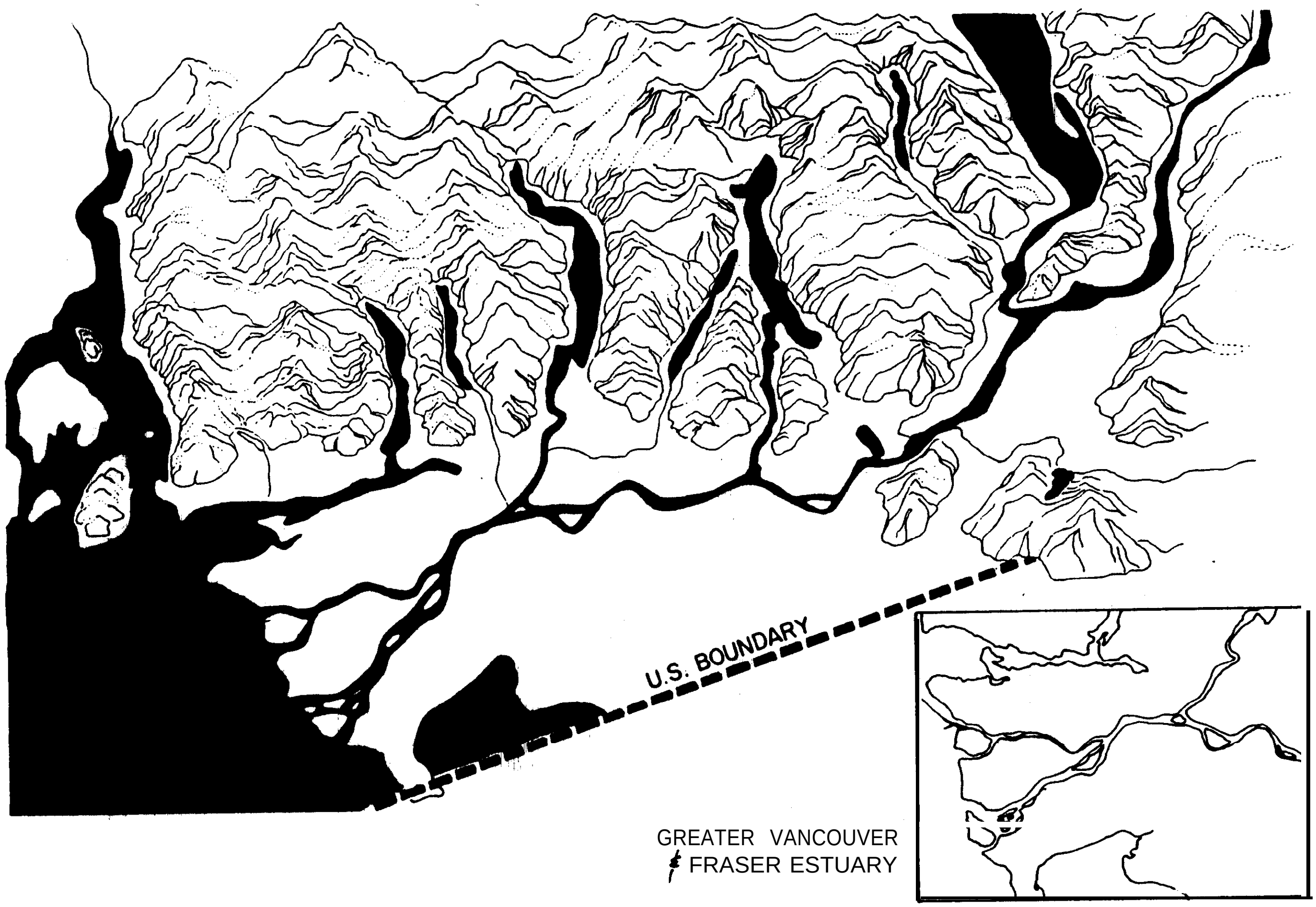

Figure A-l., Lower Fraser Valley

- changing values, awareness and knowledge of systems behavior — in the 1970s, increasing concern for environmental protection and resource conservation resulted in a growing awareness of conditions in the estuary and a new understanding of its ecosystem and the effects of developments.

As development has brought about these changes, it has become increasingly necessary to consider the cumulative effects of projects. These effects can be classified using the typology that was developed in Chapter 2 of this report:

- **Single** *project:* single action/multiple effects — the continuing discharge of the effluent from the lona Island Sewage Treatment Plant, which gives primary treatment to the combined storm and sanitary sewage from the City of Vancouver before discharging onto the banks of the estuary, has resulted in a degraded environment and accumulations of a variety of toxic materials in sediments and biota.

- *Multi-component project:* multiple actions/multiple effects — development of the Roberts Bank Superport involved construction of a causeway over Roberts Bank and an island at the end for coal storage and loading berths. The island was later expanded. As a consequence, wetland habitat has been directly lost by infill and, in adjacent areas, continuing processes of erosion and accretion have resulted in the loss and creation, respectively, of habitat.

- Area/ *development:* mutliple developments/multiple effects — the accumulation of pollutant discharges and losses of shoreline habitat are a result of a diversity of developments, as small as marinas in Ladner Slough or as large as the industrial development on the North Arm.

- Global *change (exogenous change):* areal (endogenous) effects — if scenarios of climatic change, resulting from increasing concentrations of carbon dioxide caused by development worldwide, come to pass, sea levels are likely to rise as a result of melting ice caps. These levels will, in turn, increasingly threaten to overtop the dykes in the estuary, causing massive damage to the extensive urban development on the floodplains.

In the next section, attempts since 1949 to manage cumulative effects in the estuary are examined; consideration is given to major management initiatives that included the estuary even though they did not focus on it specifically.

WHAT HAS BEEN DONE TO MANAGE CUMULATIVE EFFECTS?

There has been relatively little explicit consideration of "cumulative effects." The cumulative consequences of development, however, have been addressed implicitly in planning and impact assessment processes.

Lower Mainland Regional Planning Board (1949)

The Lower Mainland Regional Planning Board (LMRPB), established in 1949, has been described as pioneering regional planning in Canada (Parker 1968). The primary reason for its creation was a growing concern about accumulating pressures of urban development in the Lower Fraser Valley encroaching on the limited agricultural land. In addition, the 1948 "big flood" had shown the vulnerability of developments in the floodplain. The objective of the LMRPB was to apply classical principles of regional planning to "apply foresight and plan to use land wisely and to make the various communities orderly and attactive'' (Parker 1968: 163).

A series of studies, conducted by the Board, concerning the region's population, land uses, and infrastructure were used to prepare the 1964 draft Regional Plan, *Chance and Challenge.* The principle considerations in the plan were related to the location of new homes and industries, the conservation of agricultural land, and the reservation of parkland. The plan was finalized and adopted by provincial order-in-council in 1966. At its heart was a Long-Range Land Use Plan considered to be a "policy framework within which the countless matters of detail can be determined more readily by the local municipalities, as well as the basis for co-ordinating the activities of the departments and agencies of the senior governments" (Parker 1968: 17 1).

Agriculture Land Commission (1972)

In spite of measures, such as the Lower Mainland Regional Plan, losses of prime agricultural land continued to occur at an estimated 4,000-6,000 hectares a year. When only 4% of the provincial land base is considered arable and with 65 % of the province's food needs dependent on imports, it was decided that more specific controls were needed. To halt the accumulating losses of farmlands, the provincial government in December 1972 introduced a "land freeze" by order-in-council under the Environment and Land Use Act (1971).[2] The land freeze halted non-farm development of farmlands, pending the introduction and implementation of longer term statutory remedies.

In April, 1973 the Land Commission Act was enacted, creating a Provincial Agriculture Land Commission. The members, appointed by the government, were empowered to designate Agricultural Land Reserves (ALRs) throughout the province. The principle objective was the preservation of agricultural land for farm use and encouragement of the establishment of family farms. Secondary objectives were preserving green-belt land in and around urban areas, preserving a land bank for urban and industrial development, and preserving parkland for recreational use.

The initial freeze was implemented using readily available information on agricultural land capability. These designations were then refined in discussions with provincial agencies and regional districts so as to produce an ALR plan for each regional district (32,551 hectares were in the Greater Vancouver Regional District). Since 1975, these designations have been continually "fine-tuned" with inclusions and deletions, progressively working more closely with the planning processes of provincial and local agencies of government and occasionally resorting to the provisions for appeal to the provincial cabinet.

Livable Region Planning Program of GVRD (1970)

In 1968, the LMRPB was dissolved and responsibility for maintenance of the Lower Mainland Plan was jointly assigned to four regional districts, one of which was the Greater Vancouver Regional District (GVRD). As with the LMRPB, these new boards were made up of appointees from local municipal councils (although there was no provincial representative), funded by local levees and provincial grants, and a planning staff was usually developed; in the GVRD, the Planning Department was responsible for the Livable Regional Planning Program.

The GVRD initiated the Livable Region Planning Program (LRPP) in the early 1970s to establish guidelines for channelling the future growth of the metropolitan area.[3] It resulted from increasing concerns that the cumulative effects of development were reducing the "livability" of the region. Over a period of five years extensive discussion of the goals for the future of the region took place, aimed at defining indicators of "livability" and strategies for pursuing them (see Table A-l). Five integrated strategies were ultimately selected for managing growth in the region and implementation actions were identified for each of these five strategies. The Livable Region Strategies were adopted by the GVRD Board in 1975. The strategies rely on voluntary co-operation of governments and the private sector for implementation and have been successful in some areas but not all. The LRPP was viewed as providing the context for the Official Regional Plan (ORP) which focuses on land use designations and is legally binding on other actions and plans of the GVRD Board and municipalities.

Impact Assessments in the Fraser Estuary (1970s)

The proposal, in the early 1970s, to expand Vancouver International Airport by building a second runway out onto the

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2. Information in this section is based largely on Provincial Agricultural Land Commission (1983).

3. Information for this section is drawn primarily from Collier (1972), Lash (1976), and GVRD (1980).

Table A-l

Greater Vancouver Regional District's Livability Objectives and Strategies for Development.

Livability Objectives

Examples from more than 70 objectives developed for the Livable Region Program:

- Preserve the farmland now in GVRD;
- preserve unique and wilderness areas such as foreshores and mountainsides:
- reduce pollution of the air, water, and land; and reduce unwanted noise;
- avoid increasing the number of people and amount of property subject to hazard of floods;
- reduce the flood hazard to persons and property already located in the floodplain;
- provide people an opportunity to participate in government decisions;
- keep the region as self-sufficient in food supply as possible.

Development *Strategies*

- Set residential growth targets for each part of the region;
- balance jobs to population in each part of the region;
- create regional town centres;
- provide a transit-oriented transportation system linking residential areas, regional town centres, and regional work areas; and
- protect and develop regional open spaces.

banks of the estuary stimulated a concern for the cumulative consequences of development in the estuary specifically.[4] It was one of the first projects to be submitted to the federal Environmental Assessment and Review Process (EARP). Initially, attention focused on the environmental effects of the loss of marsh habitats utilized by juvenile salmon and water-fowl but expanded into socio-economic issues throughout the region (e.g., implications for economic development of alternative locations for airport expansion in the Lower Mainland). This project also raised concerns about the multiplicity of other projects and their effects throughout the estuary, culminating in demands for a moratorium on development. This experience, combined with the difficulty in dealing with multiple pollution control issues raised by the committee determining effluent treatment requirements at the new Annacis Island Sewage Treatment Plant, led to a federal-provincial agreement in 1977 to develop a management plan for the estuary. In that year the provincial government also introduced Order-in-Council 908 under the authority of the Environment and Land Use Act that required every proposed development, outside the dyking system to be subject to a mandatory environmental impact assessment prepared by the proponent. As indicated in the next section, impact assessments through the use of referrals, task forces, and public hearings have now been developed into a co-ordinated review process by the Fraser River Estuary Study.

FRES (1977)

Under federal-provincial agreements, the Fraser River Estuary Study (FRES) has been conducted in three phases: Phase I (1977-1978); Phase II (1979-1982) and Phase III (1985 1990).[5] The first two phases defined the nature of the estuary management problem, began to formulate management strategies, and evaluated alternative institutional arrangements for ongoing management. An implementation strategy was drafted based on these studies and a review of them. In the third phase, which began last year, the Fraser River Estuary Management Program (FREMP) is being implemented.

Although each phase was organized differently and varied during its course, each involved some form of management committee made up of representatives of government agencies involved in the estuary, reporting to the federal and provincial ministers of the Environment. The committees, with a small group of support staff, operate through working committees, made up of government personnel from the various levels of government, and conduct public participation programs.

The implementation strategy has three components, the first is a series of goals and general policies developed in the first two phases that "recognize the importance of the estuary's

4. This section is based on Dorcey (1981).

5. This section is based on information in Dorcey (1981 and 1986).

economic, environmental and recreational resources" (O'Riordan and Wiebe 1984: i). The second component of the strategy is the establishment of **a** Management Committee

> *. . .in tended to provide an organiza tional and co-ordina tive mechanism to ensure that the goals and policies for estuary management are achieved.. . Where conflicts arise,. .. the Management Committee will provide a forum for resolution.* (O'Riordan and Wiebe 1984: i).

The third component of the strategy is a co-ordinated series of activities to improve resource management, including provision

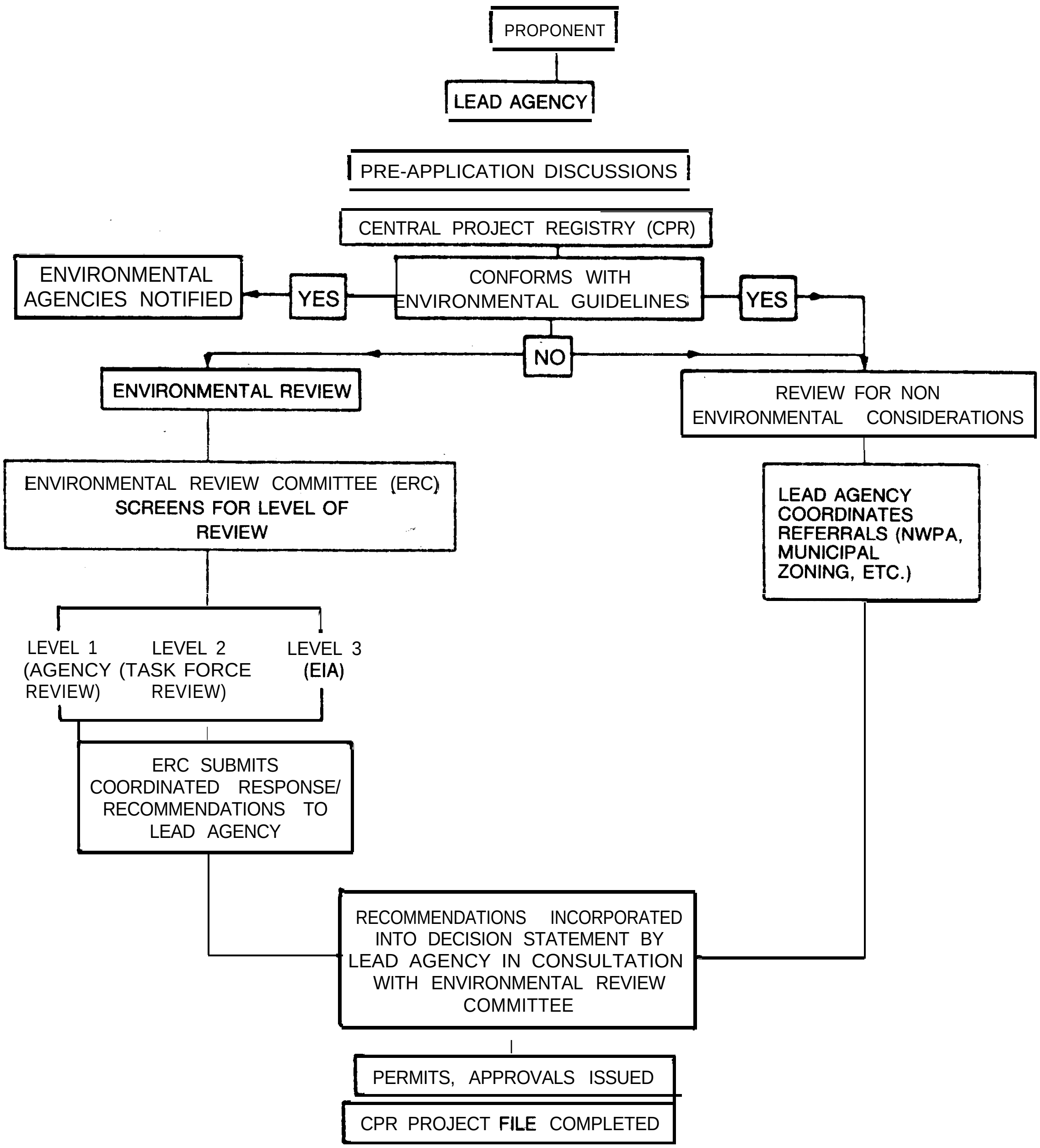

Figure A-2. Schematic Flow Diagram for Co-ordinated Project Review for public involvement through work groups, discussion of draft plans, and direct contact with agency personnel. Other key features are:

- a co-ordinated project review process (see Figure A-2);
- a system providing up-to-date information on all aspects of resource management to participating agencies and the public;
- a water quality plan designed to establish ambient water quality objectives throughout the estuary and co-ordinate water quality monitoring and enforcement (developed by work group);
- specific programs to address estuary-wide activities such as waste management, log handling, and recreation. These programs will be co-ordinated by the Management Committee and undertaken by work groups comprised of responsi ble organizations; and
- co-ordination of upland and estuary planning activities. (O'Riordan and Wiebe 1984: ii)

THREE CUMULATIVE EFFECTS ISSUES IN THE FRASER ESTUARY

In the previous section we reviewed some of the significant post-war initiatives in planning and impact assessment that responded to, and anticipated, the cumulative ecological and socio-economic consequences of development in the Fraser Estuary. Now, three major ecological cumulative effects issues are examined more specifically. The first one is flood hazard; it has been an issue for many years. The second and third are toxic materials discharges and wetland habitat losses; both of these are more recent issues.

Floods

The "big flood" in 1894 showed early settlers the vulnerability of development on the floodplain. They promptly responded by building a system of protective dykes.[6] The next "big flood" did not occur until 1948. Nearly one-third of the entire Lower Fraser Valley floodplain area was inundated; costs of relief, rehabilitation, and repairs approached $20 million ($85 million at 1979 price levels). The dyking system was rapidly rebuilt and was completed in time to contain the third highest freshet on record which occurred only two years later in 1950. The next large freshet occurred in 1972, when the rebuilt dykes held in the Lower Valley but there was flooding upstream. Since then there has not been a high runoff year to further test the protection measures.

Following the 1948 flood there have been a series of boards and studies, established by the federal and provincial governments to study and manage the problem of flood control and other uses in the basin:

- 1984 — Fraser Valley Dyking Board
  goal: reconstruct dyking system
- 1948 — Dominion-Provinical Board — Fraser River Basin
  goal: study and report on flood management as well as other uses (i.e., power production, fisheries) of the Fraser River Basin
- 1956 — Fraser River Board (replaced the Dominion-Provincial Board)
  goal: recommend specific management actions
  result: In 1963, proposed upstream storage and diversion system
- 1968 — Federal-provincial agreement to implement flood control program in Lower Fraser Valley
- 1971-1976 — Federal-provincial study on management actions (i.e., diversion project) and their impacts on resources

Since 1976, there have been no further major studies. The diversion project has not been built, the dyke improvement program is nearing completion, and there has been some progress in implementing flood management policies.

The flood hazard in the Lower Fraser has presented a variety of cumulative effects issues but the most striking is the continuing increase in expected damages. It is estimated that there is a one-in-three probability that the 1894 flood will be equalled or exceeded during the 60-year period from 1973 to 2032. At the same time, however, the value of development at risk in the floodplain continues to increase. During the 10 years from 1968 to 1978, the population in the floodplain areas increased by approximately 43 % , and the assessed values of properties increased by approximately 330%. In the same period the estimated farm income increased from $80 million to $246 million but the costs of protection measures are also increasing. The initial $36 million budget to upgrade the dykes in 1968 was increased to $61 million in 1974, to $120 million in 1976, and to $160 million in 1985. Flood control is thus a cumulative effects issue in the Fraser Estuary that has been extensively assessed and is a continuing management concern.

Toxics

Apprehension about the cumulative effects of waste discharges into the Fraser Estuary began to mount in the early 1970s.[7] In the midst of general concern, construction of the Annacis Island sewage treatment plant attracted particular attention. Municipal sewage that had previously been discharged throughout the estuary was to be diverted to a new plant on Annacis Island where, after primary treatment, it would be discharged through one outfall (Figure A-3).

There was concern that primary treatment of the consolidated discharge would be inadequate but modelling studies indicated that the BOD (biological oxygen demand) load would not cause any significant depression of the DO (dissolved oxygen); in fact, the discharge could increase many times before any significant effect would occur because of the

6. This section is based on papers in GVRD (1979).

7. Information in this section is based on Dorcey (1976), Dorcey and Hall (1981) and Dorcey (1986).

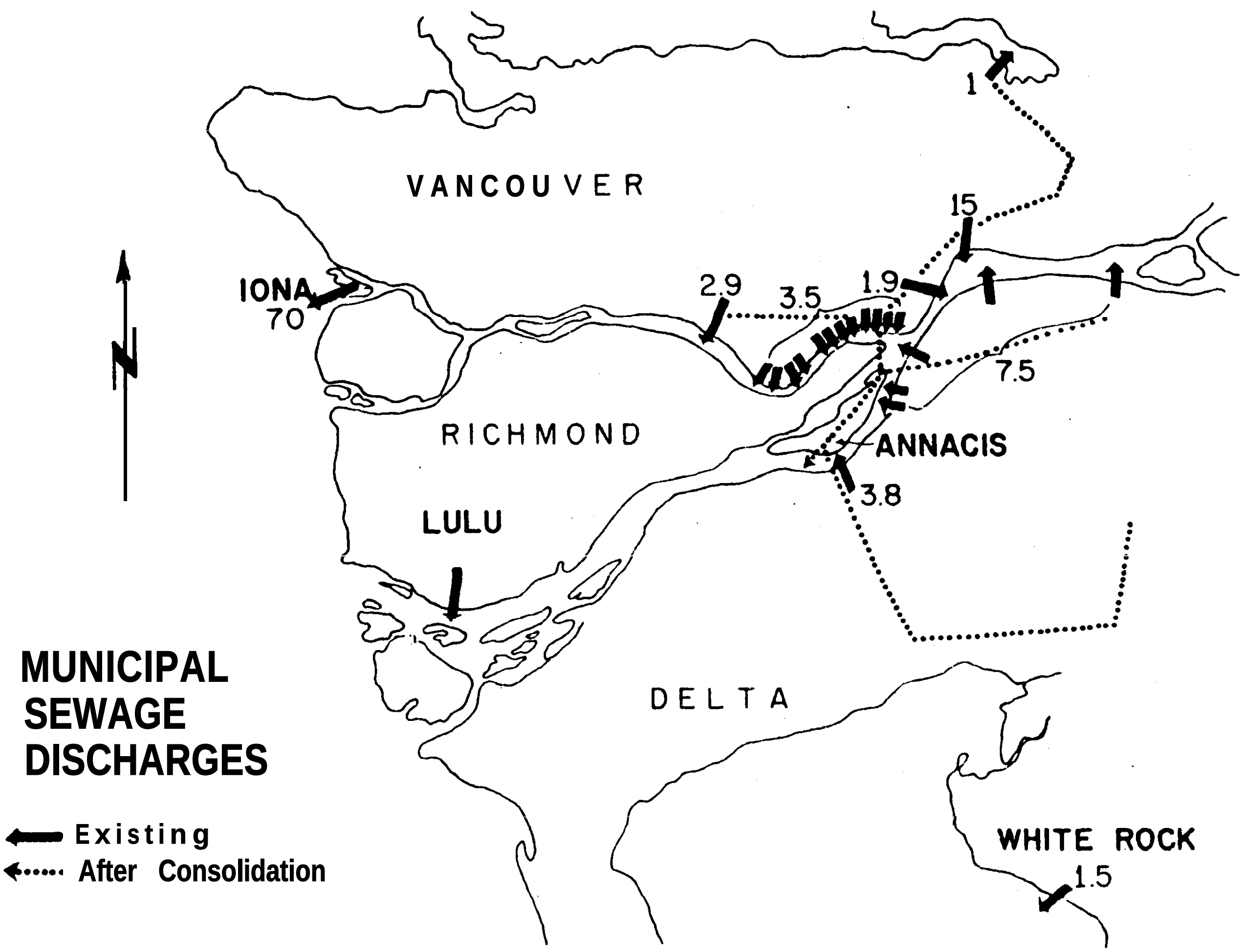

Figure A-3. Municipal Sewage Discharges in the Fraser Estuary

very large flow in the river. The model also indicated that DO concentrations would not be significantly affected by tidal conditions, even under worst case conditions. It predicted that chlorination of the effluent would reduce coliform counts, but that because of the large contribution from runoff counts in the estuary they would remain high. Subsequent experience since the plant became operational has confirmed all of these predictions.

The concern with toxicity of the effluent was not so easily resolved because of a lack of qualitative and quantitative data about not only the specific effluent, but also the state of knowledge of acute and chronic toxicity. Fragmented knowledge about the aggregate acute toxicity of municipal effluents, the toxicity of constituent materials, such as heavy metals and chlorinated organics, and the performance of different treatment processes in reducing acute toxicity and concentrations of particular constituents was used to reach a decision that primary treatment with dechlorination of the effluent would be adequate to avoid significant effects. (This vague language reflects the uncertainty felt at the time.) Since it became operational, no major toxicity effects have been recognized but there is, however, continuing concern about the effluent quality on the part of fisheries and environmental interests.

This project drew attention to the need to consider the cumulative consequences of the discharges to the estuary from all other sources, both municipal and industrial. This was one of the major reasons for launching the Fraser River Estuary Study in 1977. Since then, data collection in the Fraser Estuary and increased knowledge of toxicity from research worldwide have begun to generate some answers but also new questions. In general, water quality conditions in the Fraser Estuary appear to be relatively good but new data raise concerns about future levels of toxicity. In the smaller tributaries and more poorly flushed areas, accumulations of toxic materials in the sediments and biota are evident, particularly in proximity to outfalls. In addition, there is evidence of accumulation of toxic materials above levels established for safe consumption in the tissues of some fish, particularly bottom feeders and those at the top of the food chain (e.g., northern squaw fish and prickly sculpins, which are both resident in the estuary). While mean values for species that are eaten, such as salmon, which migrate through the estuary, are below these standards, occasional samples do exceed them. Given the enormous dilution and flushing capacity of the Fraser, this evidence can be viewed as reason for concern and more cautious policies such as a source control policy for sewer discharges and extending the outfall of a sewage treatment plant to the deeper waters. Thus although the issue has not received such extended attention as the flood hazard, the cumulative effects of waste discharges, in particular toxic materials, have also been the subject of extensive assessments and are a continuing management concern.

Wetlands

In the mid-1970s[8] concern about the accumulated losses of estuarine wetlands received greater attention after studies of fish utilization of the marshes revealed that some juvenile salmon appeared to be resident in them for a period of time before they migrated to sea. A study comparing wetland habitats in 1860 with those of the 1970s showed that about 70% of the original estuarine and floodplain system had been lost (Table A-2) by the turn of the century as a result of dyking. Losses continued over the years, however, with urban and industrial development. In addition, new marshes were formed in the mouth of the estuary as a result of the erosion and accretion processes resulting from dyking and channelling the flow. Thus, the comparative figures for the 1970s show the net effect of losses and additions.

It has proven to be extremely difficult to relate these habitat changes to changes in fish and waterfowl populations. Historical data on populations either do not exist or are confounded by many other variables. For example, in the case of salmon, major changes in habitat elsewhere in their migratory system (e.g., the Hell's Gate slide that blocked the Fraser Canyon in 1913) and variations in fishing pressures have probably had much greater influence than changes in the Estuary. While recent studies in the Fraser, and elsewhere on the Pacific coast, have refined understanding of which salmon species are temporarily resident in the marsh and for how long, little progress has been made in developing the knowledge of the functioning of the estuarine ecosystem that is required if the cumulative consequences of marsh losses are to be predicted. The limited understanding of the estuarine ecosystem has also contributed to frustrating attempts to predict the cumulative consequences of toxic materials discharges. The assessment and management of cumulative effects has thus rested largely on locally untested hypotheses based on the theories derived from studying estuarine ecosystems elsewhere. Thus; like toxic materials discharges, wetland losses have, in the last decade, posed cumulative effects problems in the Fraser Estuary that have been a focus of assessment studies and are a continuing management concern.

8. This section is based primarily on information in Dorcey and Hall (1981) and Dorcey et al. (1983).

Table A-2

Change in Area of Wetlands by Type.

Plant Community	Historic Extent (ha.)	Present Extent (ha.)
Salt Marsh	2,230	380
Bullrush Marsh	1,760	1,690
Cattail/Sedge Marsh	1,830	1,493
Wet Meadows	12,400	2,604
Wet Meadow/ Willow	2,350	258
TOTAL	20,570	6,425

HOW SUCCESSFUL HAS CEA BEEN?

One criteria for evaluating success in assessing and managing cumulative effects might be "no unpleasant surprises." This implies a desire to avoid what will be considered unpleasant, as well as an ability to anticipate it. Success, therefore, depends on institutional arrangements having the capacity to predict future consequences of development *and* how they will be evaluated, *and* to act to avoid the undesirable.

There has been substantial success in avoiding unpleasant surprises in the Fraser but there are significant uncertainties about the future:

- Agriculture: Although there continues to be controversy about the "fine-tuning" of the ALRs, their introduction has been successful in greatly reducing the rate of loss of agricultural land. This cumulative issue was one that had long been a growing concern but was not acted upon until a change in government occurred. Its future success depends on the continuing desire to maintain the ALRs, and to improve agricultural productivity and the economic viability of farming.

- *Floods:* The dykes have been adequate to protect against all freshets since 1948. There is not, however, a widespread public appreciation that a flood will eventually occur and that the expected damages are accumulating with increasing development in the floodplain. Future success depends on extreme events (including combinations of high freshets, storms and earthquakes) not occurring and on developing an improved public understanding of the risk and opportunities for reducing them.

- *Toxics*: Serious toxicity problems have not yet been found in the estuary but accumulations of toxic materials have been found in proximity to outfalls, particularly in backwater areas. Future success depends on not discovering problems hitherto unforeseen or recognized, and being able to recognize and avoid new threats from the increasing diversity and quantity of toxic materials that could potentially reach the estuary.

- Wetlands: The appreciation of wetlands has increased in the post-war years. Since a large proportion of the remaining wetlands has been designated as conservation area, the incremental loss of the remainder has been greatly reduced, and attempts at restoration and enhancement have begun. In future, success will depend on not discovering undesirable consequences of the losses to date, being able to maintain conservation areas, and the development and application of marsh restoration and enhancement techniques.

It is clearly evident that developments are increasing the potential for cumulative effects in the Fraser. In part, this results from the progressive intensity and diversity of developments but also from changing values, awareness, and understanding. It cannot, however, be clearly determined whether or not they are having an increasingly significant impact on the quality of the natural and social environments. We really only have evidence of potential problem scenarios. Is the apparent lack of what are perceived to be serious problems the results of good CEA? Is it adequate for the future?

HOW WELL HAS CEA BEEN CARRIED OUT IN THE FRASER ESTUARY?

The post-war period has not only seen radical changes in our society's values and knowledge about the environment but also major initiatives in learning 'how to manage change through both impact assessment and planning.[9] It is important to recognize this larger context for what was and is still going on in the Fraser, when we evaluate, from hindsight, the experience with CEA.

Development of Planning

Through planning there has been progressively more detailed consideration given to the cumulative consequences of development in the Fraser and how to manage those consequences Over time, the ORP, ALR, LRPP, and FREMP show the same general approach being progressively applied in more specific terms to the Fraser Estuary. The approach involves five basic ingredients:

- identifying broad goals for the use of resources;
- specifying general policy objectives for achieving these goals;
- adopting* strategies for designing and implementing programs to pursue the policy objectives;
- implementing the strategies and programs; and
- revising goals, objectives and strategies periodically.

Thus, in each case of planning, a context was provided for considering the consequences of particular projects or developments in an area in terms of their consistency with broad goals and general policy objectives. The context indicated both a desired direction and limits for controlling cumulative effects. Athough planning has followed the same general model, it is important to recognize two major changes that have evolved over time:

- planning has become more comprehensive as it has shifted from a relatively narrow focus on the orderly and efficient development of resources, as in the LMRPB, to the broader concern of balancing conflicting demands for limited resources, as in the ALR, LRPP, and FREMP; and
- there has been a shift from the early empahsis on the "plan" produced, as in LMRPB development of the ORP and ALR, to emphasizing the ongoing process of "planning," as in the ongoing planning of the LRPP and FREMP.

Planning has thus increasingly become one of the major means for regulating the cumulative consequences of development.

Development of Project Assessments

Over the last 15 years, the addition of progressively more refined project assessment procedures for the estuary has provided the potential for greater consideration of cumulative consequences. Applications for waste management permits and foreshore leases have been submitted to increasingly detailed assessment procedures; three projects submitted to EARP went through processes that were being continually refined, and the introduction of B.C. Order-in-Council 908 required assessments to be prepared for all projects outside the dyke. The assessment procedures now being implemented by FREMP provide for a co-ordinated project review process that will:

- check for conformance with environmental guidelines and regulations established in the planning process;
- initiate an environmental review process for those that do not comply; and
- instigate more extensive and detailed assessments whenever deemed necessary.

Project assessment procedures have thus increasingly provided a second and complementary means for regulating cumulative effects of development in the estuary.

Integration of Planning and Project Assessment

While planning has begun to provide a more specific direction and context for project assessment, project assessment has broadened to consider area context and groups of projects. FREMP is designed to carry this forward and implement a more integrated process of planning and project assessment for managing the estuary. In addition to implementing the Co-ordinated Project Review Process, planning is proposed for both subareas of the estuary and for each of the major activities in the estuary. One of the products of Phase II of FREMP was a map of area designations and associated conditions. This is now being used to guide present management decisions and is a basis for beginning subarea planning.

9. For a more detailed examination of this argument as it applies to water resources management in Canada see Dorcey (1987).

Of particular significance is its readily apparent potential for integrating planning (for the first time in any substantial way) on the water side of the dyke with upland planning.

At the same time, activity planning will guide decisions on the use of a particular area for an estuary-wide activity. For example, one of the more advanced activities is waste management and associated water quality planning. A preliminary set of ambient water quality objectives has been set and an initial monitoring program appropriate to them is being implemented. The objectives begin to set limits for cumulative effects and the monitoring program will begin to provide a basis for both refining the objectives and indicating where increased control over discharges may be necessary. At the same time, planning for liquid waste management in the GVRD is underway, which will begin to develop a source control and regional waste management program. This again begins to integrate planning and project assessment on the water and upland sides of the dykes.

The development of Strategic Plans for environmental resources in the Lower Fraser Valley by the B.C. Ministry of Environment (O'Riordan 1986) and the Fraser-Thompson Corridor study under EARP (FEAR0 1986) has started the complementary development of integrated planning and project assessment procedures for the adjacent upstream drainages to the Fraser Estuary

Difficulties Experienced

It is important, however, to temper this perspective on successes and the emerging potential with some of the weaknesses and difficulties that have been experienced:

- *CEA has seldom been explicit:* While the planning and project assessment approaches have undoubtedly been concerned with cumulative consequences of development and increasingly this has included environmental consequences, they have generally not been rationalized in terms of the need to assess and manage cumulative effects per se.

- *Difficulty and controversy have been continuous:* It is significant that all initiatives have been characterized by technical difficulties, long gestation periods, and political controversy. Technical difficulties have ranged through lack of appropriate data (e.g., what data on toxic materials are in discharges and the ambient environment), gaps in knowledge of key functional relationships (e.g., the estuarine ecosystem) neglect of potential analytical techniques to generate information (e.g., computer modelling for sensitivity analyses of alternative management scenarios), and a failure to set research priorities (e.g., opportunities for low-cost research that could generate valuable planning and assessment information were neglected; an experimental source control program would be an example). Long gestation periods have been the rule: *20* years to exert effective control over the rate of agricultural land losses, six years to produce the LRPP, and seven years from FRES to FREMP. Political controversy related to technical deficiencies, unreasonable constraints, and so forth have surrounded all of these initiatives. The successes of the planning and impact assessment initiatives are not widely recognized so there is myopic preoccupation with the continuing problems.

- *Gross approaches suffice until the opportunity costs become significant:* This point is of great importance because central to the strategy of controlling cumulative effects through planning has to be a willingness to make technical and value judgments, using the best available information and appropriate decision processes, that set limits to guide decisions in the interim (e.g., no net-loss of habitat). Judgments on constraints are much easier to make at earlier stages of regional development, while their opportunity costs are perceived to be low, but become increasingly difficult to defend as development intensifies. Even though the LMP and LRPP were only advisory documents, it is worth noting that the LMRPB was abolished and the planning functions of regional districts and the Agricultural Land Commission have been weakened as a result of the opposition from development interests.

- *Uncertainties are getting more difficult to cope with:* As evidenced by the cumulative effects issues associated with the assessment and management of floods, toxic material discharges, and wetland losses in the Fraser Estuary, there are great uncertainties about the relevant science and values. In general, it appears that as increasing attention is being given to management of the system, and interdependencies among the systems involved become more numerous and strong, there is a growing appreciation of the uncertainties that must be considered. For example: What are the implications of a sea-level rise due to climate warming for increasing flood hazards? Since we only find the toxicity problems we look for, what problems might be accumulating that we have not yet recognized? If it is unlikely that knowledge of the importance of wetlands for maintaining salmon and waterfowl populations can be significantly improved in less than a couple of decades with even the most optimistic scenario, how should decisions be made on their use during the intervening years?

Thus, while much has been done to develop the capability to assess and manage the cumulative effects of development in the Fraser Estuary and so far there have not been any major unpleasant surprises, it is clearly essential to consider how CEA might be further improved in the future.

WHAT IS NEEDED TO CONTINUE IMPROVING CEA IN THE FRASER?

Before considering how CEA might be stengthened in both the shorter and longer term, it is important to clarify what it is that makes CEA so challenging.

Science and Values

Planning and impact assessment involve the analysis and synthesis of scientific and value information about relevant resource *systems.* To the extent that there is uncertainty about science and values, both planning and impact assessment become more difficult, as illustrated in Figure A-4 and in the examples that follow.

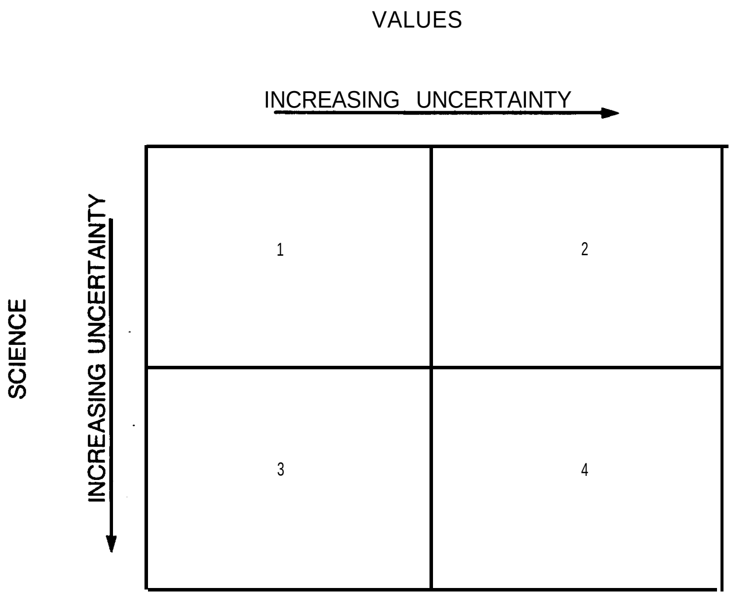

Figure A-4. Uncertainty About Science and Values

Box 1 — Little uncertainty about science or values: e.g., chlorination of sewage effluent to reduce coliform counts where discharges are in proximity to bathing beaches.

Box 2 — *Little uncertainty about science but uncertainty about values: e.g.,* there is little uncertainty that conversion of agricultural land to urban uses generally destroys its productive potential but there are substantial uncertainties about the opportunity costs of destroying farmlands in the Fraser Delta.

Box 3 — Little uncertainty about values but uncertainty about science: e.g., there is substantial uncertainty about the effects of exposure to toxic materials in the atmosphere, water, and food but generally there are strong preferences for avoiding these risks.

Box **4** — *Uncertainty about science and values: e.g.,* the implications of wetland losses for maintaining salmon and waterfowl populations are highly uncertain as are the values associated with these populations.

It is symptomatic of the emerging management challenge that almost any example of relative certainty could be contradicted by reasons for uncertainty. There might be questions about the effectiveness of chlorination in reducing coliform counts, the adequacy of coliforms as an indicator of potential health risk, the potential for creating toxic chlorinated organics in the effluent, and so on. What makes cumulative effects challenging, however, is that they are highly likely to lie in boxes **2** and 3, and particularly 4. The reasons for this are the seven types of change accompanying development in the Fraser Estuary, identified in the section "Genesis of a Need for CEA," above.

Because of pervasive uncertainty, resolution of resource management issues in general, and cumulative effects issues in particular, depends increasingly on improving both the techniques of analysis and the administrative processes within which they are used. The techniques must be capable of generating information through sensitivity analyses across three dimensions: time, space, and systems (ecological, social, and economic). Likewise, the institutional arrangements must be capable of conducting planning, impact assessments, and management across these three dimensions. This leads to suggestions for improving CEA in the Fraser Estuary in first the short term and then longer term.[10]

Opportunities for Immediate Improvement

There are three major opportunities for beginning to make immediate improvements in CEA in the Fraser Estuary. All reinforce the FREMP initiatives. Each would pay off immediately but need to be implemented progressively. All three give rise to questions that should be addressed in the longer term.

Make better use of existing knowledge and techniques of analysis. Knowledge and analytical techniques are available that could be better used in generating information in both impact assessment and planning, providing an improved basis for judgments about cumulative impacts and their manage-

10. These suggestions are based on the results of studies undertaken by the Westwater Research Centre during the last 15 years. Specific references to appropriate publications are included.

ment.[11] For example, a computer model could be built, based on the knowledge and experience of relevant people, that would analyse alternative management scenarios. As indicated in Dorcey and Hall (1981), there are numerous specific opportunities for doing this in the Fraser Estuary. Valiela and Kistritz (1979) illustrate the results of applying this kind of approach to the analysis of juvenile salmon dependence on marsh habitats.

Develop processes *for setting research priorities.* Research and experimental management strategies are critical since the nature of cumulative effects is uncertain or unknown. It is essential to create some ongoing process for establishing research priorities and revising them as more is learned. At present, there is no process for doing this but it would be relatively easy to implement a basic one.[12] Dorcey and Hall (1981) suggest that a specific set of questions to be jointly addressed by researchers and managers and applied to produce an illustrative set of priorities. The process for bringing these people together would, in fact, be complementary to the approach for improving analyses suggested above.

Increase the productivity of existing institutional arrangements. The institutional arrangements for impact assessment and planning have become increasingly refined and integrated in their design and have potential for considering many of the interdependencies that must be given greater consideration in improving CEA in the Fraser Estuary. One of the key requirements for making the existing institutional arrangements work better is to improve the skills of the people involved, in particular their ability to communicate effectively, challenge each others' arguments constructively, and successfully negotiate agreements.[13] Case study research in the Fraser and elsewhere (Dorcey 1986) has shown that weaknesses in these skills are greatly frustrating the achievement of their potential. Relatively simple skill development programs involving short courses and on the job training have been suggested by Dorcey (1986) that could produce significant improvements in the operation of the existing system. It is important to note that while this problem has often been identified, the extent to which it undermines the ability to cope effectively with issues such as CEA has not been recognized, and more seriously, little has been done to address it.

Opportunities for Improvement in the Longer Term

In the longer term, the Fraser Estuary presents an excellent opportunity for experimental development of CEA. It could be selected by CEARC as a case study of CEA in a region. There has already been a great deal of experience in developing integrated processes for impact assessment and planning. In the future, much could be learned by a detailed evaluation of the strengths and weaknesses in the innovative approaches that have been recently implemented and by combining this with a program of deliberate experimental development as part of FREMP. It should build upon and refine the suggestions for improvement in the shorter term by examining more fundamentally the causes of the problems they seek to remedy and evaluating alternative ways to deal with them. In doing this it will be essential to address in more detail questions that have received little consideration so far but that appear, from this case study, to be important. The following questions should be addressed:

- Why are existing knowledge and analytical techniques not being utilized? To what extent do analytical techniques designed for text book situations not take account of the realities of application? What might be the techniques of analysis that are appropriate to constraints of time, knowledge, and resources available for conducting planning and impact assessment?
- What analytical techniques and administrative processes should be developed for setting research priorities? How can the researcher and manager be brought together most productively? How can experimental management opportunities be best exploited to develop critical knowledge of systems behavior?
- How can the communications, challenging, and bargaining skills of participants in impact assessment and planning be improved most expeditiously? What are associated changes in incentives and opportunities that would facilitate this? How do the perspectives on appropriate technical skills change as the participants begin to improve their interactions?
- What are the changes in institutional arrangements that are necessary to change the time, space, and system boundaries considered by participants in CEA? To what extent is it necessary to change formal institutional boundaries in order to promote sensitivity analyses across all three dimensions? To what extent should the capabilities and incentives for individuals and organizations to ask questions about systems that transcend these boundaries and to operate across them be emphasized, because formal boundaries will always be inappropriate in significant ways?

EVALUATION AND DEVELOPMENT OF CEA ELSEWHERE IN CANADA

The case study of the Fraser suggests priorities for evaluating experience with CEA elsewhere in Canada and strategies that CEARC should consider for developing the principles and the practice of CEA.

Applicability of Conclusions to Other Situations

The particular characteristics of the Fraser situation make it important to consider to what extent they have made the experience unique in Canada. For example, the Fraser is a highly developed region compared with many other parts of the nation; its development history is relatively recent, it continues to be developed rapidly, cumulative problems have not been neglected, innovative procedures for planning and

11. See Dorcey (1981), Dorcey and Hall (1981), Dorcey et *al.* (1983), and Dorcey (1986) for detailed suggestions.
12. See Dorcey and Hall (1981), and Dorcey (1986, 1987) for specific suggestions.
13. See Dorcey (1986, 1987) for a detailed analysis.

impact assessment have been introduced, and so on. It is therefore suggested that CEARC should:

utilize the variety of case study research that has already been undertaken both under its. auspices and others, to determine the general applicability of the results from the Fraser case; and

identify a small number of case study situations, which differ in characteristics that are identified as important, where there is the opportunity to analyse recent experience in impact assessment and planning, and undertake a concerted program of experimental development with the organizations involved, as suggested in the Fraser.

General Research Topics

The Fraser case also suggests five general research topics that should be addressed by CEARC irrespective of further case study investigations.

Review the extensive literature on planning to identify the theory and practice, relating to techniques of analysis and decision-making processes, that have already been developed in dealing with what is de *facto* "cumulative impacts assessment and management."

Analyse why available knowledge and techniques are so little used in impact assessment and planning, and design strategies for remedying this.

Analyse how well existing policies that are being developed worldwide, such as the World Conservation Strategy, are already beginning to address the need for strategies for managing cumulative impacts, and how Canada can assist in their accelerated development and implementation.

Develop strategies for integrating the strengths and reducing the weaknesses of the biophysical scientists (who have predominated in the practice of impact assessment) with the strengths of the planners in planning (who are often weak in their appreciation of the biophysical system).

Develop strategies for the design of institutional arrangements at the local, regional; national, and international levels that would promote active questioning, of interdependencies across time, space, and system boundaries.

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NEW BRUNSWICK FOREST MANAGEMENT

Linda Rattie
with Gordon Baskerville
and Peter Duinker

INTRODUCTION

New Brunswick has the largest proportion' of land in forest cover of any Canadian province (approximately 86% or 6.2 million hectares). Most of this land is accessible and capable of growing repeated crops. The province's forests are comprised of 60 % spruce and fir stands, 10% other softwoods, and 30% hardwood. Primary and secondary forest industry directly employs 5% of the work force (16,000 people) and indirectly accounts for an additional 2,000 jobs (Versteeg 1984). Forty percent of the province's manufacturing and 38% of exports are derived from forestry. Thus, it is evident that the forest resource is an integral part of New Brunswick's economy.

Economic development has traditionally involved exploitation of the forest resource in order to promote local and regional economic growth. Simultaneously, however, undesirable local ecological impacts on forest. land have cumulated to the level of regional degradation, threatening the future of New Brunswick's forest industry. Recognition of overharvesting did not occur until the late 1970s. Since that time, there has been an effort to design and implement a set of management plans that takes into consideration the complex interactions contributing to the productive capacity of the resource. This case study will attempt to:

- document the cumulative effects of harvesting patterns and practices on wood supply;
- discuss the manner in which these cumulative effects have been assessed and managed; and
- suggest how CEA can be specifically improved in the case of forest management in New Brunswick and applied in general.

IDEAL FOREST MANAGEMENT

It is useful to describe the ideal situation for forest management because any CEA process which is implemented will have, as its objective, creation of the ideal forest management situation. Wood harvested in New Brunswick is used for pulp and paper and saw timber. It takes 40-50 years to grow pulpwood and 70-80 years to grow saw timber in New Brunswick. Existing mills, using only softwoods, produce either pulp and paper or saw timber, although some hardwoods are used for both purposes.

Under ideal forest management conditions there is a long-term even flow of wood fiber of consistent quality from the forest. This means that the area and volume of wood harvested for use in any year is replaced by an equal area and volume of wood to be harvested the following year. A balance of pulp quality material and saw log quality material is achieved by maintaining a range of stand development stages to meet both standards. In the ideal, balanced forest, the previous practice of taking annual harvests of a wood volume larger than the total volume in the oldest age class would be considered overharvesting. Overharvesting means the future productivity of the forest, represented by growing wood in younger age classes, is being removed for the sake of current economic returns and is therefore no longer available for future economic returns.

HISTORY OF FOREST RESOURCE DEVELOPMENT

Man has utilized forest resources in New Brunswick since the early 1800s. Before then, natural agents such as spruce budworm were the dominant harvesters of the forest. Forest utilization for economic growth since the 1800s has been characterized by a number of relatively local, short-term management activities which depleted particular parts of the forest base. Throughout this period the wood harvesting and processing technologies and economies adapted to accommodate a shifting species and product mix, decreasing quality in raw materials and to sustain economic growth.

The cumulative effects of these relatively local, short-term activities has been a foreseeable province-wide shortage in pulp wood and saw timber. As the resource base has shrunk, losses to natural harvesting agents, such as spruce budworm, have become of greater concern because these losses further hinder economic sustainability and growth.

Resource Development for Saw Timber

The first use of the forest resource for development of the local economy was the harvesting of the large white pine used for ship masts in the early 1800s. This high-grading of large, old white pine depleted this type of tree and the industry gradually shifted to sawmilling and exporting squared timbers. This necessitated modifying the source of raw material to include small, lower quality white pine.

Sawmilling had became the preferred industry by the mid-1800s because producing milled timber for export provided value-added economic benefits. Large white spruce were high-graded as the supply of large white pine declined. Once again, the rate of volume harvested exceeded the rate at which the forest produced the volume. The industry shifted to large balsam fir as the supply of large white spruce declined.

The sawmilling industry peaked in the early 1900s with about 600 mills in operation. In 1971, the volume of high quality saw timber was sufficient to keep less than 150 mills operating (Province of New Brunswick and DREE 1976).

Resource Development for Pulp and Paper

In the early 1920s, when the pulp and paper industry began, the lumber market was poor and high quality material for saw timber was becoming increasingly difficult to obtain. Thus, the new industry was a major development for the local economy in terms of spinoff employment and quality of jobs.

This industry was able to use entire stands of wood rather than relying on individual trees that had been high-graded from the forest. The expansion of this economic activity, however, created a demand for quantities of pulpwood that the current forest structure could not maintain. The industry adapted to this eroding resource base by changing processing technology so that some hardwoods could be used with softwoods.

Spruce Budworm

The spruce budworm is a natural agent which competes with human activity in the harvesting of forest resources in New Brunswick. Its effect on the forest has grown in importance as the existing forest base gradually declined through overharvesting.

The budworm was the most important regulating agent in forest dynamics prior to utilization of the forest by man in the 1800s. Historically, budworm was a periodic harvester of the forest with outbreaks occurring every 30-70 years (Blais 1965). These outbreaks removed most of the older fir and spruce in the New Brunswick forests. This created a forest largely composed of two age classes: a mature class to be harvested by the budworm and an immature class' released after the budworm had killed the mature overstory (Figure A-5).

'By 1950, man was in direct competition with the spruce budworm for spruce and fir forests in New Brunswick. At that time, there were six pulp and paper mills relying almost exclusively on raw material from spruce/fir stands established as a result of a budworm outbreak in the 1880s. With the threat of a new outbreak in the early 1950s, interest in protecting the resource to secure the future of the pulp and paper industry rose dramatically.

The budworm was previously of little concern as spruce and fir were not economically valuable species before this period. Thus, budworm outbreaks only began to be perceived as a problem when the harvesting of spruce and fir commenced. The harvest of the budworm, 6-10 years harvest every 30-70 years, are incompatible with the small harvests taken by the forest industry. Chemical insecticides have been used in an attempt to mitigate the impact on wood supply from budworm outbreak. Since 1952, this has been done on an average of 17% (ranging from 0% in 1959 to 68% in 1976) of all New Brunswick's forests each year. As a result, the budworm population has remained at a semi-outbreak level since spraying began instead of periodically pulsing (Province of New Brunswick and DREE 1976). The loss of forested land has been small relative to losses estimated in past outbreaks. This greater control on tree mortalify from the budworm has actually increased the total timber inventory of the province.

Budworm control and lack of budworm-induced mortality has allowed the older stands to be gradually harvested by the industry, rather than in a short period by the budworm. This has resulted in' a slower replacement of the forest land to younger age classes than would have occurred with no budworm control. If present conditions are allowed to continue, the effects of clearcutting, budworm, and fire will eventually create a balanced forest structure in which all stages of stand development are present in the forest at' any one point in time (Figure A-6). That is, continued budworm control will create a forest with a stable age class and productivity structure much like the forest under the ideal management situation.

Current State of the Forest Resource

The history of forest resource development in New Brunswick is characterized by removal and inadequate replacement of high valued, higher quality wood through time. This has been caused by local and short-term forest management decisions, which have primarily focused on altering wood harvesting and processing technology to lower value and lower quality wood fiber.

Both the pulp and paper and sawmill industries have had to bring in new technology and capital investment in order to use less valued, smaller, and lower quality raw material (i.e., specialty industries that make plywood, chipboard, laminated beams). Lower utilization standards have directly increased the yield available to convert to economic value. In this way, industry has effectively used money and innovative ideas to mitigate reduction in the quality of the resource. This has ultimately advanced the development of the economy by allocating a larger portion of the economic benefits to the local communities (Regier and Baskerville 1986).

Simply put, resource development was historically seen in terms of social and economic gain rather than in terms of productivity. The cumulative effects of this pattern of forest resource use has been a future lack of a sustained supply of quality raw material. High-grading for pulp has led to an increase in recruitment by noneconomic species, while high-grading for sawlogs has resulted in a product mix of poor quality stems and unusable species. In addition, overharvesting has prevented stands from growing beyond 100 years. The largest, best quality trees no longer exist.

Economic development based on continual lowering of standards and expansion of the product mix has reached its upper limit. The dynamic structure of the resource has been

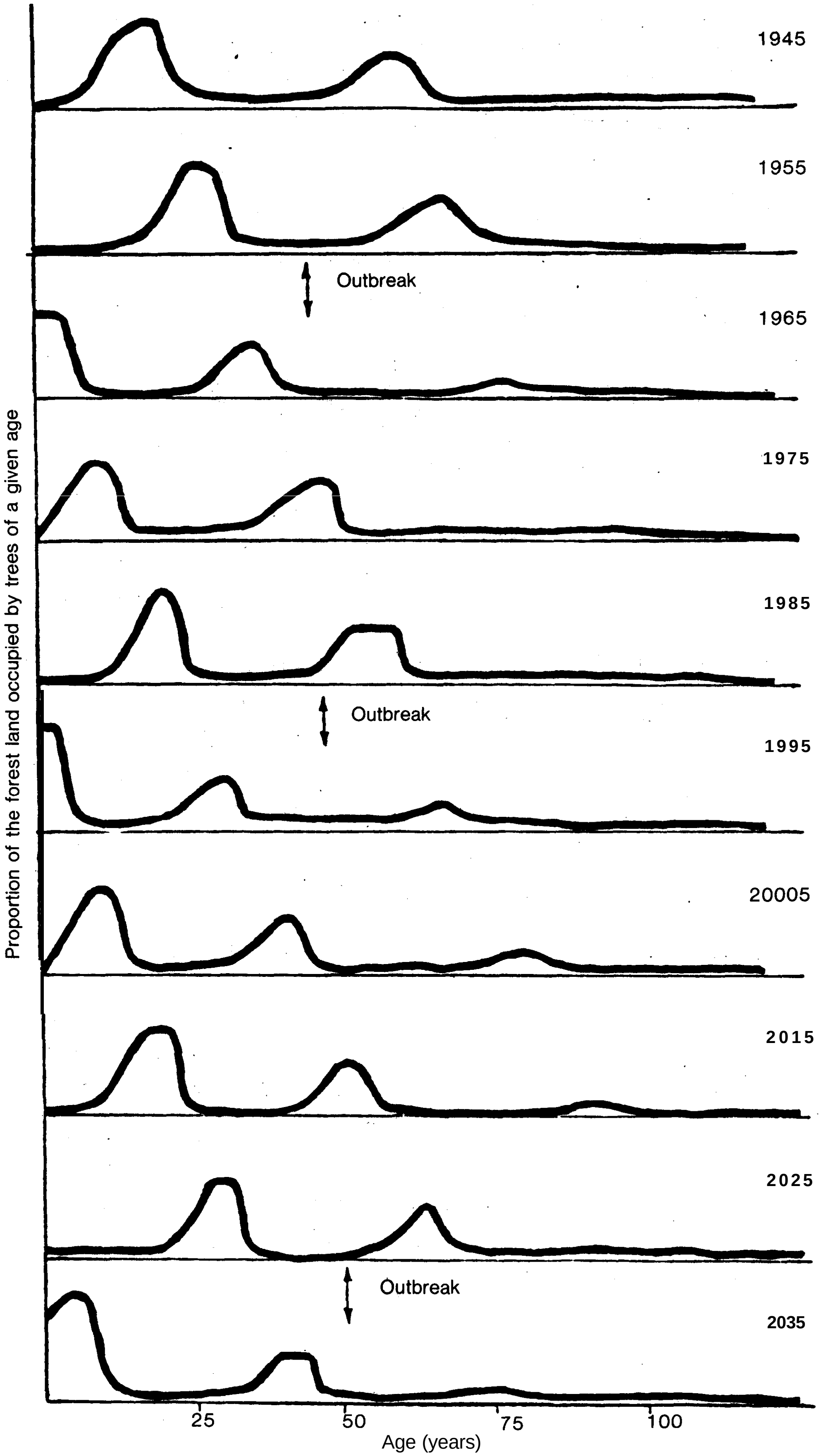

Figure A-5. A schematic representation of the development of age-class structure in the host forest over time in the absence of either budworm control or harvesting (Province of New Brunswick and DREE 1976).

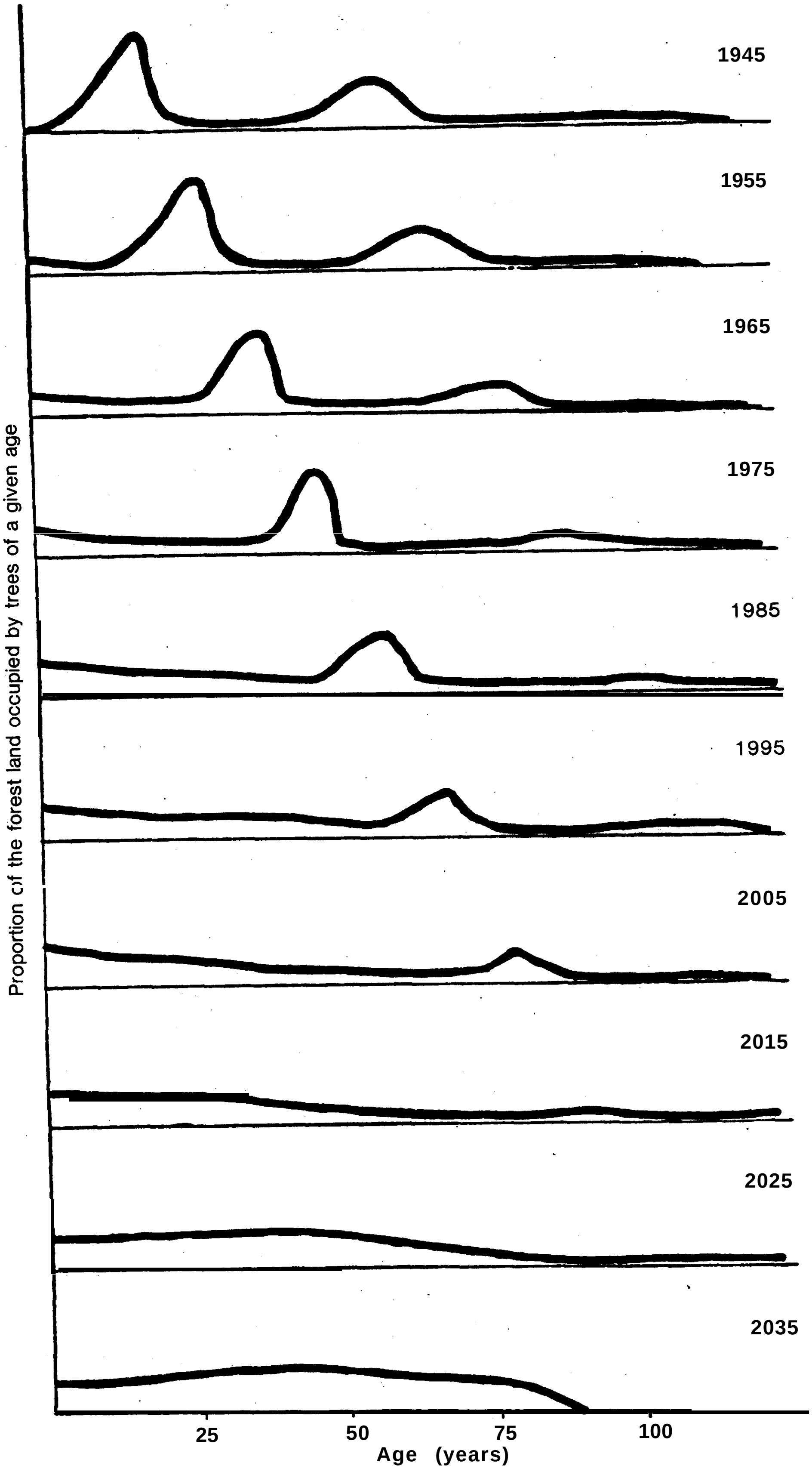

Figure A-6. A schematic representation of development of age-class structure in the host forest over time under crop protection and harvesting (Province of New Brunswick and DREE 1976).

dramatically altered. The forest age structure is unbalanced and a gap in the provincial supply of wood 30-40-years-old exists (Baskerville 1983). Changes have occurred in terms of age structure of stands, quality of wood (volume of particular species in certain size classes), and in total volume of merchantable' growing stock (Regier and Baskerville 1986) which are now viewed as unacceptable.

NEED FOR CEA

Many changes in the structure of stands and forests have accompanied the development of the forest industry in New Brunswick. Because the schedule of harvest, method of harvest, and stage of stand development all have long-term implications on development in a new stand, consideration of the cumulative effects of these actions has become increasingly important. It is estimated that it will be possible to maintain current consumption of 7.1 million cubic metres beyond the next 30 years by continuing with the current approach to management, but current quality standards cannot be maintained (Figure A-7) (Baskerville 1983).

Local industry lost competitiveness in world trade due to the high cost of raw material, resulting from changes in the forest structure through overharvesting, and potential socio-economic consequences to local communities (i.e., loss of jobs due to closures of sawmills unable to adapt technologically to smaller tree sizes). This, in turn, forced recognition of resource degradation and the need for intensive management. Recognition of this by decision makers in industry and government occurred between 1975 and 1980. Once it was agreed upon that maintaining the flow of quality material was the real problem, emphasis on designing and implementing long-term corrective measures soon followed (Regier and Baskerville 1986).

WHAT HAS BEEN DONE TO MANAGE CUMULATIVE EFFECTS?

Concepts of Forest Management

The forest industry relies on three sources for wood supply: in the short term, the old forest, and in the long term, both natural regeneration and planted new forests. The new approach to forest management attempts to control the way the whole forest develops, both temporally and spatially, so that the pattern of stands over the whole forest is continuously suitable for the purposes of management (Duinker 1986). Regulating the timing of available harvest as well as the location of stands available for harvesting is essential to reduce the risk of losing all of one stage of development to natural disaster, causing a break in the future flow of stands available for harvest. The long lag time between implementation of an action and a noticeable response in the forest structure means that management must anticipate problems and the need for specific actions 30 years into the future. Forecasting spatial and temporal development is done in each stand individually and then is combined into one forest-level forecast.

It is impossible to determine the nature .of the problem, however,, to design corrective measures, or to assess the effectiveness of a solution without knowing what temporal and

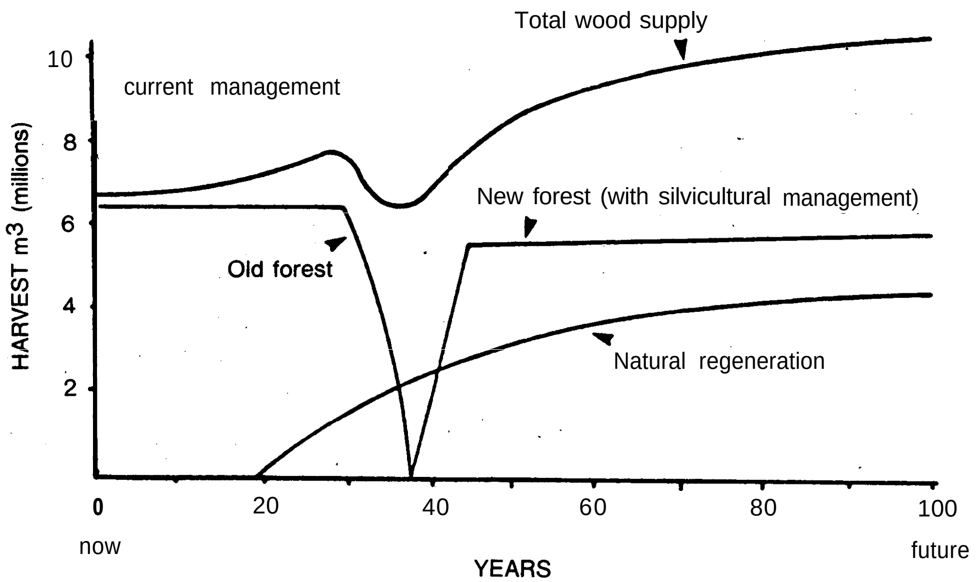

Figure A-7. The future wood supply picture with current management: total volume of wood required by industry can be maintained but quality can not (Baskervilfe 1983).

spatial patterns are suitable with respect to various stages of development in each stand type present in the forest. The approach to managing a forest is identical whether a forest is 50 hectares or 500,000 hectares, although the scale of the problem differs.

Any management plan must include all of the following four elements at the stand level:

- harvest schedule — determining when and how each stand will be harvested;
- product mix — determining what distribution of materials will be taken in each harvest to provide consistent quality supply;
- silviculture — altering stand development away from natural patterns or accelerating natural trends by means of pre-commercial thinning and planting; and
- protection — protecting stands from unscheduled harvest caused by insects, disease, or fire outbreak.

The pattern of stages of stand development that will exist in the forest over time will be determined by the manner in which the four tools in combination, applied at the stand level, are able to bring about the forest-level response sought by management control (Duinker 1986).

Recent Developments

A gap in the forest age structure under current management practices led the province of New Brunswick to commission the Forest Resources Study (1974). The purpose of the study was to collect and analyse data on the present use of forest resources; initiate a study of potential markets and recommend measures to capitalize on those markets; and develop a comprehensive forest policy, applicable to both Crown and private lands, as the basis for legislation (Province of New Brunswick 1974).

The report set the tone for developing a sound forest management program, noting the interrelationships between various problems and stating the need for stable land use policies and comprehensive forest use guidelines to optimize uses and benefits. It acknowledged the need for scheduling harvests, silviculture, and protection to maintain the productivity of the forest. Moreover, it paved the way to new legislation bringing control of timber licences to one agency, the Department of Natural Resources (DNR).

The Crown Lands and Forests Act (1982) reallocated access to Crown timber, based on the needs of mills and the ability of Crown forests to supply those needs. Under the new act, administered by DNR, all previous Crown timber licences were suspended and 10 new licences were offered to companies operating mills in New Brunswick. The licensees will be reimbursed by DNR for undertaking silviculture and other management tasks. All sawmills that were previously largely dependent on pulpwood licence holders now have legal access to Crown wood as sub-licensees, which have the equivalent rights of licensees. This dramatic change in tenure pattern in which over 100 management units were reduced to 10, has made it possible to rigorously control forest management (G. Baskerville, pers. corn.).

The Crown Lands and Forests Act can be considered successful or unsuccessful depending upon how it has affected or been accepted by various groups of people. For industrial freeholds (sawmills and paper mills) in general, it has beneficially changed the way that harvested areas are treated (P. Duinker, pers. corn.). In addition, the more costly burden of forest management is shared among users.

For private woodlot owners (nonindustrial freeholds), however, the legislation has failed. Because the majority of people owning nonindustrial freeholds do not depend on wood supply for their livelihood, they do not wish to invest money in forest management. Instead of managing their land, they have simply increased the sale of wood. In fact, they want the province to pay for forest management while they reap the financial benefits it will provide. Thus, DNR has learned that laws are unenforceable if people do not understand or see the benefits of investing money in forest management.

In general, the public (40,000 landowners), industry (50), and government (9 agencies) have become aware of the complexity of the wood supply problem and what measures can be taken to rectify it. The role of DNR has changed from one of providing silvicultural and protection services to one of designing management, reimbursing licensees to undertake silviculture, and monitoring their actions. Due to public sensitivity to herbicide and insecticide protection programs, DNR continues to supply these services (P. Duinker, pers. corn.). Public unrest has surfaced and diffused with regard to effects on health and again when the cost of long-term forest management was projected to override some short-term economic decisions (i.e., employment opportunities). An immediate return on an investment is more ‘highly valued than an equal return (i.e., quality harvest) sometime in the future. In addition, there is a human tendency to cling to an existing policy rather than to face the unknown or uncertain. Education is integral to acceptance of a policy by the public so that it can be applied (Province of New Brunswick and DREE 1976).

LESSONS

Redesigning and implementing a forest management program has resulted in the need for new types of forest data and analysis as well as new ways of thinking about cumulative effects in appropriate temporal and spatial scales,

Scientific Lessons

The old approach to forest inventories characterized forests as being static by documenting current conditions in terms of volume and mean size available for converting into immediate economic value. When an inventory in the 1970s showed less resource even after adjustments were made for tower quality standards (Regier and Baskerville 1986), the inventory approach was modified to one based on the dynamic structure of the forest. With time horizons of 40-50 years, it has become necessary to make quantitative forecasts (Baskerville 1985b) of wood availability in terms of quantity, quality, location, and timing for a variety of harvesting, production mix, silviculture, and protection scenarios. There has been a shift in problem perception from the tree or stand level, where there was adequate data, to' the forest or regional level. The development and acceptance of forecasting tools (i.e., models) has occurred at a rapid rate, which is surprising since those techniques were resisted a few years ago.

Second, with respect to interpreting scientific data, it is now known that it is incorrect to average 'the data and generalize for all of New Brunswick's forests. It must be realized that there is no New Brunswick forest, but rather many forests that make up the province. This is true for any province; there is no average Canadian forest with average problems and average solutions. Attempts to characterize forests in this manner prevent understanding of the problems in individual stands and the variable nature of their solutions (Duinker 1986). Management design must be consistent with the biological population structure of the stand — each stand being unique. Thus, forecasts of the temporal and spatial development of a forest 30 years from now must be based on forecasting the development of each stand and then aggregating these results into one forest-level forecast. A regional plan will be composed of many local factors interacting to result in a regional response.

Institutional Lessons

Designing and implementing a forest management plan will continue to be a challenge for decision makers. A dramatic change in the perceptions of management from the local to regional level has and is occurring as a result of recognizing the need to reallocate access to productivity. Implementation will continue to be on a local scale; however, it must now be consistent with a broader regional goal. Rather than making decisions on what will be done at a particular place, the question is now "what set of local actions taken in what places in the whole forest, and at what times, will cause the regional forest to transform and grow towards a particular chosen goal?" (Regier and Baskerville 1986). Changing the thinking of a generation of decision makers accustomed to acting at the local level without consideration of the larger, regional forests is proving to be a monumental task.

Perhaps even more difficult is making the actual pattern and timing of harvest, silviculture, product mix, and protection match the policy. This has only become a problem since sustaining the forest resource has become desirable. In a no-management situation, concern for harvests in the long term is nonexistent and thus actual patterns of stand development are irrelevant. Once management plans have been implemented in order to meet forecasts of sustained harvest, it is necessary to ensure that on the ground practices (real schedule of harvest) are the same as those dictated by the planned schedule of harvest (Regier and Baskerville 1986).

Social Lessons

The lack of public understanding of the interactions between the need to sustain resource productivity and local economic benefits has intensified (Regier and Baskerville 1986) since initiation of the Crown Lands and Forests Act in 1980. To date, DNR and nonindustrial landowners have not been able to reach a management agreement about the issue of who pays for management. The crux of the matter is deciding whether private land is a public resource (G. Baskerville, pers. corn.). If the answer is yes, a forest management agreement similar to that of large industrial freeholds (pulp and paper companies) might be feasible. Private landowners, however, do not consider private land to be a public resource. In Maine, private landowners have been receptive to the idea of having a governmental extension service help them manage their land. In New Brunswick, however, private landowners have formed marketing boards purely designed to help sell their wood, not to manage the forest resource. In fact, the general attitude is that if they are unable to sell the wood they have now, why should they want more in the future (G. Baskerville, pers. corn.). The general public, directly or indirectly dependent on the economic benefits of forestry, realizes that without new management, the level of economic growth will decline.

Where To Go From Here

The Forest Resources Study and subsequent Crown Lands and Forests Act are first steps in an effort to develop and make choices about the future of New Brunswick's wood supply. Scientific priorities will be to improve the reliability of forecasting tools by increasing the understanding of how the range of management tools will interact to sustain the flow of wood in the long term. Problems of particular importance are how to schedule the harvest and what measures or indicators should be used in forecasts in order to ensure the regional wood supply goal is met.

Similarly, decision makers will be developing new frameworks for analysis that place local actions in a regional context of forest dynamics. Decision makers also see the need for a policy dealing with nonindustrial freeholds. The problem is that a picture of the optimum agreement exists but the path to achieve it does not (G. Baskerville, pers. corn.). Socially innovative ideas are most certainly needed to mediate this impasse. A compromise between pride of ownership and acceptance that the forest resource is public, in the sense that economic growth depends on management, is probably what is needed. The problem remains: How can this change in perception of ownership be brought about?

IS THIS CASE APPLICABLE TO CEA IN GENERAL?

In New Brunswick, the history of forest exploitation to develop the economy illustrates generally applicable concepts of cumulative effects assessment. In this example,, stands were harvested in spatially inconsistent patterns and in volumes exceeding recruitment because no thought was given to the magnitude of impacts on either temporal or spatial scales. At the point where the need for management became essential to sustain economic development, it was quickly realized that local impacts had cumulated incrementally in time and space to create noticeable resource degradation at a regional level. No longer could decisions be made at local or stand levels without deciding what the larger, regional forests should look like. There was an apparent need to assess stands individually to reflect unique characteristics (i.e., response rates) and then to combine them to create a cumulative assessment of the forest structure as a whole. Furthermore, forecasts 40 years into the future were deemed necessary to provide adequate time to predict problems, implement solutions and monitor their success. Thus, characterizing the dynamic structure of the forest resource or any other resource requires broader spatial and temporal perspectives (Baskerville 1985a) than were traditionally thought of as adequate to sustain development.

In addition, designing and implementing policy to reallocate the resource has required a high degree of interaction between scientists, decision makers, and landowners in order to increase the understanding of the need for corrective actions and encourage people to accept the responsibility for undertaking management. In the case of industrial landowners, interaction with DNR has been somewhat successful. More silviculture is bejng done but many licensees still are not committed to complying with legislation. On the other hand, little interaction between DNR and private landowners has resulted in complete failure with regard to managing woodlots. Moreover, the media, which have been the major vehicle of public education about the problem, have misinterpreted scientific facts or taken results of findings out of context on average 88% of the time (Province of New Brunswick and DREE 1976). Misinformation is at least as bad as no information, in that public rejection of'the management program might be based on a “doomsday” picture of socio-economic conditions that disproportionately highlight costs over benefits. Thus, it is evident that there is a need to create extensive and accurate communication networks in order to obtain maximum understanding and acceptance by all groups of the need for and long-term benefits of cumulative effects management,

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IMPACT OF NORTHERN DEVELOPMENT ON RESOURCE HARVESTING

Robert Everitt

INTRODUCTION

"Destruction. by insignificant increments" is the phiase used by the Canadian Arctic Resources Committee to describe the potential effects of resource development on the people and environment of the Canadian North. In the traditional lifestyle of northern native communities, the people and their environment are one. Their life is defined by their relationship to their land. This link is most visible in native resource harvesting activities. By resource harvesting we mean the act of hunting, fishing, or trapping and the subsequent processing of fish and wildlife for food, clothing, and sale.

This case study focuses. on the assessment of social and economic effects of resource development that have potential, in the long term, to become cumulative effects. This process is closer. to the practice of environmental impact assessment than it is to planning: The effects of resource development on a small northern community, Fort Good Hope, are used to illustrate the concepts under discussion.

CURRENT SETTING

The current social, cultural, economic, and political setting in the North can be characterized as follows (Jull 1985):

- small. and distinctive cultures occupying relatively large and "undeveloped" northern areas;
- struggles by these societies to protect their social structures and livelihoods from the disruption of large population influxes;
- legal and political conflicts over the claims of land and resources, and their use and benefit, between northern people and the governmental and industrial development interests which would exploit these for southern use;
- the celebration and retention of distinct languages and cultures;
- condescension in the southern decision and opinion centers towards the demands of northerners for strengthening and continuing their lifestyles;
- stable societies based now, as they. were traditionally, on the harvesting of renewable resources;
- the utility and success of locally manageable and locally managed commercial, industrial, or public bodies for development,;
- the frequency and bitterness of environmental protection battles;
- a general apathy to industrialization;
- an emphasis on resource development questions, both on- and off-shore, as an essential element of political conflicts and aspirations;
- demands for greater legal rights, lands and for more self-governing powers and stronger representation by northern people in institutions; and
- an ultimate willingness to accept political accommodations within existing government structures, with the potential these have to offer, rather than to pursue separation.

RENEWABLE RESOURCE HARVESTING

Within this larger context, this analysis will focus on the cumulative effects of development on renewable resource harvesting. The resource harvesting system can be thought of as the nexus of three systems: economic, social, and ecological. The economic system in a small northern community revolves around four sources of income: wage employment, transfer payments, sale of commodities (e.g., furs and handicrafts), and domestic production (e.g., meat, fish, wood). The social system is, of course, the set of mores and norms that govern the relationships in the community. The ecological system comprises the populations of animals and the environment that supports them.

To simplify this analysis, we use the example of a small northern community and the local cumulative effects arising from nearby development.

Fort Good Hope

Fort Good Hope is a Dene community of about 500 people on the Mackenzie River. The Dene, a collection of about 20 Indian groups, are the original inhabitants of the Mackenzie River Valley and Delta. Over 12,000 Dene live in 26 communities in the western half of the Northwest Territories. They have, for thousands of years, depended on the renewable resources provided by the land and water; water is particularly important because all animals and fish depend on it. The Dene continue to hunt, trap, and fish; they rely heavily on fish and wildlife for both food and income. Even those Dene involved in the wage economy often harvest renewable resources on a part-time basis, or use "country food" from those who harvest full time (Fee-Yee 1985).

At Fort Good Hope, "country food, including fish, comprises approximately 80% of meat consumed...and over $150,000 is earned annually through fur sales" (Fee-Yee 1985). Based on data for the period 1977-198 1, Brown (1984) concluded that 28% of the native population in Fort Good Hope were active trappers. During this same period trapping income as a percentage of total community income varied from 25 % -10 % (Brown 1984). Many Dene feel that they will still depend on the land's resources once the current oil and gas boom is over.

Agents of Change

There are a number of agents of change that 'are a consequence of resource development: industrialization, wage employment, resource development activities, access, and competition. All these agents act simultaneously on the resource harvesting activities of the people of Fort Good Hope.

Industrialization, the general process of socio-economic change in the resource harvesting system, occurs independent of any major resource development. It is difficult to detect these changes except as long-term trends.

Wage employment affects the harvesting system by reducing the time available for harvesting while increasing the amount of cash available to purchase better equipment (e.g., traps, guns, nets, snowmobiles). Resource development often brings employment opportunities that differ significantly both in quantity and in the nature of the work available from traditional employment.

Resource development activities may have direct ecological effects on the resources harvested. This may cause a change in the distribution and abundance of fish and wildlife. Reduction in the availability of resources usually leads to changes in the amount and location of harvesting effort.

Access to new areas is created through roads and seismic lines. This has the effect of changing the location of hunting effort.

Increased competition from non-local harvesters may increase pressure on local wildlife resources or change the location of harvesting effort.

WHAT IS THE POTENTIAL CUMULATIVE EFFECT?

The answer to this question is dependent on what we choose to measure. There are two measures one can make:

Direct monitoring measurements: a relatively comprehensive monitoring of changes due to resource development could be found by looking at: harvest levels, hunting effort, employment patterns, changes in access, demographic character of the harvesters, and so on.

Indicators of structural change: for example, the loss of traditional skills, increased reliance on food imports, changes in harvesting group composition, proportion of families that "go out on the land," and the number of families or households engaged in harvesting activities.

In the context of resource harvesting, the most important cumulative effects are those that deal with structural changes in the social, cultural, and economic systems. The immediate effect of nonrenewable resource development is temporary dislocation in the traditional renewable resource economy. The cumulative effect in the longer term may be a reduction in, or even failure of, the economic and social viability of the community. This is apparent because nonrenewable resource development in the North will continue for only a short period of time, but the people wish to live out their lives and pass their culture on to the next generation.

The potential cumulative effect in the case of Fort Good Hope has the following characteristics.

Young men of employable age begin to see wage employment as an attractive alternative to the traditional lifestyle, reducing the number of people engaged in trapping. Money from wage employment is often invested in guns, snowmobiles, boats, and motors, which in turn improves the efficiency of hunting effort. Kinship relationships are such that the extended family will provide "country food" for those who have taken wage employment and have less time available for hunting. The net effect is that trapping effort may decrease and trapping income for the community may decrease as well. The time spent by the community as a whole, both on the land and in hunting activities, may decline but community harvest levels will likely remain the same. Only the older people and their grandchildren spend a significant amount of time "on the land." This leads to an erosion of hunting and trapping skills but remains unnoticed because improvements in technology compensate for the loss in skills.

Direct impacts on wildlife poputations through disturbance, direct mortality, and habitat alienation may result in decreased availability of animals to be harvested. This would have the tendency to increase the cost in time and money of harvesting. The net effect would be to either reduce the harvest levels or increase the time and money necessary to maintain the existing levels of harvest.

Increased immigrant populations increase the hunting pressure on key food species (caribou, moose, bear). This serves to further reduce the availability of resources, thus making it still more costly to harvest.

Employment opportunities in white collar jobs draws women into the wage economy. These women are then no longer available to process fish and wildlife, increasing the time spent by other family members in processing activities. Gradually an erosion of key processing skills of the women takes place. To compensate, the income from wage employment can be used to purchase food imported from 'the south. This change provides a greater variety in family diets and also reduces the amount of country food required.

Reduction in the availability of fish and game leads to increased costs in time and money to harvest resources. Income from wage employment can be used to purchase better equipment to compensate for the reduced availability but this increases the cost even more. The hunting and trapping skills of the younger people continue to erode because of the reliance on technology and the reduced time available to engage in harvesting activities.

Gradually the structure of the local economy moves away from renewable resource harvesting towards a wage economy. While people still prefer country food, there are fewer people engaged in trapping, hunting, and processing. In some cases, a given extended family does not have the labour or time available to engage in resource harvesting. Specialization takes place and a system of selling country food may replace long-established patterns of sharing, thereby causing structural changes in the renewable resource economy.

The economy can maintain itself in this new configuration as. long as the wage economy continues to provide income. If the wage opportunities decline, it is not possible to shift back to the traditional ways because skills have been lost; hunters and trappers have come to rely on imported technologies that must be paid for in dollars. The community is no longer based on a viable renewable resource economy and government social assistance and welfare are required to maintain the social system.

While there is sketchy evidence that the economies of northern native communities are shifting away from the traditional renewable resource economy to increased dependency on a wage economy, the cumulative effect described above has occurred only by degree. The recent dramatic drop in the price of oil will curtail development activity and reduce the wage employment part of the economy. The extent to which the structure of the renewable resource economy has changed will be measured by the amount of social assistance that will be required.

WHAT HAS BEEN DONE TO MANAGE CUMULATIVE EFFECTS?

The affected communities have resisted development, voicing a desire to have a say in how it goes ahead. The people have adopted an attitude that the resource development process is essentially a boom-or-bust phenomena; they wish to return to more traditional ways of life when it is over. As a result, the people have strong feelings in favour of environmental protection because they wish to ensure that the fish and wildlife upon which they depend will not be depleted by development. All these mitigate against the cumulative effects.

A fuller perspective on this question can be found be reviewing the approach, or lack of approach, taken by various formal government assessment and planning activities.

Norman Wells Oilfield Development and Pipeline Project

The Norman Wells Oilfield Development and Pipeline Project was assessed under the federal Environmental Assessment and Review Process during 1980. The panel report (FEAR0 1981) did not refer to the potential of this project, and others, to have cumulative effects on northern communities. Also, the report did not explicitly consider any effects on resource harvesting, although it did mention impacts on people living off the land, employment opportunities, and fish and wildlife resources. In his post-audit of the mitigation and monitoring of the Norman Wells Project Jakimchuk (1985: 6) noted:

> *While the Norman Wells structure (for monitoring and mitigation) addressed the Panel's concerns and recommendations, it did not provide a mechanism for dealing with broader regional environmental issues.... The structure employed would not be well suited to dealing with broader problems such as cumulative impacts or regional impacts.*

Fort Good Hope is immediately downstream of the Norman Wells Project and the community voiced and continues to voice concern over the project. At present, the residents at Fort Good Hope have experienced an impairment in fish and water quality. While these problems have not been conclusively linked to the Norman Wells Project, the Dene have concerns that extend to the environmental assessment and the monitoring and surveillance activities of the project (Fee-Yee 1985).

Beaufort Sea Hydrocarbon Production and Transportation

In the Canadian Beaufort Sea, exploration for offshore oil and gas has been underway for more than a decade. Promising results.from these activities led to serious consideration being given to the production of hydrocarbons from the region. In 1980, a concept plan for production and transportation was referred to the federal Environmental Assessment and Review Process (EARP). A comprehensive environmental impact statement was produced and extensive public hearings were held in northern and southern Canada. In 1984, the Beaufort Sea Environmental Assessment Panel released their report (FEAR0 1984), with the recommendation that phased development of Beaufort Sea hydrocarbons could be compatible with sound environmental management, subject to the implementation of a substantial number of mitigation measures.

The Panel explicitly discussed impacts on the resource harvesting system in their report. They emphasized the importance of resource harvesting, the role of the traditional lifestyles as a source of meaning, identity and community stability for northern people, and the potential for change in the present way of life. While recognizing the potential for many of the cumulative effects outlined above, the Panel never received a rigorous assessment of them during its deliberations. The Panel realized that the proponent had no methods for dealing with cumulative effects and therefore recommended one, but had little success in having it implemented. The Panel's difficulty with the cumulative effects question is evident in the letter from Panel Chairman, Dr. John Tener, to the Honourable John Munro, then Minister of Indian Affairs and Northern Development. In his August 22, 1983 letter commenting on the Panel's review of the proponent's response to the Deficiency Statement, Dr. Tener stated that:

> *A number of intervenors and the Panel believe that the discussions of cumulative and synergistic effects were not as*

informative as they might have been. The Panel recognizes the difficulty in coming to grips with the subject because of the paucity of data.. .

If little was or could be done to assess the cumulative effects over all aspects of the environmental assessment, it is not surprising that the cumulative effects on resource harvesting were not explicitly considered.

Mackenzie Environmental Monitoring Program

The Mackenzie Environmental Monitoring Program (MEMP), begun in 1985, was undertaken to recommend a scientifically defensible monitoring and research program to address the potential impacts of oil and gas development in the Mackenzie Valley and Delta. While MEMP is primarily a biophysical monitoring program, it also has a substantial resource harvesting component. The approach taken by MEMP is not only relevant to the assessment of cumulative effects on resource harvesting, but to CEA in general. In MEMP the impacts on the resource harvesting system are represented by a set of impact hypotheses comprised of the causal relationships that link oil and gas activities with valued ecosystem components (Beanlands and Duinker 19433). This set of hypotheses, taken together, represent a systematic view of the potential cumulative effects on resource harvesting of oil and gas development over space arid time. At their present state of development, however, these hypotheses do not allow for structural changes in the resource harvesting system and hence the community.

Northern Land Use Planning

In January 1986, an eight-member planning commission, Northern Land Use Planning, was established for the Northwest Territories. This signalled the formal start of northern land use planning after five or more years of work to set the stage. The need for northern land use planning is well described by DIAND (1981: S.3.2.1.2):

No *regional development framework exists at present; thus industrial projects cannot be viewed in a long-term cumulative and comprehensive context, so as to maximize regional and local socio-economic benefits and minimize environmenta/ impacts; the lack of such a framework could preclude future resource use options. Coupled with this is the lack of a focused forum within which conflicting interests may be openly debated and balanced — the interests of all those affected must be considered in the decision-making process. Fundamental questions on the pace, direction, and framework for development must be addressed in the national, regional, and local context.*

Some expect that land use planning will be able to assess cumulative effects of resource development and some even would argue that land use planning has come about because of the need to assess cumulative effects of northern development. Thus far, however, all efforts have been spent on deciding who shall participate in land use planning and the overall process of developing land use plans.

The current land use planning initiative. implies much local autonomy in land allocation decisions. This may be a problem, however, in the context of cumulative effects assessment, for there is a risk in leaving all local decisions to local people. In a cursory review of literature available on the land use planning efforts over the past few years we were unable to find any explicit references to the need for cumulative effects assessment, or the means by which such effects might be assessed.

INSTITUTIONAL RESPONSE

The native people gave early recognition to, and often reiterate, the potential for cumulative effects. The need for assessing cumulative effects first crystallized during the Berger Inquiry into the Mackenzie Valley Pipeline. The evocative title of his report, *Northern Frontier Northern Homeland* (Berger 1977), suggests that the impacts of the Mackenzie Valley Pipeline Project were going to be far more significant than the ecological impacts on a northern biome. The Berger Inquiry therefore recommended a 1 O-year moratorium on development in the Mackenzie Valley until native larid claims were settled.

For the most part, the response to the cumulative effects problem has been bound up in the political development of native communities and accompanying land claims negotiations and settlements. Thus, the response of natives to the potential for cumulative effects is to acquire more power over the management of the land and its resources. Governments, in particular the Department of Indian Affairs and Northern Development (DIAND) and the Government of the Northwest Territories, have responded by attempting to keep pace with the political development of the native groups.

The more specific response of the local communities to the potential for cumulative effects on renewable resource harvesting has been to resist development. The scientific and technical community inside and outside government, save for a few social scientists, have neglected the cumulative effects on renewable resource harvesting. The failure of EARP to address the cumulative effects issues is well documented above. For the most part, the cumulative effects on the renewable resource economy were well outside their mandate.

The Northern Land Use Planning Program is a positive response to the need to manage cumulative effects. It is hoped that this program will avoid some of the adverse social, economic, and ecological impacts. But it is too early to tell whether land use planning will be able to regulate the pace of development to mitigate against the negative impacts on the resource harvesting economy in small communities. The strong response of the native people for more say over the disposition and management of the land has forced the early phases of the land use planning process to concentrate on maximizing the role and right of native people. Consequently, land use planning has dealt with very few of the substantive land use issues thus far.

Another DIAND program that involves native people as partners in discussions about renewable resource harvesting is the Mackenzie Environmental Monitoring Program (MEMP). DIAND co-sponsors MEMP along with the Department of Fisheries and Oceans, Environment Canada, the Government of the Northwest Territories, and the Yukon Territorial Government. What began as an almost purely ecological monitoring program expanded to include resource harvesting. Almost serendipitously, MEMP began to define cumulative effects of oil and gas development on renewable resource harvesting. While, like land use planning, MEMP is in its formative stages, it may provide a mechanism for better understanding cumulative effects.

CONCLUSIONS

Existing environmental assessment techniques for the North are inadequate for addressing the problems of assessing cumulative effects on resource harvesting. Thus far, proposed planning procedures have provided little evidence that they will be better.

While there is explicit recognition of the cumulative, social, and economic impacts on resource harvesting activities in general, there is little understanding of how these impacts will manifest themselves in each of the communities.

While changes in the resource harvesting system within a community may be relatively easy to observe, it is difficult to determine the exact nature of the cause because of many confounding social, political, cultural, and economic factors. This could be applicable to most social impacts, in that it may be easier to observe the cumulative effects of a number of causative factors than it is to observe the causative factors directly.

While the formal environmental assessment procedures are currently unable to address either the impacts of resource harvesting or cumulative effects in general, both the Northern Land Use Planning Process and programs like MEMP may be steps towards better methods and processes. Both programs, however, are best thought of as supporting the management of cumulative effects.

Because of the lack of data on cumulative effects or even on the effects of development on the resource harvesting system, it is difficult to criticize present thinking about cumulative effects on resource harvesting. It seems clear, however, that most of the attention by regulatory agencies has been directed towards conducting and designing resource harvesting studies. While these studies are of value for wildlife management and monitoring purposes, they will provide little information on the cumulative effects, mostly social, that may develop. More information about the social and economic structure and culture of communities is required before cumulative effects can be assessed.

At present there are few techniques for assessing the social and economic impacts of development on resource harvesting; thus, there are even fewer techniques that show promise for the assessment of cumulative effects, This is obviously an area where more research is required.

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APPENDIX B

U.S. EXPERIENCE IN CUMULATIVE EFFECTS ASSESSMENT

U.S. EXPERIENCE IN CUMULATIVE EFFECTS ASSESSMENT

J.C. Truett

HISTORICAL RESPONSES TO CUMULATIVE EFFECTS

Responses to cumulative effect situations, such as flooding and soil erosion, have a long if undistinguished history in American experience. One public response took the unaccustomed form of regional planning: the Tennessee Valley Authority. Other regional planning responses that have been less successful are the Bonneville Power Administration in the Pacific Northwest, the river basin commissions of the 1950s, and regional commissions of the 1960s.

The environmental movement itself may be viewed as a response to the perception of cumulative effects, beginning in the early 1960s with the publication of Rachel Carson's *Silent Spring* and punctuated by such events as strip mining at Black Mesa and the Santa Barbara oil spill. Environmental quality as a cause was "available," tangible, and ubiquitous. Moreover, concrete and direct action could be taken in expressing and alleviating environmental concern (e.g., clean-up campaigns, recycling drives). The concerns of this constituency eventually became embodied in federal legislation, conspicuously the National Environmental Protection Act (NEPA).

In the early 1970s, environmental concern focused on the issues associated with urban sprawl. But these issues were later eclipsed by the "energy crisis" of 1973 and the economic recession in the late 1970s. Nevertheless, in areas of high density and amenity, the question of desirable, equitable, and sustainable growth endures; most recently it has surfaced in the form of concern over hazardous and toxic waste materials and sites.

LEGISLATIVE REQUIREMENTS FOR CEA

National Environmental Policy Act (NEPA)

The principal authority for EIA of any description is the NEPA of 1969. Several of its provisions bear on the question of cumulative effects assessment:

- the "irreversible and irretrievable commitment of resources" as a criterion of impact assessment; and
- interdisciplinarity, in the "integrated use of the natural and social sciences and the environmental design arts."

The practical effect has been to elevate environmental quality to a rank comparable with national economic development, at least in certain areas of policy application (e.g., wetlands preservation). The main feature of NEPA relevant to CEA, however, is the mandate for programmatic (generic) assessment.

Programmatic (Generic) Environmental Impact Assessment

Programmatic EIAs came into being in the mid-1970s (e.g., Energy Research and Development Administration's (ERDA) liquid metal fast breeder reactor EIS). This development was "forced" by intervenors' motivation to raise policy issues before the range of choice was reduced to siting rather than energy system type. Within the programmatic approach, project EISs were to be accomplished on an as needed basis, but within the guidelines proposed by the generic EIS (i.e., a tiered approach). It was believed that this procedure would "streamline" the EIA process under NEPA, speeding approvals and sparing costs of lengthy report preparation.

Authorizations Other Than NEPA

Although NEPA has come to symbolize environmental legislation in the United States, it by no means stands alone. Indeed, where cumulative effects assessment is concerned, authorizations such as the Clean Air Act and the Federal Water Pollution Control Act Amendments of 1972 are far more relevant and effective. Section 208 became the main impetus for comprehensive assessment and management implemented to date by a federal authority (i.e., areawide assessment; SOM et *al.* 1981). Other provisions for comprehensive planning, such as the "701" program under Section 208 (administered by the Environmental Protection Agency (EPA)), have, on occasion, taken explicit account of cumulative effects, although targeted for disadvantaged segments of the community (themselves expressions of cumulative effects in regard to equity).

SELECTED CASE EXAMPLES

Recent work funded by the U.S. Fish and Wildlife Service (Horak et *al.* 1983a, b; Cline et *al.* 1983) has provided fairly comprehensive reviews of the state of the art of cumulative effects assessment related to fish and wildlife issues in the United States. This review (summarized in Table A-3) includes discussions of attempts to conduct, or derive approaches to, cumulative effects analysis in a broad range of biophysical disciplines. Following is a case-by-case summary of four of the projects reviewed by these authors and two additional studies that have taken place since their reviews. General objectives, disciplines included, and the approaches used for each case are briefly described.

Table B-l
Summary of Ongoing Cumulative Impact Related Studies (from Cline et *al.* 1983)

Title	Sponsoring Organization	Objectives
Cumulative Watershed Impacts Study, Sierra National Forest	USDA Forest Service	A professional assessment of the sensitivity of landforms to timber management and related activities, effects of timber management activities on the fluvial system and beneficial uses of water, and recommendations for further study.
Determination of Possible Cumulative Effects of Forestland Management Activities	Washington Forest Practices Board; Washington Department of Natural Resources	Objectives are to: (1) develop a clear definition of cumulative effects, (2) identify the state-of-the-knowledge on cumulative effects, and (3) identify areas for future research and field investigations.
Secondary Impacts of Oil Shale and Coal Development in Rural Areas on Fish and Wildlife Resources	U.S. Fish and Wildlife Service's Western Energy and Land Use Team	The proposal presented here addresses the entire scope of work requested by the Fish and Wildlife Service. Phase I of the study will develop a set of planning procedures to identify and quantify (where possible) and help solve the types of secondary impact problems which typically could occur at boomtown locations in energy development areas. Users of these procedures are assumed to be resource planners and administators. Phase II of the study will apply the procedures on two sites, a coal mine and an oil shale development area.
Consortium on Energy Impacts, Research Program Plan (draft)	Planning phase: Andrew Mellon Foundation; CSI Member Institutions; Various energy companies	To identify and outline approaches to important research opportunities
Oil Shale Risk Analysis Project	U.S. Department of Energy, Oil Shale Task Force	Analyse the potential human health and environmental risks of a hypothetical one-million-barrels-per-day oil shale industry for the purpose of identifying research needs.
Cumulative Environmenal Impact Study	Colorado Department of Health and U.S. Environmental Protection Agency, Region VIII	Assess the cumulative environmental impacts of oil shale production and other energy developments in northwestern Colorado, based on two or more production scenarios and the associated population growth. During the first year the following tasks are to be completed: (1) gather and assess existing environmental data; (2) identify additional data needs; (3) inventory and assess completed or ongoing studies; (4) analyse data, studies and models; (5) develop methods for assessing cumulative environmental impacts; (6) prepare a first-cut assessment of the cumulative impacts; and (7) define the elements of a continuing program. Subsequent years, depending on funding and resources, will consist of gathering needed data, improving assessment techniques, including models and publishing cumulative environmental impact reports.
State Cumulative Impact Task Force (Colorado)	Colorado Department of Local Affairs and Department of Natural Resources	(1) To prepare cumulative impact assessments for energy development in northwestern Colorado; and (2) to provide a planning tool for the individual participants and the region
Integrated Basin Model	U.S. Fish and Wildlife Service	Predict habitat responses to water development influences for both individual and multiple projects over time

Subject Areas	Geographic Scope	Time Frame	Funding
Effects of timber management on physical processes in granitic terrain	Sierra National Forest, California	1982- 1983	currently under bid
Environmental effects on fish and wildlife, air, water, and earth	Primarily Washington	1982- 1984	115.5 K
Socio-economic effects, land disturbance, wildlife effects, mitigating measures	Wyoming, Montana, Colorado, North Dakota, Arizona, New Mexico, Utah	1981-1983	150 K
Air quality, water resources, human and community impacts, ecology	Intermountain West	1982-1987	27 million, if totally funded
Environmental exposure, population at risk, human health effects, human health and ecosystem risk	Northeastern Utah and northwestern Colorado	1981-	400 K
Land, air quality, water quality, solid wastes, noise	Delta, Garfield, Messa, Moffat, Rio Blanco, and Routt Counties in Colorado and those projects in Utah that may impact Colorado environmentally	1981-1982	4.0 FTE, during year
Socio-economic impacts	Delta, Garfield, Mesa, Moffat, Rio Blanco, and Routt Counties in north-northwestern Colorado	1981-	
Colorado squawfish and its habitat, water temperature, flow	Upper Colorado Basin, Colorado, Utah, Wyoming	1981-1982	150K

Table B-1 Continued

Title	Sponsoring Organization	Objectives
Implementation Strategies for a Wildlife Master Plan Dealing with Oil Shale Development	Colorado State University, National Wildlife Federation, and U.S. Fish and Wildlife Service	Determine and evaluate mechanisms to implement a wildlife conservation strategy in northwestern Colorado; determine feasibility
Analysis of Cumulative Impacts of the Corps' Regulatory Program	U.S. Army Corps of Engineers' Institute for Water Resources	Develop methods for cumulative impact analysis
Socio-economic Component of Oil Shale Development in Colorado, Wyoming and Utah	Bureau of Land Management	Develop the capability to analyse economic consequences from alternative oil shale development on public lands (site-specific regional or programmatic issues)
Social Effects Projects	Bureau of Land Management	Develop more effective means of addressing the social effects of coal development
Wildlife Impact Study	Northwest Colorado Wildlife Consortium	Phase I. Compile and analyse existing information on (1) wildlife populations and habitats in northwestern Colorado, and (2) methods for predicting and mitigating cumulative, regionwide, wildlife impacts associated with energy development in northwestern Colorado
Overthrust Industrial Association Cooperative Wildlife Program	Overthrust Industrial Association	1. To aid land and wildlife management personnel by providing additional scientifically valid data as well as management recommendations; 2. To assist industry planners and environmental experts by providing data which will identify potential land use issues; and 3. To assist industry planners and environmental experts by providing a wide range of solutions to lessen the effects of increased human activity, and costs associated with these solutions.

Subject Areas	Geographic Scope	Time Frame	Funding
Decision processes, wildlife information needs, decision makers	Five counties in northwestern Colorado	1981-1982	10 K
Wetlands, and use impacts, socio-economic impacts, environmental perfomance indicators	National	1978-1982	500 K
Socio-economic parameters	Northwestern Colorado, southwestern Wyoming, and nothwestern Utah	1981-1982	196 K
Socio-economic impacts	Colorado, Montana, New Mexico, North Dakota, Utah, and Wyoming	1980- 1982	200 K
(1) Big game (2) furbearers, small game mammals, and varmints; (3) waterfowl, other migratory birds, and upland game birds; (4) fishes — game and nongame; (5) nongame mammals; (6) nongame birds; (7) nongame reptiles and amphibians; (8) molluscs and crustaceans; (9) terrestrial ecosystems; (10) aquatic ecosystems; (11) wildlife impact predicting (primary and secondary), assessment monitoring and mitigation; (12) built environment and socio-economic impacts; (13) reclamation and rehabilitation; (14) laws, regulations and policies.	Moffat, Routt, Rio Blanco, Garfield and Mesa Counties in northwestern Colorado	1981-1983	200 K (year 1) 160 K (year 2)
Will be defined during scoping activity; however, studies that will be prioritized in the scoping phases will: 1. determine the relationships of increased human activity on terrestrial and aquatic species within the study areas, with special emphasis on key species of high state interest as identified and prioritized during the scoping phase; 2. determine areas of environmental sensitivities, such as winter habitats of priority species; 3. determine by type of species what effects, if any, there have been or might be on terrestrial and aquatic habitat caused by the increased human activity in the study area:	Uinta and Lincoln Counties, Wyoming; Summit and Rich Counties in Utah; and Bear Lake County in Idaho	1981-1985	800 K wildlife study 160 K enforcement officers, and 40 K on environment awareness program

Table B-1 Continued

Title	Sponsoring Organization	Objectives
Resource Management Plan or Management Framework Plan Amendment EISs	Bureau of Land Management	To analyse both the site-specific and cumulative environmental impacts of alternative levels of oil shale leasing and of different combinations of traits. Will also consider the probable levels of ongoing or proposed developments.
Climate and air quality analysis for the Powder River Basin Coal EIS	Bureau of Land Management	To prepare a comprehensive regional environmental impact statement to analyse the poential impacts of the federal coal-leasing program which will involve the mining, processing, transportation, and utilization of coal in the Powder River Basin region,

Subject Areas	Geographic Scope	Time Frame	Funding
4. determine whether affected habitat aeas are associated with altered distributions of wildlife species;			
5. update species occurrence and abundance data in terrestrial or aquatic habitats through field study, literature review and data analysis;			
6. define specific effects — both direct and indirect — to these individual habitats: and			
7. identify potential conclusions from the data and provide an initial range of management alternatives.			
Environmental effects	Colorado, Utah, Wyoming	1982- 1984	
Air quality, climate	Colorado, Wyoming, Montana	1982-1983	under bid; estimated cost 150 K-200 K

Impact of Oil Shale and Coal Development in Rural Areas

This study, sponsored by the U.S. Fish and Wildlife Service (USFWS) Western Energy and Land Use Team, and conducted by Midwest Research Institute, focused on predicting secondary impacts on fish and wildlife during proposed oil shale and coal development activities in the Rocky Mountain West. Methods included interviews with selected government personnel in order to assist in the quantification of secondary impacts. An impact table was prepared from information obtained, then a map overlay technique was used to forecast impacts. The authors present a technique for rating impacts on fish and wildlife in which the number of acres is multiplied by the value of the resource and by the impact severity. The procedures described above were revised and field-tested in late 1982 and early 1983 (Thomas et *al.* 1982).

Oil Shale Risk Analysis Project

This project was sponsored by the U.S. Department of Energy, through the Health and Environmental Risk Analysis Program, and co-ordinated through the Oil Shale Task Force. The project's goal was to quantify health and environmental risks from the proposed oil shale industry and from this basis identify research needs.

The first report (IWS Corporation and Center for Environmental Studies 1981) stated that ecosystem risk should be related to desirable ecosystem community traits such as stability, resilience, and productivity. Because species diversity provides a measure of post-disturbance community composition and structure, it can be used as a predictive tool. The risks to designated species (e.g., mule deer for terrestrial communities and trout for aquatic communities) were estimated to illustrate the use of quantitative techniques. These selections were made because of data availability and high public interest associated with those species.

The 1982 report (IWS Corporation 1982) documents a review of that procedure. During the ecosystem 'risk session, participants concluded that community diversity is not a good measure of ecosystem risk because it is not clear what a change in diversity means. The following alternative approach was proposed:

- develop a short representative list of important animal species and plant communities;
- obtain all literature available concerning the communities and species on the list;
- determine the effect of development on each community or species on the list, using productivity/niche relationships if possible; and
- if the preceding step cannot be accomplished with available information, recommend initiation of field studies to fill in data gaps.

U.S. Corps of Engineers' Regulatory Program

Since 1978, the Institute for Water Resources of the U.S. Army Corps of Engineers has been developing a manual of methods for cumulative impact analysis. The handbook (Dames and Moore 1981) presents methods for recognizing certain patterns of growth and development and associating individual, incremental permit actions within the growth pattern. The method, aimed at the permit processor, is centered around a system for tiering the analysis to the level and depth determined by project complexity. Three basic tiers are employed with a fourth or special tier for programmatic analysis, applicable to the general permit process. Concurrent with the development of a handbook, case studies are being performed (i.e., Chesapeake Bay Permits Atlas; see Kimball et *al.* 1982; environmental performance indicators; and field testing applications) and techniques are being refined (i.e., permit forecasting econometrics, land use analysis and impacts, and socio-economic impacts).

U.S. Fish and Wildlife Service Integrated Basin Model

The Instream Flow and Aquatic Systems Group of the U.S. Fish and Wildlife Service is developing an integrated basin model involving physical habitat and water temperature, quantity, and quality models. The water temperature model simulates the impacts of reservoir release temperatures on downstream water temperatures. The physical habitat model was developed to simulate physical habitat in relation to flow regime, water quality, and physical structure of streams (depth, velocity, substrate, and temperature). A pilot project is being conducted for the Upper Colorado River Basin related to the issue of new reservoirs and their effect on an endangered fish species, Colorado squawfish. The integrated model traces downstream habitat changes from upstream disturbances. The aim of the model is to predict habitat responses to water development influences for both individual and multiple projects over time.

New Mexico Cumulative Hydrologic Impact Assessment

In 1984, a Hydrology Task Force for the New Mexico Energy and Minerals Department developed recommendations and procedures for cumulative hydrologic impact assessment (CHIA) in New Mexico (New Mexico Hydrology Task Force 1984), particularly on projects related to surface mining of coal. The key elements in CHIA are as follows:

- Define surface and groundwater cumulative impact areas (CIAs). The delineations are based on the geographical boundaries of potentially affected groundwater strata and surface water systems.
- Identify baseline hydrologic conditions in each CIA, in terms of surface water, groundwater, and geomorphic characteristics.
- Assess impacts by predicting future hydrologic effects of existing water uses and then factoring in each new additional use (by simple addition of water required or by

independent modelling assessment). Separate cumulative assessments may be required for the quantity and quality of surface water and groundwater and for geomorphic conditions.

- Assess potential damage of each new water use by modelled projection of effects on the hydrologic systems in the CIA. Specific criteria for measuring impact to water quality and quantity and to geomorphic structures are yet to be established.

Cumulative Impact Assessment in a Coastal Wetland

The Institute of Urban and Regional Development at the University of California at Berkeley (Dickert and Tuttle 1985) has developed an assessment of changes in the hydrologic and sedimentological regime of a California estuary caused by changing land use patterns and episodic natural events. Their study accounted for both spatial and temporal variations in land use and runoff events by:

- using spatial boundaries defined by the watershed and subwatersheds as the planning and analysis units;
- deriving a historic trend in watershed land use and wetland change based on interpretations of historical aerial photographs; and
- accounting for the occurrence of the most catastrophic episodic event of hydrology (a 100-year flood) in their analysis period.

Their use of historical data for capturing past change provided a rough evaluation of the cumulative effects on the estuary of various levels and kinds of land use in the basin. Thus, it will enable them to predict general effects of future changes in land use.

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APPENDIX C

SUGGESTIONS FOR NEW DIRECTIONS

SUGGESTIONS FOR NEW DIRECTIONS

SCALES OF ASSESSMENT

As implied throughout this paper, rapid progress in cumulative effects assessment will probably require drastically different approaches from those now being used. This, in turn, may require the creation of entirely new government or quasi-government institutions free of the mandates and traditions that now constrain new directions of thought. A few suggestions for different ways of approaching cumulative effects assessment are described here. A basic premise to be followed in all proposed approaches is that society desires to maintain, at the very least, environmental renewability. That is, actions taken now, though they may bring about change, should not limit options for the future.

Scales of Impacts

The difficulty of conducting cumulative effects assessments is proportional to the associated scales of human activities, space, and time. We propose that different approaches be used at different scales of complexity. To illustrate, we will define two levels of the cumulative effects assessment problem: complex and simple.

Complex cases as defined here involve many (scores, hundreds or thousands) development projects, the impacts of which extend nationally or internationally, and may affect environments for scores or even hundreds of years: Simple cases are characterized by impacts of one or a few development activities confined to a small area, such as a county or township, and are limited to perhaps a decade of operation.

Strategies for Complex Cases

Given that large scales of activity, time, and space introduce unavoidable complexity, the objective in cumulative effects assessment should be to reduce the environmental variables of interest to the most basic measures of what people value now. In addition, society could choose to maintain "renewability" of environmental components for future generations who might have values differing from current generations. The following list of variables shows examples of the kinds of parameters that might be measured for change.

- Genetic Diversity: Maintenance of genetic diversity implies maintenance of viable species populations. Emphasis should thus be placed on rare and endangered species.
- *Landscape Integrity:* The ability of an area to support specific plant and animal communities, as well as its aesthetic appeal, may depend on topography — hills, canyons, floodplains — implying that impacts to these may have impacts on ecosystem renewability.
- *Water Regime Integrity:* Surface and groundwater regimes are important environmental attributes to people directly as well as to the maintenance of ecosystems.
- *Soil and Water Fertility:* Fertility of soil and water determines which plants and animals can occupy areas and what levels of primary and secondary productivity can be attained.
- *Climatic Stability:* Another basic factor that determines habitability of an area for plants and animals (including humans) is the climatic regime.
- *Levels of Toxins or Toxin-like Components:* It is obvious that renewability of ecosystems depends on the absence of toxic concentrations of chemicals, as well as adverse temperature ranges and radioactivity levels.

Given these basic measures, and perhaps a few others, it is probable that changes in environmental renewability can be monitored and cumulative effects on renewability assessed. Note that nearly all of these variables require physical/chemical (not biological) measures; gene pools are one exception. As discussed in earlier sections of this report, measures of physical and chemical parameters are much more common than measures of biological variables in successful cumulative effects analysis programs.

Because impacts in these complex cases occur widely in space and time, national or international institutions should be responsible for CEA programs at this level. And, because the variables listed above are good worldwide indicators of environmental renewability, it should be possible for international agreements to be reached on how to measure changes in them. Indeed, there is already some level of consensus about measures of gene pool and species endangerment, toxicity levels of various substances, indicators of climatic stability, and so forth.

Strategies for Simple Cases

Assessment studies of cases that are highly restricted in space, time, and levels of human activity can examine greater numbers of environmental variables. Some assessments of environmental variables can be handled with existing methodologies, in which impacts on individual species, species groups, or human uses of the ecosystem can be assessed by experimentation or well-informed judgment in combination with ecosystem models and the like. Conflicts among various users may even be sufficiently few that agreement can be reached on what impacts are acceptable.

Existing evidence suggests, however, that even many simple cases of cumulative assessment may prove too cumbersome for standard types of analyses such as species-oriented, activity-by-activity, mapping, or impact-additive. Below, we suggest three kinds of deductive logic that may help streamline the treatment of many environmental variables in these simple cases; we call them time-comparison, space-comparison, and jurisdiction.

- *Time Comparisons:* Frequently, by comparing projected environmental and development conditions in an area with various known historical conditions, reasonable judgments may be made about the probable environmental consequences of the cumulative impacts of expected development. Dickert and Tuttle (1985) applied this technique in a California watershed. This is typically the kind of mental exercise we go through to develop initial hypotheses about impacts of activities.

- *Space Comparisons:* Landscapes are typically not uniformly developed in space. By examining environmental consequences of human activities in heavily developed areas, one can frequently develop a reasonable hypothesis about what the future consequences of development might be in a presently undeveloped or lightly developed area. Similar to historical comparisons (above), this is already, in the absence of other data, frequently the basis for many impact assessment judgments.

- *Jurisdiction:* Unlike the proposed cumulative assessment strategy for complex cases, simple cases may require many value judgments to determine whether impacts are acceptable, or which mitigative measures would be most appropriate. These issues are, in most cases, rightly decided in the local arena, because the local people have to live with the changes that occur. It should be determined in such cases, however, that local choices will cause no adverse long-term or extraregional consequences to the basic "renewability" indicators (see the section "Strategies for Complex Cases," above).

There is a danger in leaving all local decisions to local people; human beings are short-sighted, valuing only the environmental attributes to which they are accustomed or that provide income. The nibbling impact of cumulative effects, coupled with the human tendency to be reasonably satisfied so long as immediate options do not diminish greatly from previous experience, may allow drastic reductions in local choices over several generations before people feel or express dissatisfaction. But, perhaps this is acceptable as long as the basic factors that guarantee long-term renewability are preserved.

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APPENDIX D

WORKSHOP PARTICIPANTS

VANCOUVER WORKSHOP PARTICIPANTS

5 – 6 February 1986

Name	Affiliation	Phone
David Bernard	ESSA Ltd., Vancouver, British Columbia	(604) 689-29 12
Sally de Becker	Pacific Gas & Electric Co., San Ramon, California	(4 15) 820-2000
Anthony Dorcey	Westwater Research Centre, University of British Columbia, Vancouver, British Columbia	(604) 228-5725
Ike Ellison	U.S. Fish & Wildlife Service, Fort Collins, Colorado	(303) 226-943 1
Robert R. Everitt	ESSA Ltd., Vancouver, British Columbia	(604) 689-29 12
C.S. Holling	Institute of Resource Ecology, University of British Columbia, Vancouver, British Columbia*	(604) 228-6677
Richard Johnson	U.S. Fish & Wildlife Service, Fort Collins, Colorado	(303) 226-943 1
David Marshall	Federal Environmental Assessment Review Office, Vancouver, British Columbia	(604) 666-6989
William A. Ross	University of Calgary, Calgary, Alberta	(403) 220-696 1
Barry Sadler	Canadian Environmental Assessment Research Council; Institute of the North American West, Victoria, British Columbia	(604) 477-8752
Peter Sagert	CIRRUS Consultants, Vancouver, British Columbia	(604) 980-0949
Jon Secter	British Columbia Ministry of the Environment, Vancouver, British Columbia	(604) 387-444 1
Nicholas Sonntag	ESSA Ltd., Vancouver, British Columbia	(604) 689-29 12
J.C. Truett	LGL Ecological Research Associates, Flagstaff, Arizona	(602). 526-5055
John Wiebe	Environment Canada, Vancouver, British Columbia	(604) 666-5885
C.P. Wolf	Social Impact Assessment Center, New York, New York	(2 12) 966-2708

MONTREAL WORKSHOP PARTICIPANTS

13 – 14 February 1986

Name	Affiliation	Phone
Gordon Baskerville	Faculty of Forestry, University of New Brunswick, Fredericton, New Brunswick	(902) 424-7044
Gordon Beanlands	Canadian Environmental Assessment Research Council; Federal Environmental Assessment Review Office, Halifax, Nova Scotia	(902) 424-7044
Pille Bunnell	ESSA Ltd., Vancouver, British Columbia	(604) 689-29 12
Ray Coté	School of Research and Environment Studies, Dalhousie University, Halifax, Nova Scotia	(902) 424-3632
Floyd Elder	National Water Research Institute, Canada Center for Inland Waters, Burlington, Ontario	(4 16) 336-4969
Robert R. Everitt	ESSA Ltd., Vancouver, British Columbia	(604) 689-29 12
Michael Gariepy	Universite de Montreal, Montreal, Quebec	(5 14) 343-7846
Patricia Lane	Dalhousie University, Halifax, Nova Scotia	(902) 424-6527
Robert Malvern	Ontario Hydro, Toronto, Ontario	(4 16) 592-407 1
Fred Meth	New Brunswick Power, Fredericton, New Brunswick	(506) 458-3266
Josie Quintrell	Marine Law Institute, Portland, Maine	(207) 780-4474
Nicholas Sonntag	ESSA Ltd., Vancouver, British Columbia	(604) 689-29 12
Gregg Weary	Andre Marsan and Associates, Montreal, Quebec	(5 14) 866-445 1
C.P. Wolf	Social Impact Assessment Center, New York, New York	(212) 966-2708

WINNIPEG WORKSHOP PARTICIPANTS

8 – 9 April 1986

Name	Affiliation	Phone
Bryon Blunt	Manitoba Environment, Winnipeg, Manitoba	(204) 945-7085
Drew Bodaly	Department of Fisheries and Oceans, Winnipeg, Manitoba	(204) 949-5218
Mark Boreskie	Provincial Planning Branch, Winnipeg, Manitoba	(204) 945-3186
Robert R. Everitt	ESSA Ltd., Vancouver, British Columbia	(604) 689-2912
Ted Langtry	Department of Indian Affairs and Northern Development, Hull, Quebec	(819) 997-9090
David Marshall	Federal Environmental Assessment Review Office, Vancouver, British Columbia	(604) 666-2431
Michael McKervan	MacLaren Plansearch Inc., Winnipeg, Manitoba	(204) 477-6650
Jon O'Riordan	British Columbia Ministry of Environment, Vancouver, British Columbia	(604) 387-4441
Barry Sadler	Canadian Environmental Assessment Research Council; Institute of the North American West, Victoria, British Columbia	(604) 477-8752
Nicholas Sonntag	ESSA Ltd., Vancouver, British Columbia	(604) 689-2912
John Wiebe	Environment Canada, Vancouver, British Columbia	(604) 666-5885
Robert Weir	Conservation & Protection, Environment Canada, Hull, Quebec	(819) 997-1731
C.P. Wolf	Social Impact Assessment Center, New York, New York	(212) 966-2708
David Wotton	Manitoba Environment, Winnipeg, Manitoba	(204) 945-7081

CANADIAN ENVIRONMENTAL ASSESSMENT RESEARCH COUNCIL

1987

Audrey Armour
Assistant Professor
Faculty of Environmental Studies
York University
4700 Keele Street
North York, Ontario
M3J 1P3

Gordon Baskerville
Dean, Faculty of Forestry
University of New Brunswick
New Forestry Building
Fredericton, New Brunswick
E3P 6C2

Robert K. Bell
R. Bell and Associates
Norplan Consultants
P.O. Box 228
1632 La Ronge Avenue
La Ronge Saskatchewan
SOJ 1L0

Raymond J. P. Brouzes
Director, Environmental Affairs
Alcan Aluminum Limited
1188 Sherbrooke Street
Montreal, Quebec
H3A 3G2

Katherine S. Davies
Department of Public Health
City of Toronto
New City Hall
100 Queen Street
Toronto, Ontario
M5H 2N2

Richard Hoos
Director, Environmental and
Socio-Economic Services
Dome Petroleum Limited
P.O. Box 200
12th Floor, First Canadian Centre
620 Third Street S.W.
Calgary, Alberta
T2P 2H8

Peter Jacobs
Universite de Montreal
Faculté de l'Aménagement
5620 Darlington Avenue
Montreal, Quebec
H3T 1T2

Andre Marsan
Biotechnology Research Institute
6100 Royal Mount Avenue
Montreal, Quebec
M4P 2R2

Jon O'Riordan
Director of Planning
Ministry of Environment
Government of British Columbia
3rd Floor
777 Broughton Street
Victoria, British Columbia
V8W 1E3

Grace Patterson
Vice Chairperson
Environmental Assessment Board
1 St. Clair Avenue West
Toronto, Ontario
M4V 1K7

Nicholas Poushinsky
Special Advisor to the Minister
Health Care Reform
7th Floor, 175 Hargrave Street
Winnipeg, Manitoba
R3C 0V8

Fred Roots
(Chairperson, CEARC)
Science Advisory
Environment Canada
23rd Floor, North Tower
Les Terrasses de la Chaudiere
Hull, Quebec
K1A OH4

CEARC SECRETARIAT

Gordon E. Beanlands
(Executive Secretary, CEARC)
Director of Research
Federal Environmental Assessment
Review Office
1318 Robie Steet
Halifax, Nova Scotia
B3H 3E2

M. Husain Sadar
Scientific Advisor
Federal Environmental Assessment
Review Office
13th Floor, Fontaine Bldg.
200 Sacre-Cceur Blvd.
Hull, Quebec
K1A OH3

Robert G. Connelly
Acting Director General
Policy and Administration
Federal Environmental Assessment
Review Office
13th Floor, Fontaine Bldg.
200 Sacre-Cceur Blvd.
Hull, Quebec
K1A OH3

Barry Sadler
Director, Institute of the
North American West
163 1 Barksdale Drive
Victoria, British Columbia
V8N 5A8

Mary Margaret Healy
(Administrative Support, CEARC)
Federal Environmental Assessment
Review Office
13th Floor, Fontaine Bldg.
200 Sacré-Cœur Blvd.
Hull, Quebec
K1A OH3

Robert H. Weir
Chief, Environmental Impact
Systems Division
Conservation and Protection
Environment Canada
15th Floor, Place Vincent Massey
351 St. Joseph Blvd.
Hull, Quebec
K1A 1C8

Elisabeth J. Marsollier
(Manager, CEARC)
Federal Environmental Assessment
Review Office
13th Floor, Fontaine Bldg.
200 Sacre-Cceur Blvd.
Hull, Quebec
K1A OH3