ASSESSING PROGRESS TOWARD SUSTAINABILITY: DEVELOPMENT OF A SYSTEMIC FRAMEWORK AND REPORTING STRUCTURE

Volume 1. Main Text

Volume 2. Appendices

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VOLUME 1. MAIN TEXT

STATEMENT OF ORIGINAL CONTRIBUTION

The original contribution of this dissertation includes the following.

1. The articulation of a broadly-based value set underlying the concepts of sustainability and sustainable development.

2. The development of a conceptual framework for guiding systemic assessment and reporting on progresss toward sustainability that reflects this value set, is consistent with systems theory and is influenced by ideas drawn from state-of-environment reporting, macroeconomics, and thirty theoretical models that address the human-ecosystem relationship.

3. A demonstration of the proposed systemic approach to assessing and reporting progress toward sustainability with a case study of the Great Lakes Basin Ecosystem.

ABSTRACT

The purpose of this dissertation is to propose a conceptual framework that can guide assessing and reporting on sustainability. The framework is rooted in a particular value set, is consistent with systems theory, and serves to focus indicator choice. Its development is influenced by a literature review that includes 220 state-of-environment reports, several key aspects of economic thought, and thirty theoretical models that address the human-ecosystem relationship.

Four strategic elements that serve as areas of diagnosis or indicator domains are identified including (I) ECOSYSTEM; (II) INTERACTION; (III) PEOPLE; and (IV) SYNTHESIS. Each domain is linked to a set of goals and objectives. For each domain, an assessment hierarchy is mapped out and example indicators are provided. The reporting system must be tailored to the needs of different decision-making groups.

The practicality of the system is demonstrated in a case study of the Great Lakes Basin Ecosystem and related regional decision-making. An overview first considers each of the four domains and provides a systematic assessment of progress toward sustainability. Detailed analyses of the energy and water sub-systems are then provided. Lastly, recommendations for further system development and for follow-up research are offered.

SOMMAIRE

L'objet de la présente thèse est de proposer un cadre conceptuel permettant de guider l'élaboration des rapports faisant état des progrès vers la pérennité. Fondé sur un ensemble particulier de valeurs, ce cadre s'inspire de la théorie des systèmes et sert à orienter le choix des indicateurs. Le développement de l'étude est influencé par une revue des écrits qui englobe quelque 220 rapports sur l'état de l'environnement, plusieurs aspects clés de la pensée économique et 30 modèles de relations entre les humains et l'écosystème.

Quatre éléments stratégiques servent à tracer les grandes lignes du diagnostic ou séries d'indicateurs: I. l'ÉCOSYSTÈME, II. l'INTERACTION, III. les INDIVIDUS, et IV. la SYNTHÈSE. Chacune de ces séries d'indicateurs est reliée à un ensemble de buts et d'objectifs. Une hiérarchie de l'évaluation et des exemples d'indicateurs sont alors établis pour chaque série. Dans son application, le système de rapports doit être adapté aux besoins des différents groupes décisionnels.

La valeur concrète de ce système est démontrée dans une étude des cas se rapportant à l'écosystème du bassin des Grands Lacs. On y présente d'abord un aperçu de chacune des quatre séries d'indicateurs puis on y fait une évaluation systématique des progrès accomplis vers la pérennité. Des analyses détaillées de sous-réseaux énergétiques et hydrographiques viennent ensuite étoffer la démonstration. Enfin, des recommandations visant le développement plus poussé du système et la poursuite des recherches sont offertes.

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PUBLICATIONS COMPLETED DURING THE PERIOD OF DOCTORAL STUDIES AND CONTRIBUTING TO THIS DISSERTATION

A. REFEREED JOURNAL ARTICLES

Hodge, R.A. and A. J. Roman, 1990. "Groundwater Protection Policies: Myths and Alternatives." *Ground Water*, 28.4 498-504.

Hodge, R.A., 1989. "Groundwater in the Great Lakes Basin: The Natural System, Use and Abuse, and Policy Implications." *Chicago-Kent Law Review* 65.2, 439-464.

B. NON-REFEREED JOURNAL ARTICLES, ABSTRACTS

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C. REPORTS

NRTEE, 1993. *Toward Reporting Progress on Sustainable Development in Canada - Report to the Prime Minister.* Ottawa: National Round Table on the Environment and the Economy. Task Force Chair and principal report author.

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DEDICATION

A project such as this touches many people. But those it touches most are my family who shoulder all the downs while not always being able to share in the ups. At project start, we were two, Ingrid and I. By project mid-point, we had been joined by Daniel-Francis and Tanya-Dominique. For the nourishment all three have provided and the future they represent, I dedicate this dissertation to them.

CHAPTER ONE

INTRODUCTION

In 1987 the World Commission on Environment and Economy made its call for a shift to sustainable development (WCED, 1987). In turn, many individuals and organizations identified the need for new ways of assessing progress. The Ontario Round Table on Environment and Economy puts it succinctly:

> How can we effectively move towards sustainability? . . . To measure our effectiveness, we require indicators of sustainability, and targets and timetables for such indicators.
>
> (ORTEE 1990, 13)

And in a similar vein, the British Columbia Round Table on the Environment and the Economy states:

> The provincial government . . . should assign an urgent priority to the development of sustainability indicators. These indicators should . . . replace the narrow set of economic indicators that are currently used to measure an economy's state of health.
>
> (BCRTEEb 1993, 72)

This is not the first time that effort has been put to developing improved indicators of progress. Earlier approaches can be traced in the literature relating to economics, social indicators, quality of life, natural resources and environment, health, and healthy communities. A dominant theme is a concern regarding the overemphasis on economic indicators and a criticism of the use of gross national/ domestic product as an overall measure of progress.

In each case a pattern that includes an initial surge of interest in indicator development followed by a subsequent loss of momentum can be identified. And while useful insights can be drawn from each body of related literature, no widely accepted new indicators have resulted.

The cause of this re-occurring pattern is at least partly related to the lack of any overall strategic approach that can frame and direct any system of monitoring, assessing and reporting on progress. In the absence of such a framework, indicator choice is made in response to current issues of concern. While doing so can be useful for tracking the results of specific policy initiatives aimed at addressing these concerns, it does not provide a basis for anticipating and dealing with issues before they become crises.

Such an anticipatory capability lies at the very core of the linked ideas of sustainability and sustainable development. These ideas provide a conceptual base that was not available to workers involved with the previous effort on indicator development noted above. This dissertation starts with the ideas of sustainability and sustainable development and:

1. develops, using a systems approach, a conceptual framework for assessing and reporting on progress toward sustainability;

2. proposes an integrated system of reporting on sustainability for use in support of improved decision-making for four decision-making groups: (1) individuals, families, households; (2) corporations and corporate groupings; (3) communities and settlements; and (4) regional, provincial, territorial, and national governments;

3. reviews the indicators related literature and suggests example indicator sets and specific measures;

4. illustrates the proposed system of assessing progress toward sustainability in a case study of the Great Lakes Basin Ecosystem;

5. synthesizes the results and make recommendations for follow-up research.

The power of the idea of sustainability lies in its ability to offer a bridging mechanism both in terms of an intellectual link between disciplines as well as a practical link between traditionally disparate groups within society. Thus, in all aspects of attempting to bring this idea from a theoretical basis to practical application, an "overlapping consensus" is sought.

The idea of "overlapping consensus" was proposed by John Rawls in 1987 as providing the strongest possible foundation for public policy. Rawls points out that a consensus affirmed by opposing theoretical, religious, philosophical and moral doctrines is likely to be both just and resilient. Public policy based on such an "overlapping consensus" is therefore more likely to be long lasting. This work attempts to apply this concept throughout, seeking to find a comon foundation for the work of many others.

Thus, immediately following this introduction, Chapters Two, Three, and Four respectively review literature on state-of-environment reporting, macroeconomics, and a range of theoretical treatments of the human-ecosystem relationship. Each of these sets of literature contribute important ideas.

Chapter Five develops the conceptual framework that lies at the core of this dissertation. Four strategic reporting elements are identified that serve as indicator domains in the proposed reporting system. Each domain is provided with an overall goal or set of goals that establish the general context for assessing progress toward sustainability.

Chapters Six through Eight then deal with a range of topics that facilitate the transition between the theoretical conceptual framework and practical application. Detailed descriptions are provided of each of the four indicator domains and a technique is introduced of mapping the assessment process as a hierarchy of contributing indicators. This technique serves to untangle the maze of potential indicators and identify what indicators are or are not important to any given assessment.

In Chapters Nine through Thirteen, a case study of the Great Lakes Basin Ecosystem is provided that illustrates the proposed systemic approach to assessing and reporting on progress toward sustainability. The case study is intended to be illustrative, not definitive. It is a demonstration of how judgements can be reached when there is a lack of scientific certainty about progress toward sustainability but when the existing limited base of data and information (often including conflicting indicators) can be successfully weighed to establish where the preponderance of evidence points.

CHAPTER TWO

REVIEW OF

STATE-OF-ENVIRONMENT REPORTS

2.1 INTRODUCTION

State-of-environment reporting is described by J. C. Ward as "systematic analysis of environmental conditions and trends" (1990, 2). The first formalized systems of environmental reporting at regular intervals began in 1969 in Japan (Comolet 1992, 4) and in 1970 with the creation of the Council of Environmental Quality in the United States. Since then, there has been a a rapid expansion of state-of-environment (SOE) reporting throughout the world.

In their 1993 directory of environmental studies in developing countries, the World Resources Institute includes 344 entries and acknowledges that they exclude an additional 145 reports from their 1990 report (WRI et al. 1992). Their listing barely reaches into the large SOE literature. If regional and national reports from developed countries were added along with municipal and corporate SOE reports and relevant reports that deal with SOE reporting as a secondary focus (such as those dealing with human health and development, healthy communities, quality of life, and regional economic development), the inventory of SOE reports would reach many thousands.

Taken as a whole, the emergence of SOE reporting reflects a significant societal value shift towards greater concern for the environment than that accorded even 20 years ago. Because this literature is dealing directly with the human-ecosystem relationship it provides a natural starting point for developing a conceptual framework for guiding reporting on sutainability.

The purposes of this review are (1) to gain insight into alternative conceptual approaches for assessing and reporting on environmental and related conditions, and (2) to see if an existing conceptual framework exists that could serve to guide reporting on sutainability.

2.2 REVIEW METHODOLOGY

A total of 220 SOE reports are included in this review. They are grouped in the eight categories listed in Table 2-1.

Macelli points out the inevitable link between the conceptual approach taken in any project and the format of the final report (1977, 1). Using this link, a summary outline of the substantive components of each report was prepared using a common format to facilitate a comparison. One-hundred and forty-four of these summaries are listed in R. A. Hodge (1991).

TABLE 2-1. SUMMARY OF SOE REPORTS REVIEWED.

report category	*number of reports reviewed*
global	23
international	9
non-U.S. national countries	68 reports from 54
U. S. national	23
provincial or regional	23 from 14 regions
municipal	9 from 4 municipalities
ecosystem component (e.g. air, water, forests, oceans)	47
company or industry	18

Each summary outline was examined to identify first, the content that it dealt with and second the conceptual approach that it reflected. Appendix V provides a complete discussion of the review along with a listing of the 220 reports.

2.3 REVIEW RESULTS

Content Analysis

State-of-environment reports vary widely in the type and range of topics they include. At the global scale they tend to either attempt a broad assessment or focus on a single theme. In the former group, the United Nation Environment Programme's ***The World Environment 1972 - 1982*** provides a typical example (UNEP, 1982). It includes three parts. The first addresses trends in the state of components of the physical environment (the atmosphere, the marine environment, inland waters, the lithosphere, terrestrial biota, agriculture, forestry and the environment). The second summarizes the human situation (population, human settlements, and health) and the third discusses major human activities affecting the environment (industry, energy, transport, tourism, environmental education, and peace and security). Examples of the kinds of themes addressed in the second group include people and the environment (UNEP 1988), and children and the environment (UNEP 1990).

A number of topics lie scattered through the reviewed reports that are not common but signal an innovative approach or are clearly topics worthy of greater attention. Included are concern for cultural implications of environmental degradation or of actions taken to rectify environmental degradation (see JRB Associates 1982), the concept of acting effectively as an 'agent of change' (Centre for Science and Environment 1985), and the special role of women (Centre for Science and Environment 1985).

Overall, reporting on cultural and social implications of environmental change lags far behind reporting on economic implications. Reporting on implications to aboriginal people who maintain a greater direct dependency on the environment is rare. There is a marked absence of any reporting and assessment from a 'traditional' aboriginal and/or 'country' (non-aboriginal subsistence) perpsective on environmental conditions.

The relationship between environmental conditions and the governing decision-making system is not generally addressed in any rigorous manner. Exceptions to this statement are the Japanese national SOE reports (Environmental Agency 1977, 1979, 1982, 1986, 1988).

In 1970, the President of the United States established the Council of Environmental Quality (CEQ). It is responsible for preparing the President's annual environmental report to congress. The report is to trace current environmental trends, assess the adequacy of natural resources to fulfill human and economic needs, review and assess activities affecting the environment, and suggest ways of remedying program deficiencies (CEQ 1970).

A standard format for CEQ reports has never been established. Through the early 1970s, specific technical problems were dealt with at a state-of-the-art level. Examples include land use (CEQ 1970, 1974), the inner city environment (CEQ 1971), environmental indices (CEQ 1972), the law and the environment (CEQ 1971), the economy and the environment (CEQ 1971), the costs and economic impacts of environmental improvement (CEQ 1972), economics and environmental management (CEQ 1973), environmental economics (CEQ 1975, 1982), economics (CEQ 1978), forecasting (CEQ 1972), local governments (CEQ 1972), human settlements (CEQ 1972, 1978, 1980), environmental impact assessment (CEQ 1976), carcinogens and the environment (CEQ 1975), and ecology and living resources, biological diversity (CEQ 1978, 1979, 1980).

There is a preoccupation in the majroity of state-of-environment reports with the sources and implications of chemical pollution. This is particularly true of the forty-seven reports focussing on air and water and the eighteen corporate SOE reports. An example of this emphasis is also provided by the work of the Washington based Conservation Foundation (1982, 1984, 1987). A major contribution of the Conservation Foundation is its recognition of the significance of cross-media movement of contaminants and the need for an integrated air-water-land approach to contaminant assessment and regulation.

The topics of enforcement and compliance are rarely treated in SOE reports, likely a reflection of the political sensitivity of the topic. More recent corporate SOE reports are being more explicit about both successes and failures in terms of compliance. Likely the best example is provided by Shell Canada 1991.

As the size of the study area reduces from international and national to regional, provincial, and local, the degree of local detail and the strength of the connection to ecosystem conditions increases. A longer sense of history can also emerge that provides a stronger background for any analysis (for example, see Colborn et al. 1990 and Puget Sound Water Quality Authority and Entranco Engineers 1986).

Anticipatory thinking is not a typical strength of SOE reports. Rather, the focus is on current issues of concern. However, the anticipatory perspectives provided in Barret and Kidd's assessment of the Toronto Waterfront (1991), Manitoba's SOE report (Manitoba Environment 1991), the discussions of the Lower Fraser prepared by Regional Consulting Ltd. and Quadra Planning Consultants Ltd. (1990), Colborn et al.'s work on the Great Lakes system (1990), and in particular, the International Joint Commission's treatment of the potential implications of toxic contaminants in the Great Lakes ecosystem (IJC 1990, 1992, 1994) are notable exceptions.

Organizing Frameworks

Greg Sheehy reviews a number of SOE reports and suggests that four organizing "perspectives" are identifiable: (1) issues of concern (for example urban air quality); (2) industrial sectors (for example energy); (3) ecosystem components (for example air); and (4) some combination of these first three (1989).

The majority of reports would fall in Sheehy's 'combination' category. Their organization is typically haphazard. Reports of the U. S. President's Council of Environmental Quality tend to follow a two-part organization that starts first with reporting on "events" of the reporting year (often split on the basis of federal, state, and private activities) followed by "conditions and trends." A number of reports are influenced by the Canadian developed stress-response framework (for example OECD 1979, 1985, 1987 a and b, 1991 at the international level; Bird and Rapport 1986 at the national level and Elkin 1987 at the municipal level). This particular conceptual approach is further discussion in Section 3.4.

Summary

It is clear at this stage in the evolution of SOE reporting, that ***there is no common set of goals and objectives, no accepted norm, no common conceptual approach or structure***. Some SOE reports are required by law, most are not. Some are more technical and data-intensive than others, some more concerned with traditional "natural resources" than others. The degree of evaluation as compared to pure description varies widely and rigorous and critical assessments are rare. Reports range in scope from local to global, from issue-specific to broad assessments. Some focus on regions defined by ecosystem characteristics (drainage basin, gulf, eco-zone) and most review politically defined areas.

While many of these reports are labelled SOE reports, a significant number carry titles such as "Environmental Profile of . . . ," "Quality of the Environment in . . .," " Natural Resource Profile of . . . ." All of this literature, however, is aimed at elucidating environmental conditions and most of the reports are directed at a similar audience: the educated public and, in particular, policy- and decision-makers.

2.4 THE STRESS-RESPONSE CONCEPT

The concept of stress at the human-ecosystem interface was first introduced at least 40 years ago from a perspective of it being something acting on and influencing human well-being. Examples include disasters causing stress on people (Janis, 1954) or human migration as an adjustment to environmental stress (Wolpert, 1966).

Recent work by the World Health Organization (WHO) aimed at integrating environmental and health issues in decision-making processes continues this approach (WHO, 1993). In their work, the World Health Organization defines ***environment*** as "the sum total of factors, whether natural or anthropocentric, influencing human health and overall well-being." ***Environmental health indicators*** are thus designed:

> to clarify environmental influences on human health and well-being . . . to serve as an aid for decision making in environment and health management.
>
> (WHO 1993, 3)

These are not definitions used in this dissertation. Defining the word environment as "factors influencing human health" is not consistent with the ecosystem approach pursued in this dissertation. However, the definitions are important to understand for interpretation of WHO documents.

Kasperson (1969) extends the earlier work on stress influencing people through examination of the broad influence of environmental stress on municipal decision-making. He developed a model of municipal stress management based on analysis of the drought and political decision-making process related to municipal water supply. His model is provided in Appendix VI, Section 6.

Kasperson defines stress as "noxious or potentially noxious environmental forces upon the individual" and strain as "the individual's perception, evaluation, and reaction to the stimulus" (1969, 484). He notes:

> . . . managers of the political system cope with the diverse stresses according to goals and objectives which they bring to office and in order to play the game of politics within the rules and constraints of their particular roles. This analysis, then, views drought within the context of other stresses acting upon the city and the differing, shifting objectives of actors in the municipal political system.
>
> . . . stress may arise as a result of gradual accumulation or by a precipitous change in the environmental framework in which the municipal political system operates. It may also be internal as well as external to the system. Stress, via strain, will become a "crisis" when the managers of the system view themselves or the system as being in a hazardous situation. In all cases, strain involves the notion of threat either to the actor or the political system as a whole.
>
> (1969, 484)

More recently, an important conceptual advance has emerged from SOE reporting and plays a key part in the conceptual approach developed in this dissertation. When faced with growing criticism of the limitations of the System of National Accounts particularly on environmental grounds in the mid-1970s (see Chapter 4), the United Nations Statistical Office began the development of a general framework of environmental statistics. As part of this work, a joint initiative with Statistics Canada led to the development of the **"Material Energy Balance Statistical System (MEBSS)."** It was to be based on actual physical flows rather than on dollars. Thus, by directly accounting for natural resource depletion and waste residual generation it would have provided a direct link to some environmental concerns. After initial investigation, work on the joint U.N./Statistics Canada project was abandoned.[1]

However, a sub-set of this work led to the development of the "**ST**ress-**R**esponse **E**nvironmental **S**tatistical **S**ystem (STRESS)" within Statistics Canada (Rapport and Friend, 1979; Friend and Rapport, 1989). STRESS focuses on the interface between production-consumption activities of humans and the transformation of the state of the environment using concepts of environmental stress and environmental response. Four categories of statistics are identified: (1) activity "**stressor**" statistics; (2) environmental "**stress**" statistics; (3) environmental "**response**" statistics; and (4) statistics on "**collective and individual human responses.**"

Three concerns motivated development of STRESS:

> (1) the need to protect and conserve environmental assets for future generations;
>
> (2) the need to maintain and enhance the quality of the ambient environment for quality of life objectives; and
>
> (3) the need to make explicit the closing of potential options by human-initiated permanent restructuring of the environment, i.e. ecosystem destruction.
>
> (Rapport and Friend 1979, 74)

In their 1989 paper Friend and Rapport link (1) indicators of environmental stress and response (through STRESS); (2) indicators of economic performance (through the SNA); and (3) indicators of demand and supply of natural resources (through satellite accounts) within a proposed "Information System for Sustainable Development" (Friend and Rapport 1989). In a further development, Friend argues for a "pluralistic" approach to national accounting that would have three equal elements: (1) natural resource accounting; (2) system of national accounts and material energy flows; and (3) state of environment reporting (Friend 1991).

The stress-response conceptual approach has had a significant impact on state-of-environment reporting around the world (see R.A. Hodge 1991, 11). Furthermore, the roots of the current OECD approach to environmental policy analysis (pressure — state-of-the environment — socioeconomic consequences — policy response; see Pearce and Freeman 1992, 63; and Comolet 1992, 4 - 5) can be attributed to Friend and Rapport's work as can recognition of the importance of linking more formalized systems of environmental statistics with state-of-environment reporting.

However, a number of limitations that have mitigated its usefulness as an overarching conceptual approach for reporting are apparent. First, any given "environmental response" to a human-induced stress may, from another perspective, be itself a stress on another part of the ecosystem. This leads to a trickle-down effect that is inevitable in complex systems but is the cause of much confusion — "response" is rarely confined to a single identifiable response. Ecologist Reed Noss puts it this way:

> . . . effects of environmental stresses will be expressed in different ways at different levels of biological organization. Effects at one level can be expected to reverberate through other levels, often in unpredictable ways.
>
> (1990, 357)

Secondly, it is rare that specific responses can be linked to specific stresses. And lastly, the language of the stress-response approach has not facilitated smooth linking with public policy and decision-making.

In spite of these limitations, their use of the concept of stress imposed on the ecosystem from human activities represents a major and critical advance beyond the older depletion/pollution model of human-ecosystem interaction (see Chapter Four). It is this concept that makes possible a more rigorous and systematic description of human-ecosystem interactions than has previously been used. Furthermore, it is this part of the stress-response model that has provided an important building block for the proposed reporting system.

The stress-response approach is somewhat analogous to the stress-strain approach of classical mechanics in which concepts of force, stress, deformation and strain are linked through idealized relationships between stress and strain. Stress is defined as the force per unit area acting at a given point and strain is the resulting deformation.

As stress is applied, strain occurs first in an elastic (reversible) mode. During this phase, if stress is released, the original form and characteristics are regained. As stress is maintained and increased, a threshold is eventually reached at which point plastic (in-elastic) deformation occurs. If stress is released during this phase, a permanent change of state will be found. However, the extent of plastic deformation (the degree of change from original state) depends on the magnitude (and direction) of the applied stress as well as the time period of application. With continued application of stress, a second threshold is eventually reached and catastrophic failure occurs.[2]

The same kind of three-part, double threshold process may be useful to consider in terms of ecosystem response to human induced stress. At low levels of applied cumulative stress, ecosystem change is reversible. Beyond these low levels, change is permanent and eventually catastrophic failure occurs. Unfortunately, unlike in theoretical mechanics, the threshold points are not predictable and more and more people are suggesting that we are closing in on the second, catastrophic, threshold point.[3]

In the natural ecosystem, properties are orders-of-magnitude more complex than those of a steel beam or concrete wall. As a result, it is important that the concept of imposed environmental stress be defined as ***a forcing phenomenon causing perturbation or disturbance.***

This definition eliminates the confusion generated by definitions of stress that depend on resulting effects rather than the applied force. For example, Selye distinguishes eustress and distress. He labels stress that stimulates normal vigorous behaviour and evokes adaptive responses, strengthening the well-being of organims as ***eustress.*** In contrast, stress that is followed by responses that may protect the organism against demise but do not lead to enhanced vitality of the system he labels ***distress*** (Selye 1973). Similarly, Costanza defines stress as "perturbation with negative effect on the system" (Costanza 1992, 244) and Rapport and Regier likewise differentiate "disturbance" and "stress":

> We distinguish between them: one kind of disruption, a disturbance, helps to revitalize the ecosystem . . . the other, a stress, debilitates it, may cripple it and if sufficiently intense, may extinguish it.
>
> (in press, 3)

The above definitions that evoke a two-part differentiation of stress types according to effect, are not helpful. The effect of any given stress or suite of stresses depends on both characteristics of the receptor as well as the exerting force. To classify according to effects blurs these two factors.

Rather, stress is best thought of as the disturbing or applied force. It exists on a continuum. Low levels of applied cumulative stress may not be necessarily "bad": the ecosystem can deal with at least some perturbation. In fact, if human health is an applicable analogy to ecosystem health as some suggest (Rapport et al. 1981; Rapport 1989) small amounts of stress may even be a good thing and lead to an invigorated ecosystem. This concept of stress is also consistent with Holling's idea that ecosystem health may be tied more to an ecosystem's ability to use stress creatively than to its ability to resist it completely (Holling 1986, 1992).

This discussion of ecosystem response using the strain analogy again serves to underline the difficulty of dealing with the response element of the stress-response conceptual approach. Instead, the proposed system of reporting draws on the major conceptual contribution from the stress-response model and takes as a starting point the need to reduce stress imposed on the ecosystem by human activities.

Historically, there has been a preoccupation with "pollution." However, human induced stresses on the environment are significantly broader than emissions of chemicals. Six stress families, one natural and five human-induced, are listed and described below in Table 2-2 along with examples of related human activities.

The stresses listed in Table 2-2 are usually imposed simultaneously and in an interlinked manner making identification of specific causes and effects virtually impossible except in rare cases. The uncertainty caused by this lack of cause-effect linkage must be seen as a characteristic of contemporary decision-making, not as an impediment. The ecosystem itself integrates the effects of many simultaneously-induced stresses and it is to the ecosystem that we must turn for assessing cumulative effects. This emphasizes the usefulness of bioindicators.

However, identifying and assessing specific stresses induced by human activity is relatively straightforward. Management and reduction of those stresses is equally possible through specific action on the part of society. This relationship between stress reduction and explicit societal decision-making is the practical link that lies at the heart of this dissertation.

TABLE 2-2. NATURALLY OCCURRING AND HUMAN-INDUCED STRESSES EXPERIENCED BY THE ECOSYSTEM.

stress group	*example*
1. EXTREME NATURAL EVENTS	weather related; wind, storms, rain, flooding, drought, freeze-thaw cycles; natural fires in forests, grasslands, and marsh areas; hurricanes, volcanic eruptions, earthquakes, landslides, tidal waves.
	disease, parasites, and other causes leading to natural population shifts.
2. ADDITION OR LOADING OF SUBSTANCES, HEAT, RADIONUCLIDES, ETC.	discharge of a vast range of chemicals to land, air, surface water, and groundwater including pesticides, industrial, municipal and transportation by-products and wastes, carbon-dioxide, and other greenhouse gases, chlorofluorocarbons that deplete stratospheric ozone;
	human induced erosion and deposition of sediments;
	discharge of phosphorous, nitrogen, and other nutrients that serve to fertilize plants and the primary trophic levels.
3. PHYSICAL RESTRUCTURING AND LAND USE CHANGE	damming, dyking, irrigating, dredging, filling or other modifications of waterways and lakes; shoreline protection (groins, seawalls etc.) and modification such as harbour construction;
	forest and bushland clearing for agriculture, industry, transportation corridor or settlement development;

	wetland drainage, excavation, and development;
	excavation, filling, clearing, or otherwise altering land areas;
	urbanization, paving.
4. HARVEST OR EXTRACTION OF RENEWABLE RESOURCES	water withdrawals (from surface water or wells), diversions, and consumptive uses;
	commercial forestry;
	aquaculture,
	fishing, hunting, trapping (subsistence, commercial, or recreational);
5. EXTRACTION OF NON-RENEWABLE RESOURCES	extraction of minerals, hydrocarbons and building materials;
6. INTRODUCTION OF NON-NATIVE SPECIES AND GENETIC MANIPULATION	stocking lakes with exotic fish species; unintended invasion of new aquatic species through canal construction, escape from aquaria, transport on boat or ships' hulls, in ballast water, etc.;
	intentional importation of plants, insects, birds, or animals;
	variety of "bio-technological" actions.

Sources: A previous form of this table is found in Hodge and Taggart 1991, 11-12. Modified from Rapport and Friend 1979; Rapport 1983; Francis et al. 1985; Bird and Rapport 1986; Regier 1988; Colborn et al. 1990.

The desire to actively pursue options for stress reduction in day-to-day life is exploding. It is reflected in:

- adjustments to legislation aimed at encouraging improved industrial practices (variety of incentives including for example, increased penalties for non-compliance, changes to tax regimes and subsidies);

- requirements for environmental impact assessments for major new projects;

- changes to criteria for liability insurance for corporations and in particular, Boards of Directors related to potential environmental problems;

- changes to corporate disclosure requirements related to the rights of investors as well as shareholders and the general public to know the environmental implications of corporate activities;

- changes in the lending criteria of the financial services industry forcing recognition of potential environmental liabilities;

- overall changes in corporate policy bringing environmental values to the forefront of decision-making (reflected in an array of activities from procurement policy through product greening, plant operational procedures, and altered design criteria);

- programs throughout society in pursuit of the 3 R's (reduce, reuse, recycle);

- programs of energy conservation throughout society;

- the expansion of environmental programs in formal educational curriculum.

Nowhere is the need to come to terms with stress on the ecosystem more apparent than in the international arena. As pointed out by MacNeill et al., in addition to the net transfer of over $50 billion from developing countries to the richer nations that occurred in 1989, a massive transfer of the environmental costs of the world's generation of material wealth is taking place from the richer nations to the developing countries (1991, 21). To support economic activity in developed countries, environmental costs are being borne by developing countries. In 1980, these costs were conservatively estimated at $14 billion; the situation has since grown much worse.

Assessing individual human activities on the basis of physical, chemical, and biological stresses provides a simple and comprehensive approach to stress assessment. The approach proposed in this reporting system includes the consideration of (1) the support provided by the ecosystem, (2) the value of resulting human activities in providing for basic needs and supporting an enhanced quality of life, and (3) the imposed physical, chemical, and biological stresses. Such balancing is analogous to but more complex than a benefit-cost analysis.

In Table 2-3, the various activities listed in Table 2-2 are regrouped in terms of physical, chemical, and biological stress "types." Table 2-3 provides a simple check list for use in assessing the stress imposed by any given human activity. Such a stress assessment is now undertaken as a requirement for development of most new major projects through the process and techniques of environmental impact assessment. However, the stresses induced by ongoing, everyday human activities are probably more significant and not the subject of any overall assessment even though it is the cumulative effect of these ongoing activities that dominates human influence on ecosystem conditions.

TABLE 2-3. HUMAN ACTIVITIES GROUPED TO SHOW IMPOSED ENVIRONMENTAL STRESSES AS PHYSICAL, CHEMICAL, OR BIOLOGICAL.

induced stress "type"	*human activity*
PHYSICAL	• physical restructuring • land use change • erosion and sedimentation • discharge of heat • noise • extraction of non-renewable resources
CHEMICAL	• discharge of chemicals
BIOLOGICAL	• harvest of renewable resources • various forms of habitat disruption • accidental or planned introduction of non-native species • biotechnological manipulation

Source: Hodge 1991, 16.

2.5 CONCLUSIONS

The following main conclusions emerged from this review of state-of-environment reports. Previous versions of this list are found in Hodge and Taggart 1991 and Hodge 1993a.

1. **RICH AND IMPORTANT SOURCE OF DATA AND INFORMATION.** State of environment reports are a rich and important sources of data and information. The dominant focus is on ecosystem conditions. A secondary focus is on factors contributing to those conditions.

2. **NO ACCEPTED FORMULA FOR SOE REPORTING.** There is no common set of goals and objectives for SOE reporting, no accepted norm, no common conceptual framework and no common report format.

3. WEAK LINKS TO DECISION-MAKING. Although the target audience for these reports is the educated public and decision-makers, few include descriptions of the decision-making system: the role of different decision-makers in society, governance and institutions, the relevant regulatory regime, the enforcement and compliance record, the use of market based incentives for action etc. Furthermore, explicit understanding of the time and space characteristics that govern ecosystem conditions, in comparison with the time and space characteristics that govern contemporary decision-making, is rarely demonstrated. As a result, the link between SOE reporting and decision-making is weak at best.

4. INADEQUATE MODEL OF HUMAN-ECOSYSTEM INTERACTION. In spite of efforts to assume an "ecological" perspective, most of these reports are driven by a "world view" that is based in the materials-energy balance model of the human-environment relationship. This world-view has roots in economic thought and theory. In this model, the environment is seen as an "asset" that provides material, energy, aesthetics, and resources to drive production and consumption activities within the economic system. As a result of these activities, waste products are formed that are then returned to the environment as pollution. The environmental issue is thus reduced to two components, one dealing with resource use (or misuse, depletion, and scarcity) and the other dealing with pollution. In turn, the solution to the environmental problem becomes one based on wise resource use and reduction of pollution. The related reporting is then focussed on the stocks and flows of resources and levels of pollution. This model is described in greater detail in Chapter Four. It does not have the breadth required to deal with the many linked human and ecosystem issues now requiring attention.

5. REPORTS ARE RARELY ANTICIPATORY. Although interest in assuming an anticipatory stance is often expressed, the form and content of most SOE reports ensures a reactive stance based on current and historic concerns. Further, a number of SOE reports are explitly limited to providing base-line conditions that others can then use for assessment of progress and projection of future implications.

6. WEAK ENVIRONMENT-ECONOMY LINKAGES. More recent reports place greater emphasis on the linkage between economic activities (and the status of the economy) and ecosystem conditions. However, no report has demonstrated a fully satisfactory approach to describing this relationship.

7. LIMITED TREATMENT OF HUMAN CONDITIONS. Human conditions are dealt with erratically and in descending priority of emphasis are treatments of health, social, culture and heritage. Reporting related to aboriginal peoples or other sub-populations that have a closer direct dependence on the natural ecosystem is rare. Nor is there treatment of disadvantaged populations such as the urban poor. The issue of equity is not a significant theme of the majority of SOE reports.

8. SOE REPORTING DOES NOT PROVIDE A MODEL FOR REPORTING ON SUSTAINABILITY. The insights into environmental conditions provided by SOE reporting are central to reporting on sustainability. However, SOE reporting is not a sufficiently robust instrument for effectively dealing with the linked human and ecosystem issues that are critical to the concept of sustainability. Insights must also be drawn from a large number of other reporting exercises, including those focussed on the economy, health and welfare, quality of life, human development, and healthy communities. Each has something to offer and no single one can deal with the breadth of topics requiring attention.

9. NEED TO STRENGTHEN SOE REPORTING BY EXPLICITLY BOUNDING ITS TASK. Lacking any formal conceptual approach, SOE reporting stands as an unbounded task carrying with it expectations and intentions that vary greatly depending on the interested party. Formally defining limits to its task would greatly strengthen its role and significance.

10. AUTHORSHIP. Althought most of these reports stem from work undertaken by government, some of the most insightful are the result of efforts by private, non-profit or academic organizations. The arms-length-from-government relationship facilitates a greater degree of assessment, critique, and consideration of non-status-quo problem solutions. Furthermore, government-initiated reporting has a tendency to assume a stance that is defensive of its various programs rather than critically objective in undertaking an assessment.

END NOTES

1. For a discussion of MEBSS, see Rapport and Friend, 1979. although Statistics Canada phased out the project, the resulting modelling expertise was captured in development of a large scale simulation model labelled the "socioeconomic Resource Framework" or "SERF." SERF is now lodged at the University of Waterloo, Faculty of Environmental Studies, as well as with Robert and Associates, Ottawa where its originators, Robert B. Hoffman and Bertram C. McInnis (formerly with Statistics Canada) are continuing developmental work in a wide range of related applications, as private consultants.

2. See any introductory text to the mechanics of solids, for example Crandall and Dahl, 1959).

3. See for example, Meadows et al., 1972, Catton, 1980, and Meadows et al., 1992 amongst many others.

CHAPTER THREE

MACROECONOMICS AND SUSTAINABILTY

3.1 IMPORTANT IDEAS FROM MACROECONOMICS

Defining Economics

In his classic volume, *The Economics of Welfare,* Pigou defines economics as "a study of mankind in the ordinary business of life" (1920, 4). The context of economics that he ardently defends is one of study leading to "practical results in social improvement:"

> Wonder, Carlyle declared, is the beginning of philosophy. It is not wonder, but rather the social enthusiasm which revolts from the sordidness of mean streets and the joylessness of withered lives, that is the beginning of economic science. Here, if in no other field, Comte's great phrase holds good: "It is for the heart to suggest our problems; it is for the intellect to solve them . . . the only position for which the intellect is primarily adapted is to be the servant of the social sympathies."
>
> (1920, 5)

Contemporary economists typically articulate a narrower focus. In their introductory economics text, Parkin and Bade suggest that economics is the study of activities arising from scarcity:

> Scarcity forces people to make choices. Economists try to understand the choices that people make. To make choices, people optimize. To optimize, they evaluate the costs of alternative actions. We call these opportunity costs, to emphasize that doing one thing removes the opportunity to do something else. Scarcity also implies that people must compete with each other.
>
> (1991, 11)

They go on to pose seven questions addressed by modern economics:

1. How do people choose what to consume and how to produce, and how are these choices affected by the discovery of new ways of doing things - of new technologies?

2. What determines people's incomes and why do some people receive much larger rewards than others whose efforts appear to be similar?

3. What are the causes of unemployment and why are some groups more severely affected than others?

4. Why do prices rise, and why do some countries sometimes experience rapid price increases while others have stable prices?

5. How do government spending and taxes influence economic life and what happens when the government has a deficit, as it does at the present time?

6. What determines the pattern and volume of trade between nations, and what are the effects of tariffs and quotas on international trade?

7. What causes differences in living standards among nations, making the people in some countries rich and in others poor?

(1991, 6-8)

Hueting describes economics as boiling down to:

> ...the study of the problems of choice entailed by the use of scarce means to satisfy wants. Welfare is defined as the satisfaction of wants evoked by dealing with scarce means. So welfare, or satisfaction of wants, is a psychical category, an aspect of one's personal experience. Economic theory assumes that, when dealing with scarce means, we try to

> maximize our welfare (the opposite is nonsensical). Besides maximization of welfare with given means, the desire to raise the level of satisfaction of wants (welfare) in the course of time is also regarded as a motive of economic action.
>
> (1991, 201)

In a similar vein, Goodland and Ledec suggest that economics is "the study of allocating the resources available to society in a way that maximizes social well-being" (1987, 20 - 21). They point out that achieving social goals involves choices. With the tools provided by economics, trade-offs can be assessed and balanced to obtain the most efficient or "Pareto-optimal" result — a result in which P. S. Dasgupta states "there is no feasible alternative allocation which makes all agents better off" (1982, 25).

It is apparent that the contemporary sense of economics is that of a discipline grappling with how to make "efficient" decisions when dealing with scarce resources. This is a marked shift from fundamental concern for overall societal welfare reflected in Pigou's work.

Efficiency and Equity

Unfortunately, as David Pearce states, achieving the goal of the ultimately efficient allocation of resources in the economics sense can be done so with an ecologically unsustainable pattern of resource use (1976) and/or as R. Goodland and G. Ledec suggest, through an ethically undesirable pattern of income distribution (1987, 21).

A simplistic view of the efficiency criteria is that decision-making is dominated by a desire to simply maximize individual self-interest. Rose, however, suggests that for the very property regime required by neoclassical economics, at least some agents must have preference orderings that the classical property theory would not predict: one that is cooperative in nature rather than driven purely by self-interest (1990, 39). She points out that our legal doctrines reflect the knowledge that these other preference orderings exist and suggests that one should not assume that all will behave as "individual self-interested utility maximizers" (1990, 48).

In a recent review, Young summarizes several important elements of the debate regarding the concept of economic efficiency (1992). The following discussion is drawn from his work.

Economic efficiency includes two aspects:

> 1. ***productive efficiency*** which seeks to avoid waste and increase productivityuntil marginal costs equal marginal revenue or benefits; and
>
> 2. ***allocative (or Pareto) efficiency*** which seeks a condition such that no alternative allocation would make at least one person better off and no one worse off.
>
> (1992, 27)

It is only possible to define economic efficiency for a given distribution of wealth, resource rights and institutional arrangements.

One of the necessary conditions for efficient resource use and investment is that all resources are bought and sold at at least their marginal opportunity cost (in some cases a higher price may be necessary to cover the costs of a previous investment decision). Marginal, rather than average cost is required: when social marginal cost equals social marginal benefit, the return to society is greatest. According to Young, to ensure use of marginal opportunity cost, the following price components must be included:

> efficient price for a resource =
>
> - marginal cost of supplying the resource to the user; plus
> - marginal cost of any lost ecological functions; plus
> - marginal cost of any pollution that the resource use imposes on other people; plus
> - marginal cost of lost future options; plus
> - marginal cost of lost existence and bequest values.
>
> (1992, 28)

Young goes on to point out that most markets malfunction because the pricing structure fails to recognize any but the first consideration. Also, the idea of an ecological function value implies a sense of understanding and certainty regarding the ecosystem that does not exist and many doubt will ever exist (see Holling 1978, 5-9). Nevertheless, there is a significant current effort underway to operationalize elements of the above pricing structure. Three principles that attempt to do so have been articulated:

1. ***Polluter-Pays Principle***. Environmental (pollution) costs are included as a cost of production thus providing an incentive for resource users (producers) to minimize pollution damage;

2. ***Beneficiary-Compensates Principle***. Beneficiaries pay for the costs of maintaining the ecological functions, option, bequest and existence attributes that they value;

3. ***User-Pays Principle***. Those who benefit from an investment must pay for its creation.

Young integrates these principles into the marginal cost pricing equation presented above to define an idealized "sustainable resource price:"

sustainable price for a resource =

- marginal cost of supplying the resource, plus
- marginal cost of replacing any lost ecosystem component; plus
- marginal cost of any pollution that the resource use imposes on other people; plus
- marginal cost of offsetting lost future options; plus
- marginal cost of offsetting lost existence values; plus
- compensation for any additional costs associated with the provision of positive non-market benefits, retaining or creating future options and retaining existence values for the community; plus
- per unit capital cost associated with resource development.

(1992, 33)

In practice, current markets are far from utilizing this price structure. However, throughout the world pressures to move in this direction are being exerted. What is of interest to this discussion, however, is that such a pricing structure reflects a shift from pure self-interest maximizing to a kind of ***enlightened self-interest*** that accepts a broad number of community or societal criteria as important in decision-making.

Young reviews a number of rules that have been proposed to deal with the equity issue. He points out that:

> Equity is largely a question of the fair or just distribution of resources, rights and wealth amongst people and over time. Relativities, not minimum standards, are important.
>
> (1992, 39)

Young also lists the following four criteria that he suggests should apply to development of all policy, economic and otherwise:

> 1. ***General Acceptability***: principles must be generally shared by different cultural traditions and be generally acceptable to different economic and political systems;
>
> 2. E***quity Amongst Generations***: no generation can exploit resources to the exclusion of future generations, nor should it have unreasonable burdens placed on it to meet the indeterminate needs of future generations;
>
> 3. ***Between-generational Value Independence***: no generation should be required to predict the values of future generations; and
>
> 4. ***Clarity***: principles should be reasonably clear in application to foreseeable situations
>
> (42-3)

Brown Weiss proposes the notion of the human community as a partnership among all generations:

> The theory of intergenerational equity says that humans as a species hold the natural and cultural environment of Earth in common both with other members of the present generation and with other generations, past and future. Each generation is both a trustee or custodian of the planet for future generations and a beneficiary of previous generations' stewardship. This circumstance imposes certain obligations upon us to care for our legacy just as it gives us certain rights to use the legacy.
>
> (1990, 8)

She suggests the use of three principles to guide human action. Each generation should be entitled to receive, maintain, and be required to pass on, a planet-wide resource and cultural base that ensures:

> 1. ***Conservation of Options*** in which each generation is provided with similar options to solve its own problems and satisfy its own values;
>
> 2. ***Conservation of Equality*** in which each generation is provided a resource and cultural base that is of comparable quality and diversity;
>
> 3. ***Conservation of Access*** in which each generation would be assured of equal rights (opportunities) of access to the legacy from the past.
>
> (1990, 9 - 10)

The active use of the above principles in decision-making would entrench a caring for future generations that has not been evident in the past. This caring is entrenched in the value set underlying this dissertation and introduced in Chapter Two.

Macroeconomics and Contemporary Decision-Making

The foregoing ideas are raised because of the apparent significance of economics in contemporary decision-making and the need to establish the optimum role for economic methodology and analysis in any system of reporting on sustainability. Schumacher points out that:

> It is hardly an exaggeration to say that, with increasing affluence, economics has moved into the very centre of public concern, and economic performance, economic growth, economic expansion, and so forth have become the abiding interest, if not the obsession, of all modern societies.
>
> (1973, 34)

He goes on to argue that the methods of economists have led to an entrenched meaning of 'uneconomic' as an activity that "fails to earn an adequate profit in terms of money ...to those who undertake it" (35). He also notes:

> In the current vocabulary of condemnation there are few words as final and conclusive as the word 'uneconomic'. If an activity has been branded as uneconomic, its right to existence is not merely questioned but energetically denied.
>
> (35)

In fact many decisions in which economic criteria are not dominant are taken. For example, in Canada many major public projects have been undertaken for political or social reasons and in spite of major economic arguments to the contrary. Ironically, politicians, while quick to use economic arguments that support favoured courses of action, are evasive at best when the same economic techniques provide data that contradict their desires.

Nevertheless, while some projects may not be motivated by economic rationale, economics does provide the measuring criteria against which the majority of individuals and all corporations and governments currently assess their success. From this perspective, economics ***has*** come to play the dominant role suggested by Schumacher.

Concerned with this dominance and recognizing that social, aesthetic, moral, political and other factors rightfully have a role to play in decision-making, Schumacher draws upon the words of John Stuart Mill to plead that economics be seen:

> ...not as a thing by itself, but as a fragment of a greater whole; a branch of social philosophy, so interlinked with all the other branches that its conclusions, even in its own peculiar province, are only true conditionally, subject to interference and counteraction from causes not directly within its scope.
>
> (34)

This sense of limits which encourages the careful use of economics (when the power of its techniques can be maximized) combined with Pigou's concern for social improvement as a driving motivation, provides the context for economics that guides the following examination of two key issues linking economic thought and the concept of sustainability.

3.2 NATIONAL ACCOUNTS AND THE LIMITATIONS OF GROSS DOMESTIC/NATIONAL PRODUCT

The national and provincial economies are monitored through use of the system of national accounts (SNA) and their provincial or regional counterparts. These accounts are a mechanism to estimate and monitor trends in the value of Canada's total production of goods and services. They provide an integrated data base of economic (institutional) transactions from which aggregate numbers such as gross national product (GNP) or gross domestic product (GDP), consumption expenditure, government expenditure, and national income can be derived. They are used for indicating short to medium term changes in economic activity and as input to a variety of macroeconomic policies. In Canada, the Provincial and Territorial accounts are also used as a basis for negotiations with the federal government on matters involving inter-jurisdictional transfers of funds (Victor 1990, 2). Debate about how to more effectively integrate environmental concerns into national accounting is a dominant topic in the literature dealing with sustainability and sustainable development.

Statistics Canada uses the SNA in three alternative but related approaches to measuring Canada's Gross Domestic Product: (1) expenditure approach; (2) factor incomes approach; and (3) output approach. The elements of the three approaches are summarized in Table 3-1.

The following is summarized from reviews of the historic development of the System of National Accounts provided in Waring (1988, 49 - 53) and Anderson (1991, 16 - 20). Attempts to estimate English income and expenditure date from the late 1600s while the concept of national income as a flow of goods and services developed in the late 1700s with work in France. Estimates of the national income for England and France were available by the late nineteenth century and estimates for Russia were prepared in 1906. By the end of World War I, estimates had also been prepared for the United States, Austria, Australia, Norway, Germany, Japan, Switzerland, the Netherlands, Italy, and Bulgaria. Beginning in Canada and the Soviet Union in 1925 and in Germany in 1929, central governments assumed responsibility for national income estimation.

TABLE 3-1. ELEMENTS OF THE THREE APPROACHES USED BY STATISTICS CANADA TO MEASURE GROSS DOMESTIC PRODUCT.

The Expenditure Approach

- consumption, plus
- investment, plus
- government purchases of goods and services, plus
- net exports, plus
- statistical discrepancy ***equals gross domestic product***

The Factor Incomes Approach

- wages, salaries, and supplementary labour income, plus
- interest and miscellaneous investment income, plus
- corporate profits, plus
- farmers' income, plus
- income of nonfarm unincorporated businesses, plus
- indirect taxes less subsidies, plus
- depreciation ***equals gross domestic product***

The Output Approach

- value added in each sector of the economy (gross domestic product at factor cost by industry, plus
- indirect taxes less subsidies ***equals gross domestic product***

Source: Summarized from Parkin and Bade 1991, 595 - 600.

However, it was U.S.A. led work on National Accounting through the 1920s and 1930s as well as British work in the late 1930s and 1940s that led to the form of national accounting that is now used throughout the world. A key contribution was provided by John Maynard Keynes (1936) who provided the theoretical framework for rigorous definition and calculation of "national income" (Anderson 1991, 17). Keynes also played a major role in designing national accounts for an industrialized country at war (Britain) and it was for this purpose that the current form of national accounting was originally designed (Waring 1988, 58).

Waring strongly criticizes use of the Gross National Product as the central indicator of economic well-being for a number of reasons, not the least of which is its inadequate treatment of poverty. (Average population income could rise while the numbers of those living at the margin of subsistence could also grow steadily). Quoting economist J. Viner (1953, 99 - 100), Waring notes that "market measures . . . assume that growth of output implies or accompanies a rise in qualitative satisfaction - which may not necessarily be the case" (58).

In spite of the kinds of critique noted above, indicators drawn from the SNA, particularly GDP, have come to be used, particularly in political rhetoric, as a measure of the well-being of society in general:

> Increase in production as measured in national income is generally called economic growth, identified with an increase in welfare and conceived as ***the*** indicator for economic success. All countries of the world give it the highest priority in their economic policy.
>
> (Hueting 1991, 194)

While there is little argument that SNA derived indicators are useful in monitoring market activities, their broader use is increasingly contested. Anderson lists 16 limitations of national income accounting in arguing that (1) GNP/GDP is not a good measurement of total output of goods and services, and (2) changes in the output of goods and services do not necessarily reflect changes in the level of welfare (or well-being, or total utility). These problems are summarized in Table 3-2.

TABLE 3-2. PROBLEMS IN THE USE OF GNP/GDP.

I. PROBLEMS RELATED TO GNP/GDP AS AN INDICATOR OF TOTAL OUTPUT OF GOODS AND SERVICES

1. **UNPAID DOMESTIC LABOUR.** Unpaid work both in and outside the home (most of which is carried out by women) has real economic value which is not included in the standard system of accounts. Analyses suggest that the value of this activity may be as high as 53 % of GNP (Adler and Hawrylyshyn 1978, as discussed in Waring 1988) although the most recent studies in Canada suggest a range of between 32 and 39 percent (Jackson 1992);

2. **NON-MONEY TRANSACTIONS OUTSIDE THE HOUSEHOLD.** Barter, work-for-favour, unpaid charity work, activity in volunteer organizations and subsistence activities all generate real economic value, take place outside the normal market economy and are not normally recorded in the economic accounts;

3. **BLACK MARKET TRANSACTIONS (THE INFORMAL ECONOMY).** An unknown but significant and growing portion of economic transactions occur outside the formal economy. Activities include not only the highly publicized drug trade but many day-to-day activities from construction to computer and car repairs.

II. PROBLEMS RELATED TO GNP/GDP AS AN INDICATOR OF OVERALL WELFARE (OR WELL-BEING, OR TOTAL UTILITY)

Problems of Averaging and Comparisons

4. **DISTRIBUTION AND INCOME.** Average and total GNP figures mask inequities in the distribution of income.

5. **DIFFERENCES IN NEEDS AND CIRCUMSTANCES.** GNP does not reflect any sense of the different needs and circumstances of sub-populations. For example, the consumption needs of an elderly person may be twice that of a baby.

6. **THE USE OF EXCHANGE RATES IN INTERNATIONAL COMPARISONS.** Variations in exchange rates and the pegging of currencies undermine validity of international comparisons.

Problems of Stocks and Depreciation

7. **WEALTH AND DEPRECIATION.** In measuring total income, GNP reflects benefits people gain from having an income. However, with the exception of housing for which an "imputed rent" is calculated, it does not reflect either benefits from existing possessions or the depreciation of these possessions.

8. **'ENVIRONMENTAL WEALTH' AND ITS DEPRECIATION.** Damage to the environment caused by economic activities is not counted as a cost; Net receipts from the extraction and sale of natural resources are counted as income and not as the consumption of capital even when stocks are

being depleted or degraded; Many so called natural resources (e.g. a forest) are valued by society as (1) economic resources (e.g. stock for lumber or pulp), (2) socio-cultural amenities (e.g. camping, birdwatching), and (3) rich ecosystem components in themselves (e.g. forest ecosystems). Capturing all three components of value is not possible within the confines of the SNA.

9. **HUMAN BEINGS AND THEIR 'DEPRECIATION'.** A person's value as 'human capital' depends on education and training, state of health, etc. These characteristics contribute to the economy as forms of 'human investment' just as buying and servicing machinery does. Similarly, 'human capital' can depreciate through loss of health. None of this is reflected in national accounting except perhaps as a tendency for GNP to rise with increased health expenditures.

10. **POSITIONAL GOODS.** Some goods derive their assigned value through status and the fact that not everyone has them. When more are produced, value falls. Economic growth dominated by a high proportion of such positional goods does not necessarily reflect growth in total welfare.

Problems of Other Sources of Welfare

11. **LEISURE TIME.** Where increased productivity and efficiency are used to produce more goods, GNP records 'economic growth.' Where the same increases are use to produce the same level of goods in less time, reducing working hours and increasing time available for leisure, GNP ignores the change. Use of GNP therefore introduces a bias towards extra production at the expense of increased leisure even though the latter may be preferred.

12. **QUALITY OF LIFE AT WORK.** The System of National Accounts entrenches a model that sees welfare derived from output, and output derived from economic activity of which work is a major component. But welfare may also be derived directly from work, i. e. people may enjoy their work. These non-money sources of welfare are not captured in GNP.

Problems of Inefficiency in Providing Welfare

13. **INEFFICIENT PRIVATE PROVISION.** GNP is biased against the use of less expensive common public services (e. g. public transport, public water supplies) compared to more expensive and less efficient privately provided goods and services (e. g. cars, bottled water). A shift from the former to the latter will register as a rise in GNP, a shift from the latter to the former will register as a fall.

14. **'INEFFICIENCY' IN CONSUMER DECISIONS.** Consumer decision-making may not be motivated by welfare concerns at all. Short-term benefits may dominate over long-term costs; limited information about choices may lead to poor decision-making; advertisers' and manufacturers' claims may misdirect; government expenditures may result in choices which bring few benefits.

15. **'INEFFICIENCY' IN PRODUCTION.** Production of a less expensive, equally good product will result in a drop of GNP even though consumers are clearly better off than they were before. Thus, GNP is biased towards goods and services that are more expensive to produce and buy.

16. **THE VALUATION OF OUTPUT REFLECTS THE DISTRIBUTION OF INCOME.** Product prices are governed both by production costs and willingness to pay. To some extent, the latter is a function of disposable income — the more one has, the more one is willing to pay. Purchases by richer people tend to be more expensive - both because they can afford them, and producers can get away with charging more. Thus, increased purchases by rich people may count more in GNP than increased purchases by poor people.

17. **DIMINISHING MARGINAL UTILITY OF MONEY.** Low-income earners can only afford to spend money on highest priorities. If income rises, it becomes possible to move down the list of priorities. Extrapolated to a whole country, with increased GNP per capita the additional goods and services bought represent lower priorities, a lower proportion of necessities, and likely a higher proportion which could be dispensed with without any significant loss to people. Growth in per-capita GNP therefore systematically overstates the rate-of-growth of welfare.

Sources: Modified from Anderson 1991, 21 - 32; See also, 1990; Daly and Cobb 1989; Waring 1988; Ahmad et. al. 1989; and Repetto et. al. 1989.

Daly and Cobb suggest that the use of GDP drawn from the SNA is appropriately left as an indicator of ***economic success***, but is totally inadequate as an indicator of ***economic welfare***, let alone overall societal well-being (1989, 371). They stress the need to counterbalance its influence by establishing social and ecological indicators of equal or greater importance. They make reference to a Physical Quality of Life Index (PQLI) built from measures of infant mortality, life expectancy at age one, and literacy. They also call for wider dissemination and use of a broad number of "environmental" indicators such as those related to air pollution, water pollution, soil loss, ozone layer depletion, and global warming.

Daly and Cobb also review alternatives to the GNP as an indicator and argue the need for a new measure that uncouples the link between economic well-being and market throughput, a linkage that is entrenched in calculation of the GNP. Instead, they propose the use of an "Index of Sustainable Economic Welfare (ISEW)" calculated by subtracting the sum of a number of "negative elements" (certain expenditures on consumer durables, health, education, and national advertising, plus costs of commuting, urbanization, auto accidents, pollution, loss of wetlands and farmlands, depletion of non-renewables, and long-term environmental damage) from the sum of what they see as "positive elements" (the value of services and consumption considered "positive").

A comparative plot showing GNP and ISEW, from 1950 to 1990 for the United States is shown in Figure 3-1a and a U.S. - Colorado comparison of ISEW per capita from 1970 to 1990 is shown in Figure 3-1b.

The graphs show a decline in ISEW for the U.S. over the past two decades while GNP has continued to rise. Further, the Colorado plot shown in Figure 3-1b demonstrates the swings of a boom-bust local economy.

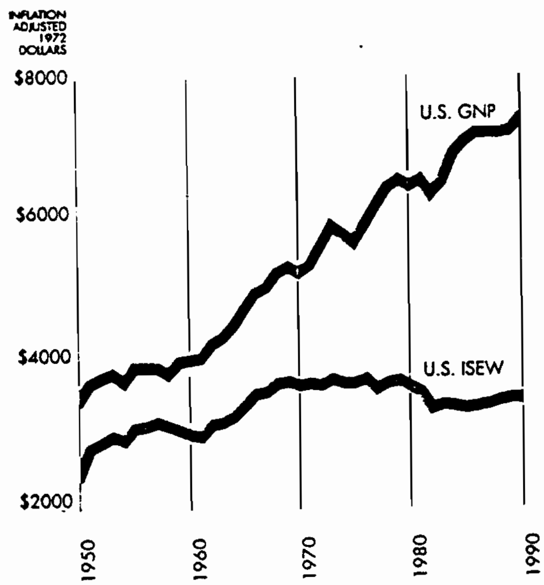


Figure 3-1a:
United States GNP and ISEW per capita 1950 - 1990
Source: Daly and Cobb 1989, 420. Copyright (C) 1989 by Herman E. Daly and John B. Cobb. Reprinted with permssion of Beacon Press.

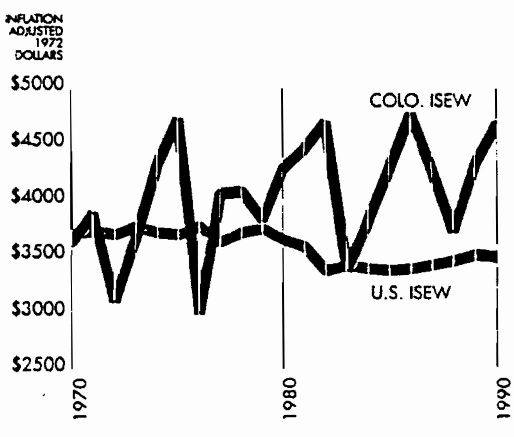


Figure 3-1b:
Colorado and United States ISEW per capita 1970 - 1990
Source: Colorado Trust 1992, 16

Figure 3-1. Comparison of Daly's Index of Sustainable Economic Welfare with Gross National and State Product. All figures are in 1972 dollars.

Daly and Cobb's ISEW is crude and as fraught with problems as is the calculation of GDP/GNP. In particular, the value base and criteria used to assign elements as "negative" or "positive" is not rigorously developed. For example, expenditures on home insulation, a consumer durable, would be included as "negative" even though the results would be positive both in terms of employment and reduction of environmental stress. Similarly, higher costs associated with urban living (from environmental and social degradation previously unassessed) are considered as "negative" while the economies of scale that motivate community settlement in the first place do not enter into their calculations. Despite these and similar criticisms, however, the ISEW does serve to stimulate further debate regarding both economic and overall well-being.

Design of the SNA is based on a macroeconomic conceptual framework that itself embodies an implicit value system. In a critique of the international economic system in general and the system of national accounting in particular, Waring states:

> ...the international economic system constructs reality in a way that excludes the great bulk of women's work — reproduction (in all forms), raising children, domestic work, and subsistence production.
>
> ...this (maintaining the UNSNA in its current form) ensures a continued vicarious and second class relationship of "the maintenance of well-being in the community" to the continued primary importance of "winning the war" and of "the market."
>
> (1988, 30; 299)

Waring argues that the current international economic order, particularly as codified in the UNSNA, embodies an implicit value system that exploits both women and the Earth. In a similar vein, Friend also criticizes the "single-layered market assumption" of the SNA by pointing out that:

> the production boundaries of the SNA is a normative concept conforming, in essence, to an institutional view of what ought to constitute a national economy.
>
> (1991, 4)

Waring also suggests that valuing human activities in terms of dollar production of goods and services is inadequate and that some measure of "time" may bring greater equity. Following-through on her suggestion would result in the elimination of the SNA in its current form.

Other attempts to deal with the limitations of the SNA are less dramatic. For example, Hueting provides a comprehensive review of the limitations to national accounting. He proposes ways to (1) avoid misinterpretation of the current national accounts by politicians and the public by being much more explicit about what the SNA mean and do not mean, and (2) deal with the issue of environmental losses by "adjusting the SNA with an estimate of the costs of the measures (including a direct decrease in activities) that are necessary to meet standards for sustainable use of the functions of the environment" (1991, 201 - 203; 194).

Still others are pursuing development of supplementary or **"satellite"** accounts which leave the current system of accounts intact while adding additional accounts involving monetary and/or physical data to monitor environmental and other issues of concern such as the depletion of natural resources or the generation of waste residuals (Victor 1990). A new set of national economic accounting guidelines is currently under development in a joint effort of the United Nations, the World Bank, and the OECD. A general framework for satellite accounts (supplementary tables) that deals with resource and ecological data alongside conventional economic data is to be included (Potvin, 1991b).

Meanwhile, within Statistics Canada, four environmental satellite accounts are under development: (1) natural resource stock accounts for oil and gas (see Born, 1993 for preliminary results) and forestry, (2) natural resource use account, (3) waste and pollutant output account (see Smith 1993, for work related to Canadian greenhouse gas emissions), and (4) environmental expenditures account (Smith 1991, and see Gaston 1993a and 1992b for preliminary results).

The issues of whether or how calculation of GNP/GDP should be modified or whether some totally new index should be developed to measure and monitor economic success (given the conclusion that it is a very poor indicator of societal well-being or welfare) is an ongoing debate and will not be resolved in this thesis. Rapport and Friend emphasize that the "point at issue is not so much the conceptual framework of the SNA but rather the unwarranted normative values placed on the national aggregates" (1979, 71). Thus, the key issue that must be addressed here is the establishment of the appropriate role (if any) that the System of National Accounts (SNA) and any indicators of indices derived from them should play in the proposed system of reporting on sustainability.

The SNA is organized with the Standard Industrial Classification (SIC), a system for arranging units of economic production into industries (See Statistics Canada, 1980, Introduction).[1] It is structured in a four level hierarchy. The base is formed by 862 individual industries or ***industry classes*** (e.g. 0111 - Dairy Farms). These are gathered into 318 ***industry groups*** (e.g. 011 - Livestock Farms), which are in turn aggregated into 76 ***major groups*** (e.g. 01 - Agriculture Industries). At the highest level of the hierarchy are 18 ***divisions*** (e.g. A - Agriculture and Related Service Industries).

Using the SIC as an organizing template, Statistics Canada gathers four sets of principle statistics:

1. employment, salary and wages and supplementary labour income;

2. sales, shipments or revenues, as may be relevant;

3. expense items accounting in total for all material inputs (e.g., raw materials; goods purchased for resale; process, operating and other supplies; energy; etc. depending on the information relevant to the activities involved); and

4. inventories (where applicable).

The above statistics are then used with Government data to calculate Gross Domestic Product in the three ways discussed previously. When value-added numbers on an industry-by-industry basis are set with employment figures, an overview of the market economy emerges that illustrates the contribution of each part to economic livelihood. As examples, figures of value-added and employment for Ontario are listed in Table 3-3.

TABLE 3-3. ONTARIO ECONOMIC INDICATORS FOR 1990.[2]

VALUE ADDED AND EMPLOYMENT BY INDUSTRY[3]

industry	value added[4] (million $1986)		employment (thousands)
Goods Producing			
manufacturing	47,814		966
construction	12,019		324
utilities	5,325		60
agriculture	2,572		138
mining	2,320		35
forestry	537		17
fishing, hunting, trapping	49		3
	70,636	sub-total	1,543
Dynamic and Traditional Services[5]			
finance, insurance,and real estate	34,081		302
commercial, business, and personal services	30,763		727
wholesale and retail trade	22,717		744
transportation , communication and storage	14,240		255
	101,801	sub-total	2,028
Nonmarket Services[6]			
education services	9,438		287
health and social services	7,413		378
federal administration and defense	6,859		158
local administration	2,935		84
provincial administration	2,568		66
	29,213	sub-total	973
GDP AT FACTOR COST	**201,650**	**TOTAL**	**4,544**
GDP AT MARKET PRICES[7]			
$ millions, 1986	228,900		
HOUSEHOLD CONTRIBUTION TO VALUE ADDED (NOT IN GDP)[8]			
$ millions, 1986	81,300		
CONTRIBUTION TO VALUE ADDED FROM VOLUNTEER ACTIVITIES (NOT IN GDP)[9]			
$ million, 1986	4,500		211

One critical aspect of dealing with human - ecosystem interaction is the identification and classification of human activities. This will be explored in Chapter Six. Because it is structured along activity lines, the Standard Industrial Classification (SIC) together with data provided by the System of NationalAccounts (SNA) provides an essential starting point for addressing the linked concerns of human and ecosystem well-being. Three observations support this approach.

First, the majority of human activities that are currently overstressing the environment are the activities driving the market system. These are the very activities described in the SIC. Secondly, the Statistics Canada data base, compiled on the basis of the SIC, provides the most complete and long-term data base available describing human activity. And lastly, because of their common use, the utilization of SIC categories facilitates a link to current societal decision-making.

The extension of the above approach is necessitated by: (1) limitations to the market driven approach to valuing human activities; and (2) the fact that additional important (but non-market) activities are not included in the SIC that both provide for human well-being and, in the process, stress the supporting ecosystem. Household activities and volunteer activities are two such categories which are included in Table 10 along with crude estimates of their contribution to value-added.

Regardless of their real limitations in indicating well-being, the figures ofTable 10 provide a first step in reporting on sustainability. The figures in this table offer a comprehensive picture of market activities to serve as a basis for assessing the linked concerns of human and ecosystem well-being. They contribute to an understanding of (1) the structure of the regional economy, its strengths and weaknesses and (2) a partial assessment of the contribution (the value-added) of each component to human well-being. These are necessary (albeit not sufficient), elements of any system of reporting on sustainability.

3.3 THE CONTEMPORARY ECONOMIST'S VIEW OF THE ENVIRONMENTAL PROBLEM

From the discussion in Section 3.1, it is apparent that the dominant contemporary sense of economics is as a study (or science) of allocating resources in a way that brings the greatest benefit. It is also apparent that the economy is seen simply as a mechanism that allocates scarce resources amongst competing uses. Resources include any "means of supplying a want or stock that can be drawn on" (OED, 1989).

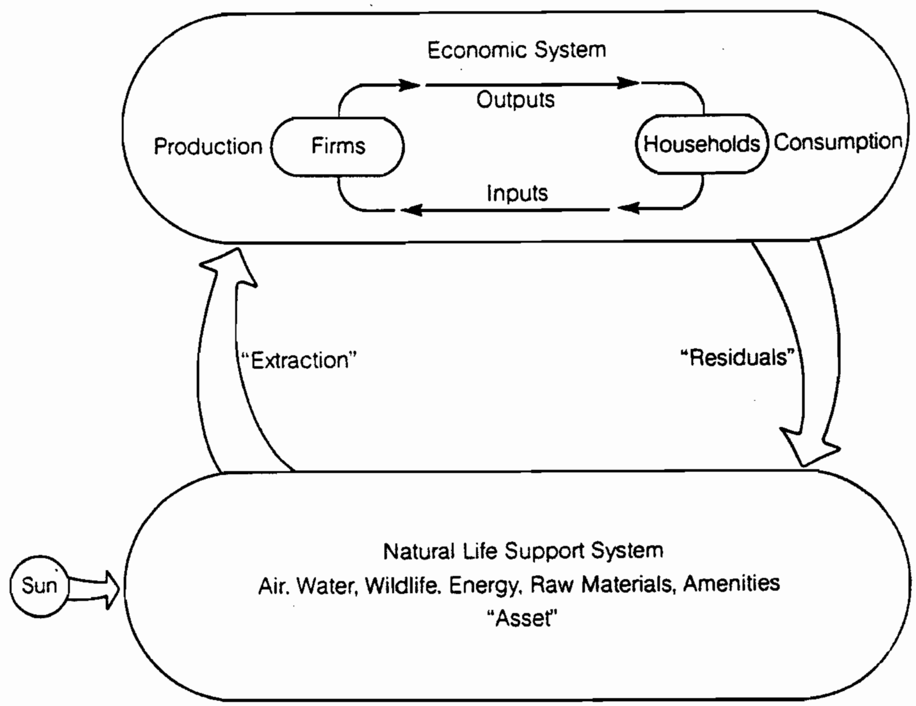
Because many of those resources are derived directly from the ecosystem, economists have been dealing with human-ecosystem interaction in some way since the beginning of economics. A discernable shift in some economists' views regarding how that interaction is conceptualized and, in particular, how the "environmental problem" is described has been apparent over the past several decades. This shift is briefly summarized below; a more detailed description is found in Appendix VI, Section 5.

The classical model of the market economy recognizes three groups of decision makers: households, firms, and governments. Factors of production include labour (brain- and muscle- power of human beings; land (natural resources of all kinds); and capital (all the equipment, buildings, tools, and other manufactured goods that can be used in production). Two mechanisms are used to achieve coordination of economic choices: command mechanisms and market mechanisms. The concept of the economy is based on a circular flow of money matched by an opposite flow of goods, services and productive factors between households (consumption) and firms (production) (see Appendix VI, Figure 15). Links between economies are made through imports and exports of goods and services. Monitoring of the state of the economic system is achieved through assessment of the dollar value of the stocks and flows of goods and services.

In the 1960s and 1970s critics of this model argued that it ignored (1) energy and material flows, (2) the basic laws of physics governing these flows, and (3) backward linkages of resources to ecosystem structure or function (see for example, Georgescu-Roegen 1971 and 1975, Freeman et al. 1973, and a recent summary in Rees 1993). As a result, over 20 years ago, a materials/energy balance model linking the economy and the environment was proposed (Kneese et al. 1970; and see also Appendix VI, Figure 16).

The ideas of the materials/energy balance model have since been integrated into most economics based models of the human-ecosystem relationship. For most economists, the environment is considered a ***composite asset*** that: (1) provides raw materials which are transformed into consumer products; (2) provides energy which fuels this transformation; and (3) provides a variety of services directly to consumers (e.g. air to breathe, nourishment, aesthetic amenities, etc.). Ultimately, the raw materials and energy return to the environment as pollution, waste products or residuals (Tietenberg 1992, 19).

Together, the above ideas reflect a depletion/pollution model of the environment-economy relationship that is repeatedly found throughout the economics literature, and well beyond. Tietenberg's schematic is shown in Figure 3-2 and additional examples are found in Appendix VI, Section 5.



Source: Tietenberg 1992, 19. Copyright (1992) by Harper Collins College Publishers. Reprinted with permission of the publisher.

Figure 3-2. Tietenberg's model of the economy-environment relationship.

The environmental "problem" can thus be reduced to two components, one dealing with resource use (or misuse, depletion, and scarcity) and the other dealing with pollution or generation of waste residuals. This is an extremely important conclusion because it then follows that the resolution of the "environmental problem" can be attained through (1) appropriate or wise resource use and (2) reduction of pollution.

For many, the depletion/pollution model has also come to embody the concept of sustainability and it is therefore argued that reporting on sustainability should be centred on resource use or depletion and pollution. Statistics Canada's choice of developing environmental satellite accounts dealing with (1) natural resource stocks accounts for oil and gas and forestry; (2) natural resource use accounts; (3) waste and pollutant output accounts; and (4) environmental expenditure accounts reflects this argument. Similarly, current work at the United Nations aimed at developing a modified System of National Accounts through a satellite system of integrated environmental and economic accounting is based on an accounting framework that is differentiated from conventional accounting:

> ...in the introduction of environmental costs of "quantitative" depletion of natural resources and "qualitative" environmental degradation (largely from pollution), mirrored in the expansion of capital asset boundaries to include natural assets (UN Department of International Economic and Social Affairs 1991, 197).

Indeed, Pearce and Freeman suggest that at a minimum, "indicators of sustainability" should include (in addition to some measure of "sustainable income" established through modified GNP accounting), indicators of renewable and exhaustible resource use (1992, 93).

However, it is by now apparent that this depletion/pollution conceptualization of human-ecosystem interaction is far from complete. A better model of the interaction is based on an assessment of human activities: how they draw on the ecosystem for provision of basic needs and enhanced quality of life on the one hand and how and to what extent they stress the ecosystem on the other. The classification of stress that recognizes the complete range of physical, chemical, and biological stresses imposed by human activity (introduced in Tables 2-2 and 2-3) is fundamental to this new approach. This classification uses as a starting point the pioneering work of Rapport and Friend (1979) which itself draws on combined knowledge of economics, ecology and statistics.

END NOTES

1. In Canada, the first Standard Industrial Classification was formalized in 1948. Revisions occurred in 1960, 1970, and 1980 and a fourth revision is currently being developed. Compatibility tables that allow ranslation to the U.S. SIC are available.

2. Because of the variety of data sources, figures must be considered rough estimates. However, they are useful for indicating relative contributions.

3. Compiled from Conference Board of Canada 1991; Statistics Canada 1990 a, b, c; and data from the 1986 census; Ontario Office of Economic Policy 1992.

4. Conference Board (1991) estimates unless otherwise noted.

5. The service sector structure is from Betcherman et al. 1991.

6. Value added figures for nonmarket services are estimated from both Conference Board 1991 and Statistics Canada 1990b.

7. Ontario Office of Economic Policy 1992.The difference between this figure and the total of contributions to value-added by the various components above is accounted for by the addition of indirect taxes minus subsidies.

8. The most recent estimates of the value of household work (VHW) in Canada are given by Jackson 1992. Using both opportunity cost and replacement cost valuation methods, he estimates that the VHW in Canada ranges from 32 % to 39 % of GDP. The figure in Table 10 is simply the average of these percentages applied against the 1990 GDP figure. VHW is not included in calculation of GDP.

9. Ross, D. P., 1990. Ross estimates the economic value of volunteer activities for 1986/1986 (29). The figure for value added used in Table 10 has been modified upward from \$4.2 to \$4.5 billion to approximate 1990 conditions. The figure in the employment column is Ross's estimate of volunteer hours as full-time equivalent positions. For Ontario, this represents 5.3 % of all full time employees.

CHAPTER FOUR.

HUMAN-ECOSYSTEM MODEL REVIEW

4.1 INTRODUCTION

A large number of theoretical models have been developed over the years that in some way address human-ecosystem interaction. These models have been motivated by a variety of interests and disciplines including: economics, geography, ecology, health, planning (community, urban, regional, water resources, etc.), resource management, and most recently the broad interest areas of sustainable development and sustainability.

In this review, thirty different models of human-ecosystem interaction are examined. Like the review of state-of-environment reports, there are two motivating purposes. The first is to search for an existing conceptual framework that could serve to guide reporting on sustainability and the second is to gain insight into alternative conceptual approaches that address the human-ecosystem relationship — the components, structure, communication, and feedback mechanisms that are identified.

4.2 REVIEW METHODOLOGY

The review included two steps. First, the potential of each model to provide a framework for reporting on sustainability was examined. The following five questions provided the assessment criteria:

1. Are the definitions of components and their relationships clearly stated and unambiguous?

2. Does the model reflect the value base underlying the concept of sustainability?

3. Does the model reflect a systematic approach to describing human-ecosystem interactions — did it serve to facilitate dealing with not only components but also with the whole system so that emergent properties could be recognized?

4. Does the model accurately describe the physical system being dealt with and its relationship to human decision-making so that the reporting function could be appropriately targeted?

5. Does the model lead easily to an organizational framework for compiling data and information, assessing progress toward, and reporting on sustainability?

Secondly, the nature of each model was examined — the structure, the components, the relationships, and the boundaries. An attempt was made to establish important characteristics that should be reflected in the conceptual framework for reporting on sustainability. Again, this is an application of John Rawls' idea of attempting to establish an "overlapping consensus" by drawing on characteristics that are common to many models that emerge from different disciplines (1987).

The thirty models are grouped into the eight categories listed in Table 4-1.

TABLE 4-1. SUMMARY OF MODELS REVIEWED.

	category	*number of models reviewed*
1.	the common "social-economic-environmental" model	6
2.	health variations of the three-part model	6
3.	models from economics literature	3
4.	stress and stress-response models	3
5.	general ecological models	2
6.	additional models from the sustainable development and sustainability literature	4
7.	AGENDA 21	1
8.	a miscellaneous grouping that includes models addressing regional analysis, watershed analysis, carrying capacity, aboriginal development, and quality of life.	5

4.3 REVIEW RESULTS

No model was found that fully meets the five assessment criteria listed above. Key observations that emerged from the review are summarized in the following paragraphs. A full discussion of the review including an illustration of each model is provided in Appendix VI.

THE COMMON ENVIRONMENTAL-SOCIAL-ECONOMIC MODEL

Over thirty years ago, Walter Firey pointed out that three broad groupings of knowledge were pertinent to natural resource use: (1) ***ecological,*** which takes the physical habitat as its point of departure; (2) ***ethnological,*** which stems from the culture of human beings; and (3) ***economic***, which begins with the attribute of scarcity which attaches to human activities (1960, 20). Firey's theory of resource use lies at the root of much of today's conceptualization of the human - ecosystem interface. His three-part model (ecologic, ethnologic, economic), and his assertion that a balancing of criteria drawn from each component is required in analysis of natural resource use is prevalent in contemporary thought (Mitchell, 1991). In the 1990s, the three elements are often referred to as (1) ecological or environmental; (2) social or cultural, and (3) economic.

In the late 1980s, Firey's three-part model was adopted by a number of workers attempting to operationalize the concept of sustainable development (Mitchell 1991, 268). Included are the contributions of Sadler (1988, 1990), Dorcey (1991a, b, c), The British Columbia Round Table on the Environment and the Economy (BCRTEE 1992, 1993), The Prairie Farm Rehabilitation Administration (PFRA, 1992), and the Canadian International Development Agency (CIDA, 1991).

From another perspective, health professionals were also developing various forms of the same three-part model. Included here is the conceptual work underpinning the Healthy Community Movement (Hancock 1985, 1989, 1990; Hancock and Perkins 1985; Crombie 1991), the Canadian Institute for Advanced Research's model of the determinants of health (Evans and Stoddart 1990); the Canadian Medical Association's model of sustainable development (CMA 1991), the conceptual framework for Canada's proposed System of Health Statistics (NTFHI 1991), and the organizational framework for sustainable society indicators proposed by Health and Welfare Canada's Steering Committee on Indicators for a Sustainable Society (Gosselin et al. 1991, 1993).

While there is variation in the labels that are used, each of the above contributions reflects the three-part model that stems from Firey's work. Table 4-2 groups these contributions by each component of the three-part model.

TABLE 4-2. SUMMARY: THREE-PART MODEL.

component	*contributor*
1. Environmental	
ecology:	Firey 1960
environment:	Saddler 1988, 1990; Dorcey 1991; BCRTEE 1992; Hancock 1989, 1990; CIDA 1991; CMA 1991; Gosselin et al. 1991, 1993
physical environment:	Evans and Stoddart 1990
natural resource and environmental development:	PFRA 1992
physico-chemical (external milieu):	NTFHI 1991
2. Social, Cultural, Community, Health	
ethnology (culture):	Firey 1960
social:	Saddler 1988, 1990; Dorcey 1991; CIDA 1991
social system:	BCRTEE 1992
social/cultural:	PFRA 1992; NTFHI 1991
cultural:	CIDA 1991
community:	Hancock 1989, 1990
health:	Hancock 1989, 1990; CMA 1991; NTFHI 1991; Gosselin et al. 1991, 1993
political:	CIDA 1991
equity:	Gosselin et al. 1991, 1993
3. Economy	
economy:	Firey 1960; Saddler 1988, 1990; Dorcey 1991; BCRTEE 1992; Hancock 1989, 1990; CIDA 1991; CMA 1991; Gosselin et al. 1991, 1993; PFRA 1992; NTFHI 1991
physical prosperity:	Evans and Stoddart 1990

The three-part model enjoys certain attributes that have contributed to its relatively broad appeal. It makes a significant contribution by clearly identifying the need to balance different sets of values and goals. This point is made by Firey (1960), emphasized by the Brundtland Commission (WCED, 1987) and reinforced by Sadler (1988, 1990), Hancock (1989, 1990) and Evans and Stoddart (1990). Further, it serves to emphasize that this balancing involves more than two factors and is not a black and white, economy verses the environment debate. It thus expands the frame of thinking to include factors that are often not simultaneously considered.

However, the three-part model is characterized by three deficiencies that limit its use as an organizing framework for reporting on sustainability. First, the elements of the three-part model are not tightly defined. The different models are not always consistent in their usage of the same terms. For example, in some models, "social" is used to bring a focus to the equity issue (Sadler 1988) while for others broad social-cultural development is implied (PFRA 1992). Its relationship to "health" and "politics" is not always clear. And as Horn points out, in some ways 'social' overlaps with 'economic' — "because social demands are subject to economic restraints and because economic processes are linked to their social and societal environment" (1993, 146). These different nuances of meaning all contribute to a lack of clarity which detracts from the three-part model's ability to frame reporting on sustainability.

Words like social, environmental, and economic may well be appropriate for designating general categories of knowledge necessary in assessing wise natural resource use (Firey, 1960), concerns or goals (Sadler, 1988, 1990), aspects of development (PFRA, 1992), or challenges (BCRTEE, 1993). However, these labels do not describe a well-defined set of system components that systematically capture the human-ecosystem relationship.

Second, applying systems theory to the idea of sustainability, the three-part model can be seen to be mixing unequal system parts. The "natural ***environment***" or "**ecosystem**" is comprised of a set of interacting physical components that can be identified and described in physical, chemical, and biological terms. Economics has come to mean the study of human activities arising from scarcity and the ***economy*** is the human created system used to make decisions about allocating certain resources (See Chapter Four). ***Health*** is a characteristic of people. ***Social*** is "concerned with the mutual relations of people or classes of people" (OED, 1989). People are linked through a wide range of ***socio-cultural*** relationships.

Lastly, the three-part model does not adequately describe or bound the system that must be considered for assessing progress toward sustainability. In particular, the "economy" deals only with human activities and related stocks and flows of materials that are transacted through the market system. It does not deal with housework and volunteer activity, two sets of activities that contribute greatly to human well-being while creating significant environmental stress.

With its roots in the theory of resource use, it is not surprising that the three-part model is limited in dealing with the broader issue of reporting on sustainability. However, the related literature contains a number of useful insights. Dorcey's use of the conceptually simple "human system" nested within the "natural system" points to resolution of some of the conceptual inconsistencies of the three-part model.

Evans and Stoddart's (1990) argument for human well-being as the objective of not only health policy but all human activity is important because it is fundamental — people do what they do to improve their lot. For example, it is not for the benefit of the economy that jobs are created - it is for the benefit of people and their well-being. These kinds of fundamental understandings often become hidden beneath secondary and tertiary concerns.

The key roles of community, health, and culture in determining human well-being (Hancock 1989, 1990; CMA 1991, PFRA 1992, and Gosselin et al. 1991) serve to highlight the need to include these factors in any assessment of progress toward sustainability.

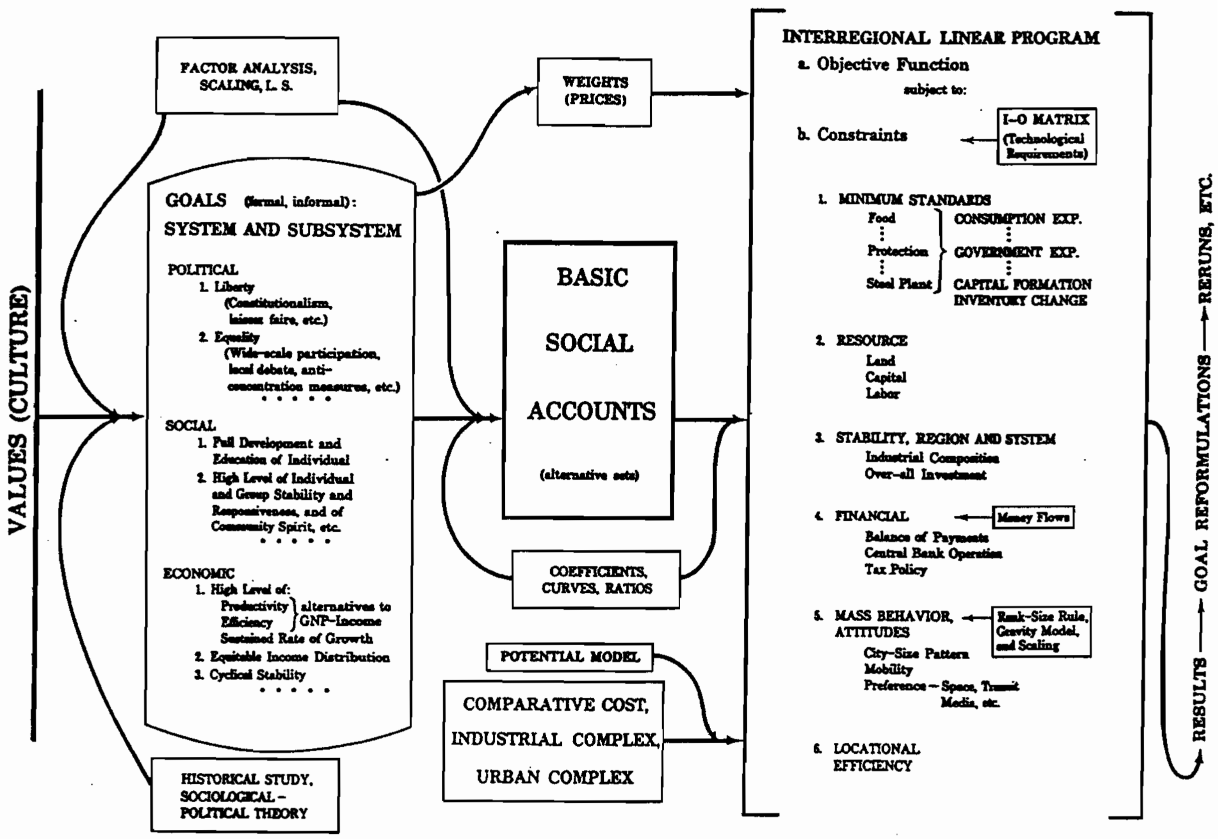
Sadler's consideration of micro (individual project) analysis and lessons from the environmental and social impact assessment literature along with overall macro analysis provides an important linkage. Jacobs (1987) points out that further progress in project level environmental assessment awaits the evolution of a paradigm that "circumscribes the whole" and together, Sadler and Jacobs (1990) argue for development and use of "sustainable development assessments". This quest is no different than the very aim of this dissertation.

ISARD'S EARLY WORK ON REGIONAL ANALYSIS

Walter Isard pioneered many of the pragmatic and operational techniques for undertaking regional analysis. Thirty years ago, he presented five alternative "channels" for synthesizing regional planning analysis (1960, Chapter 12).

The first three depend on optimizing regional systems using a variety of tools including interregional flow analysis, industrial location analysis, interregional and regional input-output techniques, industrial complex analysis, interregional linear programming, and gravity, potential, and spatial interaction models.

The fourth is a conceptual approach driven by culturally-based values that lead to definition of goals (political, social, and economic) which in turn govern design of "social accounts". This approach is shown below in Figure 4-1.



Source: Isard 1960, 684. Copyright (C) 1960 by The M.I.T. Press. Reprinted with permission of the publisher.

Figure 4-1. Isard's values-social goals framework for regional analysis.

Isard points out that at the time of writing, 1960, the process by which the social system established goals was not well understood. As a result he identifies a need for greatly improved sociological, psychological, and anthropological theory and methods. In addition, he suggests that significant advances in political theory and administrative analysis are required before the value-based approach can be effectively applied.

In his fifth "channel" he reverts to an optimization approach while attempting to factor in at least the values and goals that are subject to approximate quantitative representation.

Isard's work pre-dates the rise in environmental concern that occurred in the late 1960s. Thus, it is not surprising that ecosystem conditions do not figure in his work until much later. However, this early attempt to systematically factor values and goals into a formal and sophisticated systems approach to regional analysis is noteworthy.

Models from Economics Literature

A review of economics literature reveals a series of conceptual shifts over time regarding the treatment of human-ecosystem interaction. The conventional definition of the economy simply sees a circular flow of money matched by an opposite flow of goods and services and productive factors that include labour, land, capital . "Land" can be seen to include environment in its broad sense.

The evolution of this model through a material-energy balance model to the currently popular pollution-depletion meodel was described in Chapter Three. There are many examples in the literature of this later including those provided by Tietenberg (1992, 19); Siebert (1981,9); Kneese and Bower (1979, 17); Young (1992, 9-10); Manning (1990, 294); and Leeman and Cox (1990, 5). Tietenberg's form was shown previously in Figure 3-2.

However, as pointed out in Chapter Three, a growing number of workers are recognizing that this conceptualization is not complete. Human activities impose a range of stresses on the ecosystem, not simply the drawing of resources and the generation of pollution. In turn, the role of the ecosystem is far greater than merely the provider of energy and material resources.

Hamilton's Population Environment Process (PEP) Model recognizes this larger suite of interactions (1991). It is shown in Figure 4-2 and is based on the following five principles:

1. the **socio-economic system** is an artificial system embedded in a natural environment;

2. the human-created and human-controlled processes within the socioeconomic system have **two types of direct impact** on the environment:

   (a) restructuring as a byproduct of production and consumption, and

   (b) extracting, harvesting, and using the natural environment as processes providing necessary resources for the socioeconomic system;

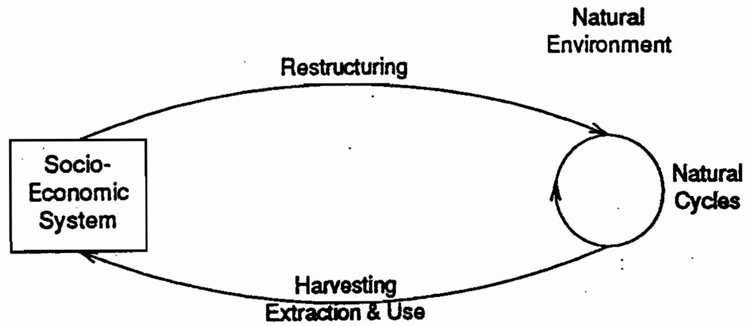
3. **restructuring** includes three basic expressions:

   (a) **physical** (construction of dams, roads, power lines, mines, dump sites, and other changes to the natural landscape;
   (b) **chemical** (release of pollutants and wastes into the environment); and
   (c) **biological** (harvesting and the introduction of exotic species).

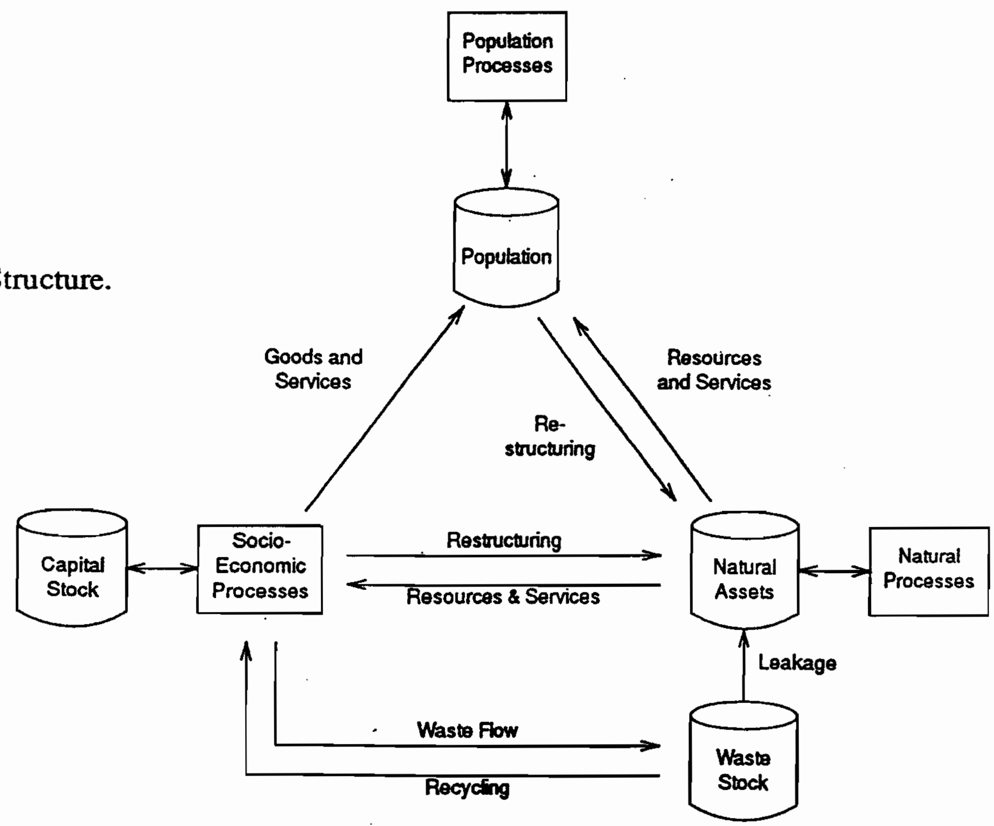
4. the **natural environment** is affected by the outputs and inputs to the socioeconomic system, and the state of the environment changes as a result;

5. the change in the state and quality of the environment, in turn, affects the quantity and quality of resources available to the socioeconomic system.

(Hamilton, 1991)



(a) Concept.



(b) Structure.

Source: Hamilton, 1991. Reprinted with the authority of the Minister of Industry, 1994.

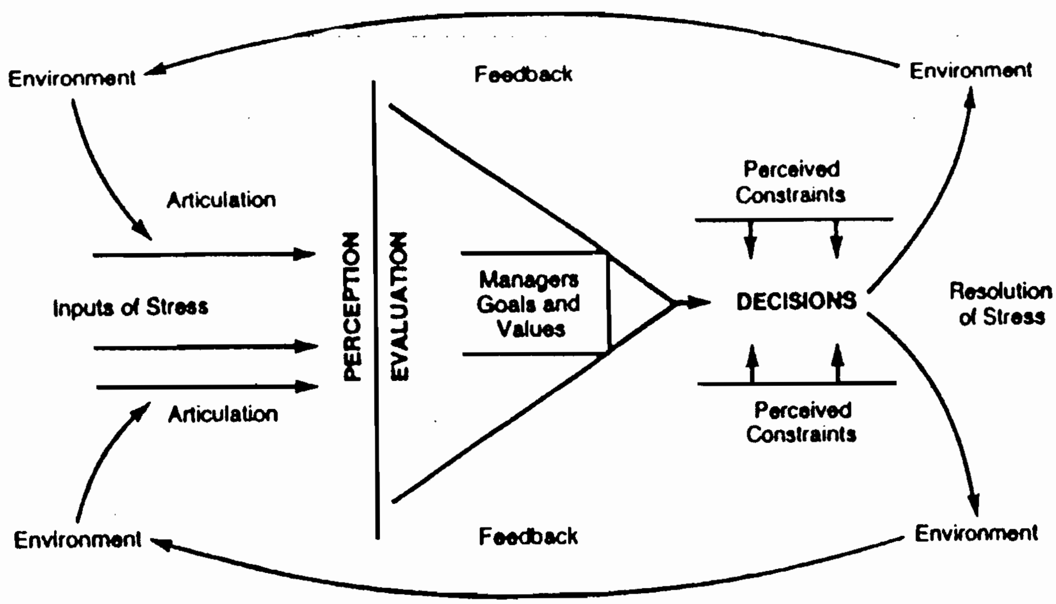
Figure 4-2. The Population-Economy-Process (PEP) Model

By showing the by-products of socioeconomic activity as interacting with the environment to produce changes in the resources on which these activities depend, PEP forms an interactive closed loop. Hamilton identifies three sets of components: (1) stocks that are measured by state and stock variables (population, capital, natural assets, and wastes); (2) processes that are measured by activity variables (population, socio-economic, natural); and (3) interactions that are measured by flow and restructuring variables (socio-economic processes with population, natural assets with population, natural assets with socio-economic processes, population with natural assets, socio-economic processes with natural assets, wastes with natural environment, socio-economic processes with wastes) (1991, 215).

Hamilton's recognition that human-ecosystem interaction is influenced by what he calls: (1) physical, chemical, and biological restructuring; and (2) the drawing of resources for use by the socioeconomic system represents a significant conceptual advance from the earlier depletion/pollution model. It's limitations include its entrenchment in economic jargon and a reflection of value that appears limited to concern for the provision of natural assets for human use. Because it has not been developed within the concept of goals for assessing progress toward sustainability, its focus is not on human and ecosystem well-being but rather on processes that serve and encompass human activities.

Stress and Stress-Response Models

The concept of stress at the human-ecosystem interface was discussed in Chapter Two(2.4). It was first considered a phenomenon acting on and influencing human well-being. This perspective is reflected in Kasperson's model of municipal decision-making shown below in Figure 4-3.

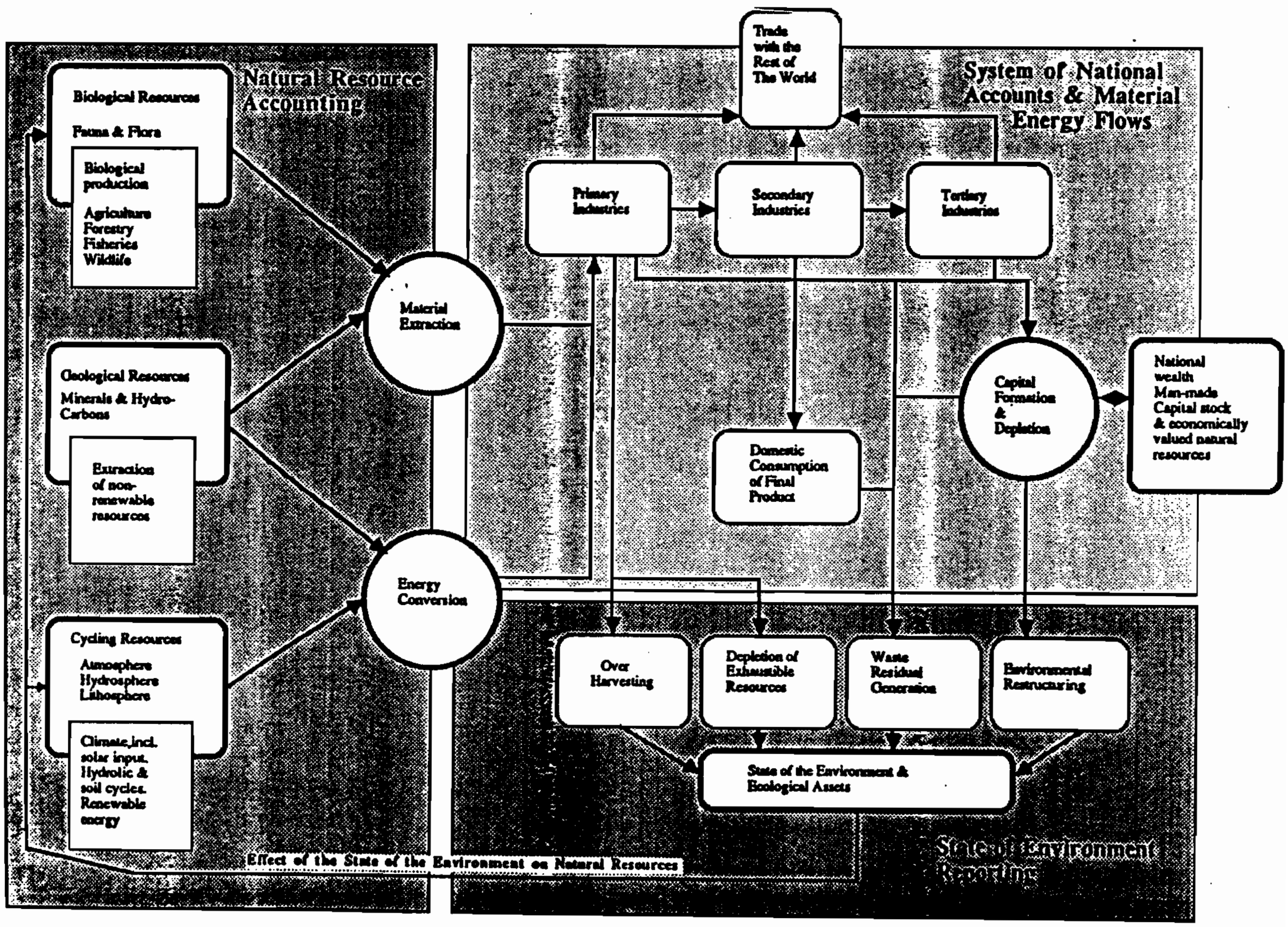


Source: Kasperson 1969, 485.

Figure 4-3. A general model of municipal stress management.

Rapport and Friend's stress-response model expanded this concept by recognizing that stress included both (1) stress imposed on the ecosystem as a result of human activities and (2) stress imposed on human beings by the environment (1979). While the idea of response has not gained greater clarity over time, their recognition of the two-way nature of stress and their multifaceted categorization of stress on the environment have facilitated a significant growth in understanding of human-ecosystem interactions.

Friend and Rapport's more recent work aimed at developing an information system for sustainable development and Friend's pluralistic approach to national accounting provide useful systems based approaches to these issues (Friend and Rapport 1989, 1990; Friend 1991). This latter model is shown in Figure 4-4. However, it is not apparent that these recent initiatives effectively build on the integrative power of the concept of sustainability while drawing on the really powerful elements of their own earlier work. Furthermore, just as with Hamilton's Population-Environment-Process model there is a limitation to their approach because assessment goals are not articulated and explicitly linked to the models. Thus, the focus is on data sets (for example, the national accounts) rather than on human and ecosystem well-being.



Source: Friend 1991, 8.

Figure 4-4. Framework for a "pluralistic" approach to national accounting.

MODELS USED IN ANALYSES FOR SUSTAINABILITY

Four contributions are included here. The first is drawn from the work of John Robinson and the Sustainable Society Project (SSP) that began at the University of Waterloo and is now housed with the Sustainable Development Research Institute at the University of British Columbia (Robinson 1989 and 1991). The second emerges from development of the first and second World Conservation Strategies (IUCN et al. 1980 and 1991). The third is Stuart Hill's model of the theory and practice of sustainable development (Hill 1989) and the fourth is John Nault's examination of requirements for sustainable farm practices (Nault 1991). While none of these contributions provide a conceptual framework that met the criteria listed in Section 4.2, each offers important insights.

Robinson's Sustainable Soceity Project initiated early work on indicators and reporting. Their models and the related analysis are noteworthy for at least four reasons: (1) recognition of its normative nature and its explicit listing of governing values; (2) its systematic approach that includes a pioneering attempt to map out a hierarchical assessment process; (3) its use of a well-founded conceptual framework — a variation of Rapport and Friend's stress-response approach; and (4) its use of Rapport and Friend's comprehensive stress classification which takes it conceptually past the old depletion - pollution model.

The major limitation of these models is that their focus is limited to human activities, environmental implications, and actions to change both. While these are critical elements of the sustainability equation a context that places this set of system elements within the overall ecosystem (including the human subsystem) is absent.

The IUCN led work on World Conservation Strategies shows a significant conceptual shift between the first document (IUCN et al. 1980) and the second (IUCN et al. 1991). In the first, the conceptual heart is captured in a commitment to three objectives: (1) maintenance of essential ecological processes and life-support systems; (2) preservation of genetic diversity; and (3) sustainable utilization of species and ecosystems (IUCN et al. 1980). In the second there is an added recognition of the need to monitor and assess both human conditions (they suggest assessment of quality of life) as well as ecosystem conditions (they emphasize maintenance of life-support systems and biodiversity; sustainable renewable resource use and minimum depletion of nonrenewables; and ecosystem carrying capacity limitations) (IUCN et al. 1991). The IUCN work is insightful but is not presented in a systematic way that lends itself to articulation of a framework for reporting on sustainability.

Hill focuses on human activities as the key to the analysis of sustainability (Hill, 1989). This is a critical insight. His realization that there are both natural and cultural aspects of what he calls "capital" is important. Unfortunately, the elements of his model are not crisply defined and neither the model nor its components are systematically organized and presented. As a result, application as an organizing framework for a system of reporting is impeded.

Nault's farm system analysis is influenced by Hill's work and also lacks a systematic approach. However, his recognition that farm system health is dependent on (1) a social support system; (2) a natural/environmental support system; and (3) resources provides a useful perspective and one that will be seen to be consistent with the framework proposed in this dissertation (Nault, 1991).

AGENDA 21 Macrostructure

The United Nations Conference on Environment and Development (Earth Summit) was held in Rio de Janeiro, Brazil, 8-14 June, 1992. The concept of sustainable development, championed in the report of the World Commission on Environment and Development five years earlier (WCED, 1987), was identified as the driving theme. AGENDA 21 provides an overview of the conference outcome. Table 4-3 lists its overall structure and content. Drawing again on Macelli's (1977, 1) insight that the conceptual approach taken in any project is reflected in the format of the final report, AGENDA 21 macrostructure can be seen to represent a conceptual model of sustainable development.

Six observations emerge from a review of AGENDA 21. These observations are not intended to detract from recognizing AGENDA 21 and the process leading to its creation as the remarkable achievements that they are. First, the four-part structure of AGENDA 21 reflects a primary concern with human conditions and a secondary concern for resource management, part of which includes protecting the environment as a source of resources for human needs and wants. Thus, the conceptual framework that emerges for sustainable development from this document could be described as a two-part model dealing with (1) people and (2) natural resource management.

Second, while AGENDA 21's explicit recognition of the human dimension of sustainable development is important, its focus on resource management reflects the pollution/depletion model at best and in many ways its organization and content reflect ideas that were prevalent in the 1970s and before.

TABLE 4-3. THE STRUCTURE AND CONTENT OF AGENDA 21 (AGENDA 21 CHAPTER REFERENCES ARE IN BRACKETS).

1. Social and Economic Dimensions

- accelerating sustainable development (2)
- poverty (3)
- consumption patterns (4)
- population growth (5)
- human health (6)
- human settlements (7)
- integrating environmental costs into decision making (8)

2. Resource Management

- atmospheric protection (9)
- land-use (10)
- deforestation (11)
- desertification (12)
- mountain development (13)
- agriculture and rural development (14)
- biodiversity (15)
- biotechnology (16)
- ocean protection (17)
- fresh water protection and management (18)
- toxic chemicals (19)
- hazardous waste (20)
- solid waste, sewage (21)
- radioactive waste (22)

3. Strengthening Major Groups

- participation (23)
- women (24)
- children and youth (25)
- indigenous people (26)
- non-governmental organizations (27)
- local authorities (28)
- workers, unions (29)
- business, industry (30)
- science, technology (31)
- farmers (32)

4. Implementation

- financial resources and mechanisms (33)
- technology transfer (34)
- science for sustainable development (35)
- education and public awareness (36)
- capacity building (37)
- international institutions (38)
- legal institutions and mechanisms (39)
- bridging the data gap (40)

Source: UNCED, 1992.

Third, AGENDA 21 does not recognize the fact that while human society does indeed manage the use of "resources" that are within the operating human system (e.g., copper ingots, bags of sugar, tins of fish), human society does not manage or make decisions directly controlling the environment. Rather, human society manages and makes decisions about human activities which in turn have an influence (along with other known and unknown factors) on the ecosystem (NRTEE 1993, 9). Thus, emphasis is best placed on improving the management of human activities, not on managing the environment.

Fourth, AGENDA 21 does not assume an approach to human activities that attempts to balance the value of these activities with the stress they impose upon the ecosystem. There is discussion of integrating environmental and economic accounting (Chapter 8) and adding natural resource satellite accounts to national accounts (Chapter 40). However, AGENDA 21 does not facilitate consideration of human activities in a way that balances their contribution to human well-being with the stress imposed on the ecosystem (and/or their restorative contribution).

Fifth, while there is discussion about broadening participation in decision-making and various sub-populations are identified and discussed, there is no recognition of either the different groups of decision-makers within any society or of the differences between various societies.

Lastly, AGENDA 21 does not provide an overall sense of the system that would facilitate anticipation of weak-links or even system-breakdown. Rather, individual chapters serve as a check-list of current concerns that must be dealt with by the needed reporting system as well as by contemporary public policy.

Given the above observations, AGENDA 21 macrostructure does not provide a framework that is appropriate for use to guide a systemic assessment of progress toward sustainability. Such a model should reflect an understanding of the whole system allowing identification of both what is being given priority consideration as well as what isn't. It is only with such an understanding that an anticipatory capability is generated.

Table 4-4 below groups the same elements according to the conceptual framework that will be proposed in Chapter Five. A number of gaps become evident: (1) not all ecosystems are addressed; (2) not all human activities are addressed; (3) the range of physical, chemical, and biological stress imposed by human activities is not considered; (4) the potential for human activities to restore ecosystem functions is not recognized; (5) an overall perspective on human well-being is not provided but rather a listing of special interests appears; and (6) a synthesis that would provide a sense of the overall system and relevant actions to be taken with this in mind is lacking completely.

TABLE 4-4. ELEMENTS OF AGENDA 21 GROUPED BY THE PROPOSED FRAMEWORK (CHAPTER REFERENCES IN BRACKETS)

Domain I. Ecosystems

- air and climate (9)
- forest ecosystems (11)
- dry-land ecosystems (12)
- mountain ecosystems (13)
- cultivated ecosystems (14)
- freshwater ecosystems (18)
- coastal, island, and marine ecosystems (17)
- biological diversity (15)
- data, information, and analysis (40)

Domain II. Interaction

- trade (2)
- poverty (3)
- consumption (4)
- settlements (7)
- other activities contributing to atmospheric conditions (energy production and use, transportation, industrial development, agriculture and land use)(9)
- deforestation (11)
- desertification (12)
- agriculture (14)
- biotechnology (16)
- fishing, shipping, tourism (17)
- other activities contributing to freshwater conditions (18)
- hazardous waste generation, storage, and management (20)

- solid waste generation, storage, and management (21);
- radioactive waste generation, storage, and management (22)
- data, information, and analysis (40)

Domain III. People

- trade and cooperation (2)
- poverty (3)
- consumption (4)
- demographic dynamics (5)
- human health (6)
- settlements (7)
- women (24)
- youth (25)
- indigenous people (26)
- non-governmental organizations (27)
- local authorities (28)
- workers and trade unions (29)
- business and industry (30)
- scientific and technological community (31)
- farmers (32)
- technology transfer (34)
- financial resources and mechanisms (33)
- science (35)
- education and public awareness (36)
- capacity building (37)
- institution building (38)
- legal instruments and mechanisms (39)
- data, information, and analysis (40)

Domain IV. Synthesis

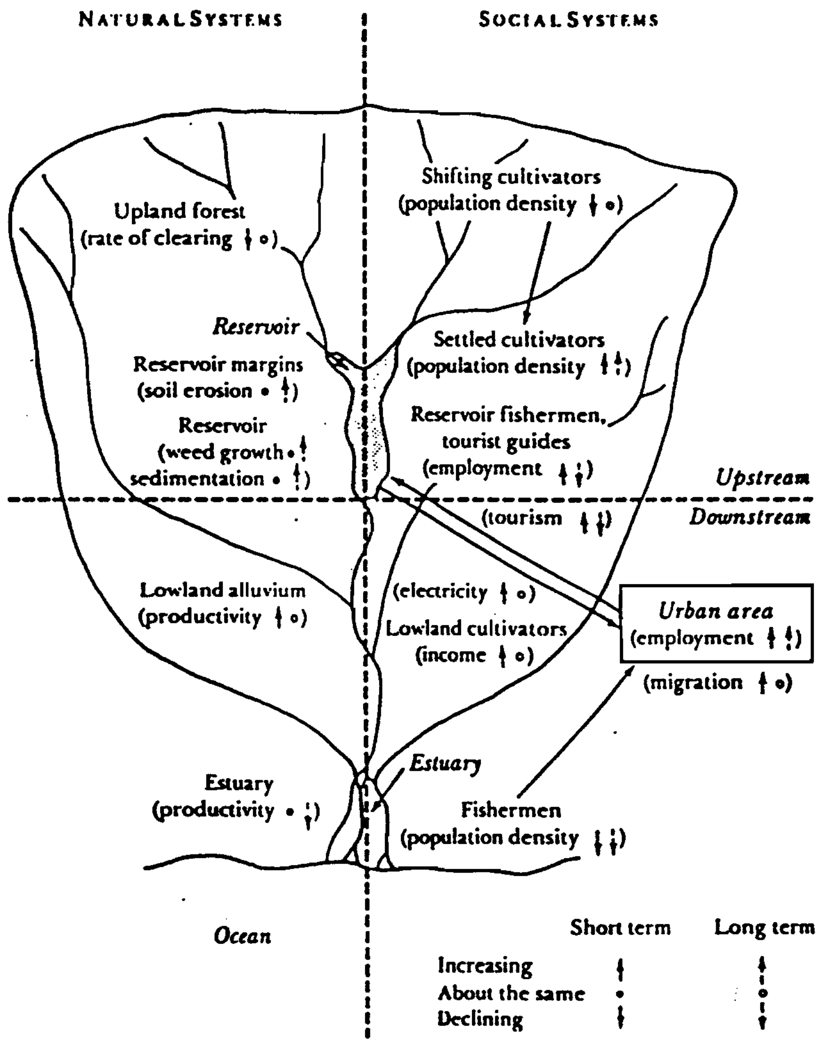
- integrated policy-making for sustainable development (8)
- integrated land-resource management (10)
- data, information, and analysis (40)

Source: Hodge 1993, Appendix V.

Additional Models Reviewed

Six additional models are reviewed in this category including Easter et al.'s conceptual approach for analyzing watershed resource management (1986), Stankey's analytic framework for guiding wilderness management based on the concepts of ecological and sociological carrying capacity (1972), two general ecological systems models (Dansereau, 1975, Miller 1978), use of the medicine wheel as a conceptual guide for aboriginal development (DIPSC 1991), and Murdie et al.'s proposed framework for assessing quality of life (1992).

Easter et al. undertake an assessment of watershed resource management drawing on a variety of case studies throughout Asia and the Pacific (1986). Their analytic framework is shown in Figure 4-5.



Source: Easter et al. 1986, 8. Reprinted with permission of the author.

Figure 4-5. Easter et al.'s analytic framework for watershed resource managment.

The model shown in Figure 4-5 recognizes interacting "natural" and "social" systems. Like so many of the models in this review, in practical application and applying systems ideas, Easter et al. find it useful to work with an ecosystem dimension (the "natural system") and a human subsystem within (the "social system"). This two-part conceptual aproach is consistent with the systems approach that is taken in this dissertation.

Stankey's analytic framework for guiding wilderness management is also noteworthy in its identification of a human or sociological dimension and an ecological dimension (1972). His human dimension deals systematically with use activities and his ecological dimension deals systematically with ecosystem components. This core conceptual model is appropriately nested within a management model.

A different perspective on human-ecosystem interaction is provided by general ecological models. Two such models were included in this review, one proposed by Pierre Dansereau (1975, 1976, 1990), and one by James Miller (1978). Although both of these models offer many insights into the nature of ecosystem processes, both are complex and do not lend themselves to easy application in the hands of contemporary decision-makers. Neither provides an obvious organizing template for reporting on sustainability.

In 1991, the Development Indicator Project Steering Committee of Indian and Northern Affairs Canada proposed a framework for guiding aboriginal community development that attempts to integrate the North American Indian ***medicine wheel*** with planning concepts. The result is a ***development wheel.***

For assessing progress, indicators are listed in terms of the following categories: (1) economic development; (2) social development; (3) cultural - spiritual development; and (4) political - organizational development. While the "ecological" environment is identified as important in the ***medicine wheel*** the development wheel focuses on human development and no mention is made of ecosystem conditions. In its current form, the development wheel is not an appropriate template for reporting on sustainability.

Signalling a return to interest in quality of life that was so dominant in the 1960s and 1970s, the Canada Mortgage and Housing Corporation commissioned a study of quality of life indicators (Murdie et al., 1992). They propose a conceptual framework for analysis of quality of life and a community oriented model of the lived environment. The second model leads to "indicators of liveability" that draw on economic, social, environmental, and cultural components. In both models, ecosystem characteristics are recognized as key contributors to the quality of life. However the explicit focus is on human quality of life and not on the broader concept of sustainability.

4.4 REVIEW CONCLUSIONS

The review led to the following conclusions.

1. **ALMOST ALL OF THE MODELS REVIEWED OFFER USEFUL INSIGHTS FOR THE NEEDED CONCEPTUAL FRAMEWORK AND REPORTING SYSTEM.** They represent a rich source of ideas spanning a broad range of perspectives.

2. **NO EXISTING MODEL EMERGED THAT COULD SERVE AS A FRAMEWORK FOR REPORTING ON SUSTAINABILITY.** No one of these models rigorously and systematically describes the ecosystem and its relationship to the human sub-system in a way that lends itself to broad application in support of improved decision-making. It is apparent that any discipline- specific model is unlikely to provide the needed framework. For example, economics-derived models have evolved from a conventional circular model through a material-energy balance model to the now dominant depletion/pollution model. While the latter model is encouraging consideration of some important environment-economy relationships, it is inadequate for dealing with the broad range of physical, chemical, and biological stresses imposed by human activity on the ecosystem. Its portrayal of the nature and role of the ecosystem itself is also incomplete.

3. **MANY FACTORS ARE APPARENT THAT MUST BE TREATED SYSTEMATICALLY IF CONFUSION IS TO BE AVOIDED.** Definitional clarity regarding system components, relationships between components, and processes at play within or influencing the system is critical.

4. THE ECOSYSTEM, THE HUMAN SUBSYSTEM, AND THE INTERACTION BETWEEN THE TWO, ARE THE PRINCIPAL SYSTEM COMPONENTS THAT ARE COMMON TO THE MODELS REVIEWED. These elements represent the common ground of all of these models and offer the possibility of finding an area of "overlapping consensus" upon which to build a bridging conceptual framework.

5. ONLY A FEW OF THESE MODELS ARE ORIENTED TOWARDS BALANCING CONCERN FOR BOTH PEOPLE AND THE ECOSYSTEM. Some of the models emphasize human well-being, while others focus on the health or integrity of the ecosystem. Only the work of Easter et al. (1986) aimed at watershed resource management and Stankey's (1972) framework for wilderness management based on ecological and sociological carrying capacity seem to strike this balance. At a project level, recognition in the early 1980s of the need for both environmental impact assessment and social impact assessment within an "ecological framework" is a significant precursor to such a model (Beanlands and Duinker 1983).

6. SURPRISINGLY LITTLE EFFORT HAS BEEN DIRECTED AT DEVELOPING A SYSTEMIC APPROACH TO ANALYZING THE CONTRIBUTION OF HUMAN ACTIVITES TO HUMAN WELL-BEING TOGETHER WITH THE STRESS THEY IMPOSE ON THE ECOSYSTEM. Human activities — the contribution they make to human well-being and how that contribution is valued, how they draw from the ecosystem and how they in turn impose stress — are the primary areas that can be managed and controlled by human decision-making. A systemic treatment of human activities is therefore critical to reporting on sustainability. Hill's (1989) model of the Theory and Practice of Sustainable Development rightly centres on human activities and Isard's work on regional analysis also deals systemically with human activities. Rapport and Friend's (1979) description of both human activities and human imposed stress on the ecosystem is also a major contribution.

7. ASSESSING PROGRESS TOWARDS SUSTAINABILITY MUST INVOLVE BOTH QUANTITATIVE AND QUALITATIVE MEASURES. JUDGEMENT WILL BE REQUIRED TO BALANCE COMPETING AND SOMETIMES CONTRADICTORY FACTORS. This review of models and the related discussion served to demonstrate the potential complexity of the related data and information. Inevitably the resulting indicators (at whatever level of aggregation) will never all trend in the same direction. In practice, contradictory evidence will require assessment. This implies a judgement process that will require balancing competing and sometimes contradictory factors.

8. VALUES PLAY A CRITICAL ROLE IN ASSESSING PROGRESS TOWARD SUSTAINABILITY AND EVERY ATTEMPT SHOULD BE MADE TO TREAT VALUES EXPLICITLY. Explicit expression of values is a difficult task: many, perhaps most people have never attempted to identify their operating value set let alone express it. Many, perhaps most, individuals are motivated by at least partly conflicting values that come into play at different times. Furthermore, values shift as new insights are gained. Isard's early work on regional analysis (1960) and Robinson's work on the Sustainable Society Project (1989, 1991) demonstrate the importance of doing so. The overall topic emerges as an important focus of needed research.

CHAPTER FIVE

CONCEPTUAL FRAMEWORK

5.1 INTRODUCTION

This Chapter describes development of a systemic framework that can serve as an organizing template for assessing and reporting on progress toward sustainability. With such a framework, indicators emerge naturally, appropriately honed to the needs of a given locale or a given set of decision-makers. In the absence of such a framework, choice of indicators among the many that are possible, occurs in a vacuum and the results are ad-hoc, reactive to current concerns, and potentially an impedement to anticipatory thinking.

5.2 THE PURPOSE OF REPORTING

The general purpose of a system of reporting is to improve decision-making and decision-making processes. The reporting system is thus a sub-system of the larger decison-making system. Five specific objectives can be identified:

1. to communicate key signals to targeted decision-makers, in particular to give early-warning signals for required policy, institutional, and/or behavioural change;

2. to ensure accountability;

3. to encourage initiative by giving credit where credit is due;

4. to identify knowledge gaps and provide rationales for giving priority to filling these gaps; and

5. to provide a systematic framework for designing and staffing research in support of assessing progress toward sustainability and ultimately for determining the organization and content of the final assessment report.

5.3 DEFINING SUSTAINABILITY, SUSTAINABLE DEVELOPMENT, AND DEVELOPMENT

Definitions of sustainability, sustainable development, and development provide a starting point for this work. Appendix I traces the origins of these concepts. The most recent surge in interest stems from the work of the World Commission on Environment and Development or Brundtland Commission and their call for a shift to sustainable development throughout the world (WCED, 1987). Since then much debate has occurred regarding how to find practical expression of their call.

All three of these concepts are normative (Opschoor 1988, Pearce et al. 1989, Robinson et al. 1990, Dorcey 1991, Costanza et al. 1991 and Holtz 1992). Thus, their interpretation will depend on the set of values that are applied.

In this work, sustainability is defined as ***the persistence over an apparently indefinite future of certain necessary and desired characteristics of both the ecosystem and the human subsystem within*** (modified from Robinson et al. 1990). The sustainability of development (sustainable development) is the anthropocentric sub-component and is defined as the Brundtland Commission puts it, as ***development which meets the needs of the present without compromising the ability of future generations to meet their own needs*** (WCED 1987. 8). The terms 'environmentally sustainable economic development' (Goodland et al. 1992), 'environmentally sustainable socio-economic development' (Dorcey 1991a, 4), 'ecologically sustainable economic development' (Braat and Steetskamp 1991, 271), and 'ecologically sustainable development' (Potvin 1991a; Victor et al. 1991, and Ruitenbeek 1991), are all consistent anthropocentric modifications of the more simply stated sustainable development.

The term development is taken to mean ***the expansion or realization of the potential of; the gradual establishment of a fuller, greater, or better state*** (after Daly 1989, 4). It has both qualitative and quantitative characteristics and is to be differentiated from growth which applies to a quantitative increase in the physical dimensions of the subject.

5.4 VALUES, GOALS AND VALUE-DRIVEN SYSTEM CHARACTERISTICS

Hazel Henderson points out that:

> . . . value systems, far from being "subjective," "peripheral" (merely because they are inconveniently unquantifiable), are the dominant, driving variables in all economic and technological systems.
>
> (1981, xv)

Values are "one's life code — the building blocks of acceptable and unacceptable ideas and behaviour" (Nitken and Powell 1993, 57). They reflect a person's world view or ***Weltanschauung***. Much has been written regarding the factors affecting currently dominant world views. Many of the key ideas that have emerged in this discussion are summarized in Appendices II and III.

A dominant train of thought in much recent literature is that two competing world views can be recognized. The first has roots in the 16th and 17th centuries and can be described as human centered, cartesian/mechanical, utilitarian, and reductionist. The second emerged in the 18th century and in simple terms can be thought of as one that sees people as a small part of a larger ecological system. It has been variously labelled as whole, biophysical, environmental, or ecological (see discussion in Catton 1980, Cotrove and Duff 1980, Capra 1982, Charles Taylor 1985, Milbraith 1989, Costanza et al., 1991, Duncan Taylor 1992, and Peet 1992). Charles Taylor suggests that these world views do not exist in a clinically pure form in any individual or group but rather there is a mix that evokes tension both within individuals and within our society as a whole (1985, Chapter 10).

This dissertation is explicitly dominated by the second of these world views. This choice is made because the very roots of the concept of sustainability lie in such a value set. Simply stated, the idea of sustainability draws from a realization that the well-being of people is dependent on the health and integrity of the ecosystem; that people are a sub-system of the ecosystem. This realization translates to a value set that is best expressed as a parallel care and respect for people and for the enveloping ecosystem — not one or the other, not one more than the other, but both together.

Most importantly, expression of this value set facilitates articulation of the overall goal of progress toward sustainability. It is ***to maintain or improve human and ecosystem well-being.***

Specific implications of the value set will vary for any group of decision-makers. However, when it is applied to assessing progress toward sustainability and reporting the results, it will channel attention in certain ways — ensuring that chosen strategic directions and related indicators reflect the parallel care and respect described above. In turn, the reporting system can be seen to be governed by a set of value driven characteristics that are a form of design criteria. A set of these characteristics is offered below in Table 5-1.

TABLE 5-1. VALUE-DRIVEN CHARACTERISTICS OF A SYSTEM OF REPORTING ON SUSTAINABILTY

A SYSTEM OF REPORTING ON SUSTAINABILITY SHOULD FOCUS ON:

I. RESPECT AND CONCERN FOR THE ECOSYSTEM - BY

1. using a time horizon in the reporting system that captures both human (short) and ecosystem (short and long-term) time scales;

2. adopting a spatial frame of reference for assessing actions and decisions that extends beyond political and other boundaries to encompass the full extent of affected ecosystems; and

3. analyzing individual ecosystem components (e.g. air, groundwater, surface water, soil, fauna, flora etc.) within the context of the connected ecosystem.

II. THE INTERACTION BETWEEN PEOPLE AND THE ECOSYSTEM - BY

4. addressing the complete range of chemical, physical and biological stress on the ecosystem — including that occurring naturally and that imposed by human activities;

5. adopting an anticipatory perspective when dealing with the manner in which indicators, time-horizons and analyses are expressed, so that in the reporting process there will be a forward-looking thrust instead of just a description of past and current conditions;

6. recognizing and accepting uncertainty as an inevitable occurrence instead of an impediment to good decision-making.

III. RESPECT AND CONCERN FOR PEOPLE - BY

7. using assessment criteria that respect the existence of alternative and changing values when evaluating progress;

8. assessing the distribution of environmental, economic, social, and cultural costs and benefits by examining their impacts on different social groups;

9. including ways to measure participation and control in decision-making; and

10. using both quantitative and qualitative measures that draw on both objective data and information as well as subjective information such as intuitive understanding based on experience of everyday life, including experience gained from subsistence and traditional life styles.

Sources: Earlier versions of this table are found in Hodge (1991, 78-79) and Hodge and Taggart (1992, 19-20). Important influences include Schumacher 1973; Holling 1978; IUCN et al. 1980 and 1991; Capra 1982; WCED 1987; NTFEE 1987; YTG 1988; Gardner and Roseland 1989; Goldberg 1989; Conservation Council of Ontario 1989; NRTEE 1990; MacNeil et al. 1991; Ruitenbeek 1991 a and b; ORT 1991; NRTEE 1992; OCHS 1993; BCRTEE 1993 a, b, and c; and R. Kidder 1993, personal communication.

5.5 SYSTEMS IDEAS

Over the past fifty years, systems ideas have emerged and evolved to become an important body of knowledge. The evolution of these ideas is described in Appendix IV.

Earlier systems work tended to emphasize the definition of objectives and the optimization of approaches to achieve those objectives. The development of techniques to incorporate a range of alternative values in decision-making systems (for example see Isard, 1960) and the emergence of the "ecosystem approach" to man-environment relationships (in particular as reflected in the governance of the Great Lakes Basin Ecosystem: GLWQA, 1978) are two important developments that have served to enrich systems thinking in ways probably not envisioned by early systems workers.

In recent years, there has been a recognizable shift in systems thinking from optimization of systems with well-defined objectives to an emphasis on systemic processes of learning related to problems or issues with ill-defined objectives. This shift has facilitated the use of systems thinking to deal with many ill-defined, real-world situations (Checkland and Scholes 1990). The issue of assessing progress toward sustainability falls well within the bounds of this latter category of problems. At the core of this challenge lies the need to go beyond reaction to today's concerns in a way that anticipates and deals with issues before they become crises.

Throughout the evolution of systems ideas, a core element has been a commitment to the idea of the "whole" system which can respond to stress and survive in a changing environment. Such systems are characterized by (1) **emergent properties** which are critical for understanding the whole but may have little or no meaning in terms of constituent parts; (2) a **hierarchical structure** in which systems are nested within other systems; and (3) processes of **communication, feedback, and control** that allow adjustment and adaptation in the face of stress (Atkinson and Checkland 1988; Goldberg 1989; Project Management Team 1989; Checkland and Scholes 1990).

Systems thinking involves the use of conceptual models to link components to the "whole" and the identification of controls and feedback loops. It is in the need to assess the state or performance of the constituent parts, controls, feedback loops, and the whole system, that the use of indicators or performance measures arise. However, without the conceptual framework and the related value structure, the choice of indicators occurs in a vacuum (Checkland and Scholes 1990, 112).

The use of the conceptual models provides a mechanism against which the real world can be set to facilitate learning. This comparison often leads to constructive tension, debate, and hopefully to the accommodation of different interests and values. The objective is improved decision-making. However, the models themselves should not be thought of as truly capturing the real world, the complexity of which is beyond current knowledge. To do so can lead to entrenchment of current perceptions along with all their limitations.

5.6 CONCEPTUAL FRAMEWORK

The conceptual framework proposed in this project reflects the underlying value base, is consistent with systems theory, and draws on the reviews of state-of-environment reporting, macroeconomic ideas, and theoretical treatments of the human-ecosystem relationship described in Chapters Two, Three, and Four respectively.

This approach is motivated by a belief that any successful conceptual approach must be built on the common insights of many others. As such, this aspect of the project is an attempt to apply Rawls' idea of "overlapping consensus" (1987). Rawls points out that a consensus affirmed by opposing theoretical, religious, philosophical and moral doctrines is likely to be both just and resilient. Public policy based on such an "overlapping consensus" is therefore more likely to thrive over generations.

Drawing from all of the above leads to the following evolution of ideas. Figure 5-1A is a simple schematic showing the ecosystem and the human subsystem within. Figure 5-1B shows a conceptual split thus enabling illustration of the interaction between the two. This part of Figure 5-1 can be considered a "free-body diagram"and reflects a technique used in applied mechanics. It is an analytic convenience and does not mean that people (the human subsystem) are being considered as separate from the ecosystem. Figure 5-1B provides a model of the physical system that must be considered in assessing progress toward sustainability.

This physical system must be conceptually linked to human decision-making in a way that allows practical defintion of the elements of a reporting system. This step is taken in Figure 5-1C. Figure 5 provides the core conceptual framework for this work.

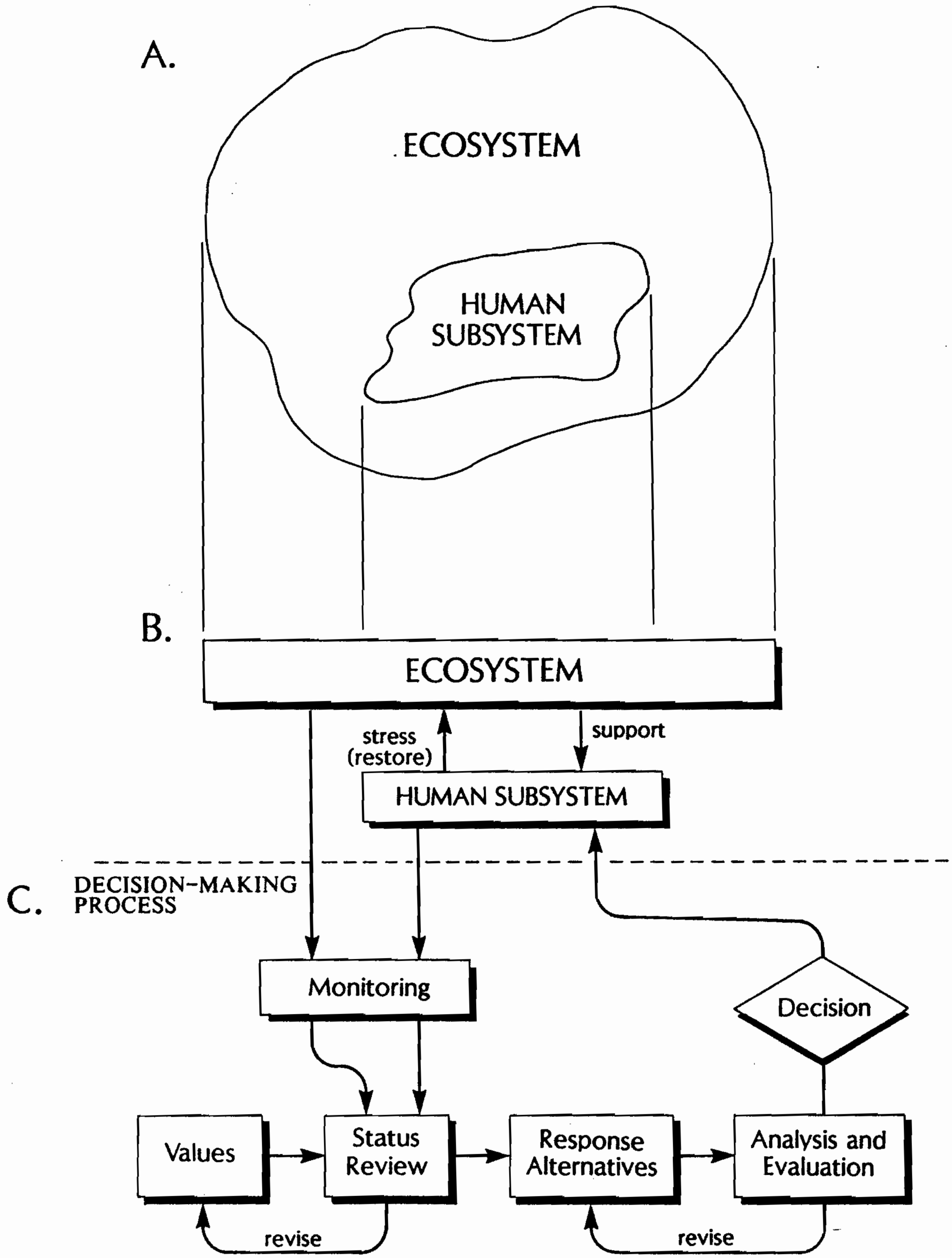


Figure 5-1. Conceptual framework.

5.7 STRATEGIC REPORTING ELEMENTS

Four strategic elements emerge from this conceptual framework that serve as areas of diagnosis or indicator domains in the proposed reporting system. They are listed in Table 5-2.

TABLE 5-2. THE FOUR STRATEGIC REPORTING ELEMENTS NEEDED FOR A SYSTEMIC ASSESSMENT OF PROGRESS TOWARD SUSTAINABILITY

I. ECOSYSTEM

Data and information that facilitate an assessment of the integrity and health of the ecosystem;

II. INTERACTION

Data and information that facilitate an assessment of the interaction between people and the ecosystem: how and to what extent human activities contribute to provision of basic needs and the quality of life - how these activities are valued; how these actions stress, or contribute to restoring the ecosystem; and how successful we have been at meeting the goals and objectives of policies, regulations and legislation.

III. PEOPLE

Data and information that facilitate an assessment of the well-being of people including the range of physical, social, cultural and economic attributes.

IV. SYNTHESIS

Data and information that facilitate the recognition of emergent system properties and provide an integrated perspective for decision-making and anticipatory analysis that spans Domains I, II, and III.

The first three of the domains listed in Table 5-3 fall easily from Figure 5-1B, the heart of the conceptual framework. The fourth includes the other three but is more than simply the sum of the parts. Here, emergent system properties can be sought from this connected whole that are not apparent from independent analysis of the first three domains. Further, this domain offers a perspective for decision-making and anticipatory analysis that spans Domains I, II, and III. In so doing, it provides the opportunity to integrate human and ecosystem concerns that is consistent with the values underlying the concept of sustainability. While Domains I, II, and III would cut horizontally through Figure 5-1B, Domain IV is rooted in figure 5-1C and extends through Figure 5-1B.

Each domain spans a complex set of data and information. Together they provide a template to be applied in support of different decision-making groups in society (individuals, communities, corporations, regions, provinces/states, nation, other decision-making groups). Each decision-making group is motivated by different needs and priorities. As a result, a different expression of the reporting system will emerge for any given group of decision-makers. However, the fundamental four elements will remain.

These strategic elements provide an effective organizing template because:

(1) in concept they are simple, clearly defined, and understandable;

(2) they emerge from the underlying value set while reflecting the system being considered;

(3) they keep the focus where it needs to be for identifying needed actions — on people, on what they do, and the ecosystem;

(4) they reflect traditional areas of knowledge that can be respectfully brought to bear;

(5) they link easily to decision-making; and

(6) they allow an amount of "compartmentalizing" that is useful for strategic thinking but only within the concept of the whole system.

5.8 LINKING THE OVERALL GOAL TO THE CONCEPTUAL FRAMEWORK

In practical application, the assessment of progress toward sustainability must begin with the definition of general goals that facilitate development of specific measurable objectives. The domain-specific goals listed below in Table 5-3 result when the overall goal that was described in Section 5.4 is expressed in terms of the four strategic elements of the reporting system.

In practice, these goals must be supported by a large number of specific measurable objectives that apply to each system component. Development of such objectives will depend on the decision-making group in question. Reporting on sustainability for four such decision-making groups is examined in Chapter Six and the issue of objectives is addressed in Chapter Seven.

TABLE 5-3. GOALS FOR ACHIEVING PROGRESS TOWARD SUSTAINABILTY.

DOMAIN I GOAL

1. To maintain or improve ecosystem health and integrity;

DOMAIN II GOALS

2. To increase the ability of human activities to contribute all aspects of human well-being including economic, physical, social, and cultural attributes;

3. To reduce the physical, chemical, and biological stress imposed on the ecosystem by human activities;

4. To increase the extent to which human activities restore ecosystem health and integrity;

DOMAIN III GOAL

5. To maintain or improve human well-being;

DOMAIN IV GOAL (OVERALL)

6. To maintain or improve human and ecosystem well-being.

CHAPTER SIX

THE FOUR INDICATOR DOMAINS AND THEIR APPLICATION TO FOUR GROUPS OF DECISION-MAKERS

6.1 INTRODUCTION

The conceptual framework introduced in the previous chapter led to the identification of four strategic reporting elements that serve as areas of diagnosis or indicator domains in the proposed reporting system. In this Chapter, each of these domains is examined and their application to four different decision-making groups is described.

6.2 THE FOUR INDICATOR DOMAINS

DOMAIN I — ECOSYSTEM

Domain I includes the data and information that facilitates an assessment of ecosystem well-being as well as related decision-making processes. Ehrlich and Roughgarden point out that:

> An ***ecosystem*** consists of all the organisms in an area and the physical environment with which they interact.
>
> (1987, 521)

Two important issues that must be dealt with arise from this definition. One is ecosystem boundaries and one is the choice of a classification system to deal with ecosystem components.

The Boundaries Issue

Christie et al. explain that the term "ecosystem" has come to mean natural or artificial subdivisions of the biosphere whose boundaries arbitrarily defined to suit particular purposes. Thus they state:

> It is possible to speak of your personal ecosystem (you and the environment on which you depend for sunshine, air, water, food, and friends), the Great Lakes basin as an ecosystem (interacting communities of living and non-living things in the basin), or our planetary ecosystem...
>
> (1986, 4 - 5)

It is important to note that ecosystems defined and/or bounded by ***natural*** characteristics (e.g. a drainage basin or forest limit) are rarely coincident with political jurisdictions or areas defined in law by ownership.

This lack of coincidence almost inevitably leads to discordance between ecosystem functions and the results of human decision-making. From a reporting perspective, this creates the need for "multiple boundaries," an approach that superimposes the area that is the direct responsibility of the decision-maker (boundary 1) on the "n" implicated ecosystems (boundaries 2 to n). This system encourages decision-makers to recognize the ecosystem(s) with which they are connected.

These additional boundaries may significantly extend the area of interest. Air emissions can travel hundreds of kilometers a day. "Particulate life" can be 5 to 10 days, as it is for PCBs, and deposition in water can be followed by revolatization with the contaminant continuing its global journey (Summers and Young 1987). Migrating wildlife can also traverse vast areas and stress imposed in one part of the world (physical, chemical, or biological) can significantly affect the food web in another.

The issue of the relationship between human activities in one jurisdiction and/or ecosystem and its implications for environmental and social conditions in other jurisdictions and/or ecosystems is a complex one. The effects of international trade on this already complex issue have only recently been given attention (see for example WCED 1987, Ch. 3). Important issues include the international regulation of resource use, trade in endangered species, subsidies, environmental requirements in foreign investment, transfer of environmentally friendly technologies, enforcement, and dispute resolution.

On a more local but equally critical scale, Rees has attempted to develop a methodology for calculating the "ecological footprint" of urban areas — that is, the extent of ecological carrying capacity of areas beyond urban boundaries that are implicated by urban activities (Rees, 1992).

The above discussion serves to demonstrate why the differences between the boundaries of decision-making jurisdictions and natural ecosystems need to be recognized and an attempt be made to deal with the implications of these differenceswhen assessing progress toward sustainability. With computerized Geographic Information Systems, portrayal of data and information and related analyses dealing with such boundary problems is now more possible than ever before.

The Classification Issue

The simplest and most common classification of ecosystem components is listed below in Table 6-1. It is used in various forms in the majority of state-of-environment reports where, for example, sections can be found addressing individual components of the ecosystem such as water or air.

The use of a component type classification has been criticized as insensitive to ecosystem linkages, driven by administrative convenience, and artificial and naive (Rapport and Friend 1979, 74). Ecosystem-defined areas such as river basins or terrestrial ecoprovinces are usually proposed as preferred alternatives.

TABLE 6-1. COMMON CLASSIFICATION OF ECOSYSTEM COMPONENTS.

I. AIR AND CLIMATE

- outdoor air quality (including ozone depletion)
- indoor air quality
- atmospheric radiation
- climate change

II. INLAND SURFACE WATER

- hydrology and water quantity
- surface water quality
- bottom sediments

III. GROUNDWATER

- hydrogeology and water quantity
- groundwater quality

IV. MARINE WATERS

- marine hydrology
- marine water quality
- ocean levels

V. LAND

- geology and geologic history (including long term global change)
- hazards (for example, earthquakes, landslides, mudflows, floods, volcanic eruptions)
- soils (erosion, quality, fertility)
- special areas: wetlands, coastlines, mountains, plains

VI. BIOTA

- terrestrial fauna
- exotic species
- flora
- freshwater fish and aquatic fauna
- marine water fish and aquatic fauna

Source: drawn from the review of state-of-environment reports summarized in Appendix V.

Rapport and Friend argue for classification based on a choice of spatial units that accommodates both the decision-making space and the natural process space. They list the following three steps:

> 1. that the terrain of the country be divided into natural units which make sense in ecologic terms;
>
> 2. that these natural units be classified on a hierarchical basis, i.e., biomes and their sub- component ecosystems, which can be aggregated into areas that are well matched to the space-time horizon of decision-making at regional, national, and international levels; and
>
> 3. that the correspondence between "stress-impact space" and natural units be designated so that the recorded information show not only indicators of the state of the environment, whether natural or already transformed by human activity, but also show the major human activities which influence the state and its future transformation.
>
> (1979, 4)

An attempt to utilize this approach in establishing the spatial framework used in the first state- of-environment report for Canada has been made (Bird and Rapport, 1986). However, the attempt has been only partially successful. A terrestrial ecozone classification with ecozone defined as "a discrete system that has resulted from the interplay of the landform (physiography), water, soils, vegetation, climate, wildlife and various human uses" resulted (Bird and Rapport 1986, 9). These fifteen ecozones for Canada have a strong ecological basis for definition, but have little link to decision-making jurisdictions except for the national aggregate. Aquatic ecosystems were simply classified as either oceanic or freshwater.

The flaw in Rapport and Friend's critique is that it confuses a classification of ecosystem components with a classification of ecosystem space. Historically, decision-makers have focussed on ecosystem components (e.g. water or air) and not ecosystem relationships within meaningfully bounded areas. Perhaps this is not surprising given that systems ideas did not really mature until the 1960s. It was only in the mid-1980s that recognition of the "cross-media" cycling of contaminants (land to air to water etc.) from a policy perspective was made (The Conservation Foundation 1984).

This lack of recognition of the systemic connectedness of the physical world is one of the fundamental reasons why environmental degradation has proceeded to is present level. However, this does not render the standard classification of ecosystem components (Table 6-1) artificial and naive as suggested by Rapport and Friend. Rather, it is inadequate in the absence of a systematic spatial framework to provide the needed linkages.

Furthermore, different components of the ecosystem function within different spatial scales (see Table 3, Appendix III). Thus, no one spatial classification will ever resolve all spatial concerns. Under some circumstances, the ecozone classification proposed by Rapport and Friend may be the most useful. Under other circumstances the definition of ecosystem boundaries on the basis of drainage basin limits can also be useful.

A classification that provides a different perspective than those noted above has been developed by Robert Prescott-Allen. He differentiates between four ecosystem types:

1. NATURAL: ecosystems where since the industrial revolution (1750) human impact has (a) been no greater than that of any other native species, and has (b) not affected the ecosystem's structure;

2. MODIFIED: ecosystems where human impact is greater than that of other species but structural components are not cultivated;

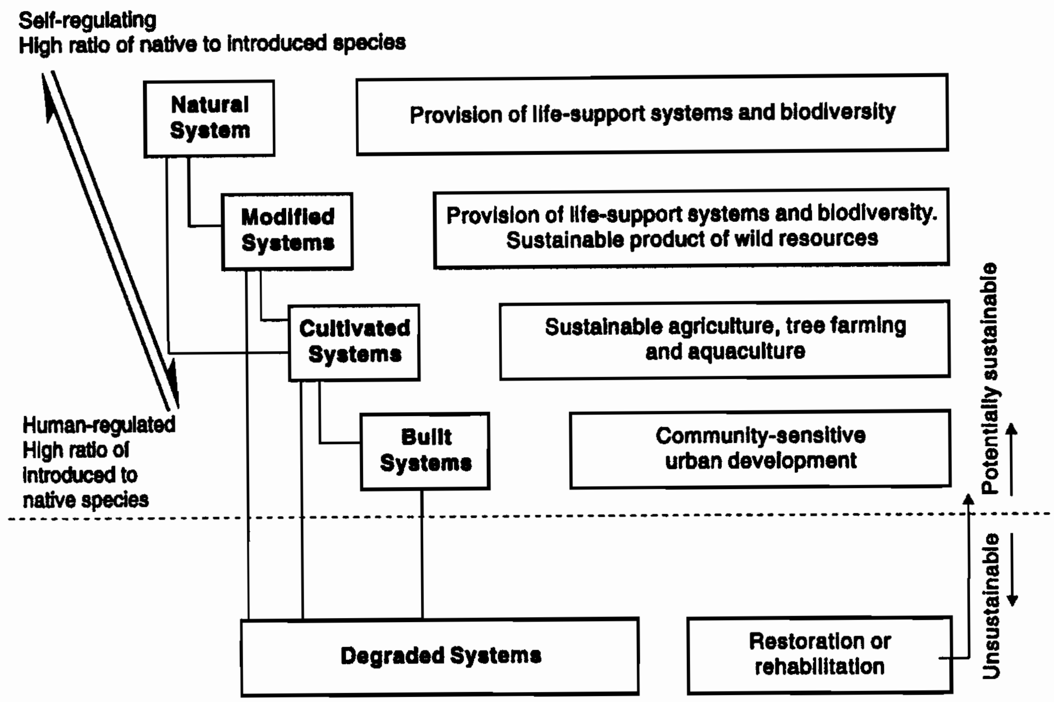
3. CULTIVATED: ecosystems where human impact is greater than other species and most structural components are cultivated; and

4. BUILT: ecosystems dominated by human structures

(IUCN et al. 1991, 34)

Prescott-Allen's schema is shown in Figure 6-1. Using his classification he suggests that living sustainability calls for protection of natural systems, sustainable production of wild renewable resources from modified systems, sustainable production of crops and livestock from cultivated systems, development of built systems in ways that are sensitive to human and ecological communities, and restoration or rehabilitation of degraded systems. This approach is particularly useful because it facilitates inclusion of the built ecosystem in an elegant way.

In practice, a multiple boundary approach will almost always be required to link natural ecosystem units to the decision-making jurisdiction.



Source: IUCN 1991, 34.

Figure 6-1. Prescott-Allen's ecosystem classification.

Assessing Ecosystem Health

A final topic to be addressed in the discussion of this domain relates to the ongoing debate on how and whether it is even possible to define and measure ecosystem health or integrity.

Three approaches to organizing an assessment of ecosystem health and integrity are described above: by ecosystem component; by terrestrial and aquatic eco-provinces (including drainage basins); and by Prescott-Allen's four-part ecosystem classification (natural, modified, cultivated, built). No one of these approaches on its own, provides an adequate framework although each has useful characteristics to offer. In practice, these approaches must be integrated and matched with known issues of concern and data availability.

Haskell et al. suggests that:

> Defining ecosystem health is a process of involving the identification of important indicators of health (such as a species or a group of species), the identification of important endpoints of health (such as relative stability and creativity), and, finally, the identification of a healthy state incorporating our values. . . indicators and endpoints do not require much integration and are quantifiable with a fairly high degree of precision. Measures of a "healthy state" are less precise but are much more comprehensive and relevant and require integration and modelling.
>
> Before health can be measured, we need to identify the relevant indicators, endpoints, and parameters . . . that we are going to use in assessing the health of a particular ecosytem.
>
> (1992,7)

They also note that while many such variables have emerged in the ecological literature, there are significant impediments to their establishment. First, each ecosystem is unique and therefore must be assessed independently. Second, change causes ecosystem adaptation which demands that indicators be adequately robust in order to respond and last, each scientist evaluating an ecosystem is likely to choose a different set of variables depending on his or her specific interest and expertise.

In spite of these impediments, decision-makers must come to grips with ecosystem conditions. They will often make a trade-off between the contribution that a given set of human activities will make to supply of basic needs or an enhanced quality of life and the associated stress that will be imposed on the ecosystem. Thus, the issue of assessing ecosystem health and integrity cannot be avoided.

Characteristics of stressed ecosystems have been identified by a number of workers a compilation of common biological symptoms is presented in Table 6-2 below.

TABLE 6-2. TYPICAL BIOLOGICAL CHARACTERISTICS OF AN ECOSYSTEM UNDER STRESS.

1. decline in the number of native species and in species diversity;

2. reversion to ecological communities that are unstable in the long term and to an earlier stage of succession that is not typical for the particular area;

3. decrease in system stability - stressed ecosystems tend to fluctuate more widely than unstressed similar systems;

4. shift to more opportunistic species;

5. reduction in average size of dominant biota: alteration in community structure to favor short lived smaller life forms;

6. unnatural rapid alteration in the quantity of either living or dead biomass;

7. impaired biological productivity;

8. changes in primary energy production and energy flow through the system;

9. higher susceptibility to disease (except in instances where the stress weakens the disease more than the host) reflected in an increase in the rate of disease prevalence;

10. changes in mineral macronutrient stocks;

11. enhanced leaching of nutrients in terrestrial ecosystems and their accumulation in recipient aquatic systems; and

12. enhanced circulation of contaminants and toxic substances and their bioaccumulation in the food web.

Source: modified from Bird and Rapport 1986; Herricks and Schaeffer 1987; Environment Canada 1991; Torrie Smith Associates and The Institute for Research on Environment and Economy 1993

In an attempt to provide a rigorous starting point, a definition of ecosystem health has been proposed by a multidisciplinary workshop that included representatives of the disciplines of ecology, resource management, public policy, economics, and philosophy. The participants conclude:

> An ecological system is healthy and free from "distress syndrome" if it is stable and sustainable — that is, if it is active and maintains its organization and autonomy over time and is resilient to stress.
>
> (Haskell et al. 1992, 9)

They thus identify three components of ecosystem health: activity or vigor, organization, and resilience. Suffice it to say that the topic is the subject of much debate and ongoing research (see Costanza et al. 1992).

Domain II — Interaction

Domain II includes the data and information that facilitates an assessment of the interaction between people and the ecosystem as well as related decision-making processes: how and to what extent human activities contribute to basic needs and the quality of life (as reflected in how they are valued); how these activities stress or contribute to restoring the ecosystem; and how successful we have been at meeting the goals and objectives policies, regulations and legislation governing these activities.

The human-ecosystem interface is controlled by two sets of factors:

> (1) natural conditions and events that set the conditions in which the human sub-system functions; and
>
> (2) human activities which draw on the ecosystem for support, simultaneously impose stress, and in special cases, facilitate restoration of ecosystem functions.

Human decision-making processes cannot and do not control natural conditions and events; people do not manage the environment. Rather, it is human activities that people influence through their decision-making and for which people are fully responsible (NRTEE 1993, 9). Rapport and Friend correctly describe human activities as the motor or lever of the required information and reporting system (1979, 75).

Ideally, human activities would be classified and assessed in terms of their "value" (contribution to provision of basic needs and an enhanced quality of life) and the physical, chemical, and biological stresses imposed on the ecosystem. However, three limitations are apparent. First, a comprehensive activity classification that can serve as a basis for such an assessment does not exist. Second, current ability to value activities is limited, and third, current ability to assess the physical, chemical, and biological stress imposed on the ecosystem by human activities is in the earliest stage of development. Each of these is dealt with below.

Classifying and Valuing Human Activities

In Chapter Three, the issue of human activities is approached through economics. This is because the Standard Industrial Classification (SIC), which is structured along activity lines, and the valuation of human activities through the System of National Accounts (SNA) provide an essential starting point for dealing with the human activities issue.

However, in addition to the market-driven or dollar-measured activities captured in the SIC, many other human activities occur that both provide for human well-being and in the process, stress the supporting ecosystem. These activities must also be included in a systemic assessment of progress toward sustainability. Important examples include:

- non-wage household and home operation, maintenance, and improvement; childcare and rearing (most of which is carried out by women). The value of these activities may be as high as 53 % of GNP (Adler and Hawrylyshyn 1978; Waring 1988) although a more common estimate is roughly one- third (Burns 1975) and recent work in Canada suggests a range of 32 - 39 percent (Jackson 1992);

- voluntary activities. Statistics Canada estimated that for 1986/87, 5.3 million Canadians were involved with volunteer work which was valued at $12 billion using an average service sector wage (Ross 1990).

- subsistence activities. The extent and value of subsistence activities is significantly greater in rural areas than urban. In a country such as Canada, while the proportion of total contribution to wealth may be small, for some jurisdictions (e.g. the Yukon and Northwest Territories) the significance is large (see for example, YTG 1988, 52-53; Usher and Staples 1988; and Victor 1990).

- the underground economy: illegal and black-market activities.

In addition to both market and non-market human activities, a number of activities deserve careful consideration for policy purposes and consist of "useful combinations" of activities. Some of these combinations are recorded within the market economy and some are not. Obvious examples are:

- energy production, transportation and use;
- water use and distribution;
- tourism and recreation;
- generation of waste, accidents, and spills, etc.

Many of the above activities are studied by different groups of professionals who group and classify their data and information in ways that may or may not be compatible with the SIC. Thus the lack of a common taxonomy of human activities is a major practical impediment to integrating different data bases that contribute to current policy and decision-making.

The STANDARD ACTIVITY CLASSIFICATION (SAC) shown below in Figure 6-2 is proposed here to overcome the above concerns at least conceptually.

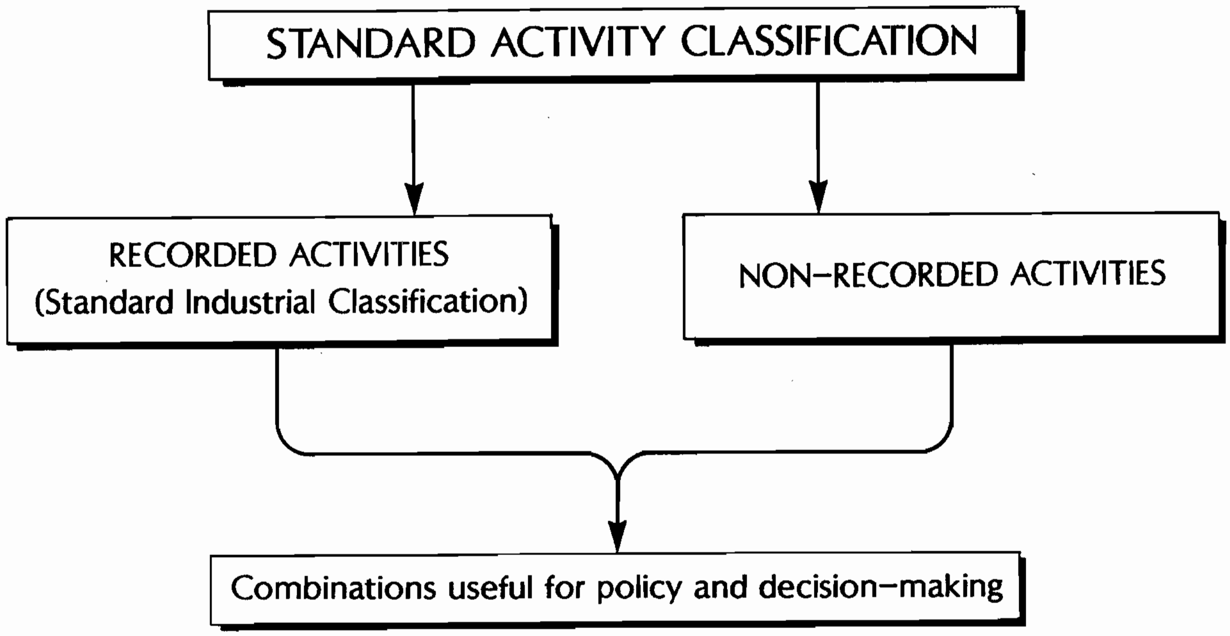


Figure 6-2. General framework for a Standard Activity Classification (SAC)

In application, an initial crude assessment of the "benefit" of human activities can be obtained by combining figures for value-added by industry (from the National or Provincial accounts or equivalent) with "employment" data. This approach to compiling "activity indicators" is shown schematically in Figure 6-3 and was earlier applied in Table 3-3.

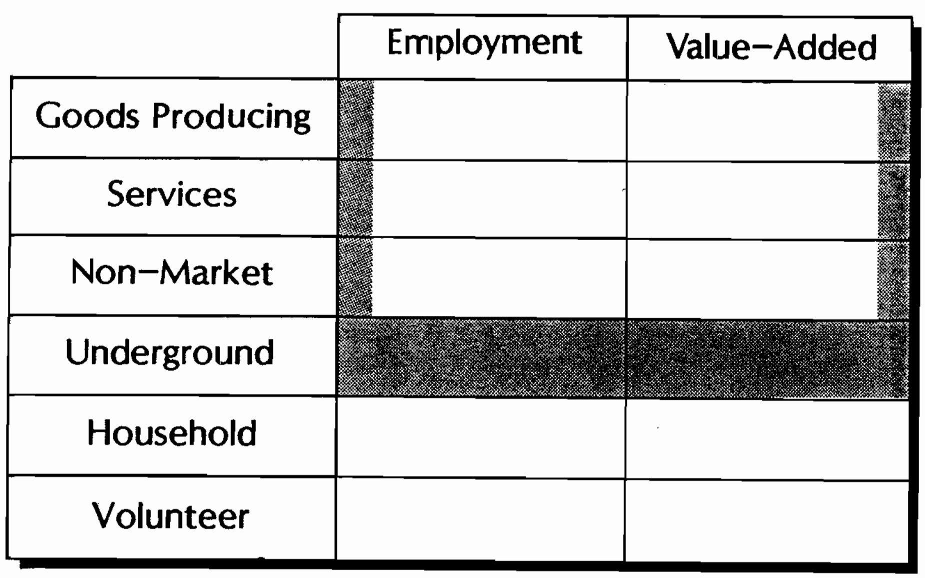


Figure 6-3. Matrix classification of activity indicators. The shaded area shows schematically the extent of the underground economy.

In the above discussion, the value-added of human activities, whether included or not in the Standard Industrial Classification, is described in dollar terms and used as a surrogate for "value." In fact, this is a controversial topic. For example, in addition to money-based assessments of value-added, time-based (Waring, 1988), land-based (Lands Directorate 1983), and energy-based (Susan Holtz, personal communication), valuation approaches have been suggested for human activities.

Rationale for these alternative approaches centres on the need to be more sensitive to the issues of ecosystem integrity, equity, and social justice. These concerns are often masked by the value set driving contemporary macroeconomic analysis. This topic remains unresolved and is a subject of current research. Unfortunately, while there is a vast literature regarding the "value" of the environment, treatment of the valuation of human activities, except as it relates to pricing of market activities, is sparse. This imbalance suggests a major research gap.

Stresses Imposed by Human Activities

The classification of imposed stress as suggested by Rapport and Friend (1979) was introduced in Section 2.4. These stresses are subsequently listed, described, and grouped as physical, chemical, or biological (Tables 2-2 and 2-3). It is this three-part classification of stress that is used in this project.

The Environment and Wealth Accounts Division of Statistics Canada has made some progress in quantifying and tracking changes in certain imposed stresses. A general impact classification has been developed and applied to establishment and employment figures at ecozone, provincial, and national scales.[1] This work allows broad generalizations to be made, e.g. 60 % of those employed in manufacturing in Ontario are involved in "high impact" activities as are 40 % of manufacturing establishments (Statistics Canada 1991, 52-53).

A more effective treatment of chemical stresses than the above impact classification will be the result of Statistics Canada's generation of a Waste and Pollutant Output Satellite Account to the System of National Accounts. The account will integrate available data on the output of unwanted by-products from Canadian production and consumption activities categorized in the SIC. This initiative represents a major step towards systematically gathering information regarding chemical stresses imposed on the ecosystem. Initial results of a pilot version are described by Smith (1993). Smith's work is based on linking greenhouse gas emissions to economic activity through the use of input-output modelling.

A total of four environmental satellite accounts are being developed: (1) Natural Recource StockAccount; (2) Natural Resource UseAccount; (3) Waste and Pollutant OutputAccount; and (4) Environmental ExpenditureAccount. In spite of this progress resources have not yet been allocated to systematically monitoring the broad range of not only chemical but also physical and biological stresses imposed on the ecosystem by ongoing everyday activities.

Ecosystem Restoration

A growing human effort is aimed at consciously reducing stress imposed on the environment and taking actions to facilitate restoration of ecosystem functions. These activities also require recognition within the reporting system. Interestingly, increased interest in restoration ecology as a science is reflected in the existence of a learned society, The Society for Ecological Restoration, which publishes a biannual journal, *Restoration and Management Notes*. An early scan of many of the main ideas of restoration ecology was prepared by the Canadian Broadcasting Corporation (CBC (1992).

Domain III — People

Domain III includes the data and information that facilitate an assessment of the well-being of people and related decision-making including the range of physical, social, economic, and cultural attributes. Thus, people and their well-being are the subject of this domain — individuals and their families, communities, and the institutions that people create to achieve their ends.

While objective measures of physical and material well-being have long been gathered, the last several decades have seen an increasing emphasis on assessment by psychologists and sociologists of people's "subjective well-being" — their feelings of happiness and their sense of satisfaction with life. Meyers summarizes more recent work and concludes that for the United States:

> ...our becoming much better-off over the last thirty years has not been accompanied by one iota of increased happiness and life satisfaction . . . Once beyond poverty, further economic growth does not appreciably improve human morale.
>
> (1992, 44)

This set of conclusions has significant implications for reporting on sustainability. Factors required to assess human well-being likely vary depending on the degree of poverty/wealth. Simply put, objective measures of physical welfare are more effective at indicating the well-being of impoverished people than they are for those beyond poverty. In this latter group, subjective factors become increasingly important with increasing material wealth.

Table 6-3 provides a list of types of topics that might be included in a comprehensive assessment of human well-being. This list is compiled from health, quality of life, human development and healthy cities literature.

TABLE 6-3. POTENTIAL VARIABLES TO INCLUDE IN AN ASSESSMENT OF HUMAN WELL-BEING.

I. FOOD, NUTRITION, HEALTH, AND SURVIVAL

A. PREVENTATIVE /ANTICIPATORY

- food/nutrition: consumption habits, obesity, malnutrition
- sleep
- worry
- physical fitness
- spiritual well-being: importance and self-evaluation of spiritual well-being; formal and informal religion
- freedom/loss of freedom
- personal savings and debt
- fear of, or confidence in the future
- dependency: individual self-reliance
- breadth of active interests as an indicator of the depth of personal support system
- life satisfaction of individuals

B. Reactive

- occurrence of disease
- life expectancy
- mortality: under 5 years old; maternal; untimely deaths
- characteristics of the health care system: facilities, personnel, program delivery

II. KNOWLEDGE, LITERACY, AND EDUCATION

- knowledge and literacy levels
- formal and informal schooling: types, participation rates, opportunities; government and private support
- skill development: types, participation rates, opportunities; government and private support

III. MATERIAL WEALTH, POVERTY, UNPAID WORK, AND EMPLOYMENT

- material wealth: annual income; difference between income and expenditures; savings rate
- poverty: population below the poverty line; numbers of homeless; nature of social assistance required
- unpaid work: types, participation rates, satisfaction
- employment: types, rates, labour organizations, satisfaction, opportunities for rewarding employment, financial and otherwise
- public aid and debt

IV. LEISURE

- activity options and participation rates
- support organizations
- government/private support

V. COMMUNITY: SOCIAL FABRIC AND COMMUNITY WELL-BEING

- empowerment 1: amount of community participation and control in decision-making
- empowerment 2: participation rates in elements of the "civil society" (self-defined non-government organizations)
- community: sense of satisfaction and spirit
- dependency: collective self-reliance
- cultural characteristics/diversity
- cultural interrelationships
- presence of special community features and cultural events leading to community identity and pride

- existence or loss of freedom and openness
- family structure; family break-up
- safety and crime
- social security expenditures

VI. COMMUNITY: STATE OF BUILT INFRASTRUCTURE AND SUPPORT SYSTEMS

- housing (ownership, physical characteristics, surroundings, overcrowding, length of residence, satisfaction, likes and dislikes)
- infrastructure condition: supply and demand; life expectancy, trends in maintenance costs; estimates of replacement costs.
  - commercial facilities
  - water and sewage infrastructure
  - energy supplyinfrastructure
  - transportation infrastructure
  - recreation facilities
  - health care facilities
  - educational facilities

Sources: Compiled from literature on the determinants of human health (Evans and Stoddart 1990; Hertzman 1990); quality of life (Dann 1984); state of human development (UNDP 1991, 1992, 1993; UNICEF 1993); and healthy cities (WHO 1987; YUCHS 1990, Hancock 1990a and b; Jacksonville 1992; Sustainable Seattle 1992, 1993; City of Toronto 1993).

Domain IV — SYNTHESIS

As described in Chapter 5, in this Domain, the conclusions of the investigations on ecosystems, interatctions, and people are synthesized. Without this synthesis, components remain isolated and emergent properties relating to the whole system will not be recognized. At this point a sense of the whole must once again be sought. In doing so, aggregated indicators may emerge that are not apparent when considering the earlier domains individually. The synthesis must be tailored to the needs of the decision-making group being addressed thus this Domain serves to provide an overarching strategic perspective for decision-makers. It is here that an integrated perspective for decision-making and anticipatory analysis is achieved that spans Domains I, II, and III and provides the opportunity for practical application of the idea of sustainability.

It was not possible within the scope of this project to undertake an extensive exploration of Domain IV analysis. Thus, while Domain IV analysis is one of the most important aspects of the proposed process of assessing progress toward sustainability, it is the least tested. It is here that one of the priority areas for follow-up research exists.

6.3 APPLYING THE PROPOSED APPROACH TO ADDRSSING THE NEEDS OF FOUR DECISION-MAKING GROUPS

Any system of reporting is a system nested within a larger decision-making system. Decision-making processes begin with an assessment of current status. This assessment is controlled by available data and information as well as by operating values that facilitate any judgement. Alternatives are then identified and weighed, and a decision is made. Opportunities for revision lie at several points in this process.

Jack Ruitenbeek points out that even if the theoretical basis for choosing key indicators of sustainability was agreed upon,

> ...the manner in which this information is used within the decision-making process is in itself significant. The final outcome of policy deliberations and, implicitly, the route to sustainable development, will depend on both the nature of the decision mechanism and the role of indicators within that mechanism.
>
> (1991b, 62)

He then reviews the role of environmental information within different decision-making regimes that include those that are non-coercive (e.g. competitive market, voluntary exchange); coercive (e.g. benevolent dictator); democratic (majority rule and modifications); and other (structurally induced equilibrium). Ruitenbeek rightly emphasizes the fact that different decision-structures may have different information requirements.

Ruitenbeek brings an international perspective and his analysis focuses on the broad range of political decision-making regimes in different countries. A central position taken by this dissertation is that equally significant differences exist ***within*** the market-economy driven western democracies. For purpose of developing a system of reporting on sustainability for any given society, these internal cultural differences must be recognized.

Within any society, different groups of decision-makers can be differently characterized in terms of values, motivation, and needs. Thus, corporate culture can be differentiated from, for example, bureaucratic culture which in turn is different from the culture of academics and so forth. To be broadly applied, the system of reporting on sustainability must be sensitive to these different cultures and tailored to the needs of different decision-making groups. In this project, the following four decision-making groups are chosen as the most significant decision-making groups in Canadian and American society:

- individuals, families, and households;
- corporations and corporate groupings;
- communities and settlements;
- regional, provincial, territorial and federal governments

The choice is pragmatic although it can be seen as an extension of the three components of the conventional model of the market economy which deals with firms, households, and government.

INDIVIDUALS, FAMILIES, AND HOUSEHOLDS

Individuals, families, and households are the fundamental decision-making units of our society. Personal and household decision-making regarding food, housing (purchase, rental, operation, maintenance), transportation, clothing, recreation, and the broad range of other consumer activities and purchases all have major implications for stressing the environment as well as for supporting a desired quality of life. In Canada, the 1991 Census documented 27.3 million people living in just over 10 million households. Three-quarters were located in an urban setting, one-quarter rural.

Ideally, the reporting needs of individuals, families, and households would be met by a practical form of data and information that addresses the topics listed in Table 6-3. However, with the exception of energy use statistics from utilities, the vast majority of individuals and households are not provided with or encouraged to generate the above information in any systematic way. Computerized home audit programs are now available but they are not widely used. Limited consumer product information is provided by manufacturers and some through popular literature and government programs. Some comparative data and information from national surveys undertaken by Statistics Canada are available (see for example, Statistics Canada, 1992). In addition, there are sporadic provincial and large municipality surveys. Lastly, most of projects included with the Healthy Cities initiative are generating data and information relevant to this topic.

Table 6-4 applies the proposed reporting framework to the needs of individuals, families and households.

TABLE 6-4. SYSTEMIC ASSESSING OF PROGRESS TOWARD SUSTAINABILITY FOR INDIVIDUALS, FAMILIES AND HOUSEHOLDS.

DOMAIN I - ECOSYSTEM

- assessment of the health and integrity of ecosystems (natural, modified, cultivated, and built) with which the individual, family, or household has interaction: state/quality of home, workplace, neighbourhood and community and assessment of the impact that state has on the individual and family; comparative data with others

DOMAIN II - INTERACTION

- activity stress assessment (physical, chemical, biological); data to allow comparison with other individuals, families, and households
- identification of opportunities for stress reduction, success at doing so
- opportunities for and success at restoration

DOMAIN III - PEOPLE

- personal and family well-being
- profile and valuation of personal and family activities

DOMAIN IV - SYNTHESIS

- recognition of emergent properties and provision of an integrated perspective for decision-making and anticiaptory analysis that spans Domains I, II, and III.

Source: modified from Hodge 1993, 25.

Corporations and Corporate Groupings

The corporate universe is diverse. In Canada for example, it includes approximately 1.1 million elements and spans for-profit corporations, not-for-profit voluntary organizations, professional associations, cooperatives, hospitals, unions, universities and colleges.[2] Government also functions as a corporate entity. However, because of its special status as society's rule-maker, it is considered separately.

The following comments regarding the nature of corporate reporting are summarized from NRTEE 1993 and relate to for-profit corporations which include about eighty-five percent of incorporated enterprises in Canada. Financial status and employee safety are the traditional focus of corporate reporting. Reports have been targeted at shareholders and investors, senior management, the board of directors, employees, and customers. Many of these reporting responsibilities are controlled by law.

Over the past three years, for-profit corporate leaders have adjusted reporting procedures, expanding both the list of stakeholders that are targeted for receipt of information (to include host communities) and the value base that drives the reporting process (to include environmental and ethical concerns). Social, environmental, ethical, and procurement issues have been added to traditional reporting topics.

Motivation for this shift has been (1) expanding environmental and ethical awareness; (2) tightening environmental standards at all levels including local, regional, national, and international; and most importantly, (3) a shift in the stance of the Financial Services Industry and its recognition of long-term liability particularly that related to contaminated land and contamination of groundwater systems (see Cassils 1993).

The proportion of total firms reporting in this new way is small but growing. In 1993 less than one-percent of large corporations and a significantly smaller proportion of the total for-profit corporate world are regularly reporting on these new issues. Not-for-profit organizations that do so are the rare exceptions.

Ideally, corporate reporting on sustainability would include the elements listed in Table 6-5.

TABLE 6-5. SYSTEMIC ASSESSMENT OF PROGRESS TOWARD SUSTAINABILITY FOR CORPORATIONS AND CORPORATE GROUPINGS.

DOMAIN I - ECOSYSTEM

- assessment of the health and integrity of the ecosystems (natural, modified, cultivated, and built) with which the corporation has interaction.

DOMAIN II - INTERACTION

- activity stress assessment (physical, chemical, biological); comparative data to allow comparison with other corporations
- identifications of opportunities for stress reduction, success at doing so
- opportunities for and success at restoration
- record of compliance with laws and regulations

DOMAIN III - PEOPLE

- corporate well-being (financial and otherwise)
- profile and valuation of corporate activities (benefits contributed to shareholders, employees, community etc.)
- well-being of the community with which the corporation interacts

DOMAIN IV - SYNTHESIS

- recognition of emergent properties and provision of an integrated perspective for decision-making and anticiaptory analysis that spans Domains I, II, and III.

Source: modified from Hodge 1993, 27.

Communities and Settlements

Daly and Cobb point out that a society can be called a community if:

> 1. membership in the society contributes to self-identification;
>
> 2, there is extensive participation by its members in the decisions by which its life is governed;
>
> 3. the society as a whole takes responsibility for its members; and
>
> 4. this responsibility includes respect for the diverse individuality of these members.
>
> (Daly and Cobb 1989, 172)

By this definition, ethnicity, gender, religion, interest, geography, or political jurisdiction could motivate the formation of a community. However, for community level statistical purposes, data and information are usually linked to the existence of a local government of some type.

In Canada for example, the fundamental unit used by Statistics Canada is the ***Census Subdivision*** - usually a municipality or equivalent such as Indian reserve, Indian settlement or unorganized territory. A ***Census Agglomeration (CA)*** is designated around any urban area with a core population of 10,000. The adjacent urban and rural areas, which have a high degree of economic and social integration with the core, are included. When the core attains 100,000 the area is designated a ***Census Metropolitan Area (CMA)***. Finally, Statistics Canada also identifies ***Urban Areas*** as an area which has attained a population of at least 1,000 and a density of 400 per square kilometre.

On a provincial basis, local government designations include cities, municipalities, municipal districts, regional districts, counties, towns, townships, villages, parishes, hamlets, and Indian reserves (NRTEE 1993, 25). Definitions vary from province to province and coincidence with Statistics Canada's statistical units may or may not occur although it is usually possible to aggregate Census Subdivisions to a close approximation of any given community.

From a reporting perspective, any government entity has the responsibility for:

1. reporting to the electorate on its performance as a corporate entity; and

2. monitoring and assessing the well-being of the people, the nature of the human-ecosystem interface, and the integrity of the ecosystem within its jurisdiction.

The first category is in principle no different than the corporate reporting described above and should include the elements listed in Table 6-5. Category two reporting on sustainability would include the elements listed in Table 6-6.

TABLE 6-6. SYSTEMIC ASSESSMENT OF PROGRESS TOWARD SUSTAINABILTY FOR COMMUNITIES AND SETTLEMENTS.

DOMAIN I - ECOSYSTEM

- assessment of the health and integrity of the ecosystems (natural, modified, cultivated, and built) with which the community has interaction

DOMAIN II - INTERACTION

- activity stress assessment (physical, chemical, biological); comparative data with other communities
- identifications of opportunities for stress reduction, success at doing so
- opportunities for and success at restoration
- record of compliance with laws and regulations

DOMAIN III - PEOPLE

- the well-being of community members and how that compares to other communities;
- profile and valuation of community activities

DOMAIN IV - SYNTHESIS

- recognition of emergent properties and provision of an integrated perspective for decision-making and anticiaptory analysis that spans Domains I, II, and III.

Source: modified from Hodge 1993, 29.

Regional, Provincial, Territorial, and National Governments

In addition to reporting to the electorate for its performance as a corporate entity (Table 6-5), reporting on sustainability for this group of decision-makers should ideally include the elements listed in Table 6-7.

Table 6-7. Systemic assessment of progress toward sustainability for regional, provincial, territorial, and national governments.

DOMAIN I - ECOSYSTEM

- assessment of the health and integrity of the implicated ecosystems (natural, modified, cultivated, and built).

DOMAIN II - INTERACTION

- activity stress assessment (physical, chemical, biological); comparative data to allow comparison with other communities
- identifications of opportunities for stress reduction, success at doing so
- opportunities for and success at restoration
- record of compliance with laws and regulations

DOMAIN III - PEOPLE

- overall assessment including that of individuals, corporations, corporate groupings, regions, provinces and the nation as a whole; how that compares to others;
- profile and valuation of activities

DOMAIN IV - SYNTHESIS

- recognition of emergent properties and provision of an integrated perspective for decision-making and anticiaptory analysis that spans Domains I, II, and III.

Note: modified from Hodge 1993, 30.

END NOTES

1. Results of this work have been reported in the 1978, 1986, and 1991 editions of Human Activity and the Environment (Statistics Canada 1978, 1986a, and 1991). Using the commodities information gathered by Statistics Canada as part of the principal statistics, a high-medium-low impact classification has been established and applied to: (1) use of raw natural resources (commodities extracted from the ground); (2) energy use (generally as consumed fuel); (3) use of commodities for which there is a concern about toxic or hazardous properties; and (4) use of water. The high- medium-low classification is based on a percentage of the total value of input represented by the particular commodity type.

2. Canada's corporate universe of approximately 1.1 million enterprises includes:

   - roughly 900,000 for-profit businesses (including crown corporations) of which 97% are small businesses (less than 50 employees); In 1988, the small business share of total business sales, profits, and assets are 26, 51, and 14 percent respectively;

   - about 140,000 not-for-profit voluntary organizations of which half qualify for tax-exempt, charitable status;

   - about 18,000 professional associations;

   - about 7,000 cooperatives: 4,096 non-financial cooperatives, 2,807 credit unions and Caisses Populaires with a membership in 1989 of nearly 9.2 million, or 35 % of the population. and 11 insurance cooperatives with 9 million policy holders in 1989;

   - 1,227 hospitals which together account for about 35 % of Canada's total health care costs which in 1992 stood at $48 billion;

   - 945 unions; and

   - 249 universities, colleges, and community colleges.

(NRTEE 1993, 37 - 38)

CHAPTER SEVEN

THE DEFINITION AND

APPLICATION OF INDICATORS

7.1 INTRODUCTION

An extensive literature exists that pertains to the definition and application of indicators. All indicators are value-based, a fact that lies underneath much of the controversy about indiator choice. This Chapter begins then, by examining alternative definitions and establishing the definition that is used in this dissertation. A set of desirable characteristics that can be used as indicator selection criteria are then proposed.

The quest for a broadly based set of indicators of progress has a history that extends at least to the early part of this century. This hisory is reviewed next. In the context of this dissertation, indicators are chosen and used in order to judge progress toward sustainability. This judgement process is addressed in the final discussion of the chapter.

7.2 DEFINING THE TERM "INDICATOR"

The discussion of systems theory in Chapter Five and Appendix IV served to introduce indicators as system descriptors — of both the components and the whole. The conceptual framework (model or paradigm of the system) provides the organizing template that facilitates the identification of components and their relationship to each other. Most critically, it identifies the explicit link to underlying values that govern both indicator selection and subsequent assessment. Without such a conceptual framework, indicator choice can only occur in a vacuum.

In the large body of relevant literature, a range of alternative definitions are evident (Table 7-1). Most of these definitions are not built from a systems theory starting point. Rather, they are articulated as a necessary clarification by workers with interest in monitoring and assessing social, quality-of-life, health, environmental, or sustainable development related conditions. A number of divergent lines of thinking that give rise to several questions are apparent:

1. does an indicator depend on a single simple variable or can it be composed of several?

2. is the focus of an indicator more appropriately the *objective* measure, the *subjective* judgement that is implied by the indicator, or some combination; in other words, is an indicator limited to a quantitative 'value-free' function or can it encompass qualitative, normative characteristics?

3. does an indicator necessarily imply a time series; does an indicator become an indicator only when trends can be suggested or can point-in-time state be included?

4. is an indicator only a surrogate, that is, does it necessarily imply some phenomenon that cannot be measured directly; does an indicator, by definition, have some significance beyond its face value or be representative of a wider and more complex system?

TABLE 7-1. INDICATOR DEFINITIONS

definition	*reference*
1. social indicator: a statistic of direct normative interest which facilitates concise, comprehensive and balanced judgements about the condition of major aspects of society	Cohen 1969, 57
2. environmental indicator: a single quantity derived from one pollutant variable and used to reflect some environmental attribute	Ott 1979, 8
3. repeated measurements made of the same phenomenon over time, the time series allowing the identification of long-term trends, periodic change and fluctuations in rates of change	Rossi and Gilmartin 1980
4. the empirical specification of conceptions that cannot (fully) by operationalized on the basis of generally accepted rules	Vos et al. 1985, 5

5. simple measures (in various units of measurement) or dimensionless indices which can be used to simplify comparisons, allow trends to be recognized, and to facilitate interpretation of the world .... VHB 1989, 3

6. a variable used to identify the presence or condition of a phenomenon that cannot be measured directly - an alternative, surrogate, or proxy measure which is used when it is not technically or financially feasible to observe and/or record the actual phenomenon; it may also serve to synthesize or summarize a series of other data variables; two or more simple indicators may be combined in a composite indicator or index .... Gélenas and Slaats1989, 2

7. sustainable development indicator:
a single quantity which reflects conditions in socio-economic activity in relation to the goal of sustainable development .... Sheehy, 1989

8. environmental indicator: time series data that directly bear upon a given condition .... WRI 1990, 3

9. environmental indicator: a characteristic of the environment that, when measured, quantifies the magnitude of stress, habitat characteristics, degree of exposure to stress, or degree of ecological response to the exposure .... USEPA 1990

10. environmental indicators: signals which reflect changes in the state of the environment and which obviate the need to peruse all variables that have been measured .... Ward 1990

11. quantitative descriptors of changes .... Verbruggen and Kuik1991, 8

12. models or representations of components or processes of real world systems .... Braat 1991, 58

13. measuring devices used to evaluate problems, their causes, and the steps taken to overcome them .... Indicators Task Force 1991, 2

14. a figure used to give a picture of changes in a specifically defined condition; does not provide detailed and exact information but rather indicates the broad outlines .... CBS, 1992

15. policy-relevant environmental indicators: statistical measures that tell us about the status of an environmental concern in relation to a broad social goal such as economic welfare, human health, social welfare and equity, ecological sustainability, aesthetic appreciation, and more... policy relevant indicators indicate how well or poorly we are doing to achieve a perceived goal .... Tunstall 1992, 1

16. environmental indicators: key measures which may show the health of the environment, the source and quantities of activities which may cause stress to the environment, and the kinds and volumes of activities aimed at environmental stress reduction .... CCME 1992, i

17. descriptive indicator: simple description of a particular state .... Adriaanse 1993, 7

18. policy indicator: the presentation of a quantitative picture, obtained on the basis of a model, which reflects a complex process. A value judgement is added to the obtained picture by comparing it with a chosen policy target which serves as a reference value .... Adriaanse 1993, 8

19. simple data or more complex statistics that are representative of a wider and more complex system - a sort of 'sample' of the system, perhaps summarizing a range of different data and representing a particular time period .... WHO 1993, 6

20. signals that facilitate quantitative and qualitative evaluation of progress toward meeting policy objectives .... Gordon et al. 1993

21. sustainability indicators: parameters to measure progress towards sustainability in the environment, the economy and social well-being .... BCRTEE 1993c, 47

22. a piece of information that (1) is part of a specific management process and can be compared with the objectives of that management process; and (2) has been assigned a significance beyond its face value .... van den Born et al.1993, 9

Ott limits the meaning of "indicator" to a mathematical function based on one variable while assigning the term "index" when two or more variables are involved (1979, and see Table 22, no. 2). Application of Ott's definition would see the concentration of a single chemical in water (mg/l) labelled an indicator while emissions per unit of gross domestic product (kilograms per $GDP) would be considered an index. In recent years, this limited definition of indicator has been set aside in favour of a broader context which includes within the term indicator:

- single parameter indicators by Ott's definition;
- sets, profiles, or batteries of indicators;
- composite indicators or indices

(VHB 1989; Gélenas and Slaats 1989; Ward 1990, Gosselin et al. 1991; Indicators Task Force 1991; van den Born et al. 1993)

The use of bioindicators (for example, monitoring the characteristics of a single or group of species as an indicator of the health of a whole ecosystem) extends the sense of integrating many variables even farther (see Jeffrey and Madden 1991 for a recent compilation of papers). In this case, the cumulative effects of many stresses (biological, physical, chemical; natural and human-imposed) are integrated in the condition of the species. It is a rare exception when the exact combination of stresses can be ascertained even though the cumulative effects of these stresses can be observed and measured.

The distinction between *subjective* and *objective* indicators is identified and discussed in the quality of life literature (see Dann 1984 for a useful overview and Murdie et al. 1992 for a more recent compilation with a Canadian emphasis). As social indicators and quality of life research evolved through the 1960s and 1970s, researchers began examining the validity of using so-called objective measures to reflect subjective experiences of life.

Much of the impetus came from disenchantment with objective economic indicators and the growing evidence of a significant discrepancy between these and life satisfaction (Dann 1984, 2 - 3). Campbell et al. (1976,3) and Schneider (1975, 505) amongst others argue that many assumed correlations between objective conditions of *welfare* (for example, levels of housing, employment/unemployment, and health care etc.) and subjective states of *well-being* (feelings of pleasure, satisfaction, security, hope etc.) were weak. They urged the study of individuals' perceptions of how life is actually experienced.

The recognition that quantitative 'objective' measures are limited in their ability to describe many important qualitative characteristics has inevitably resulted from this debate. Thus, Milbrath notes:

> Quality of life is defined as being necessarily subjective and measured by subjective indicators; this approach should be distinguished from physical measurement of objective conditions . . . Both kinds of measures are useful and should be utilized in studies of quality of life.
>
> (1982, abstract)

In practice, there is need for both quantitative 'objective' measures as well as for information derived from qualitative inquiry (for example see YUCHS 1990, 7). For both, measurability is critical. A complete review of this topic is beyond the scope of this dissertation. However some basic aspects of quantitative and qualitative measurement are addressed in Appendix VII.

The issue of grasping human perceptions through some suite of indicators is difficult enough. Further complications arise when non-human components of the ecosystem that cannot communicate their perceptions are dealt with. This train of thought leads into theological debate and is also beyond the bounds of this dissertation. Suffice it to say that in practice, in assessing the ecosystem (including the human sub-system), there is an inevitable dependency on the human perception of not only how humans (individually and collectively) are faring but also how everything else is faring. This is the root of the special responsibility assigned to human-kind that has been identified and championed by the environmental movement throughout this century.

Indicators, then, are both quantitative and qualitative in natureand the choice of indicators is a normative process. They are given significance and meaning because an underlying value set deems them important. For this reason all indicators, quantitative or qualitative, must be considered value-based.

Rossi and Gilmartin (1980) and WRI (1990) suggest an indicator by definition, requires a time series of data. This is not strictly the case. The current level of infant mortality in the world is an important and useful indicator on its own merits. However, the power of any indicator is greatly enhanced if <u>both</u> temporal and spatial distribution are available. And as Robert Horn points out in reference to a number: "we need statistical series and systems to unlock its indicative content" (1993, 5).

Characteristics like the availability of time series data or the degree of significance beyond face value are not appropriately included as definitional conditions of indicators. Rather, drawing on systems theory, the following definitions are used in this dissertation:

INDICATORS:

> measurable descriptors, quantitative or qualitative, of normative interest which facilitates assessment of the past, current, or future state or performance of system constituent parts, controls, and feedback loops (as well as the system as a whole).

Indicators of Sustainability:

indicators (as above) which:

- reflect a parallel care and respect for people and the enveloping ecosystem now and in the future (the normative interest);
- facilitate assessment (past, current, future) of progress toward sustainability of the system described in Figure5-1 using the goals listed in Table 5-4.

7.3 THE QUEST FOR IMPROVED INDICATORS

The current surge of interest in indicators has its roots in at least seven previous phases of indicator-related activity. Each phase has been marked by a significant body of literature. Figure 7-2 lists these phases and provides an approximate time line reflecting the emergence of a systematic treatment of indicators in each case.

There is little doubt that a pivotal event is John Maynard Keynes' theoretical treatment of national income in the mid-1930s. The subsequent development of national accounts in the 1940s (eventually with state/provincial counterparts) organized with the standard industrial classification (SIC) has resulted in measures of total national income and use of gross national/domestic product. Almost as soon as the GNP/GDP was created, debate about this indicator began: its use, misuse, and how it might be improved. That debate continues today (see discussion in ChapterThree).

Alternative approaches to economic indicators have been discussed throughout this time (Anderson 1991). Feminist scholarship has provided a particularly useful critique of macroeconomic analysis (for example, see Waring 1988). Recently "ecological economics" has been proposed. This subject is now addressed by The International Society for Ecological Economics (ISEE) and its learned journal, *Ecological Economics*.

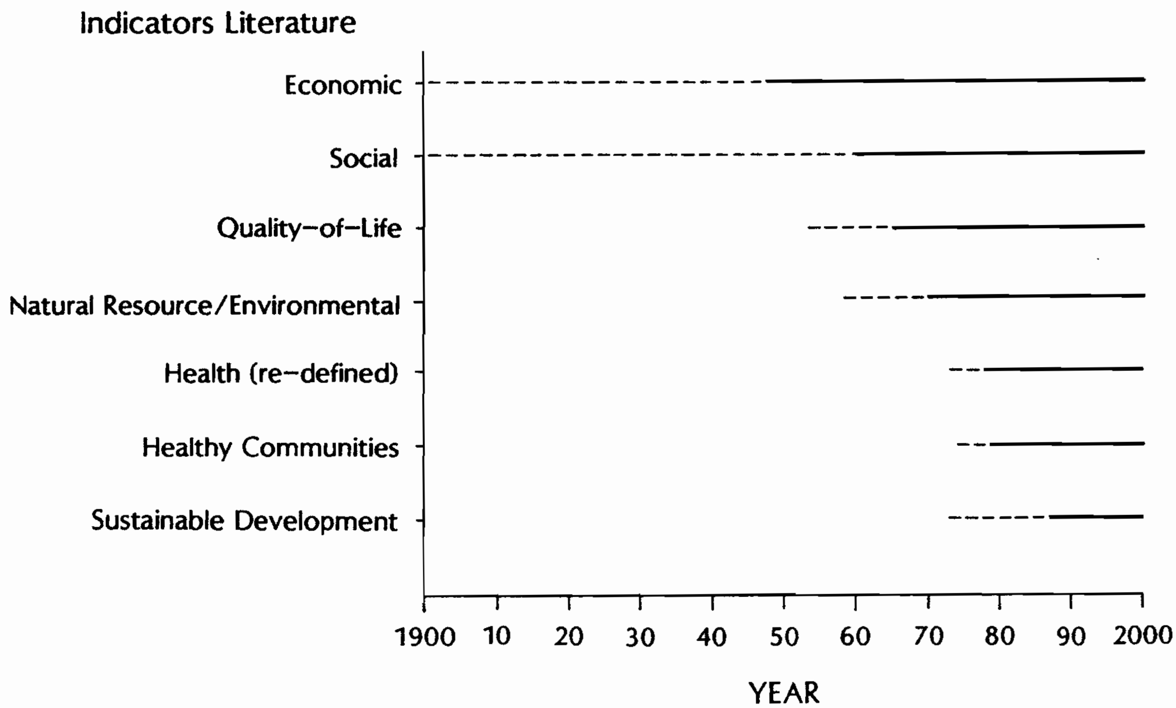


Figure 7-1. Indicator literature: historical profile.

Natural resource accounting has received much attention through the efforts of the United Nations, the Organization for Economic Co-operation and Development, the World Bank, and workers in a large number of countries around the world including Australia, Brazil, Canada, Costa Rica, France, Germany, India, Indonesia, Japan, Mexico, the Netherlands, New Zealand, Norway, Papua New Guinea, the Philippines, Tanzania, Thailand, the United Kingdom, and the United States (Hamilton et al. 1993).

Dann points out that the overall disenchantment with economic indicators was a prime motivation for the rise in interest in social indicators in the 1960s (1984, 2). The aggregation of economic and social indicators in quality-of-life indicators soon followed (see Murdie et al. 1992).

In the 1970s, the rise in interest in systematically assessing environmental quality provided new impetus for indicator development. In both Canada and the United States, projects were initiated in the early 1970s to define a single or small set of environmental indices to more effectively communicate environmental conditions (see Inhaber 1976 for a description of the Canadian work and CEQ 1972 and Tunstall 1979 for the corresponding American story).

The 1970s saw a major shift in the concept of health from the simple idea of it reflecting the absence of disease to a much more proactive concept of health as a broad resource for everyday life. In the 1980s this led to the rise of the healthy communities movement and in turn, significant effort has since been made to define healthy community indicators. The following discussion is summarized from Jackson and Nishri (1988) and Hancock (1988, 1990a and b, 1991).

In 1974, the Lalonde Report (Health and Welfare Canada, 1974) recognized that the major determinants of health are much more than medical and hospital care and included environment, lifestyle and the human biology. In 1977, the World Health Organization (WHO) established the broad social goal of attaining "health for all by the year 2000." At the time, they reaffirmed the definition of health as a state of complete physical, mental, and social well-being that had been written in 1947 (WHO, 1947).

At a 1986 Ottawa conference, WHO and Health and Welfare Canada established health promotion as the key to achieving their goal of health for all. They define health promotion in terms of empowerment: "the process of enabling people to increase control over and improve their health" (WHO 1986; Health and Welfare Canada 1986). From then on, both WHO and Health and Welfare Canada have considered health as "a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity." Health can be defined as:

> ...as a resource for everyday life that has to be maintained and enhanced, and that good health enables people to both cope with their circumstances and to take steps to improve them. Both are concerned with the extent to which individuals have access to basic prerequisites to health, among which one should include a ***healthy and secure environment.***
>
> (Hancock 1990b, 3-4; emphasis added)

The same 1986 conference also gave rise to "The Ottawa Charter" (WHO 1986) in which five strategies for health promotion were proposed: (1) building healthy public policies; (2) creating supportive environments; (3) strengthening community action; (4) developing personal skills for health; and (5) reorienting health services (as summarized by Hancock 1990b).

It is the application of these strategies at the local level that constitutes the healthy city/community projects in Europe and Canada. The approach has been motivated by the observation that:

> ...the greatest contribution to the health of the nation over the past 150 years was made, not by doctors or hospitals, but by local government.
>
> (Parfitt 1987)

The concept of healthy cities emerged at the 1984 conference "Beyond Health Care" held in Toronto. Leonard Duhl, a medical and planning specialist from Berkeley, California, is credited with its origins (Wolfe, 1993). WHO Europe established its Healthy Cities Project soon after and the Canadian Healthy Cities Project followed. As of January, 1994, 154 Canadian communities are engaged in Health Communities projects (Burch, 1994).

Participants in the healthy cities movement have come to the general agreement that the health of a city and its people needs to be assessed in terms of physical, mental, and social well-being or fitness as much as, if not more than the rates of mortality and morbidity (Cappon 1990). While there is no agreement on what the specific indicators should be (see Hayes and Willms 1990), they note that at least as much attention to subjective as to objective assessments of well-being are required. These assessments must be holistic, and deal with both state and process (Hancock 1991, 5). The related literature, particularly that dealing with indicators, is both vast and rich in ideas (see for example, WHO 1987; Jackson and Nishri 1988; Hancock 1989, 1990a and b, 1991; YUCHS 1990a and b; Willms and Gilbert 1990; Hayes and Willms 1990; Feather and Mathur 1990; Cappon 1991; Gariepy unpublished manuscript; and Wolfe 1993).

During the past five years, the soaring costs of health care have prompted a review of health information systems (for example see NTFHI 1991). New approaches to identifying the determinants of well-being that attempt to better integrate economic and environmental factors with those traditionally considered are being explored (Evans and Stoddart 1990). In turn, these new approaches to describing the determinants of health are being translated to discussions of indicators (WHO 1993).

In the late 1980s the popularization of the concept of sustainable development brought a new wave of interest in indicators. In May, 1989, the Ministerial Council of the Organization of Economic Cooperation and Development (OECD) called for "a next generation work programme on environmental economics that would integrate environment and economic decision-making more systematically and effectively as a means of contributing to sustainable development" (OECD 1991, 8).

The subsequent 1989 Group-of-Seven (G-7) summit held in Paris asked the OECD:

> ...within the context of its work on integrating environment and economic decision-making, to examine how selected environmental indicators could be developed.

The same theme was echoed at the 1990 G-7 summit held in Houston:

> We encourage the OECD to accelerate its very useful work on environment and the economy. Of particular importance are the early development of environmental indicators...
>
> (OECD 1991, 8)

In Canada, the response to this international interest was rapid. In February, 1990, Environment Canada created an Indicators Task Force which produced its first formal report in April, 1991 (Indicators Task Force 1991). The Task Force's work is ongoing.

Simultaneously, a second initiative coordinated through the Health Promotion Directorate of Health and Welfare Canada resulted in the creation of a Steering Committee on Indicators for a Sustainable Society. Their final report was issued in May, 1991 (Gosselin et al. 1991)

In a third activity, the Canadian Environmental Advisory Committee initiated a systematic review of issues related to indicators. Studies were commissioned on (1) economic theory, (2) the concept of ecological integrity and alternative theories of ecology, and (3) the decision-making process. These formed the basis for a series of workshops. Results are found in Victor et al. 1991, Ruitenbeek 1991 and Potvin 1991.

The National Round Table on the Environment and the Economy led a more specific initiative aimed at selecting energy indicators to be used at a national level in Canada (Western Environmental and Social Trends 1991; Marbek 1991). The Council of Great Lakes Research Managers also proposed a general framework for developing "indicators of ecosystem health" (Council of Great Lakes Research Managers 1991).

A high level of activityaimed at establishing improved indicators of progress is continuing both in Canada and abroad (see for example, NRTEE 1993; van den Born et al. 1993 and WHO 1993). However it is apparent from the historical review that there is an identifiable pattern of strong interest in improved indicators and a subsequent loss of momentum. And while useful insights are gained with each new phase of activities, widely accepted new indicators have not emerged.

7.4 INDICATOR SELECTION CRITERIA

A number of authors provide lists of desirable indicator characteristics that can serve as selection criteria. Such criteris for what are labelled "environmental indicators" are offered by Liverman et al, 1988, Gelinas and Slaats 1989, VHB 1989, Ward 1990, Indicators Task Force 1991, WRI 1990, Tunstall 1992, and van den Born et al. 1993. The World Health Organization lists selection criteria for what they call "environmental health indicators" (WHO 1993). Selection criteria for indicators of a sustainable society are listed by Gosselin et al. 1991; for provincial indicators of sustainability by the British Columbia Round Table on the Environment and the Economy (BCRTEE 1993); for indicators of a sustainable city by the Sustainable City project (Sustainable Seattle 1992); and for sustainable energy use by MacNeill and Runnalls (1993). Table 7-2 lists the seven dominant characteristics that emerge from a review of this literature.

TABLE 7-2. DESIRABLE INDICATOR CHARACTERISTICS THAT CAN BE USED AS SELECTION CRITERIA.

INDICATORS OF SUSTAINABILITY SHOULD:

1. link directly to specific objectives which in turn are nested within general goals motivated by the concept of sustainability;

2. accurately and unambiguously reflect the degree to which the system component being measured meets the related objective;

3. be measurable and based on data which are either available of easily obtainable with a reasonable degree of accuracy;

4. facilitate forward, anticipatory application as well as historic and current analysis;

5. be sensitive to changes over time, space and in the case of the human subsystem, be sensitive to differences between sub-populations;

6. facilitate comparison between like system components being assessed; and

7. facilitate action needed to both reinforce positive results and correct negative ones.

7.5 THE PROCESS OF MAKING AN ASSESSMENT

The overall process of making an assessment of progress includes the following four steps:

1. developing general goals that are usually abstract and not directly measurable but reflect the operating value system;

2. identifying specific objectives that:

   - provide a clear link between the general goals and the system components within the conceptual framework

   - are practical and measurable;

3. choosing measures (one form of indicators) and families of measures that serve the specific objectives;

4. using either explicit or implicit standards or criteria to make judgement regarding the achievement of progress .

Steps 1, 2, and 4 are addressed in the remainder of this chapter. Choice of measures (step 3) will vary widely depending on the nature of the ecosystem and human subsystem being considered as well as the decision-maker in question. A technique for considering indicators systemically is introduced in the next chapter.

Goals for Achieving Sustainability

A number of writers have opted for focussing the definitional debate surrounding the concept of sustainable development by limiting their concern to physical characteristics. For example, while economist David Pearce suggests that the overriding criteria for assessing sustainability should be that human well-being must not decline over time, he argues that the long term degree of well-being cannot be assessed on the basis of today's state of well-being. Thus, he concludes that "defining sustainable development as sustained well-being over time is of only limited help in real world development planning." Instead, he states that:

> ...the clues to sustainability lie in the quantity and quality of a nation's *capital stock*. Part of the intuition here is that nations are like corporations. No corporation would regard itself as sustainable if it used up its capital resources to fund its sales and profits expansion. As long as capital assets are at least intact, and preferably growing, any profit or income earned can be regarded as 'sustainable'. On this analogy, nations are no different. Sustainable growth and development cannot be achieved if capital assets are declining.
>
> (1993, 48 - 49)

Pearce defines capital assets to include 'man-made' capital (machines, roads, factories etc.), human capital (knowledge, skills etc.) and natural capital (environmental assets). A "weak sustainability" criteria would see the aggregate of these capital assets maintained. In this criteria, natural and man-made capital are assumed to be perfect substitutes - an approach that ecology demonstrates is not true. A "strong sustainability" criteria would maintain natural capital as constant or growing (51 - 53). There is much debate about application of these criteria (for example, see Pezzy 1993 9 - 16; Schrecker 1993).

Pearce also raises the issue of irreversibility suggesting that it should play some role in the assessment of sustainable development:

> The more irreversible the damage done by the current generation, the fewer the degrees of freedom future generations will have to expand their own well-being.
>
> (1993, 51)

Pearce's concept of sustainability criteria, whether the "weak" or "strong" version is considered, is incomplete for assessing sustainability. It cannot be assumed that maintenance of capital assets (man-made, human, natural) implies maintenance of human well-being. It may be a necessary condition; yet it is certainly not a sufficient condition. And there is no motivation for maintenance of capital assets if human well-being is deteriorating. Similarly, a simple dependency on the assessment of human well-being is insufficient for the very reason expressed by Pearce as well as because the use of the human species as a bioindicator for the earth's ecosystem has not been justified to date.

A broader set of goals is required as a starting point for undertaking a practical assessment of progress. These goals must be guided by the underlying values of sustainability, internally consistent with the conceptual framework guiding the reporting system, and reflect a realization that human activities are currently overstressing the ecosystem as well as not adequately providing for human well-being (WCED 1987; UNDP 1993; UNICEF 1993; World Bank 1993; Brown et al. 1993; and many others). The list of goals for achieving progress toward sustainability provided in Table 5-4 was motivated by the above factors.

Supporting Goals With Specific Objectives

Under each of the goals listed in Table 5-4, a large number of specific, measurable objectives can be listed that must be developed by and tailored to the needs of different decision-makers: city or rural homemaker, farmer, fisher, logger, plumber, truck driver, corporate manager, town mayor, premier, or prime minister and so on. Table 7-3 sets out a number of specific objectives organized by goal. It serves to illustrate the breadth and depth of this task.

Table 7-3. Examples of specific objectives organized by goal.

DOMAIN I GOAL: TO MAINTAIN OR IMPROVE ECOSYSTEM HEALTH AND INTEGRITY

Example Definitions:

- An ecological system is healthy and free from "distress syndrome" if it is stable and sustainable (maintains its structure and function over time) - that is, if it is active and maintains its organization and autonomy over time and is resilient to stress. Sustainability is related to maintenance of structure and function over time; it is a comprehensive, multiscale, dynamic measure of system resilience, organization, and vigor. "Distress syndrome" refers to the irreversible process of system breakdown leading to collapse.

(Haskell et al. 1992, 9; Costanza, 1992, 248)

Example of this Goal:

- To restore the chemical, physical, and biological integrity of the waters of the Great Lakes Basin Ecosystem.

(Great Lakes Water Quality Agreement
(GLWQA), Article II,1978)

Examples of Specific Objectives:

- To maintain ambient concentrations of common and toxic contaminants in air, inland surface water, marinewaters, and groundwater within their natural range;
- To maintain the available volume and flow rate of water in a given surface water or groundwater system within the natural range;
- To maintain rates of soil erosion at levels at or below the natural range for a given area;
- To maintain soil quality at levels at or above the natural range;
- To maintain or enhance species health;
- To maintain biological diversity;
- To maintain or enhance adequate habitat for desired diversity and reproduction of organisms;
- To maintain natural capital (environmental assets) as constant or growing

(Pearce 1993, 51 - 53)

DOMAIN II GOAL: TO REDUCE THE PHYSICAL, CHEMICAL, AND BIOLOGICAL STRESS IMPOSED ON THE ECOSYSTEM BY HUMAN ACTIVITIES

Example Definition:

- stress:
  a physical, chemical, or biological phenomena causing system perturbation.

Example of this Goal:

- To prohibit the discharge of toxic substances in toxic amounts and to virtually eliminate the discharge of any or all persistent toxic substances.

(GLWQA 1978, Article II)

Examples of Specific Objectives:

- To virtually eliminate present inputs of persistent toxic substances;
- To anticipate and prevent future inputs and problems; and
- To remediate problems from past and present inputs.

(VETF 1993, Vol. 1, 3)

- To reduce the production of waste then reuse, recycle and recover waste by-products of our industrial and domestic activities;

(NRTEE 1992b, 10)

- To reduce the energy and resource content of all human activities; to harvest renewable resources on a sustainable basis; and to make wise and efficient use of our non-renewable resources;

(NRTEE 1992b, 10)

DOMAIN II GOAL: TO INCREASE THE EXTENT TO WHICH HUMAN ACTIVITIES RESTORE ECOSYSTEM HEALTH AND INTEGRITY

EXAMPLES OF SPECIFIC OBJECTIVES:

- To ensure that for every hectare of land removed from natural state by human endeavor, another hectare somewhere else is returned to natural state;
- To restore the North Atlantic groundfish populations;
- To restore or replace the fish habitat destroyed by the damming of streams and rivers in Ontario.

DOMAIN II GOAL: TO INCREASE THE ABILITY OF HUMAN ACTIVITIES TO CONTRIBUTE TO HUMAN WELL-BEING

EXAMPLE DEFINITION:

- human activities: the complete range of human activities including those monitored within the market system, housework, volunteer, and non-market underground activities;

EXAMPLES OF SPECIFIC OBJECTIVES:

- To increase the proportion of people undertaking meaningful work;
- To increase the value-added generated by both market and non-market activities

DOMAIN III GOAL: TO MAINTAIN OR IMPROVE HUMAN WELL-BEING

EXAMPLE DEFINITIONS:

- well-being: the sense of life satisfaction of the individual.

  (Evans and Stoddart 1990, 40)

- health:

  (1) a state of complete physical, mental, and social well-being, and not just the absence of disease or infirmity

  (WHO 1947);

  (2) "a resource for everyday life" which enables an individual and group "to identify and to realize aspirations, to satisfy needs, and to change or cope with the environment"

  (WHO, 1986 (Ottawa Charter for Health Promotion), as paraphrased by Hancock 1989, 3);

- healthy community/city:

  one that is continually creating and improving those physical and social environments and expanding those community resources which enable people to mutually support each other in performing all the functions in life and in developing to their maximum potential.

  (Duhl and Hancock 1986)

EXAMPLE OF THIS GOAL:

- To attain by the year 2000 a level of health throughout the world that will enable people to lead socially and economically satisfying lives (Health for all by the year 2000). This is the main goal of the World Health Organization adopted at the 1977 World Health Assembly.

  (see discussions in Deliege 1983, 349 and Hancock 1989, 4 and 49)

EXAMPLES OF SPECIFIC OBJECTIVES:

INDIVIDUALS / FAMILIES

- To maintain a level of caloric and nutrient intake that matches body weight, activity level, age, and life phase requirements;
- To maintain a desired level of physical fitness;
- To attain the number of hours of sleep required to fulfill personal needs;
- To attain a degree of physical, financial, and social security that fulfills personal needs and wants;

Communities

- To provide:
  - adequate food, water, shelter, income, safety and security, work;
  - a clean, safe, and high quality built environment;
  - a healthy supporting ecosystem;
  - a diverse, vital and innovative economy;
  - access to diverse experiences and resources;
  - an enabling institutional structure that facilitates a high degree of public participation and citizen control over the decisions affecting their lives;
  - a sense of historic, biological and cultural connectedness;
  - a strong, mutually-supportive and non-exploitive community;
  - a high health status with appropriate, high quality and accessible public health and sick care services

(modified from Hancock, 1987).

For-profit Corporation

- To maintain or increase financial strength (for example, shareholder return on investment, credit ratings, return on equity, earnings growth, productivity, and indebtedness);
- To maintain or improve strong employee satisfaction reflected in low turnover rates and a high degree of participation in decision-making;
- To maintain or increase the level of resources available for research and development;
- To maintain or enhance a positive public image and a strong relationship with the surrounding community.

(Hodge and Taggart 1992, Appendix III, 7; BM 1993)

Territory

- To attain an economic standard equal to anywhere else;
- To increase territorial control over its economic future: more regional and local decision-making, increased community authority, greater level of in-territory ownership;
- To preserve the option for residents to support themselves through work in the territory;
- To ensure equality of economic chance;
- To broaden the territorial economic base and in particular, to stabilize the non-renewable resource sector

(YTG 1988 and 1990 as summarized in R. A. Hodge 1991, 7)

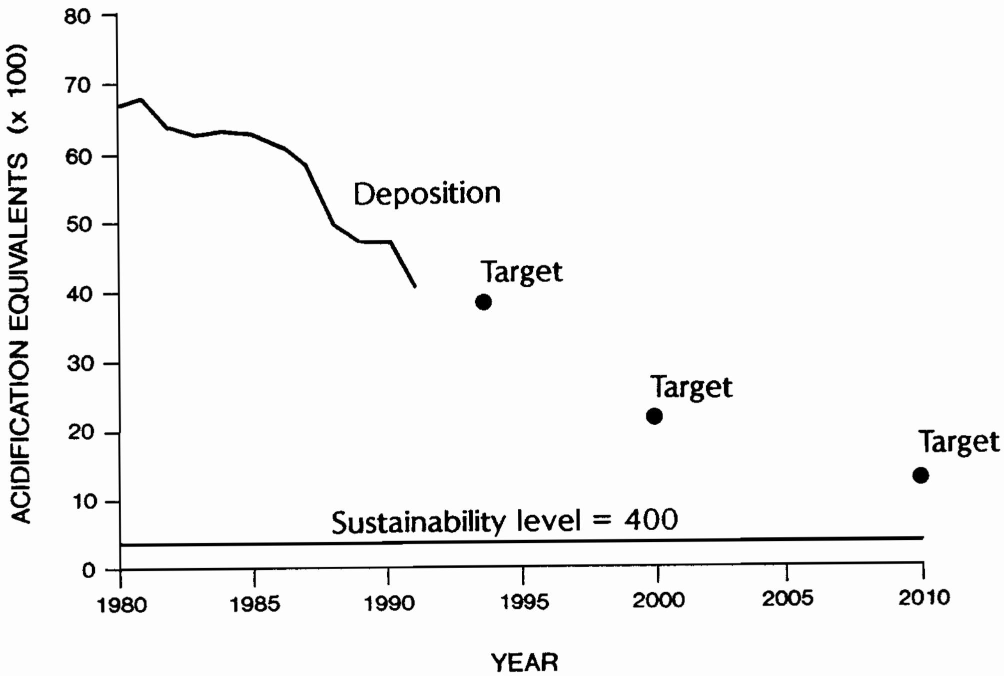
Standards and Criteria

Judging the significance of an indicators requires comparison of its value with a standard or criteria that provides the basis for assessment. A standard usually enjoys some elevated status. For example, if incorporated within a formal regulation, it can have the weight of law. A standard sets a minimum or maximum value that is absolute and must be achieved to be acceptable. Examples include water quality standards, emission standards, manufacturing standards, electrical wiring standards and highway safety design standards. The relevant objective would be to achieve the standard. Subsequent assessment is simply one of judging whether or not the standard has been achieved.

Criteria are not entrenched in law but can carry significant weight. They are usually expressed as a minimum or maximum that is desirable. Examples include bridge design criteria, targets for emissions reductions, or targets for drinking water quality (often expressed as drinking water quality objectives). The relevant objective would be "to maximize (or minimize)..." Subsequent assessment is then based on assessing how close to the maximum or minimum has been achieved.

The above use of the term "criteria" is not universal. Recent work aimed at developing a system for monitoring, assessing, and reporting on sustainable development of boreal and temperate forests describes assessment criteria as measurable "facets or features that must be considered in setting objectives or policy" (Gordon et al. 1993, 1). For example, conservation of biological diversity is described as a criterion for the conservation and sustainable management of termperate and boreal forests (Montreal Process, 1994). In this dissertation, conservation of biological diversity would be considered an objecive that falls within the Domain I goal of maintaining or improving ecosystem health and integrity.

Canada's Indicators Task Force points out the need to have criteria in the form of target or threshold levels against which to compare indicators (1991, 4-5). Adriaanse also takes up this theme (1993, 7-8). For simple descriptive indicators (such as temperature), significance is only obtained when comparison is made to some known experience (for example, winter). However, for indicators designed to assess policy performance, Adriaanse argues that targets are essential to serve as a norm or reference value. Figure 7-2 provides an example of his work drawn from the Dutch National Environmental Policy Plan.



Notes:

The quantity of potentially acidic components that end up in the soil is expressed as deposition in acidification equivalents (Aeq) per hectare per year. In 1980, the deposition consisted of 6,700Aeq and in 1991 of 4,100Aeq. This deposition derives both from foreign and domestic sources. In 1980 and 1989 the share of Dutch sources in the Dutch deposition was 48% and 54% respectively. The sum of the deposition of the three main acidic compounds (sulphur dioxide, nitrogen oxides, and ammonia) is shown.

The policy target is to reduce deposition to 4,000 Aeq by 1994, to 2,400 Aeq by 2000 and to 1,400 Aeq on forests by 2010. The sustainability level, or in other words the target value, is approximately 400Aeq. These targets relate to the total deposition, which includes the foreign contribution. The total acidic deposition in 1991 was down approximately 39% on 1980.

Source: Adriaanse 1993, 33.

Figure 7-2. Adriaanse's analysis of acidification.

Adriaanse's approach for tracking the success of specific policies is powerful. However, two points need be made. Firstly, the existence of numerically expressed, point-in-time targets to serve as assessment criteria are the rare exceptions rather than the rule. In practice, assessments are required in the absence of such explicit criteria and thus dependence must be placed on making judgements on the basis of best available data, information, experience and often, intuition. In this case, it is one's operating value set that imputes assessment criteria.

Secondly, point-in-time targets as used by Adriaanse (see also Indicators Task Force 1991) are only one potential type of criteria. A simple hierarchy of potential types of criteria exists that includes:

- state: point-in-time
- change-of-state: trend
- rate of change-of-state: change of trend

This hierarchy, of course, represents the variable, first derivative with-respect-to-time, and second derivative with- respect-to-time sequence of calculus.

For example, many situations may be envisioned where the ultimate "sustainability" criteria is simply not possible to establish. However, it may also be clear that current levels (for example of contaminant emissions) are seriously excessive. The policy target could then be set as a decreasing trend for the foreseeable future. Many aspects of stress imposed on the ecosystem by human activity are in this situation.

It must be emphasized that the process of setting standards and criteria is dynamic. As values change and as scientific knowledge increases, assessment standards and criteria evolve. For example, drinking water quality standards set to protect human health were once thought to provide adequate long-term protection not only for humans but for all aspects of the ecosystem. However, this opinion was undermined by the recognition of the processes of bio-accumulation, in which particular organisms serve as collectors of contaminants, and bio-magnification in which concentrations increase as nutrients work their way up the food-web. Standards have been subsequently adjusted to reflect this "new" scientific knowledge.

The above discussion focuses on standards and criteria set in relationship to carefully defined and limited environmental concerns. An additional aspect of this issue relates to the establishment of criteria for assessing overall progress in society. The State of Oregon has assumed an innovative approach.

In 1989, the Oregon Progress Board was created to translate a state strategy for achieving prosperity into measurable objectives for Oregon (OEDD, 1989). They call their measurable objectives "benchmarks." Following a broadly based, participatory process, the first set of Oregon Benchmarks was proposed to the Oregon Legislature in January, 1991 (Oregon Progress Board 1991). Their second report was filed in December, 1992 (Oregon Progress Board 1992) and additional reports are required at two year intervals.

Oregon Benchmarks include 272 factors which serve to monitor human, environmental, and economic well-being (Oregon Progress Board 1992). For each benchmark, targets are set for the years 1995, 2000, and 2010 and expressed as simple numbers (for example pregnancy rate per 1,000 females ages 10 - 17; percentage of 1970 agriculture land still preserved for agriculture use; total and per worker payroll in a given industry). The Benchmarks place priority on measuring outputs or results (for example, adult literacy) rather than inputs or efforts (for example, the amount of money spent on literacy education).

From the full set of 272 benchmarks, The Progress Board identifies a subset of 26 "urgent" benchmarks — immediate priorities relating to:

- children and families;
- education and workforce preparation reforms;
- work force training;
- value added products and global business;
- health and health care;
- physically liveable communities;
- socially liveable communities;
- clean natural environment; and
- government efficiency and revenue reform.

They also list 20 "core" benchmarks that they consider enduring measures of Oregon's vitality and health. There is some overlap with the immediate priorities but these are recognized long-term priorities and include:

- knowledge and education;
- healthy individuals and families;
- clean environment;
- livable communities; and
- personal income, economic diversity, and international trade.

In addition to facilitating the assessment of progress and monitoring the success of government programs, the Benchmarks have become an important tool for directing state program and budget priorities and for seeking inter-agency cooperation (Oregon Progress Board, 1992). The choice of particular benchmarks would inevitably vary depending on the values and needs of the decision-making group motivating the assessment as well as the ecological (including human) characteristics of the jurisdiction being assessed.

The original set of Oregon Benchmarks was developed with input from six citizens' committees and was subject to a state-wide public review involving 12 public meetings and several hundred written interventions prior to being formalized for presentation to the state legislature. Public input on Benchmarks is an ongoing process (Oregon Progress Board 1991, 1, and 1992, 1). The broadly participatory process used for setting the benchmarks, the public reporting system, and the long-term commitment for follow-up are all noteworthy.

Making Judgements of Progress Toward Sustainability

In coming to a judgement of progress, conflicting signals must be weighed and combined in some way. This is done either with mathematical models that apply weighting factors and aggregate using formal rules or through some other process of judgement. All process of judgement involve weighting factors although they are not always explicit.

One process of judgement is the "weight-of-evidence" approach used every day in our courts of law. Its use as an approach to environmental assessment has been pioneered by the International Joint Commission in the Great Lakes basin ecosystem (IJC 1990, 1992, 1994). The approach is now being used in the assessment of priority substances under the Canadian Environmental Protection Act (CEPA) (for example see CEPA Pulp Mill Effluent 1991; CEPA Cadmium 1994). Jerome Nriagu uses the approach in an assessment of heavy metals in the Canadian environment (Nriagu 1995).

Use of the weight-of-evidence can cause discomfort for those schooled in reductionist science and technology. In a sense, its use is an admission that the situation being considered is imperfectly understood. As a result of this uncertainty, it is important to instill as great a degree of rigour as is possible. A key aspect of so doing is to clearly and explicitly articulate rationale for assessments ("reasons-for-decisions"). In this way, the resulting assessment can be scrutinized, tested, and modified as new information becomes available.

CHAPTER EIGHT

FROM THEORY TO PRACTICE

8.1 INTRODUCTION

Three practical issues arise in bringing the proposed conceptual framework from theory to practice. First there is a need to untangle the maze of potential indicators in some systemic way. Second, the possibility must be dealt with that some indicators can directly indicate the state of one system component while indirectly suggesting the state of another. And third, the strengths and limitations of indices must be understood. This Chapter first addresses these three topics. Examples of indicators by decision-making group are then offered followed by a discussion of the feasibility of identifying a short list of key indicators of sustainability. Finally generic institutional issues related to each decision-making group are reviewed.

8.2 ASSESSMENT HIERARCHIES

Each of the four indicator domains consists of a hierarchy of indicator families that range from the most general at the apex through a progressively finer level of detail towards the bottom. Specific measures are located at the very bottom.[1] Examples of such hierarchies for each of the four domains are shown in Figures 8-1, 8-2, 8-3 and 8-4 respectively.

These assessment hierarchies provide a map of the assessment process. For example, Figure 8-1 shows that to undertake a comprehensive assessment of the health or integrity of a given ecozone or river basin, natural, modified, cultivated and built sub-systems of the ecosystem need consideration. Within each of these, air and climate, water, land, and biota must be assessed. To assess the water sub-system, groundwater, surface water, and marine water require assessment. For each of these, water quality, water quantity, and temperature are factors. And within each of these, a large range of specific measures can potentially come into play.

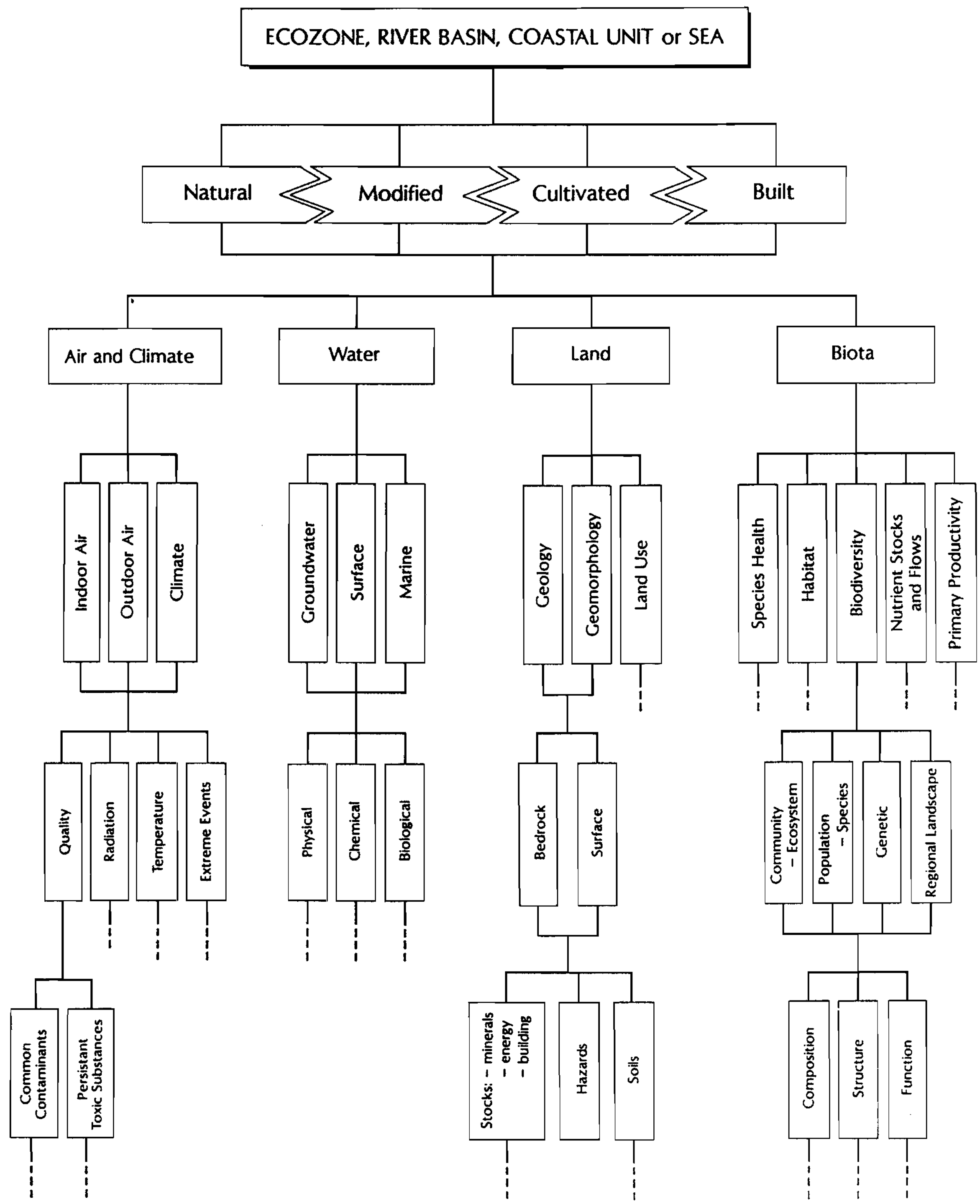


Figure 8-1. Domain I (ECOSYSTEM) assessment hierarchy

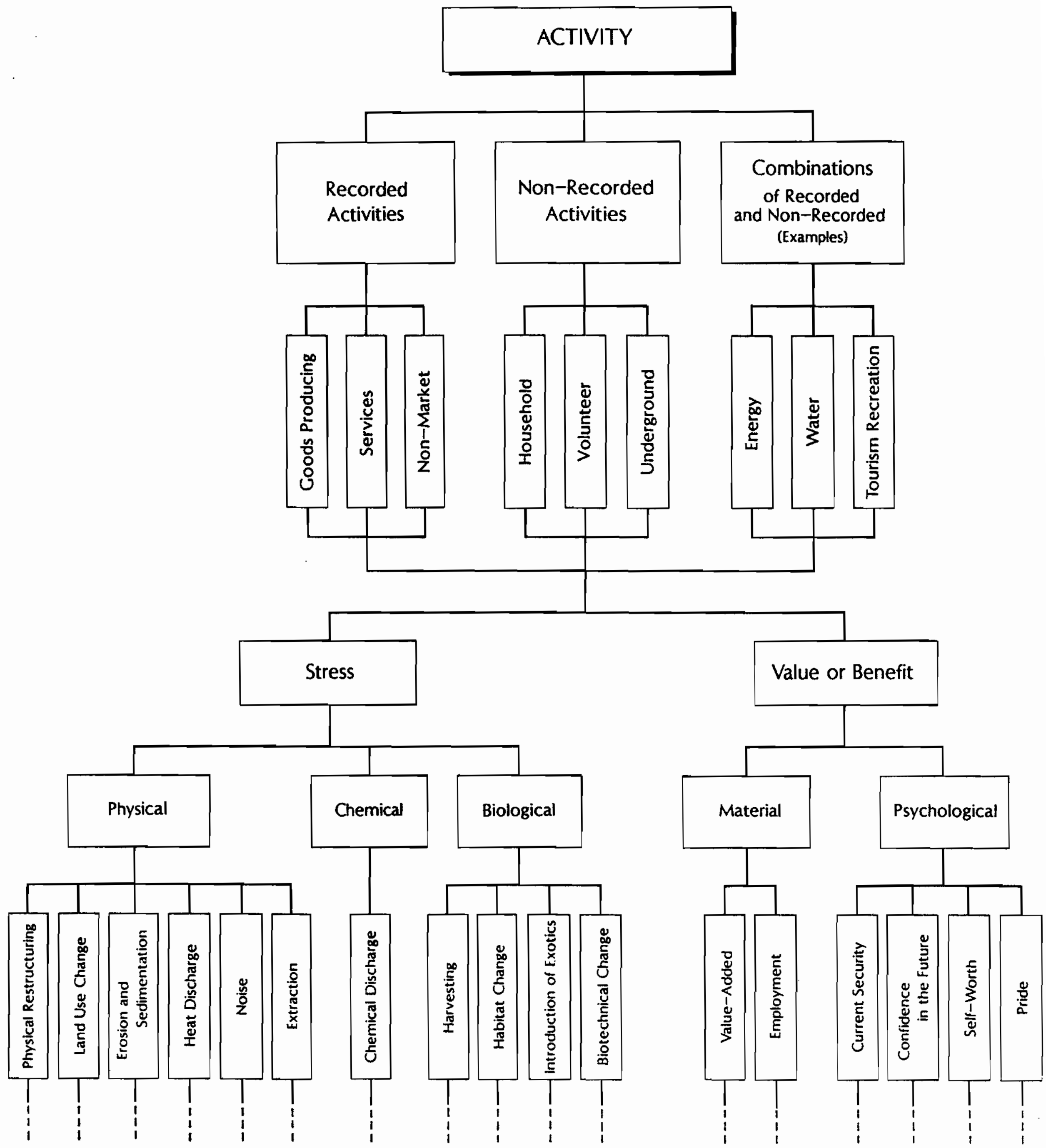


Figure 8-2. Domain II (INTERACTION) assessment hierarchy.

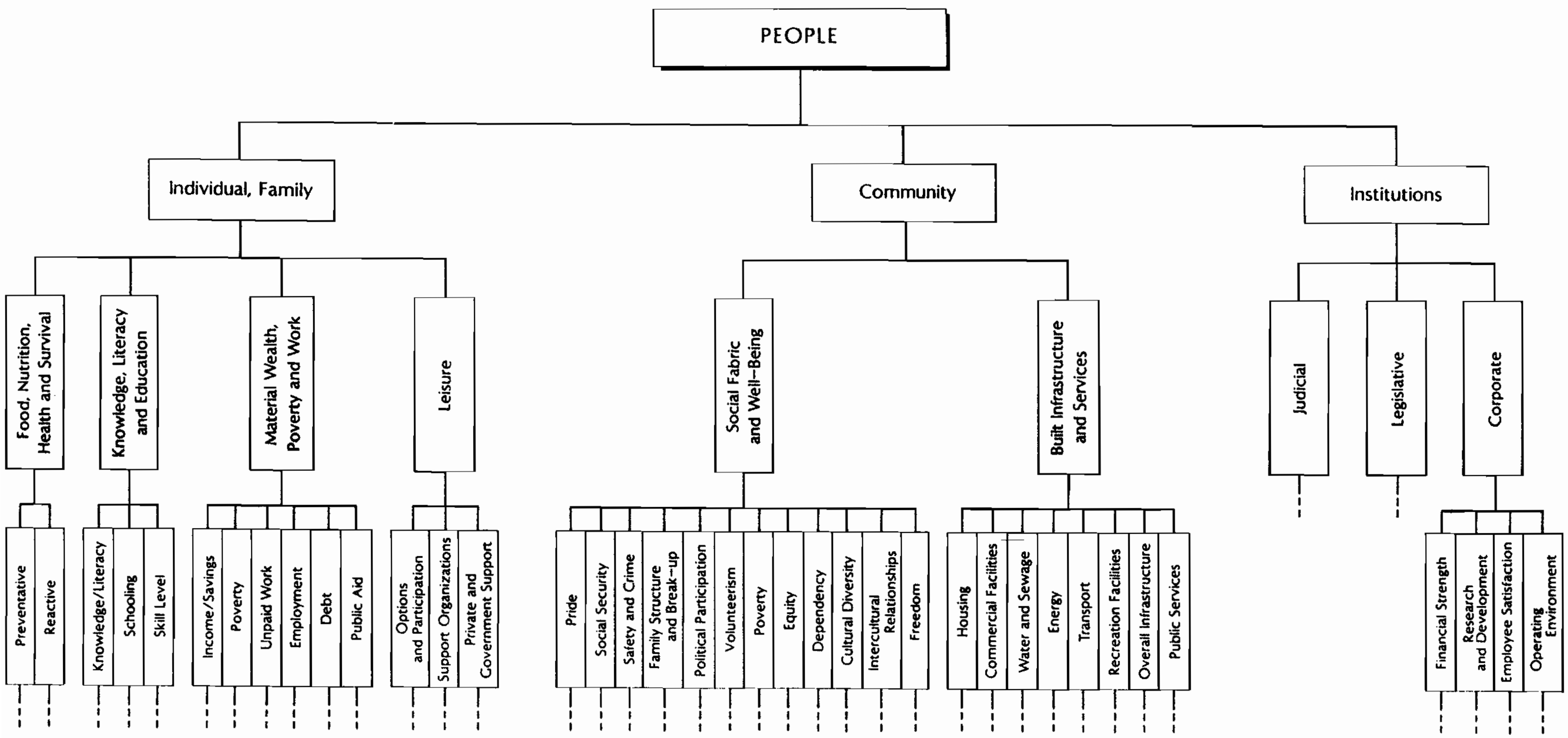


Figure 8-3. Domain III (PEIOPLE) assessment hierarchy

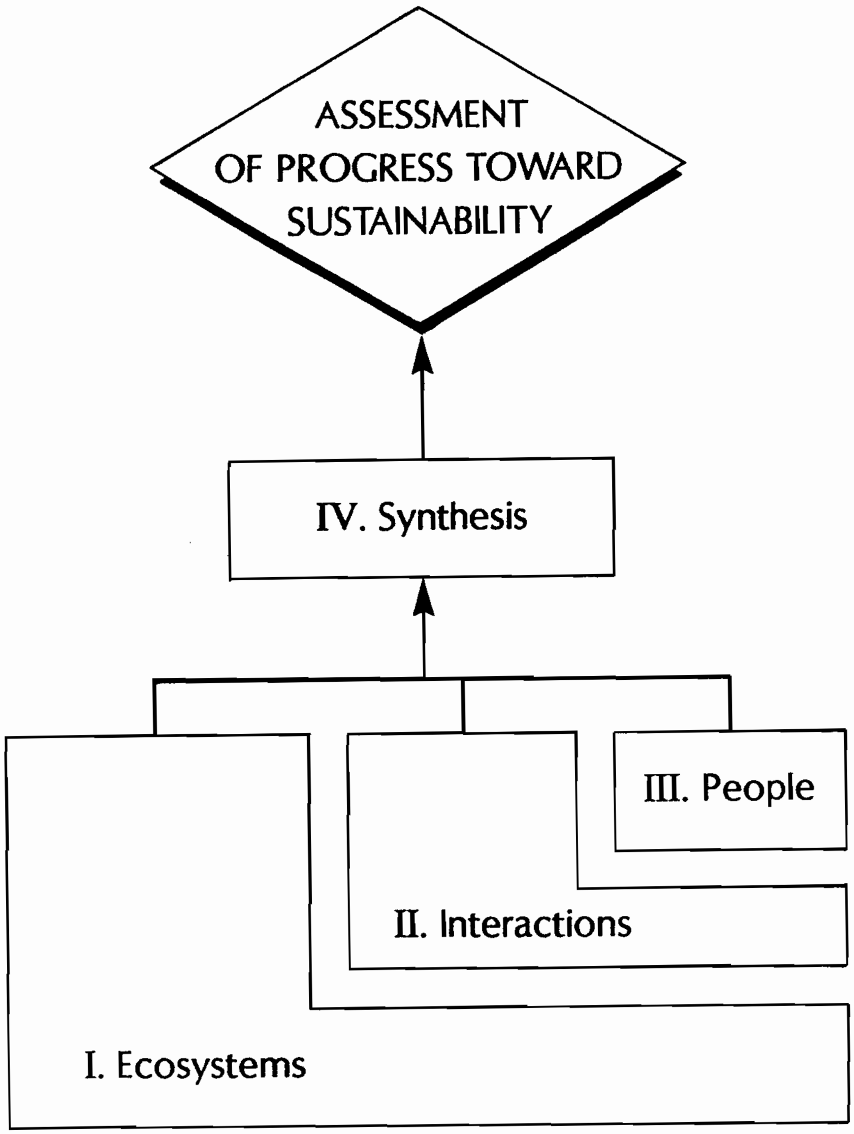


Figure 8-4. Domain IV (SYNTHESIS) assessment hierarchy IV

Working in the other direction, the concentration of a given contaminant is an indicator of water quality. In turn, water quality is one of several indicators of the overall state of the water sub-system. The state of the water sub-system is an indicator of say, the modified component of the ecosystem which itself is an indicator of the overall health and integrity of the ecozone or river basin. The assessment process builds from specific measures to the apex, drawing on the best available knowledge.

Development of the assessment hierarchies is essentially one of choosing an appropriate set of classifications to apply under each domain. Thus, the Domain I (ECOSYSTEM) assessment hierarchy (Figure 8-1) combines the use of an ecosystem classification with Prescott-Allen's four-part classification (Figure 6-1) and the more common classification of ecosystem components listed in Table 6-1

The Domain II (INTERACTION) assessment hierarchy (Figure 8-2) is built on the classification of human activity shown in Figure 6 -2 as well as the classification of stress described in Tables 2-2 and 2-3. The Domain III (PEOPLE) assessment Hierarchy (Figure 8-3) draws on a number of classifications including those addressing the determinants of human health, quality of life, state of human development, healthy communities/cities, and corporate (financial, ethical, and environmental) reporting. And lastly, the Domain IV assessment hierarchy (Figure 8-4) draws all of the previous three together.

The particular choice of classifications reflected in these assessment hierarchies is not unique. Their choice is based on the literature reviewed for this dissertation. Because of the interdisciplinary nature of this exercise, experts on a given topic might well suggest modifications to these assessment hierarchies as they are portrayed here.

The assessment hierarchies do not attempt to map the lateral relationships that might exist between cells. They map the assessment process, not the system, providing a technique to visualize what indicators are or are not contributing to any given assessment within the hierarchy.

8.3 DIRECT AND INDIRECT INDICATORS

In a number of cases, a given indicator can contribute to more than one line of assessment. It can also appear in more than one assessment hierarchy because the same indicator has relevance to more than one system component or characteristic.

When this situation occurs within a single assessment hierarchy, the process is mapped either by repetition or by crossing connector lines. The latter, however, can become complicated.

When the indicator appears in more than one assessment hierarchy it is usually a ***direct*** indicator in one and an ***indirect*** indicator in the other(s). An example is employment, an important indicator of human activity (Domain II) as well as human well-being (Domain III). In fact, employment is a ***direct*** measure of human activity (how many people are doing what) and only an ***indirect*** measure of well-being (the result of the job, not the activity itself). Indirect indicators always depend on an underlying assumption about its relationship to topic of interest. In this case it is assumed that being employed is so important to human well-being that employment figures can be used to indicate human well-being.

The difference between direct and indirect indicators is particularly important when addressing the interaction between people and the ecosystem (Domain II). Here, every ***direct*** indicator of human activity is also potentially an ***indirect*** indicator of stress imposed on the ecosystem. This characteristic is shown below in Figure 14 which provides a more detailed picture of Domain II than has been previously presented.

The complex inter-relationships that exist between the value or benefit produced by a given human activity and the stress imposed on the environment are not the subject of this dissertation. Exploration of these relationships is ongoing and the task of many different workers from a variety of disciplines.

The very presence of people, measured in terms of population density, is sometimes used as an indicator of stress on the ecosystem. In reality, population density is a direct indicator of human living/working conditions and only an indirect indicator of stress imposed on the ecosystem.

An example from the fishing industry serves to further illustrate this point. In simple terms, the "value-added" of the fishing industry in a given year is a function of the size of the catch, the going price of fish, and the costs of fishing (which in turn depend on many other prices). Figures for value-added (value of catch minus costs) are part of society's way of monitoring activity level. However, the size of the catch (the harvest) is, more importantly, a direct indicator of the stress imposed on the fish stock.

Because the value-added of fishing depends on the size of the fish catch, it is also an indicator of stress on the fish stocks. However, it is an ***indirect*** indicator of stress because the current price of fish and the costs of doing business are also part of its calculation. The value-added could go up as a result of an increase in fish

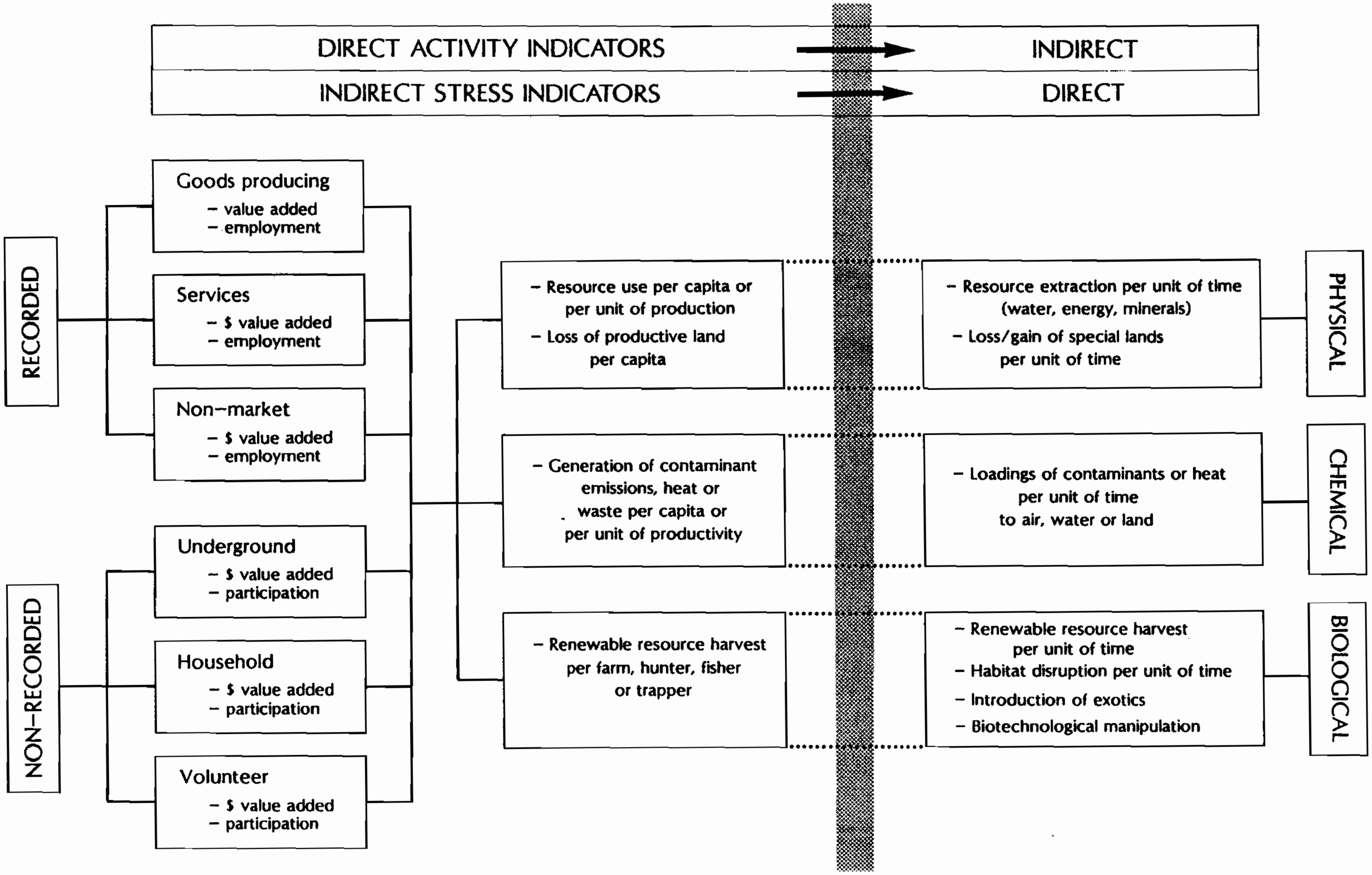


Figure 8-5. Direct and indirect indicators, Domain II.

price, a decrease in costs, an increase in catch or some combination that may or may not be related to catch size.

Much care must be taken to recognize underlying assumptions in using indirect indicators. As an example, growth in energy consumption was enthusiastically supported for the first three-quarters of this century. During this period, energy use was often singled out as an (indirect) indicator of growth in economic activity. This use was appropriate as long as a proportional relationship between the two variables existed. In the 1970s, the various energy crises and the heightened sensitivity to the costs (financial and environmental) of energy production led to an uncoupling of this relationship. Increased energy use is no longer linked to economic growth. In fact, significant effort is now being directed to the reduction of energy use. Energy content of economic activity (joules or barrels of oil equivalent per unit of GDP) is now monitored as an (indirect) indicator of energy use efficiency (for example, see Indicators Task Force 1991, 87; UNEP 1992, 380). This particular example is further discussed in Chapter Eleven.

8.4 INDICES

"Compound indicators" or "indices" depend on more than one variable. There are thousands of such indices associated with almost every aspect of numerically monitored human endeavor in specialized use. The aggregation process of developing any index must weight contributing components. This weighting entrenches a particular relationship between variables — it sets the significance of each. If this assumed relationship is correct, such indices can be powerful. If the relationship changes, is not valid in the first place, or important variables are missing, indices can be misleading.

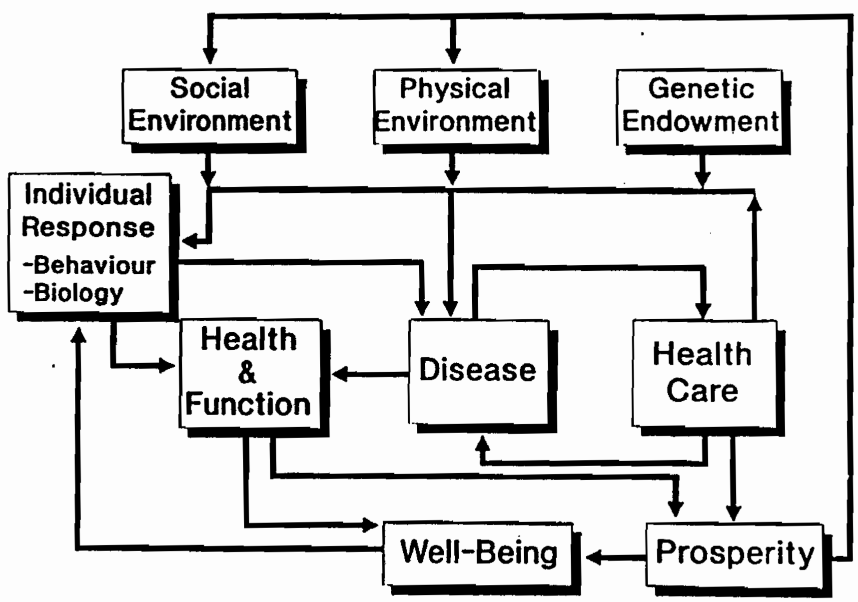
A particular problem arises when an index developed for one purpose becomes popularized and misused. The prime example of this situation applies to gross domestic product as already discussed. In using any index, care must be taken to ensure that underlying assumptions are valid and the components of an index respond to the question being posed (see discussions in Ott 1978 and K. Smith et al. 1993, 161 - 162).

8.5 ASSESSMENT HIERARCHIES, SYSTEM MODELS, AND APPLICATION

Assessment hierarchies map the assessment process showing what indicators contribute to what part of the assessment. Because the approach is simple and linear, it masks many complex relationships found in the real world. Assessment hierarchies should not, therefore, be thought of as system models.

Three examples serve to illustrate this point. One deals with human well-being (Domain III), a second examines indicators of biodiversity (Domain I), and the last, stems from an analysis of urban transportation energy use and related emissions (Domain II).

Evans and Stoddart's conceptual framework of the determinants of human health elegantly shows how human well-being is not really a characteristic that sits at the end of a (linear) string of factors but rather is best thought of as one component of an interconnected system (Figure 8-6). While human well-being is influenced by a number of factors including social environment, physical environment, genetic endowment, disease, health, health care, and prosperity, it is in turn a major influence on an individual's behavioural and biological response which in turn feeds back into disease and health which each influence prosperity.



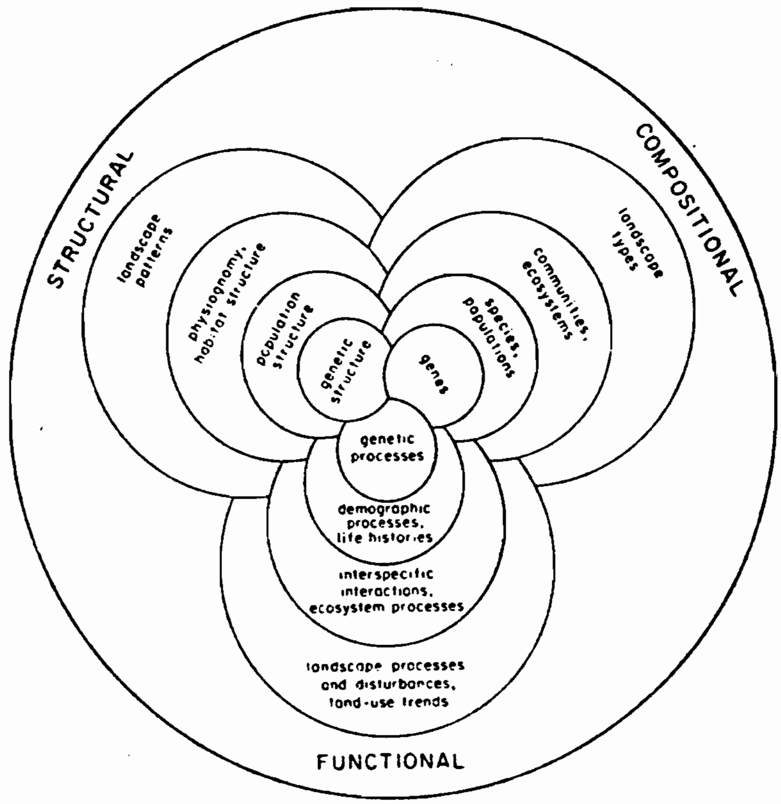
Source: Evans and Stoddart 1990, 51.

Figure 8-6. Model of the determinants of health.

Reed Noss provides a second example dealing with biodiversity. He argues that assessment of biodiversity must include attention not only to compositional diversity but also to structural and functional diversity. He develops a conceptual framework in the form of the "nested hierarchy" of three interconnected spheres shown in Figure 8-7.

Noss argues that:

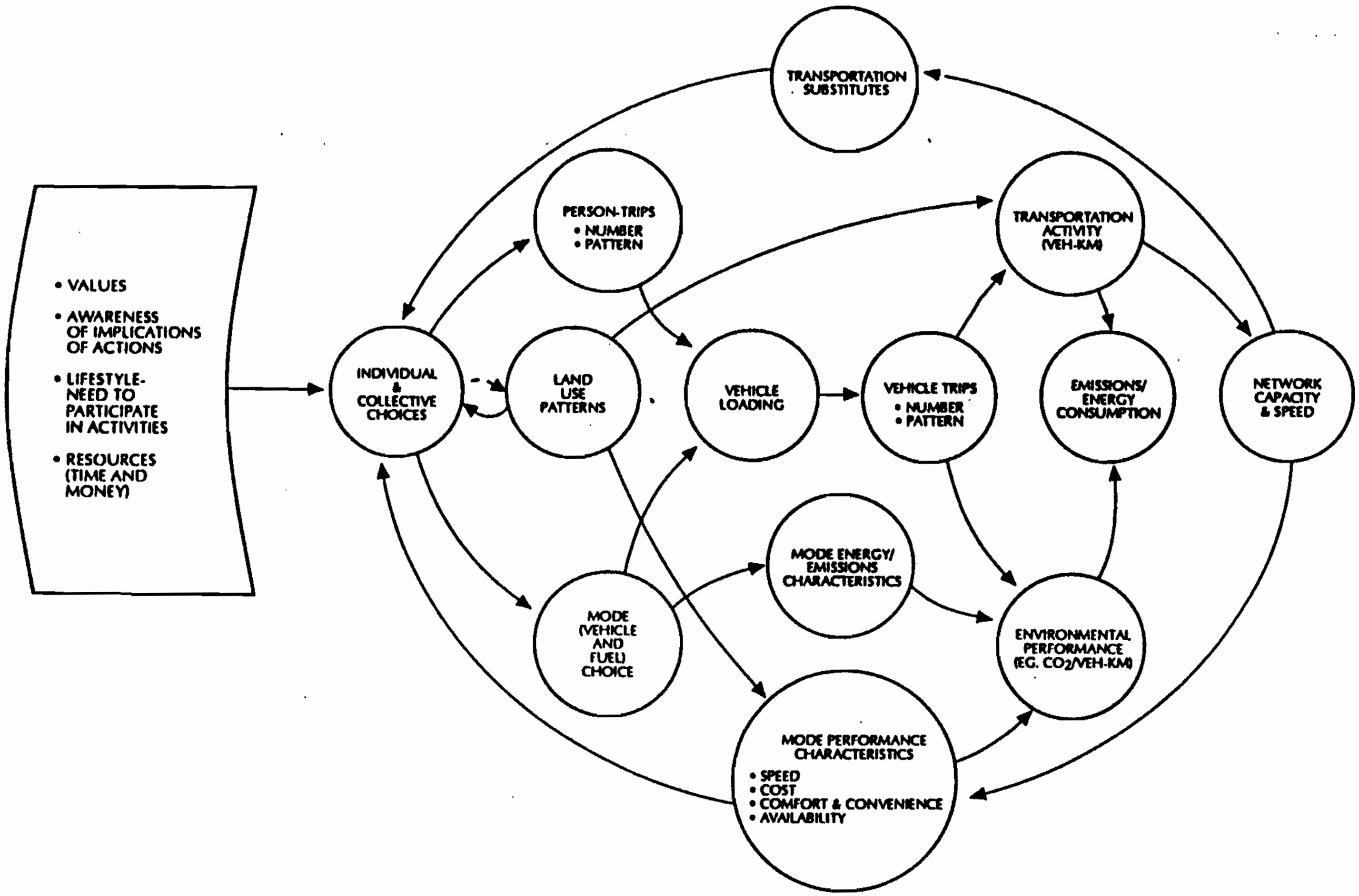
> The hierarchy concept suggests that biodiversity be monitored at multiple levels of organization, and at multiple spatial and temporal scales. No single level of organization (e.g. gene, population, community) is fundamental, and different levels of resolution are appropriate for different questions. Big questions require answers from several scales. If we are interested in the effects of climate change on biodiversity, for instance, we may want to consider (1) the climatic factors controlling major vegetation ecotones and patterns of species richness across continents; (2) the availability of suitable habitats and landscape linkages for species migration; (3) the climatic controls on regional and local disturbance regimes; (4) the physiological tolerances, autecological requirements, and dispersal capacities of individual species; and (5) the genetically controlled variation within and between populations of species in response to climatic variables. "Big picture" research on global phenomena is complemented by intensive studies of the life histories of organisms in local environments.
>
> (1990, 357)



Source: Noss 1990, 357.

Figure 8-7. Noss' three-dimensional hierarchical model for selecting indicators of biodiversity.

The third example is drawn from an examination of current and potential measures to reduce energy consumption and related emissions in Canadian urban transportation (Irwin and Schibuola 1993). In order to identify the dominant factors influencing a city's transportation energy consumption and emissions characteristics, they develop a conceptual model which has at its core individual and collective decision-making regarding transportation and land use. Their model is presented in Figure 8-8.



Source: Irwin and Schibuola, 1993, Exhibit 7.

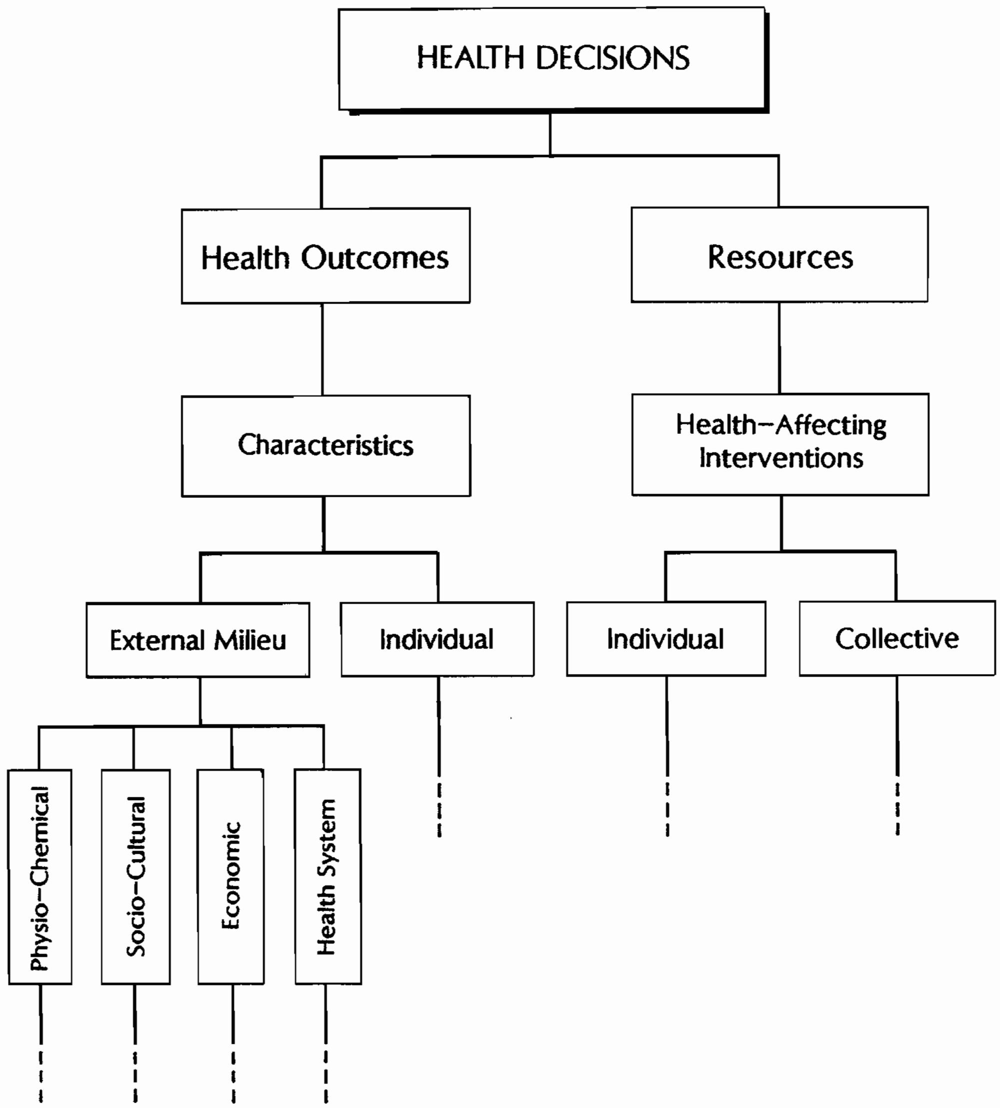
Figure 8-8. Urban transportation, energy, and emissions: a model with feedback and interactions

In each of the above three examples, feedback loops that add a degree of complexity beyond that of a simple linear model exist. This kind of feedback is not recognized in the kind of simple, linear assessment hierarchies shown in Figures 8-1 through 8-4.

In spite of the limitations discussed above, there is an important practical reason motivating a simple hierarchical approach: the models shown in Figures 14 - 16, while conceptually appealing, are difficult to apply in their current form. In moving beyond the conceptual to practical application, workers in each of the three examples develop simplified linear approaches.

Application of Evans and Stoddart's model is discussed by Wolfson (1990) and reflected in the System of Health Statistics proposed by the National Task Force on Health Information (see Appendix VI, Pt. 3, this dissertation; NTFHI 1991, 29). They develop a template for health information that is shown as a simple hierarchy in Figure 8-9 below.

Similarly, in using his concept of biodiversity for practical application, Noss develops the matrix of indicators shown below in Table 8-1. Figure 8-10 shows the same matrix as a simple hierarchy.



Sources: NTFHI 1991, 29 Evans and Stoddard 1990, 51; (see also, APPENDIX VI, Pt. 3, this dissertation)

Figure 8-9. The proposed System of Health Statistics portrayed as an assessment hierarchy.

TABLE 8-1. NOSS' MATRIX OF BIODIVERSITY INDICATORS.

	Indicators			
	Composition	*Structure*	*Function*	*Inventory and monitoring tools*
Regional Landscape	Identity, distribution, richness, and proportions of patch (habitat) types and multipatch landscape types; collective patterns of species distributions (richness, endemism)	Heterogeneity; connectivity; spatial linkage; patchiness; porosity; contrast; grain size; fragmentation; configuration; juxtaposition; patch size frequency distribution; perimeter-area ratio; pattern of habitat layer distribution	Disturbance processes (areal extent, frequency or return interval, rotation period, predictability, intensity, severity, seasonality); nutrient cycling rates; energy flow rates; patch persistence and turnover rates; rates of erosion and geomorphic and hydrologic processes; human land-use trends	Aerial photographs (satellite and conventional aircraft) and other remote sensing data; Geographic Information System (GIS) technology; time series analysis; spatial statistics. mathematical indices (of pattern, heterogeneity. connectivity, layering, diversity, edge, morphology, autocorrelation, fractal dimension)
Community-Ecosystem	Identity, relative abundance, frequency, richness, evenness, and diversity of species and guilds; proportions of endemic, exotic, threatened, and endangered species; dominance-diversity curves; life-form proportions; similarity coefficients; C4:C3 plant species ratios	Substrate and soil variables; slope and aspect; vegetation biomass and physiognomy; foliage density and layering; horizontal patchiness; canopy openness and gap proportions; abundance, density, and distribution of key physical features (e.g., cliffs, outcrops, sinks) and structural elements (snags, down logs); water and resource (e.g., mast) availability; snow cover	Biomass and resource productivity; herbivory, parasitism, and predation rates; colonization and local extinction rates; patch dynamics (fine-scale disturbance processes), nutrient cycling rates; human intrusion rates and intensities	Aerial photographs and other remote sensing data; ground-level photo stations; time series analysis; physical habitat measures and resource inventories; habitat suitability indices (HSI, multispecies); observations, censuses and inventories, captures, and other sampling methodologies; mathematical indices (e.g., of diversity, heterogeneity, layering dispersion, biotic integrity)
Population-Species	Absolute or relative abundance; frequency; importance or cover value; biomass; density	Dispersion (microdistribution); range (macrodistribution); population structure (sex ratio, age ratio); habitat variables (see community-ecosystem structure, above); within-individual morphological variability	Demographic processes (fertility, recruitment rate, survivorship, mortality); metapopulation dynamics; population genetics (see below); population fluctuations; physiology; life history; phenology; growth rate (of individuals); acclimation; adaptation	Censuses (observations, counts, captures, signs, radio-tracking); remote sensing; habitat suitability index (HSI); species-habitat modeling; population viability analysis
Genetic	Allelic diversity; presence of particular rare alleles, deleterious recessives, or karyotypic variants	Census and effective population size; heterozygosity; chromosomal or phenotypic polymorphism; generation overlap; heritability	Inbreeding depression; outbreeding rate; rate of genetic drift; gene flow; mutation rate; selection intensity	Electrophoresis; karyotypic analysis; DNA sequencing; offspring-parent regression; sib analysis; morphological analysis

Source: Noss 1990, 358.

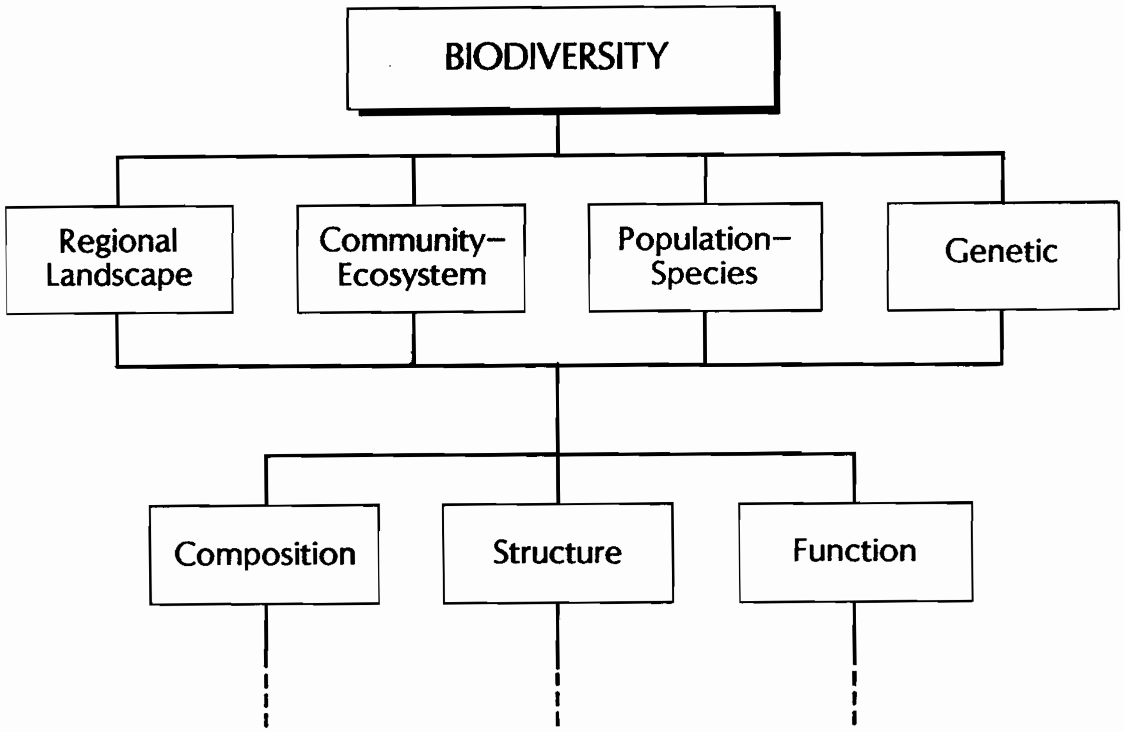
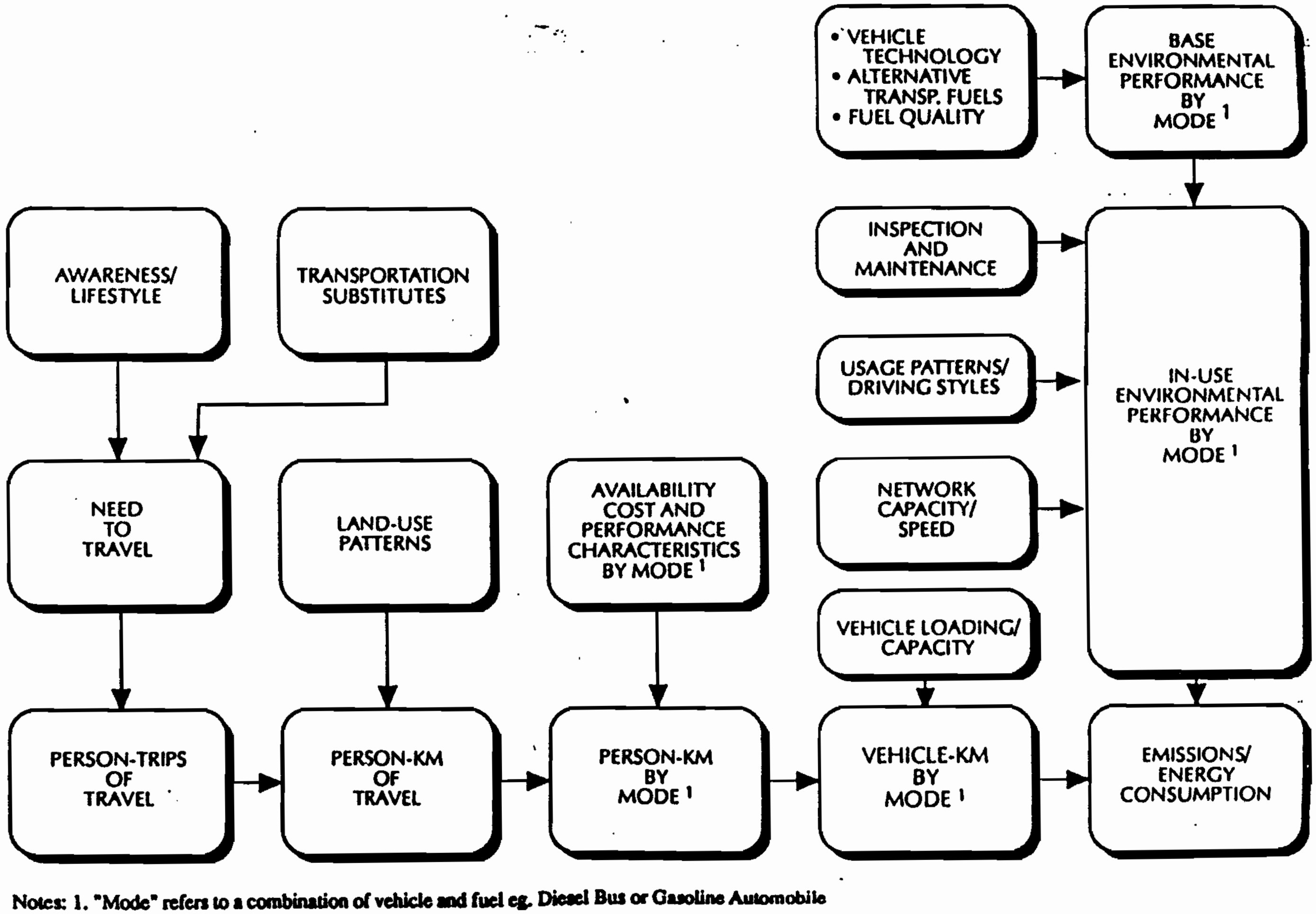


Figure 8-10. Noss' matrix of biodiversity indicators in the form of a simple hierarchy.

In the third example, Irwin and Schibuola themselves point out that:

> The model ... is a useful thought-model for exploring different initiatives and the factors which they directly and indirectly affect, and for identifying which initiatives and policy levers might be most effective in reducing transportation energy use and emissions. However, it is difficult to operationalize into a simple working model.
>
> (1993, 10 - 11)

Instead, they develop a simple linear model without feedback loops to guide practical application. Their "second generation" model is shown in Figure 8-11 in original form and in Figure 8-12 as a simple hierarchy.



Source: Irwin and Schibuola 1993, Exhibit 8.

Figure 8-11. Irwin and Schibuola's linear model of urban transportation, energy, and emissions.

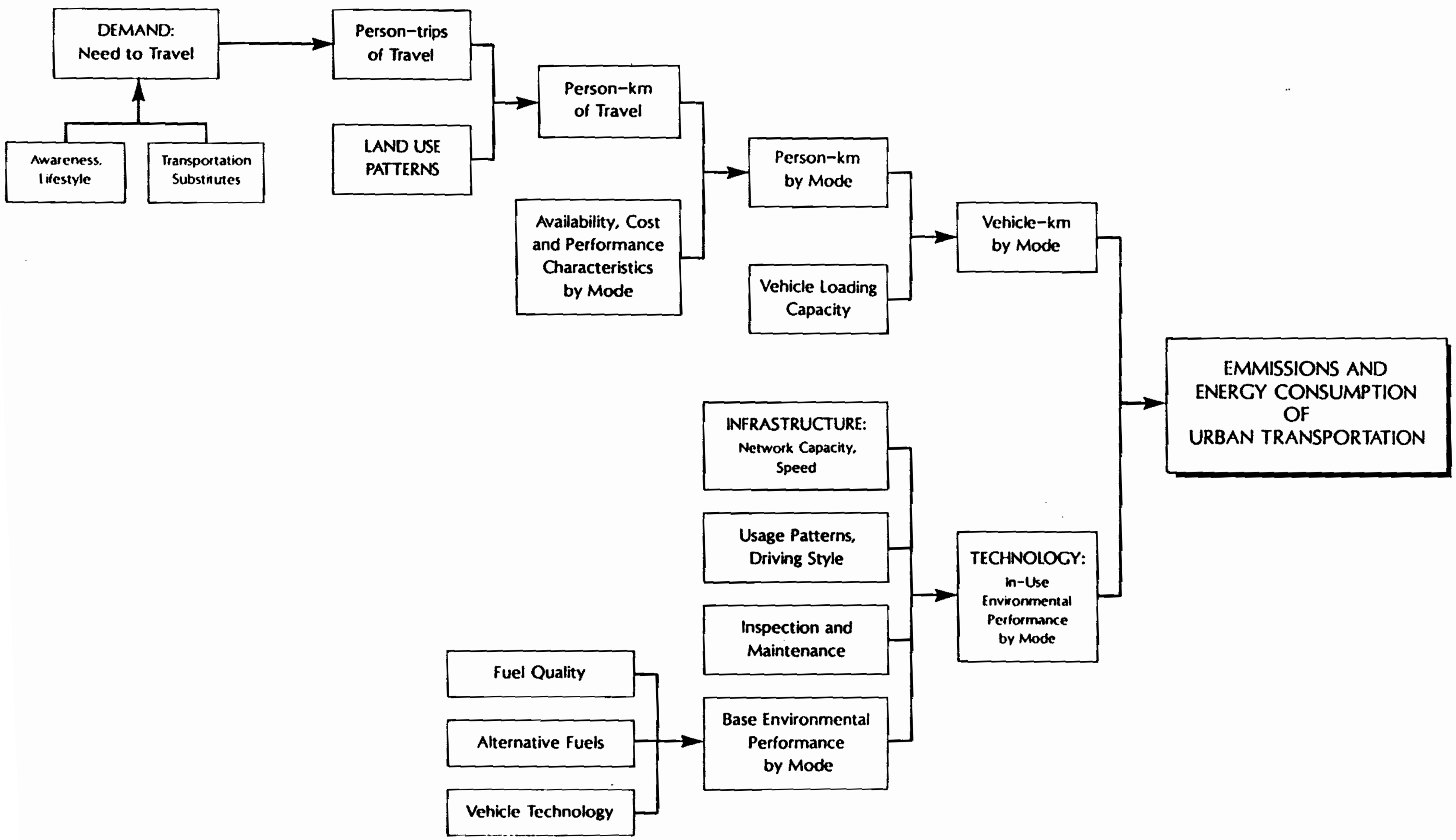


Figure 8-12. Simple hierarchical form of Irwin and Schibuola's linear model

In application then, a simple linear indicator hierarchy can play an important role. However, it should never be thought of as the overall conceptual framework of the system in question but rather as a useful and practical simplification. Describing the conceptual framework in its own right, independently of indicator identification, while clearly identifying the link to underlying values remains the essential first task. As demonstrated in the above three examples, development of the assessment hierarchy is a ***second*** step.

8.6 EXAMPLES OF INDICATORS OF SUSTAINABILITY ORGANIZED BY DECISION-MAKING GROUP

Tables 6-5 to 6-8 provide a reporting framework organized on the basis of the four domains for each of the four decision-making groups considered in this dissertation. In this Chapter, Figures 8-1 to 8-4 provide a map of the indicators that that contribute to the assessment within each of the four domains. It is now possible to combine these elements and list examples of specific indicators, by decision-making group and organized on the basis of the proposed reporting framework. Appendix VIII takes this step.

APPENDIX VIII must be considered an initial step in a longer term process. Further development, testing, and modification must be driven by a range of expertise applied within the context of the needs and wants of actual decision-makers. The need for this decision-maker driven process emerges as one of the central recommendations for subsequent research.

8.7 DEVELOPING A SHORT LIST OF INDICATORS OF SUSTAINABILITY

Much of the recent interest in indicators has been motivated by a desire to identify a small group of key indicators of sustainability that provide a mechanism for effectively monitoring and communicating progress. This interest is subject to a long-standing debate between government policy-makers on the one hand and scientists on the other. The former, faced with a responsibility to account for government activity, argue that simple indicators, few in number, are required to monitor and communicate progress on public policy issues. The latter, understanding the complexity of the systems being monitored are resistant to building simple indicators on assumed causal relationships that are weak at best. Furthermore, the process of peer review which is engrained in every scientist, demands a transparency in data measurement and interpretation that is often side-stepped by "nutshell" information sought by policy makers (Bartelmus 1993, 5).

The issue is complicated by the fact that the ecosystem and the human sub-system are dynamic. And what is considered a critical concern today in terms of sustainability will inevitably be overtaken by other concerns tomorrow. This is the nature of our evolving society.

Common sense must prevail in this matter also, — there is no universal answer. Certain key issues may appropriately dominate public policy in any given political jurisdiction and at any given point in time. It may be entirely possible to capture the essence of progress related to these issues with a few simple measures (a form of indicators) that aid both the monitoring and communicating processes. Such measures fall at or near the bottom of the assessment hierarchies shown in Figures 8-1 through 8-4. This is exactly the approach taken by Canada's Indicators Task Force (1991) and the Dutch work so well illustrated by Adriaanse (1993).

However, choice of these kinds of indicators is inevitably tied to the identification of current issues of concern. As such, an anticipatory assessment that might point to critical issues not currently of high priority is precluded. Thirty years ago, the choice of such indicators would not have included toxic contaminants in the environment or the depletion of stratospheric ozone which are two of todays dominant concerns.

An alternative approach is to draw a short list of indicators from the top or near the top of Assessment Hierarchies I, II, and III (Figures 10 through 12). For example, assessments of (1) ecosystem health, (2) support for humans well-being provided by human activities; (3) stress imposed by human activity on the ecosystem, (4) the contribution of human activities to ecosystem restoration, and, (5) human well-being each become indicators of progress toward sustainability. This approach is demonstrated in Chapter Ten as part of the Great Lakes Case Study.

It may be possible to develop indices that formally aggregate data and information for some of these five indicators. For example, the degree of success of human activities in contributing to human well-being may be very effectively monitored by a modified form of the gross national/domestic product. However, not all of these indicators are amenable to such a treatment. Instead, dependency must be placed on "weight-of-evidence" judgements.

On its own, the identification, development, and subsequent dependency on a short list of indicators of sustainability drawn from the base of the assessment hierarchies could serve to inhibit anticipatory thinking. Again, the importance of the conceptual framework emerges. It is motivated by an overall sense of the system, not by what happens to be a concern according to today's values. It provides a testing mechanism for today's issues and facilitates the kind of anticipatory perspective that is needed. While tomorrow's values cannot be predicted, long-term implications of today's activities can be based on current knowledge.

Thus, to supplement the monitoring of current issues of concern, a periodic comprehensive review of the complete system that includes an overall assessment of progress and a concise articulation of the rationale for any judgements made is required. In completing such a review the best science must be brought to bear as must professional judgement and the real-world experience of policy-makers. Indicators, short list or long, are simply a tool in that process and not an end-point in themselves.

CHAPTER NINE

GREAT LAKES CASE STUDY: PURPOSE, BOUNDARIES, AND HISTORICAL CONTEXT

9.1 PURPOSE AND APPROACH

The purpose of this case study is to demonstrate a practical application of the proposed systemic approach to assessing progress toward sustainability. The conceptual framework developed in the previous chapters is used as a template for organizing data and information drawn from existing literature. Organized in this way, the result is an assessment of progress that (1) is systemic in nature; (2) facilitates anticipatory thinking; (3) reflects the value set underlying the idea of sustainability; (4) is more rigorous and complete than is the case if indicators were chosen on an ad-hoc basis; (5) helps to identify gaps in the existing data and information base. In making judgements about whether or not progress has occurred, conflicting evidence is weighed and conclusions drawn on the basis of the accumulated weight-of-evidence. These judgements are therefore subjective in nature although supported by a broad base of scientific data and information.

In development of the system, four decision-making groups are identified: 1) individuals and households; (2) communities; (3) corporations and corporate groupings; and (4) regional, province/state, or federal governments. Testing the system for each decision-making group is outside the scope of this dissertation. In this case study, a regional perspective is assumed with a primary focus on the Great Lakes Basin Ecosystem. This perspective supports regional decision-making. The case study does not attempt to deal with the other decision-making groups.

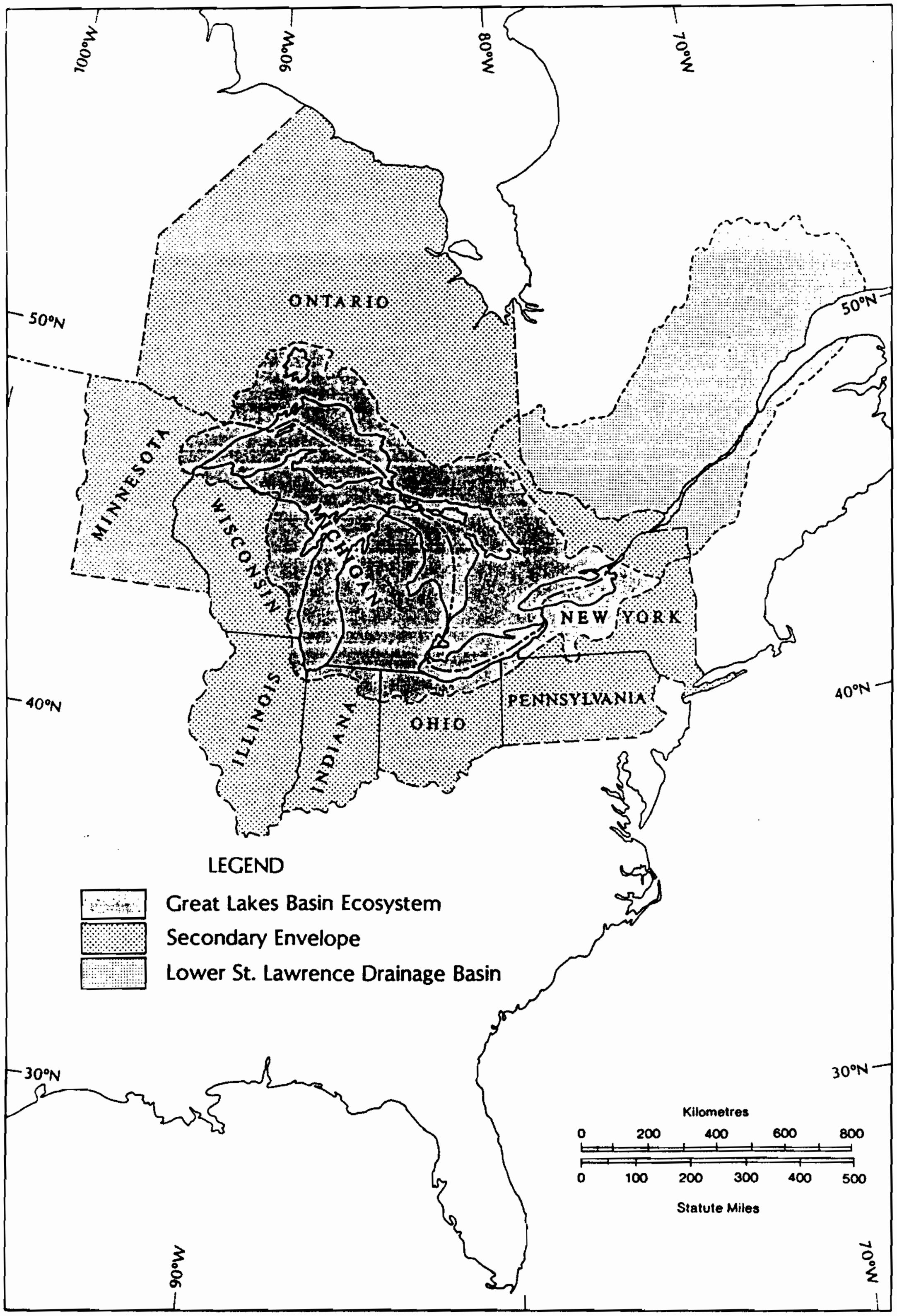


Figure 9-1. The Great Lakes Basin Ecosystem and the state/province decision-making envelope.

9.2 BOUNDARIES

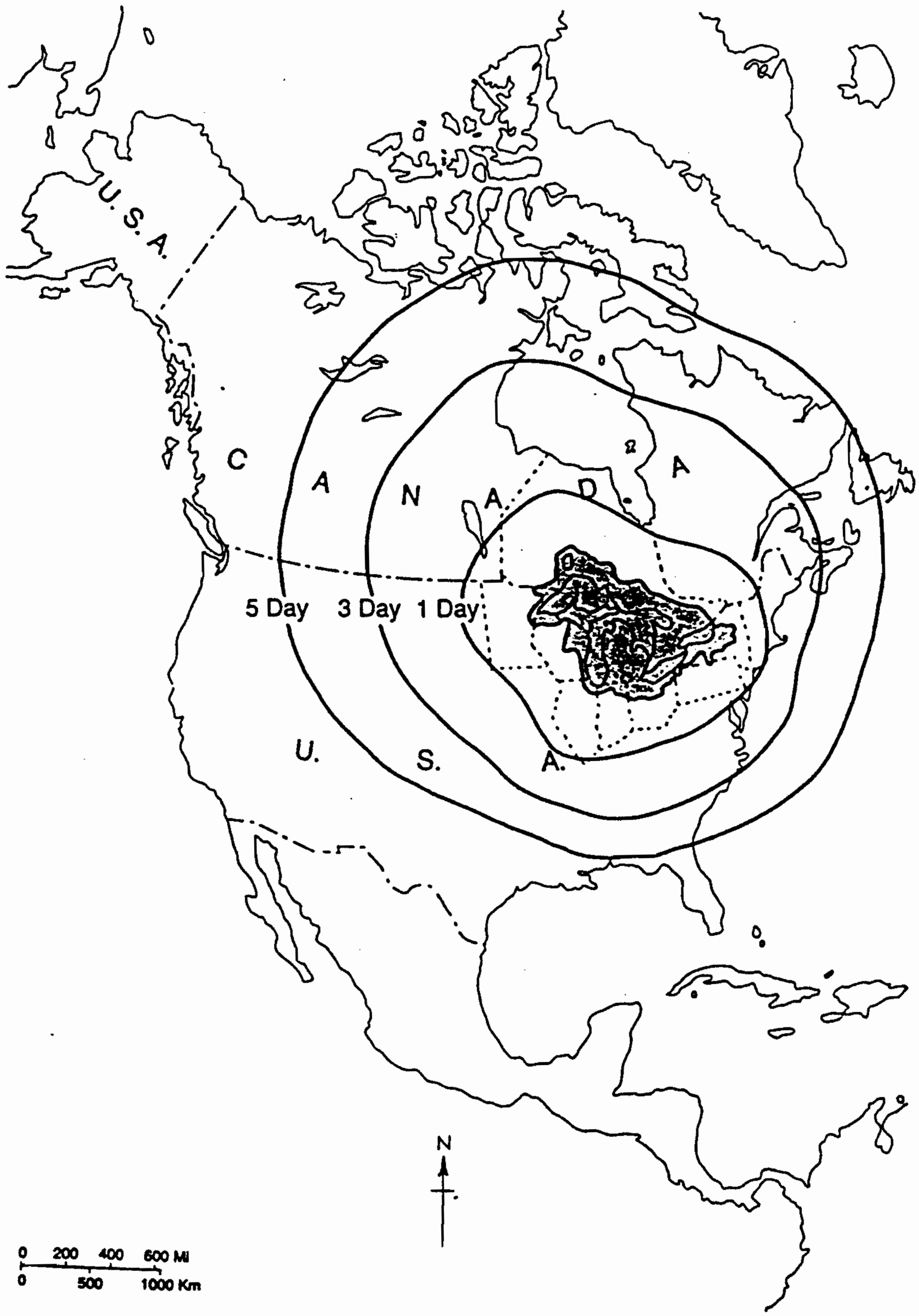
The Great Lakes Basin Ecosystem serves as a primary focus for this assessment of sustainability. It is defined in the 1978 Great Lakes Water Quality Agreement as:

> ...the interacting components of the air, land, water and living organisms, including *humans*, within the drainage basin of the St. Lawrence River at or upstream from the point at which this river becomes the international boundary between Canada and the United States.
>
> (IJC 1988, 4)

It is an area shared by eight Great Lakes states (Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania, and Wisconsin) as well as the Province of Ontario. In the 1980s the sense of community within the Great Lakes Basin Ecosystem was strengthened with the surge in the volume and nature of cooperative ventures directly between and among the states and provinces. Notable institutions for collective action include The Great Lakes Commission, The Council of Great Lakes Governors (which includes Ontario as an observer), The Great Lakes - St. Lawrence Conference of Mayors, the Council of Great Lakes Counties, and The Council of Great Lakes Industries (McNulty 1991, 132). These mechanisms are in addition to the variety of transboundary boards, task forces and committees of the International Joint Commission, the International Association of Great Lakes Research, and Great Lakes United, the coalition of over two-hundred environmental, sportsmen, union, governmental, and small business organizations throughout the basin.

Because the eight U. S. states and Ontario make decisions within the context of their entire jurisdictions, there is a second, broader boundary that must be considered in this assessment. It encompasses the eight states and Ontario. Figure 9-1 shows the Great Lakes Basin Ecosystem with a primary boundary defined by the surface water drainage system this secondary boundary defined by the state/province decision-making envelope. Also shown is the Lower St. Lawrence drainage basin which would be included along with Quebec, Vermont, New Hampshire, and Maine if the entire St. Lawrence drainage were to be considered.

These boundaries, while providing a needed context for undertaking an assessment, are porous. The bounded areas are profoundly linked with the "outside world." Transboundary movement of water, air, energy, fish, wildlife, people, and their products including waste, is constant.



Source: Summers and Young, 1987.

Figure 9-2. One, three, and five day atmospheric regions of influence for the Great Lakes. Lines indicate the median starting point of air trajectories one, three, and five days prior to arrival at the lakes. For example, the 3-day line indicates that half of the time the air in the basin would have originated 3 days earlier within that line and half the time beyond it.

A graphic illustration of the importance of this interconnectedness is illustrated in Figure 9-2. It shows the "atmospheric regions of influence (AROI)" felt by the Great Lakes Basin Ecosystem. These regions illustrate how far distant sources of air emissions can influence Great Lakes Basin Ecosystem conditions through long range transport of airborne pollutants (LRTAP). Figure 9-2 is derived from a 10-year data base of air movement measured at 6 hour intervals (Summers, P., 1990, personal communication).

The potential impact of a given pollutant source depends on it's location within the AROI and the resident time or "life" in the atmosphere of the emitted contaminant. For example, PCBs have an initial particulate life of 5 to 10 days (they can deposit in water and then revolatize to continue their global journey) while nitric acid and sulphur dioxide have a life of about one day (Summers, P., 1990, personal communication).

9.3 HISTORICAL CONTEXT

A brief overview is sketched below of change in the Great Lakes Basin Ecosystem through the last two centuries. No attempt is made to be comprehensive. In itself, such a review would fill volumes. Rather, a number of key changes are highlighted that provide a context for the assessment of progress toward sustainability contained in the following chapters. It is an interpretation of events and is therefore a form of the story of the Great Lakes.

Thomas Kaplan suggests that a number of workers, faced with the limitations of the generalizing power of empiricism have turned to the study of "softer" forms of interpretation often practiced in the study of literature or legal precedent (1993, 169). The technical term for their approach is ***hermeneutics***, a Greek word meaning "interpretation." Their work is aimed at establishing methodological principles of interpretation. Formal organization of hermeneutics dates from the middle of the last century, but in the last decade there has been renewed effort to place hermeneutics in a modern context dealing both with different interpretive arguments and provides guidance for choosing the best arguments in a given situation (Kaplan 1993, 170).

The power of applying hermeneutics in this situation lies in the ability of the narrative to reveal a number of overall trends important to the sustainability question. This approach draws from the practical maxim developed by Richard Neustadt and Ernest May in their analysis of the use of history in policy analysis: "don't ask 'What's the problem?' ask, 'What's the story?' — that way you'll find out what the problem really is" (1986, 274, 106).

Frank Fischer and John Forester (ed.) examine the role of narration in policy analysis and planning (1993). Narration as a formal aspect of the methodology of reporting on sustainability has not been examined to date. It is a priority topic for follow-up research.

Early Post Settlement Changes

In the almost four centuries since Etienne Brulé, a scout for Samuel de Champlain, reached Georgian Bay an explosion of human activity has vastly altered the region. From the beginning it was the ease of exploitation of the region's abundant natural resources that provided motivation for development.

Through the 1800s, vast regions of forest in the Great Lakes region were stripped to clear land for agriculture. This deforestation along with subsequent activities, provided the first massive set of imposed stresses on the Great Lakes Basin Ecosystem. Simultaneously, the first major assault on the region's aquatic ecosystem occurred:

> To power the grist mills that were needed to grind wheat and other grains, the settlers constructed dams along the thousands of streams and rivers flowing into the Great Lakes. The dams in turn changed the character of the water flowing to the Lakes. Direct sunlight on the impounded water increased its temperature, and the dams blocked the migration of river-spawning fish.
>
> (Weller 1990, 41)

In time, wood products were sought for markets not only in the U.S. and Canada, but also in Europe. Creeks and rivers were further dammed to provide energy for milling operations while spring logging drives added to the damage of river ecosystems.

The result was large-scale and irreversible ecological change. By the mid-1800s, in addition to the vast deforestation, the eastern subspecies of elk and the passenger pigeon had been slaughtered to extinction and a large number of other wildlife species were drastically reduced including the timber wolf, wolverine, fisher, marten, otter, beaver, and wild turkey (Weller 1990, 39 - 40). At the time, these changes were accepted as a matter of course.

TRANSPORTATION

The combination of an in-place water transport infrastructure with the strong natural resource base, including ready supplies of energy, promoted population settlement, agricultural development and subsequent industrial development. Today, because of its central importance to human activity in the Great Lakes region, monitoring the nature and state of the transportation system is an important aspect of assessing sustainability.[1]

No comprehensive assessment of the complex transportation system has been completed. However a number of indicators have been compiled that give cause for concern. For example, Thorp and Ballert point out that fully one-third of the bridges in the eight Great Lakes states are now considered deficient (1991). This conclusion is consistent with assessments of the Canadian roadway system that have been completed for the Council of Ministers Responsible for Transportation and Highway Safety. Surveys they have commissioned conclude:

- 33 per cent of the national highway system in Canada is below minimum geometric design standard;
- 18 per cent of the system has serviceability deficiencies (i.e. could not support a 90 km/h operating speed under normal conditions or are below the appropriate local standard); and
- 26 per cent of the system falls below the minimum standard for pavement strength and quality.

(Fields and Ruitenbeek 1992, 11)

The Roads and Transportation Association of Canada articulates similar concern arguing that "current spending levels are almost $2 billion annually under what they need to be just to maintain existing service and surface condition levels at what they were in 1978 - without allowing for further growth" (RTAC, 1990).

Energy

The evolution of the Great Lakes system of energy production and use stands shoulder to shoulder with development of the transportation system as a contributing factor to the nature and pace of change. Early settlers found a ready supply of wood for direct burning or manufacture of charcoal. With settlement, use of hydraulic power for grist mills, saw mills, and other factories quickly took hold. However, it was the harnessing of hydraulic power for electricity generation that provided the impetus for the huge leap in industrial that occurred early in the 20th century. By 1896, an alternating current hydro-electric system was in place at Niagara Falls and a transmission line to Buffalo in operation. Buffalo was the first city in the world to be illuminated by alternating current (Braider 1972; Goldman 1983). Coal, oil, gas, and nuclear sources of energy all now contribute to the energy regime in the Great Lakes Basin Ecosystem.

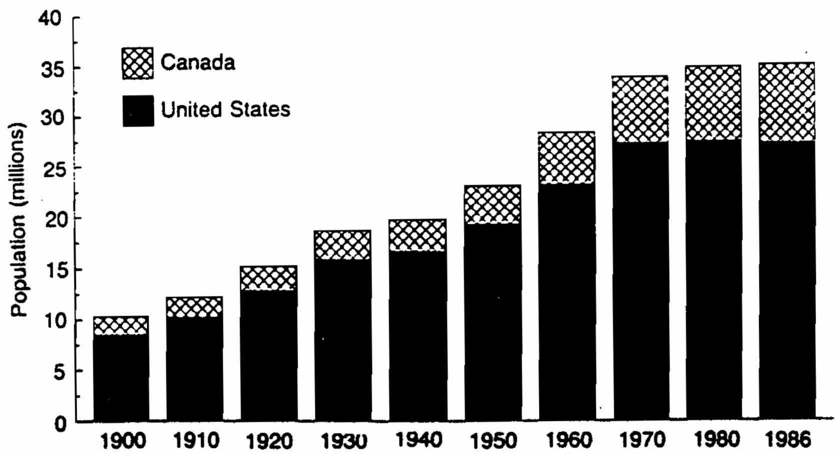
Manufacturing

The dawning of the age of hydroelectric power brought profound change. Inexpensive hydropower provided the underpinning of an iron and steel industry that drew ore from Lake Superior and coal from Pennsylvania. The chemicals industry emerged with its similar need for both energy and a transportation system to bring the needed feedstocks as well as distribute the resulting products.

This phase of economic development brought the second wave of imposed stress with resulting massive ecological change. Different than the dominantly physical stresses imposed by deforestation, land-clearing, and water-course modification of the first phase, this set of activities generated chemical stresses the full significance of which is only now emerging. Municipal and industrial waste products were discharged indiscriminately to the air, rivers, and lakes or were buried in the mistaken belief that the subsurface provided safe and stable storage.

Population and Settlement Trends

Through the past four centuries, the human population of the Great Lakes Basin proper has grown from a few hundred thousand to over 35 million. In-basin population trends for the period 1900 - 1986 are shown in Figure 9-3 and 1970/71, 1980/81 and 1990/91 figures for the eight Great Lakes states and Ontario are listed in Table 9-1.



Source: Colborn et al. 1990, 56. Copyright (C) 1990 by The Conservation Foundation and The Institute for Research on Public Policy. Reprinted with permission of the publishers.

Figure 9-3. Population in the Great Lakes Basin Ecosystem, 1900 - 1986. Estimates for the United States are on the even year of the decade (1900, 1910, etc.); Canadian estimates are for the first year of a decade (1901, 1911, etc.).

TABLE 9-1. POPULATION IN THE EIGHT GREAT LAKES STATES, ONTARIO, CANADA, AND THE UNITED STATES.

state/province	*population (thousands)*		
	1970/71	1980/81	1991
Minnesota	3,806	4,076	4,432
Wisconsin	4,418	4,706	4,956
Indiana	5,195	5,490	5,610
Ontario	7,703	8,625	10,085
Michigan	8,882	9,262	9,380
Ohio	10,657	10,798	10,941
Illinois	11,110	11,427	11,541
Pennsylvania	11,801	11,864	11,958
New York	18,241	17,558	18,055
total	81,813	83,806	86,958
Canada	21,568	24,343	27,297
United States	203,302	226,546	252,160

Sources: U. S. Bureau of the Census, Statistics Canada

In 1991, the total population of the 8 Great Lakes states plus Ontario stood at 86.9 million and included 30.5 percent of the total U. S. population and 37 percent of the population of Canada. Hart suggests that this combined state/province population may have peaked around 1990 (1991, 28). In-basin population on the U.S. side has been essentially stable since 1970 while the Canadian in-basin population continues to grow.

The basic pattern of settlements in the region has persisted for well over a century. Original settlements are now the largest, serving as the economic and political capitals of their areas:

> They were port cities —Toronto, Buffalo, Cleveland, Detroit, Chicago, and Milwaukee on the lakes, Pittsburgh at the head of the Ohio River, and Minneapolis - St.. Paul at the head of the Mississippi. The port cities were the gateways to the region. They were the jumping-off places, the outfitting centres where the early settlers could equip themselves with the tools and implements they would need to tame the frontier.
>
> (Hart 1991, 30)

There are now 28 cities with populations of more than 50,000 people within the Great Lakes Basin Ecosystem (Environment Canada et al. 1991, Vol. I, 3). While the basic pattern of cities has remained constant, the central cities of metropolitan areas are losing population as their suburbs continue to gain (Hart 1991, 28).

Unrecognized Costs of Development

The history of economic development sketched above leaves a mixed legacy. In 1990, the combined value-added or gross state/province product of the eight Great Lakes states and Ontario stood at 1.9 trillion $U.S. (Table 9-2). This figure is roughly twice that of the United Kingdom and three times that of Canada. Only Japan ($2.9 trillion) and the United States as a whole ($5.5 trillion) exceed the amount generated in the Great Lakes region (World Bank 1992, 222).

The region's intensive development brought with it a material standard of living that had never before been witnessed on such a massive scale (Testa 1991, iv). However, there have been hidden costs — paid for partly in human life but borne mostly by the Great Lakes Basin Ecosystem itself. Some of these costs are now appearing in the form of expenditures required to rehabilitate degraded land areas or water bodies, restore ecological functions, repair damage to private property, manage accumulations of buried waste, improve and/or replace a wide variety of built infrastructure, and cover the related costs of human health care.

TABLE 9-2. GROSS STATE OR PROVINCIAL PRODUCT FOR THE EIGHT GREAT LAKES STATES AND ONTARIO, 1990.

state / province	gross state/provincial product (millions of $US current)
Minnesota	100,005
Wisconsin	100,617
Indiana	111,851
Michigan	188,041
Ontario	209,500
Ohio	222,126
Pennsylvania	244,634
Illinois	272,197
New York	466,828
1990 TOTAL GREAT LAKES	1,915,799
Canada	667,843
United States	5,498,793

Sources: Bureau of Economic Analysis 1994; Statistics Canada 1992b, 1993b.

Over the past century, Great Lakes society has reacted to five environmental "crises" (modified from Colborn et al. 1990, xxiv - xxvi). These crises include (1) widespread death from cholera and typhoid at the turn of the century; (2) the destruction of the Great Lakes Fishery; (3) massive eutrophication; (4) record high lake levels in the mid-1980s leading to extensive flooding and erosion of lake shorelines and severe damage to lakeshore properties (5) contamination by persistent toxic substances. Together, these crises suggest a need for change - as if the Ecosystem itself was providing a set of early warning signals.

Crisis 1: Death From Cholera and Typhoid

In 1882, 180 people of every 100,000 in Ontario died of typhoid, cholera, or similar diseases (Koci and Munchee, 1984). In 1910, the death rate in American Great Lakes cities of 100,000 population or more was averaging 23.75 deaths per 100,000 population, five times the rate recorded in same-size northern European cities (Sullivan et al. 1982, 95). Contamination of drinking water supplies with raw sewage was the cause. Chlorination of drinking water resolved the immediate problem, the epidemics passed, and this first crisis appeared to end. Ironically, tests undertaken in the 1940s and 1950s (IJC, 1951) showed that the levels of harmful bacteria were triple those found earlier in the century and it was not until the 1970s that municipal sewage treatment would begin to bring this problem under control.

Crisis 2: Collapse of the Fishery

In the 1930s, the Great Lakes fishery collapsed. In early settlement time, the Great Lakes teamed with an abundant fishery. With development, three factors threatened the fish populations simultaneously: competing exotic species introduced through the canal and shipping system;[2] degradation of water quality as a result of massive discharges of both nutrients and toxic contaminants; and overfishing.

The fishery has since been rebuilt and a multibillion dollar sport-fishery created. While on the surface, the crisis has been successfully met and overcome:

> ...the "quality" of fish has not recovered. Several key species including the lake trout, are no longer naturally self-sustaining and remain only because of expensive artificial stocking programs. New exotic organisms (with unknown impact on the ecosystem) continue to find their way into the

> Great Lakes in the bilge water of ships. Advisories warn against high levels of fish consumption because of toxic contaminants. Although fish have become readily catchable once again, whether they are fit for human consumption is questionable.
>
> (Colborn et al. 1990, xxv).

Crisis 3: Eutrophication

By the 1960s, water quality degradation had reached an extreme, especially in Lake Erie. There, nutrient enrichment, mainly phosphorous from municipal and industrial sewage, had led to excessive eutrophication. In this process, abundant algae growth occurs which in turn dies, decays, and depletes the water of life-supporting oxygen. Colborn et al. describe the situation in Lake Erie as follows:

> Huge algal blooms piled up rotting on beaches. Lakes and rivers near numerous municipal and industrial areas in the region were devoid of visible aquatic life. The Cuyahoga River in Cleveland, Ohio ran a chocolate brown or rust color and was choked with debris, oil, scum, and floating organic sludges. On June 22, 1969, the Cuyahoga was carrying such high concentrations of oil and other flammable industrial wastes that it caught fire and burned two railway bridges beyond use. Some observers pronounced Lake Erie "dead." Perhaps the other Great Lakes were not far behind.
>
> (1990, xxv)

The United States and Canada had commissioned studies of boundary water pollution in both 1912 (IJC, 1912) and the late 1940s (IJC, 1951) through the International Joint Commission. In both cases, while loud warnings were sounded little action occurred. Again in 1964 studies were initiated (IJC, 1964). In this case, the result was the Great Lakes Water Quality Agreement of 1972 which set targets for nutrient reduction. Funds were earmarked for sewage treatment infrastructure and controls on phosphorous discharges were introduced. By 1989, more than U.S. $10 billion had been spent. In many parts of the lakes (not all) the eutrophication problem has been brought under control (Colborn et al. 1990, xxvi). While the residual problems are still significant, for many, the reduction of the eutrophication problem to date represents a significant success story.

CRISIS 4: FLUCTUATING WATER LEVELS

In the mid-1980s, after some twenty years of above average precipitation and below average evaporation, water levels in all of the Great Lakes except Lake Ontario reached the highest levels of this century. Lake Superior reached levels 0.3 meter (one foot) above the long-term average while Lakes Michigan, Huron, and Erie rose a full meter (three feet) above average.

When these conditions were combined with storm activity, the result was extensive flooding, erosion, and severe damage to lake shore properties. Millions of dollars of damage resulted (Levels Reference Study Board 1993, 1-2).

The high water levels experienced in the mid-1980s were in fact the sixth occurrence of water level extremes this century. Extremely high water levels occurred in 1929, 1952, and 1973. Extreme lows occurred in the dry years of the early 1930s and early 1960s. The highs that occurred in 1985 and 1986 set new records. Recovery by 1987 to near-normal levels served to illustrate the changeable nature of the system as a result of variations in weather and climate.

The Final Report of the Levels Reference Board, released in June, 1993 points out that the financial and environmental costs of human regulation of lake levels to control damage far outweigh benefits (Levels Reference Study Board, 1993). However, underneath the Board's work, it is apparent that the "crisis" of fluctuating water levels is really one of inappropriate land and shoreline use, use that has been allowed in the absence of any recognition of natural ecosystem conditions. In short, like the other crises listed here, the cause is human, not natural. They recommend that comprehensive and coordinated land use and shoreline management programs be instituted.

Crisis 5: Persistent Toxic Substances

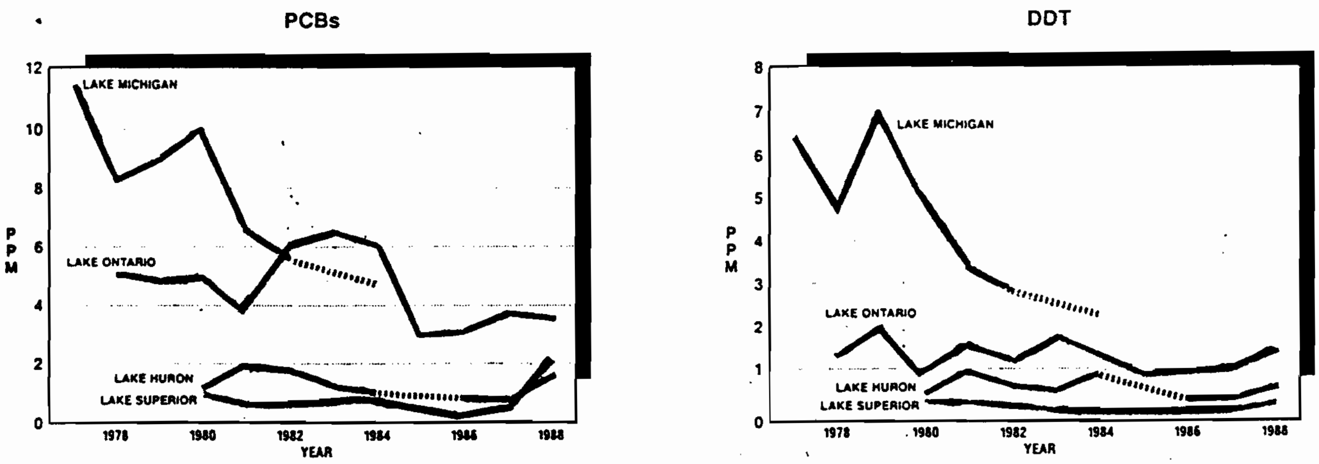
The 1970s brought recognition of a new and much more complex chemical problem than eutrophication: persistent toxic substances. Toxic substances are substances which:

> ...can cause death, disease, behavioural abnormalities, cancer, genetic mutations, physiological or reproductive malfunctions or physical deformities in any organism or its offspring, or which can become poisonous after concentration in the food chain or in combination with other substances.
>
> (IJC 1988, 7)

In turn, those considered persistent are "any toxic substance that is difficult to destroy or that degrades slowly, i.e., with a half-life in water greater than eight weeks" (Environment Canada et al. 1991, 51).

Since the end of World War II, western development has been characterized by an extraordinary increase in the use of manufactured chemicals.[3] Many of these are characterized by properties that allow them to gain entry into organisms and bioaccumulate as transfer occurs up the food web.

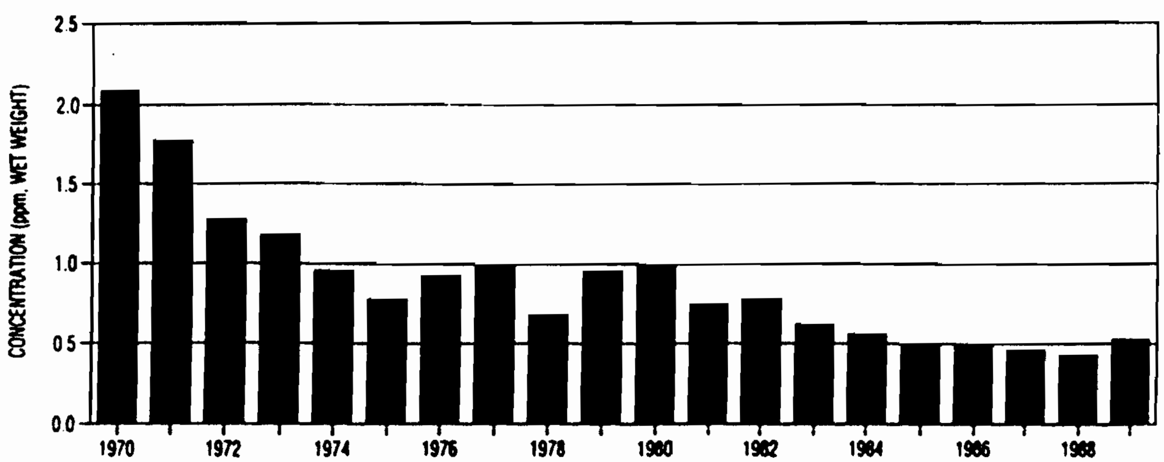
In 1978, the Great Lakes Water Quality Agreement was amended to add a focus on persistent toxic substances. Since then, a significant reduction in concentrations of contaminants has been observed - in water and in organisms. However, by the late 1980s, monitoring data indicated that the downward trend of concentrations of contaminants had levelled off and in some cases, increases were again evident. For example, Figure 9-4 shows concentrations of PCBs and DDT in lake trout from the Great Lakes, 1977 - 1988; Figure 9-5 shows the average mercury concentration in Walleye collected from Lake St. Clair, 1970 - 1989; Figure 9-6 shows mean concentration of PCB in rainbow Trout collected at the Ganaraska River, 1976 - 1992; and Figure 9-7 shows DDT concentrations in Lake Ontario rainbow smelt (whole fish), 1977 - 1990.



Note: These are the average annual concentrations in parts per million wet weight of total PCBs and DDT in whole lake trout. Fish from the Canadian lakes are 4 years of age; fish from Lake Michigan are between 620 and 640 mm in length.
The pesticide DDT is metabolized by biological systems to several other compounds. Total DDT refers to the complex of DDT and its metabolites.

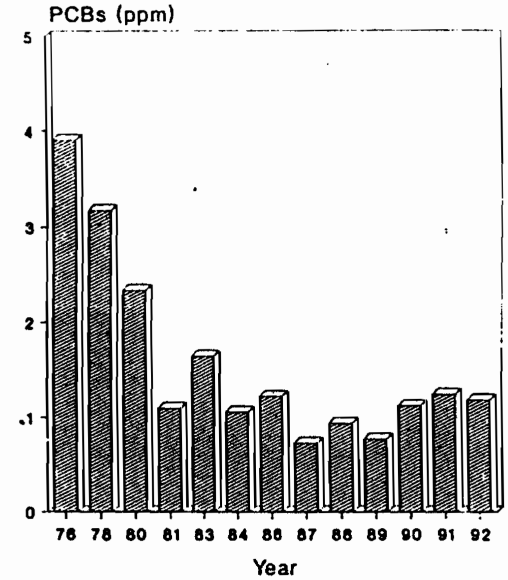
Source: Environment Canada et al. 1991, Volume I, 13.

Figure 9-4. Concentrations of contaminants in lake trout from the Great Lakes, 1977 - 1988.



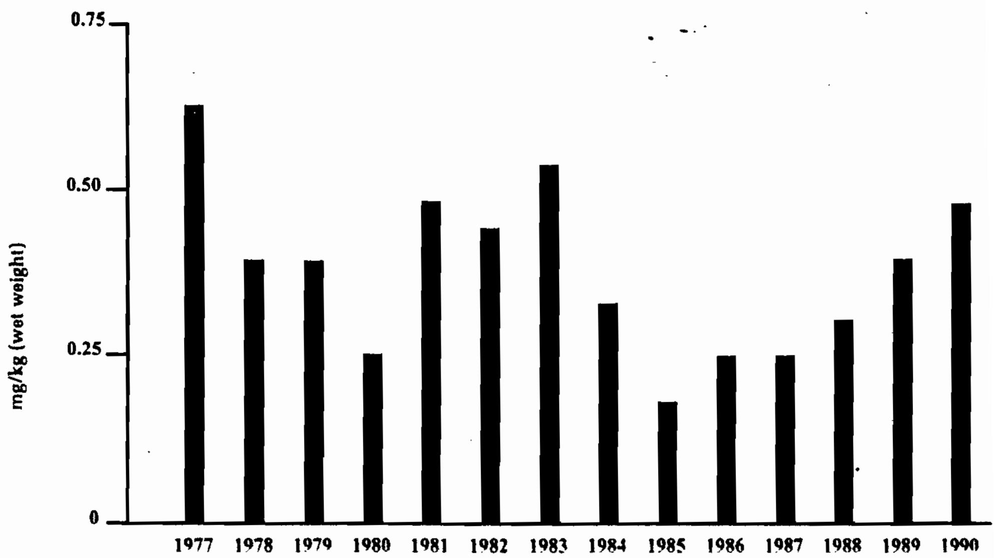
Source: Virtual Elimination Task Force 1993, Vol. II, 109.

Figure 9-5. Average mercury concentration in Walleye collected from Lake St. Clair, 1970 - 1989;



Source: Virtual Elimination Task Force 1993, Vol. II, 109.

Figure 9-6. Mean concentration of PCB in rainbow trout collected at the Ganaraska River, 1976 - 1992.



Source: Virtual Elimination Task Force 1993, Vol. II, 110

Figure 9-7. DDT concentrations in Lake Ontario rainbow smelt (whole fish), 1977 - 1990.

The kinds of trends shown above are cause for concern because injury to living organisms is still occurring despite reductions to date. For example, while the bald eagle has returned to the shores of the Great Lakes, reproductive success is limited. Hatchery-reared lake trout introduced to the Great Lakes thrive but do not reproduce (Foran 1993, 6). A summary of contaminant-related effects on wildlife documented in the Great Lakes is provided in Table 9-3.

TABLE 9-3 PRINCIPAL CONTAMINANT-RELATED EFFECTS OBSERVED IN GREAT LAKES WILDLIFE.

Species	Population decrease	Effects on reproduction	Eggshell thinning	Congenital malformations	Behavioral changes	Biochemical changes	Mortality	Alterations in recruitment
Mink	X	X	NA	NE	NE	NE	X	?
Otter	X		NA	NE	NE	NE	?	?
Double-crested Cormorant	X	X	X	(X)		X	?	?
Black-crowned Night-Heron	X	X	X	X		X	?	?
Bald Eagle	X	X	X	NE		NE	NE	?
Herring Gull		X	X	X	X	X	X	
Ring-billed Gull				X		NE	X	
Caspian Tern		X		X	NE	NE		X
Common Tern		X	X	X		X		
Forster's Tern		X		X	X	X		
Snapping Turtle	NE	X	NA	X	NE	NE	NE	NE

X = effects documented
NA = not applicable
NE = not examined
? = suspected since population declined
1. Observations marked with an X have been reported in the published literature.
2. Unpublished records of congenital malformations exist for the double-crested cormorant, great blue heron and the Virginia rail.

Source: Environment Canada et al. 1991, Volume II, 563.

There is growing evidence that the effects on wildlife listed in Table 30 are early warning signals of like effects on human beings. A summary of established linkages between persistent toxic substances and effects they cause is found in Table 9-4.

TABLE 9-4. CAUSE-EFFECT LINKAGES OF PERSISTENT TOXIC SUBSTANCES.

Contaminant	Species	Effect
DDE, dieldrin, PCB	Bald Eagle	Eggshell thinning; embryo mortality; adult mortality
PCB	Forster's tern	Embryonic mortality; deformities
Dioxin, PCB, DDT	Double-crested cormorant	Embryo deformities; eggshell thinning
PCB	Snapping turtle	Embryo abnormalities; embryo mortality
PCB, dioxin	Mink and otter	Reproductive dysfunction
PAH	Brown bullhead	Liver and skin tumors
PCB	Lake trout	Unable to reproduce normally; hatchability and fry mortality
Dioxin, PCB, DDT	Herring gull	Embryonic mortality; porphyria; thyroid hyperplasia; Vitamin A depletion; deformities; feminization; poor parenting
PCB	Human offspring	Short-term memory deficits (visual, verbal, quantitative, pictorial); growth retardation; activity retardation
Lead	Human offspring	Hyperactivity; permanently reduced intelligence; neurobehavioural abnormalities
Mercury	Human offspring	Learning and motor skill deficits

Source: Virtual Elimination Task Force 1993, 93.

Of particular concern, many chemicals such as DDT and its metabolites, dieldrin, PCBs, dioxin, PAHs, lead and mercury, among numerous others, have demonstrated the ability to disrupt the endocrine system of laboratory animals, producing the symptoms observed in wildlife and summarized below in Table 9-5 (Thomas and Colborn 1992, 365).

TABLE 9-5. OBSERVED DISRUPTION OF THE ENDOCRINE SYSTEM IN WILDLIFE AS A RESULT OF PERSISTENT TOXIC SUBSTANCES.

Effect / Species	BIRDS	FISH	SHELLFISH	TURTLES	MAMMALS
Thyroid Dysfunction	•	•			
Decreased Fertility	•	•	•		•
Decreased Hatching Success	•	•		•	n/a
Gross Birth Defects	•	•		•	
Metabolic Abnormalities	•	•			•
Behavioural Abnormalities	•				
Demasculinization / Feminization	•	•			•
Defeminization / Masculinization	•	•	•		
Compromised Immune System	•				•

n/a = not applicable

Source: Virtual Elimination Task Force 1993, 93.

The disruption to the endocrine system appears to be a result of certain chemicals acting like the female hormone, estrogen. These same hormonally active chemicals are now being found in human tissue as well (Thomas and Colborn 1992, 365). A particular worry has risen because it is apparent that the resulting developmental effects occur in the off-spring of exposed parents, rather than in the parents themselves (Colborn and Clement (eds.) 1992, 2).

In 1990, 1992, and again in 1994, the International Joint Commission signalled their concern about this topic to the governments of Canada and the United States. Most recently, they reiterated:

> ...mounting evidence continues to reinforce concerns about the effects of persistent toxic substances. Long-term exposure of fish, wildlife, and humans to these substances has been linked to reproductive, metabolic, neurological and behavioural abnormalities; to immunity suppression leading to susceptibility to infections and other life-threatening problems; and to increasing levels of breast and other cancers. Available evidence also points to long-term reproductive and intergenerational effects.
>
> One growing concern is effects on endocrine systems. Research has shown persistent chemicals such as PCBs, dioxins, atrazine, hexachlorobenzene, as well as other organochlorines and polycyclic aromatic hydrocarbons (PAHs), to be strongly implicated in the disruption of endocrine systems, including estrogenic effects, in laboratory animals and in wildlife. The substances appear to act as artificial, external hormones that disrupt the normal balance of hormonal activity in animals.
>
> (IJC 1994, 4)

On the basis of the "weight-of-evidence" provided by the many studies indicating injury or the likelihood of injury together, the International Joint Commission concluded in 1992 that a causal relationship can be established between persistent toxic substances and injury to both wildlife and humans (IJC 1994, 10). It has strongly urged that input of these substances into the Great Lakes be stopped and that

> ...the burden of proof must shift to the proponent (manufacturer, importer, or user) of the substance to show that it does not or will not cause the suspected harm, nor meet the definition of persistent toxic substance.
>
> (IJC 1994, 10)

To emphasize the nature of the risks now being faced in the Great Lakes Basin Ecosystem, the Commission posed the following three questions:

- What if, as current research suggests, the startling decrease in sperm count and the alarming increase in the incidence of male genital tract disorders are in fact caused in part as a result of ***in utero*** exposure to elevated levels of environmental estrogens?

- What if, as current research suggests, the epidemic in breast cancer is a result in part of the great numbers and quantities of estrogen-like compounds that have been and are being released into the environment?

- What if the documented declining learning performance and increasing incidence of problem behaviour in school children are not functions of the education system? What if they are the result of exposure to developmental toxicants that have been and are being released into the children's and parents' environment, or to which they have been exposed ***in utero***?

(IJC 1994, 5)

It goes on to point out that the implications of any one of these questions being answered in the affirmative is overwhelming; if all of them were so answered, it would be catastrophic. These conclusions lead the International Joint Commission to describe this crisis as "the most significant problem to be confronted in the Great Lakes Basin Ecosystem" (IJC 1994, 6).

The Costs of Inaction

Each of these five "crises" has led to unexpected costs to society - costs in terms of human life and health, a degraded Great Lakes Ecosystem, "property," and dollars. Only a tiny portion of these costs are factored into the estimates of gross state and provincial product that are used to assess "success" and which identify this region as a major player in the global market. In fact, it is a quirk of the systems of national accounting that expenditures to rectify these crises appear as a contribution to the growth of state, provincial, or national product. Further, many of these costs are not amenable to measurement in dollars.

However, to provide a crude context, tens of billions of dollars are estimated to be required for initial clean-up of 43 "Areas of Concern" located around the perimeter of the Great Lakes (Davidson and Hodge 1989, 24).

By 1989, the National Priority List of the U.S. Superfund program contained 890 sites, of which 116 are within the Great Lakes basin (Colborn et al. 1990, 61). Clean-up and management, in perpetuity, of buried hazardous waste, particularly in the Great Lakes states will also likely cost tens of billions of dollars.[4]

A 1992 study estimated that the economic value of environmental damage in Ontario is more than one-hundred million dollars annually (Haney and Sonnen 1992).

Loss of the fishery, costs of water treatment, health care costs, lost land value of contaminated waste sites, depressed property values surrounding waste sites, and costs of property damage due to inappropriate use of coastal zones are some of the additional hidden and growing costs resulting from these self-inflicted crises (see discussion, Virtual Elimination Task Force 1993, Vol. 2, 96 - 97).

9.4 SUMMARY

The Great Lakes region may well be at a critical point in its evolution. The continuous population growth and economic expansion through the last century may be coming to an end. At the same time, there is a growing realization that certain costs of development in terms of human life and ecosystem degradation have been long hidden and must now be accounted for. Re-establishing an enhanced quality of life through ecosystem restoration is emerging as a key to economic renewal. From here on the region can move into a phase of overall decline or it can change its direction to achieve long term stability in terms of both human and ecosystem well-being.

In sum, the Great Lakes Basin Ecosystem together with the secondary decision-making envelope provided by the aerial extent of Ontario and the eight Great Lakes states provides an ideal test case for the proposed systemic approach to assessing progress toward sustainability.

END NOTES

1. The following comments regarding transportation are summarized from Thorp and Ballert (1991) unless otherwise noted.

Canals and Shipping

In 1825, the Erie canal was completed, a 586 km link between Albany on the navigable Hudson River and Lake Erie at Buffalo. The canal opened up the American Midwest to settlement, and laid the basis for Buffalo's 9th century prosperity, as well as that of New York City. It provided the first link of the Great Lakes to the Atlantic Seaboard.

The same year, the Lachine Canal in Montreal opened, the first step in making the St. Lawrence a navigable waterway to Lake Ontario. Four years later the first Welland Canal was completed providing a route past Niagara Falls to Port Robinson on the Welland River and opening the second canal route to the Atlantic. In 1833, the canal was extended to Port Colborne on Lake Erie. In 1932, the Rideau Canal offered a route around the rapids on the Upper St. Lawrence.

In 1835, the Ohio Canal was completed, spanning the state of Ohio and connecting the Ohio River on the Mississippi River drainage system to Cleveland on Lake Erie. It provided the third external shipping link for the Great Lakes, this time to the Gulf of Mexico at New Orleans.

By 1850, ships could sail from Lake Michigan to the sea along channels at least nine feet deep; ships from Europe could reach Chicago on Lake Michigan. Additional tributary canal building led to the commerce of the entire United States Midwest feeding through the Great Lakes (Sullivan et al. 1982, 88).

In 1855, the Sault Canal provided the last link in the canal system providing access for the big ships from the Lower Lakes to Lake Superior and a route for export of the mineral riches of the Canadian Shield.

Improvements to shipping facilities peaked in 1959 with completion of the St. Lawrence Seaway, the immense deep-draft shipping link that stretches 2,340 miles from the Atlantic Ocean at the Gulf of St. Lawrence to the center of North America at the twin ports of Duluth-Superior (Minnesota/Wisconsin). From 1959 through 1989, Seaway tonnage amounted to 1.3 billion metric tons with an estimated value of $200 billion.

Rail

The mid-1800s also saw an explosion of railroad building in the Great Lakes region. Between 1840 and 1860 alone, total railroad mileage increased from 2,818 to 31,246 miles. The railroad network that soon laced the Great Lakes region was both competitor with and partner to the shipping system.

Road

The Great Lakes region is the birthplace of automobile assembly as well as much of the basic vehicle technology. Auto, bus and truck assembly in the Great Lakes states today represents about three-fifths of United States production. Michigan alone produces one-third of all autos in the United States.

Road construction quickly gathered momentum with development of the automobile. A vast road network now spans the region. The eight Great Lakes states account for close to one-fourth of the interstate highways in just 12 percent of the land area of the U.S. (Erdevig 1991, 26). In 1988, 52.8 million motor vehicles were registered in the Great Lakes states, some 28.5 percent of the U.S. total.

network also provides the needed infrastructure for bus and truck transport. In 1977, the Great Lakes states accounted for about one-third of U.S. person-trips by bus (at least 200 miles round-trip) although in recent years long-distance bus travel has declined.

In 1988, commercial trucks hauled 2.45 billion tons of freight in the Great Lakes states with revenues of $240 billion. The number of major motor carrier operations in the Great Lakes states is about 12,000, some 30 percent of the major regulated carriers in the United States.

Since the middle part of this century, Air transport, passenger and cargo, has played an increasingly important role. Chicago's O'Hare International airport was ranked first in the world in 1989 in terms of passenger emplanements and deplanements. Twelve of the regional airports in the Great Lakes states are in the top 50 in the U. S. in terms of emplanements. Toronto is Canada's busiest airport.

Business travel is the dominant purpose for air travel, a characteristic that underlies the use of airplane travel statistics as a barometer of business activity. The Great Lakes region is home to 237 of the"Fortune 500"largest industrial company headquarters and 192 of the 500 largest nonindustrial company headquarters (Erdevig 1991, 26). These statistics underlie the importance of air travel to the Great Lakes region.

2. Dochoda et al., reports that 69 exotic species have been introduced of which 27 are a result of uncontrolled discharge of ballast water (1990, 24).

3. World-wide, about ten million chemical compounds have been synthesized in laboratories since the beginning of this century. The European Inventory of Existing Commercial Chemical Substances (EINECS) lists 110,000 chemicals. In 1982, it was estimated that there were 60,000 chemical substances on the market and that the production of synthetic materials had increased some 350 times since 1940. This trend continued until the number of commercially-available chemicals reached the 100,000 mark of today, with 1,000 new substances becoming available every year. Existing test facilities world-wide can only process half of these. In contrast to its small beginnings before World War II, the chemical industry in the late 1970s produced about 400 million tonnes of products a year and employed about four million people (UNEP 1992, 249).

   In water of the Great Lakes, The International Joint Commission has developed a working list of 362 chemicals (both metals and organic chemicals) that are "considered to be unequivocally present" (Environment Canada et al. 1991, Volume I, 6)

   In 1977, the U.S. Fish and Wildlife Service identified nearly 500 organic compounds in adult lake trout and walleye collected from the Great Lakes. The number of man-made chemicals detected in the basin's environment may be in excess of 1,000 (Virtual Elimination Task Force 1993, Vol. II, 89).

4. In 1988, and after a decade of lawsuits, a landmark decision of the United States District Court found Occidental Petroleum Corporation liable for the full cost of cleanup of the Love Canal hazardous waste site in New York's Niagara Peninsula. These costs were then estimated at $250 million ($US) and did not include costs of perpetual monitoring.

CHAPTER TEN.

SYSTEMIC ASSESSMENT OF PROGRESS

TOWARD SUSTAINABILITY

IN THE GREAT LAKES BASIN ECOSYSTEM

10.1 INTRODUCTION

This Chapter applies the proposed reporting framework to assessing progress toward sustainability in the Great Lakes Basin Ecosystem. The four domains are addressed in turn. In each case a set of indicators is developed using the four assessment hierarchies presented in Chapter Eight as a guide (Figures8-1, 8-2, 8-3, 8-4). Data are reviewed and an assessment of progress toward sustainability is then made using the goals that were listed in Chapter Five to provide the comparative framework.

10.2 DOMAIN I — ECOSYSTEM

DOMAIN DESCRIPTION: Data and information facilitating an assessment of ecosystem well-being.

GOAL: To maintain or improve ecosystem health and integrity.

Figure 8-1 provides the organizing template for this Domain. Table 10-1 below lists nineteen indicators grouped in eight categories. Each of the nineteen line items is supported by a number of specific measures or indicators. In turn, each line item becomes an indicator for the more aggregated assessment to which it contributes.

Table 10-1does not exactly mirror Figure 8-1. In the ideal, it would. Data and information limitations make such coincidence currently impossible. For example, an analysis that looks separately and comprehensively at the natural, modified, cultivated, and built components of the Great Lakes Basin Ecosystem has never been completed.[1] Such an analysis is beyond the scope of this study.

TABLE 10-1. INDICATORS OF GREAT LAKES ECOSYSTEM HEALTH AND INTEGRITY.

Factor	*Response time*	*Basin limited?*	*Current status / trend*
1. AIR QUALITY			
a.	days to months	no	Emissions data generally signal reductions over the last two decades that have likely contributed to an overall improvement particularly for common pollutants such as SO_2 and suspended particulate matter. Hydrocarbon emissions and oxides of nitrogen have increased during this period. Conditions are periodically unacceptable in major cities, particularly because of ground-level ozone. Monitoring of airborne toxic substances is inadequate and additional concerns may be identified as air quality monitoring systems are upgraded.
2. SURFACE WATER QUALITY (CHEMICAL AND BIOLOGICAL CHARACTERISTICS)			
a. nutrients	months to years	yes	Excess nutrient problems in the Great Lakes proper have been greatly reduced since 1972 although trophic conditions are still not at targeted levels in some areas such as in the deep waters of Lake Erie. Eutrophication remains a significant problem in a number of nearshore areas and both eutrophication and acidification remain serious problems in many inland lakes. Concentrations of nitrogen compounds continue to rise — implications are not yet clear.

b. months to decades no
toxic contaminants

Concentrations of toxic contaminants has generally declined over the past two decades. Their are some exceptions. Cumulative concentrations of metals in three of the Great Lakes are at elevated levels. Although concentrations of some persistent toxic substance meet ambient water quality standards, the processes of bioaccumulation and biomagnification mean that concentrations below water quality standards are still high enough to cause injury to fish, wildlife and humans. Forty-three lakeshore Areas of Concern, all of which are characterized by elevated contaminants in lake water require a massive remedial effort. A similar assessment of inland locations within the basin has not been completed.

c.
loadings

Continuing point sources remain a concern, particularly the cumulative affect of all point sources. Both urban and rural nonpoint contaminant sources remain a serious problem.

d. decades to centuries yes
contaminated lake or river bottom sediments

Serious problem in 42 of 43 Areas of Concern. In general, recent deposition of sediments is less contaminant laden contributing to an "improvement." However bottom sediments remain a continuing source of contaminants and excess nutrients in the food web.

3. Groundwater

a.	decades to centuries	yes

With preventative activities in their infancy and sources increasing in both number and magnitude, it is likely that groundwater quality is degenerating. Degraded conditions will last long into the future. Sub-system is ill-understood.

4. Cultivated Land

a. Conversion of high quality agriculture land to urban uses	days to years	yes

An overall loss is continuing although the loss per capita is decreasing over time suggesting a slow improvement.

b. Soil productivity	years to decades	yes

Generally stable although there is a growing concern regarding chemical inputs and their long term implications.

c. Soil erosion	months to decades	yes

There is continuing natural erosion. Conditions are generally stable compared to other parts of North America.

5. Other Special Lands

a. Wetlands	years to decades	yes

Two-thirds of the original wetlands have been destroyed since the beginning of European settlement. Further destruction has been slowed but not stopped.

b. Shorelines	days to years	yes

There is continuing natural erosion. The inappropriate use of vulnerable shorelines is continuing, often leading to unnecessary damage to property.

6. The Built Environment

a. Built infrastructure	years to decades	yes

There are growing concerns regarding the ongoing quality, maintenance and replacement costs of a wide range of built infrastructure. No overall infrastructure assessment has been completed.

7. Biota

a. Body burdens of persistent toxic substances	intergenerational effects; decades	no

Significant improvements have been recorded since the early 1970s. However since the late 1980s, trends are inconsistent with a number of contaminants showing either little further change or an increasing trend. For many substances, levels remain above objectives specified in the Great Lakes Water Quality Agreement or other quidelines and standards. Continued high levels of substances whose use has been restricted signals releases of contaminants previously deposited in the ecosystem, continued release from improper storage of waste and remaining stocks, or continuing use in remote areas outside the basin linked with a transport mechanism into the basin.

b. Population health status	years to decades	no
		Variable: some recovering, some key species such as lake trout and eagles are still unable to establish self-sustaining populations. Biota remain threatened in acidifying inland lakes. Many populations are not well monitored and an overall assessment has not been completed.
c. Wildlife Habitat	days to centuries	yes
		All human-occupied land represents some extent of wildlife habitat loss. Blockages of creeks, streams and rivers from dam construction has dramatically altered 'aquatic habitat. No overall assessment of aquatic and terrestrial habitat has been completed although in recent decades, the rate of loss and deterioration appears to have slowed.
d. Forests	decades to centuries	yes
		Many forests are maturing again after recovering from massive overcutting and fires during the 19th and early 20th centuries. Second growth species and age distribution is markedly different than the original forests. Forests remain at risk from overcutting, airborne contaminants and potential climate change. An overall assessment of forest ecosystem health and integrity has not been completed.

e. Health of plant communities	months to decades	yes

Little monitored and geographic specific. There are clearly some concerns although no overall assessment has been completed.

f. Overall Biological Diversity	decades to centuries	no

An initial assessment has identified 22 critically imperilled, 30 imperiled, and 79 rare ecological elements using a global frame of reference. Of these, 31 are natural ecological community types, 49 are plants, 21 are insects, 12 mollusks, 9 fish, five birds, three reptiles and one mammal. Ongoing human-induced stresses are cause of concern and without stress reduction, biological diversity will continue to erode.

8. HUMAN HEALTH AND WELL-BEING
(USED AS AN INDICATOR OF ECOSYSTEM INTEGRITY)

a.	days to generations; decades	no

There is little indication that the health of adults due to toxic contaminants is being compromised.Certain sub-groups (children, child-bearing women, aboriginals dependent on country food) are at elevated risk and there is growing concern regarding subtle chronic and intergenerational effects. Data are available that suggest that the overall state of well-being is not increasing although average income levels continue to grow in real terms.

Sources: Colborn et al., 1990; Canada, 1991; Environment Canada et al., 1991; IJC, 1982, 1984, 1986, 1989, 1990, 1992, 1994; GLWQB 1989; Myers 1992; Thorp and Ballert, 1991; The Nature Conservancy, 1994.

The origins of Table 10-1 lie in the Great Lakes state-of-environment assessment documented in Colborn et al. 1990 (see especially 187 - 191). On the basis of their work, they conclude:

> Despite regulatory vigilance to rein in polluters and significant government cleanup efforts over the past two decades, the environment of the Great Lakes basin is still in trouble. Dramatic evidence remains that the Great Lakes are imperiled by continuing habitat destruction and the long-term accumulation of toxic chemicals, which are increasingly pervasive throughout the ecosystem.
>
> (Colborn et al. 1990, xix)

Similarly, the authors of *The State of Canada's Environment* who completed a similar assessment conclude:

> Despite the gains of the last two decades, the Great Lakes ecosystem is still threatened. Conditions for fish and other wildlife remain degraded, and human health as well as ecosystem well-being are at risk. Many bays, harbours, and channels remain severely degraded, and assessment of the cost of rehabilitating these degraded areas has brought to light a significant environmental "mortgage" of tens of billions of dollars.
>
> (Canada 1991, 18-28)

Several important observations can be drawn from the above work. First, trends shown by indicators are not all in one direction. In this case, four suggest at least partially improving conditions (1a, 2a, 2b, 2d), ten deteriorating or continuing cause for concern (2c, 3a, 4a, 4b, 5a, 6a, 7a, 7c, 7f, 8a) ; and the remaining four suggest no change, uneven progress, or are not clear enough to assess (4c, 5b, 7b, 7d). Assessing and balancing these various indicators inevitably involves judgement.

Second, specific standards, criteria, or targets that might facilitate a more exact assessment of a given topic exist for only a minority of these indicators. This lack does not impede an assessment. Trends that signal improvement or deterioration can be identified in the absence of such standards, criteria, and targets.

Third, data and information weaknesses can be identified in almost all of the nineteen indicators. Of greatest concern are data describing: toxic substances in air; the groundwater system; the state of built infrastructure; wildlife population health status; plant community health status; human health and well-being.

And last, while the compilation has been developed within a perspective of the whole ecosystem, not all ecosystem components are addressed. Rather, the nineteen indicators provide a pragmatic compilation based on available data and information. Using Figure 8-1 as a systematic "check template" a number of gaps can be identified including assessments of the status of indoor air quality, surface water quantity, a range of potentially useful bioindicators, and the stocks and flows of non-renewable resources.

This later topic is part of the subject of natural resource accounting — a topic that has received significant theoretical attention in the last decade but has yet to find practical application in the Great Lakes region.

As it stands, Table 10-1 must be considered only an initial step in undertaking a systematic Domain I assessment. Although the listed indicators facilitate an assessment of ecosystem health and integrity, each individual component requires more rigorous treatment. In a complete assessment of the Great Lakes Ecosystem, portrayal of original data would be required. This is a major task and well beyond this study.

However, in Chapter Twelve a more detailed analysis of one ecosystem subsystem, water, is provided. There, a set of twenty-three indicators are defined that deal with both the surface water and groundwater components.

Another approach to assessing ecosystem health and integrity is to identify characteristics of the Great Lakes Ecosystem that have come to be recognized as signals of an ecosystem under stress (see Bird and Rapport 1986; Herricks and Schaeffer 1987; Canada 1991; Torrie Smith Associates and The Institute for Research on Environment and Economy 1993). A list of such characteristics evident in the Great Lakes ecosystem is provided below in Table 10-2.

TABLE 10.2. BIOLOGICAL CHARACTERISTICS INDICATING THE GREAT LAKES ECOSYSTEM AS A STRESSED ECOSYSTEM.

1. decline in the number of native species and in species diversity;
2. decrease in system stability - stressed ecosystems tend to fluctuate more widely than unstressed similar systems;
3. shift to more opportunistic species;
4. reduction in average size of dominant biota: alteration in community structure to favor short lived smaller life forms;
5. unnatural rapid alteration in the quantity of either living or dead biomass;
6. impaired biological productivity;
7. changes in primary energy production and energy flow through the system;
8. higher susceptibility to disease (except in instances where the stress weakens the disease more than the host) reflected in an increase in the rate of disease prevalence;
9. enhanced leaching of nutrients in terrestrial ecosystems and their accumulation in recipient aquatic systems; and
10. enhanced circulation of contaminants and toxic substances and their bioaccumulation in the food web.

10.3 ASSESSMENT OF GREAT LAKES ECOSYSTEM HEALTH AND INTEGRITY

From a synthesis of the above, a well-founded assessment of ecosystem health and integrity can be made — in spite of the limitations in available data and information that have been identified. It is a "wight-of-evidence" assessment based on existing data and information. While improvements have been achieved in a range of ecosystem characteristics over the past several decades, ***the integrity and health of the Great Lakes Ecosystem remains depressed.*** Most importantly, ***current trends do not collectively signal that ecosystem health and integrity are being maintained or improved, the goal of this domain if progress toward sustainability is to be achieved.***

10.4 DOMAIN II — HUMAN-ECOSYSTEM INTERACTIONS

DOMAIN DESCRIPTION: Data and information facilitating an assessment of the interaction between people and the ecosystem and related decision-making: how and to what extent human activities contribute to provision of basic needs and the quality of life - how these activities are valued; how these actions stress, or contribute to restoring the ecosystem; and how successful we have been at meeting the goals and objectives of policies, regulations and legislation.

GOALS: To maintain or increase the ability of human activities to provide support for human well-being. To reduce the physical, chemical, and biological stress imposed on the ecosystem by human activities; and To increase the extent to which human activities restore ecosystem health and ntegrity.

Four related tasks lie at the core of the Domain II assessment: (1) identifying, classifying, and assessing human activities; (2) assessing their contribution to human well-being (their value or benefit); (3) assessing the stress they impose on the ecosystem; and (4) identifying their contribution to ecosystem restoration. The assessment hierarchy shown in Figure 8-2 provides the organizational template for addressing these four tasks.

HUMAN ACTIVITIES AND THEIR VALUE

Classifying human activities and compiling figures for value-added and employment by activity provides a starting point for the first two of these tasks. Data for Ontario and the eight Great Lakes states are found in Appendix IX.

These data provide a picture of human activities and their relative "value" for a single year at a coarse level of aggregation. Much finer level data are available and time series extend at least 25 years. These numbers along with population and settlement trends provide the foundation for much more comprehensive regional macroeconomic analyses that consider trends in demographics, economic structure, the adequacy of support infrastructure, research and development effort, investment flows, and diversification. The most recently compiled synthesis for the region points out that population growth is close to zero and economic restructuring is occurring in response to changing global conditions (Federal Reserve Bank of Chicago and the Great Lakes Commission, 1991). They suggest

> ...the region's course lies in a more favorable direction in comparison to yesteryear... development policies and public discussion have changed from being reactive to being proactive, from adversarial to cooperative, and from inward-looking to global. This turnabout, in addition to the region's economic resurgence in the 1980s, have allowed the region's decision makers to make changes work for them rather than against them.
>
> (1991, vi)

In short, there is optimism that past economic success can be extended.

Human Activities and the Stress they Impose

The tables of Appendix IX, however, have an equally important second function. They provide a framework for assessing stress imposed by human activities on the ecosystem as well as restorative efforts initiated by human activities.

A summary assessment of human-induced stresses organized by stress type is provided in Table 10-3. Twelve indicators are listed that together enable an assessment of overall trends. Minor variations between the indicators on this table and the lower levels of the assessment hierarchy exist because of the nature of available data.

TABLE 10.3. SUMMARY ASSESSMENT OF HUMAN-INDUCED AND NATURAL STRESSES ON THE GREAT LAKES ECOSYSTEM.

PHYSICAL STRESS

1. PHYSICAL RESTRUCTURING

The major physical restructuring likely occurred historically: removal of forests and clearing of land, damming of streams, building of roads and other transportation arteries that limited the continuity of the natural ecosystem. There is growing concern with ongoing expansion of urban areas. Localized environmental concerns are often mitigated in new projects, but little broad ecosystem perspective is used in current practice in private or public decision making. For example, decisions regarding shoreline development rarely consider long term fluctuations of lake levels; wetland drainage to facilitate development is still occurring although programs to stop this practice and rehabilitate wetlands are now in place.

2. EROSION AND SEDIMENTATION

Soil erosion in agricultural lands with subsequent removal in runoff and deposition in water courses is ongoing and the volume of transported soil is considerable. In the early 1980s, rates of erosion in the agricultural areas on the United States side of the Great Lakes basin were assessed to be largely at or below the "tolerable loss rate" although long term soil productivity is not necessarily assured.[2] In Ontario, non-farm off-site costs of agricultural soil erosion have been estimated at \$74 - \$91 million per year.[3] Programs have been established in the last five years in most parts of the Great Lakes to change agricultural practices to minimize soil loss. These initiatives have been limited in both scope and impact.[4]

Erosion and sedimentation is also a by-product of a large range of construction activities. An overall assessment of erosion and sedimentation in the Great Lakes basin has never been completed.

3. Heat Discharge

Thermal loading is likely increasing as a function of increased human activity with population growth. No overall assessment for the region has been completed.

4. Noise

Noise levels are likely increasing in most urban areas as a function of increased human activity with population growth. It is a particular problem adjacent to active transportation corridors and some industrial facilities. No over all assessment for the region has been completed.

5. Water Withdrawals

Current requirements for water extraction from surface water are within the ability of available renewable supplies. Pressure to increase diversion of water both in and out of the basin can be expected, particularly if the projected effects of changing climate occur.

Severe local problems exist due to mining of groundwater resources.[5]

6. Extraction of Non-Renewable Resources

Extraction of petroleum products, coal, minerals, and building materials is ongoing. An assessment of the short and long-term implications of current extraction rates and the overall state of the stocks of these resources has not been completed.

CHEMICAL STRESS

7. Loadings of Contaminants

Some point source emissions to air and water in the basin are declining but serious ongoing discharges remain.[6]

Out-of-basin point sources are becoming increasingly significant to contamination within the Basin.[7]

Nonpoint sources[8] are stable at best, perhaps getting worse. They have emerged as the dominant ongoing concern for both conventional and toxic contaminants.

Accidents leading to unanticipated spills or emissions continue to be a significant concern.[9]

8. Waste Generation and Storage

Hazardous Wastes

In 1985, hazardous waste generation in the eight Great Lakes states and Ontario was estimated to total 56.5 million tonnes (62.2 million tons). Time series data are not available to signal trends in the volume and severity of generated waste. Management of hazardous waste sites, including clean-up, represents a large and growing drain on the economy. In 1989, the United States Environmental Protection Agency listed close to 3600 sites in the Great Lakes Basin that either cause or have the potential to cause environmental harm. The National Priority List of the U.S. Superfund Program lists 116 sites within the Great Lakes Basin. In Ontario, 3,850 active and inactive waste sites have been identified of which 80 percent are in the Great Lakes basin. Of those in the basin, 1,748 are thought to have the potential to pose health hazards to humans.[10]

Municipal Solid Wastes

In statistical terms, each of the 35 million residents in the Great Lakes basin generates about 2 kilograms (4.5 pounds) of municipal waste per day. These wastes are generated by households, industries, commerce, and government. They are a problem not only because of the sheer volume generated but also because of environmental stress from subsequent leachate. Most of this waste is deposited in landfills with a small proportion being incinerated or recycled. Limits on the capacity of existing disposal sites are reaching crisis proportions in many areas. Disposal costs are increasing rapidly. Some local programs to "reduce, reuse, and recycle" have achieved some success in lowering rates of waste generation. An overall assessment for the eight Great Lakes states, Ontario, and the basin has not been completed.[11]

BIOLOGICAL STRESS

9. Harvesting of Renewable Resources

Forestry

Over the past two centuries, human activity - clearing for settlement, agriculture, human-induced wildfire and commercial harvesting of forests has radically altered the original forest cover. Vast tracts of second-growth forest have emerged that are ecologically young and biologically complex.[12] Second growth trees are generally lower valued species than the original old-growth. Ongoing harvesting practices are subject to much debate. Shifting values and increased public pressure are leading to adjustments in forest practices that reduce stress, are more sensitive to ecological principles and non-commercial values.[13]

Fishing

Commercial fishing is at levels far below historic highs while the popularity of sport fishing has exploded in the last two decades.[14] Fish communities have changed dramatically since 1900 and although the changes differ in degree and type, depending on the lake, the end result has been a general decline in the highly valued, native fish species which was often accompanied by an increase in low valued fish species. Efforts to reintroduce the lake trout by stocking have been successful but reproduction is not occurring except in Lake Superior. The current fishery is not self-sustaining but maintained by stocking.

Hunting and Trapping

Stress imposed by terrestrial wildlife harvesting (trapping and hunting) has never been assessed in terms of overall wildlife population robustness although fur-bearing and game species are monitored by government agencies and harvest levels are limited to maintain populations.

Farming - Soils

Soil productivity in farmed areas appears to be stable in the region but no long term assessment has been completed.

10. Habitat Change

Ongoing habitat change involving a range of physical, chemical and biological stresses continues with expanded levels of human activity in the basin. No overall assessment has been completed but recent work has identified three critically imperiled, eight globally imperiled, and twenty globally rare natural communities.[15]

11. Introduction of Non-native Organisms

Some sixty-nine exotic organisms have been reported in the Great Lakes ecosystem since the late 1800s of which twenty-seven have been introduced through discharge of ships' ballast water.[16] These exotics have severely disrupted the Great Lakes Basin Ecosystem.[17] Volunteer programs are in place to control ballast discharge but there is ongoing concern regarding detrimental exotic species entering the system.

12. Biotechnological Change

No assessment of the environmental stress imposed by biotechnological change has been undertaken.

Sources: Colborn et al., 1990 plus specific sources listed in the end notes.

Like the elements of Table 10-1, the elements of Table 10-3 are supported with a large set of specific measures. A complete analysis of these measures is beyond the scope of this case study. However, one important general observation can be made. Of the three stress types, imposed chemical stress has received the greatest emphasis, is the easiest to measure, and enjoys the greatest data base. The idea of chemical pollution is popularly understood. In contrast, imposed physical and biological stress are less understood, more difficult to measure and are not generally well documented.

In this case, with the exception of clear indications of a decrease through time in some point source emissions of contaminants, all of these indicators signal stress levels that are either increasing or at best, stable. Thus, the weight of evidence suggests an unsustainable trend.

Table 10-3 also provides the key to identifying actions required to reduce stress on the Great Lakes ecosystem. Its limitation lies in the fact that it is only partially activity-specific and therefore only partially able to link to the activities listed in Appendix IX. To effect such an integration, an activity-by-activity stress assessment is required or, from another perspective, the cumulative stress assessment must be disaggregated by activity. Such a step is critical because it will facilitate identification of how activities might be altered to achieve stress reduction. Standards, objectives, and criteria must be applied, and monitoring must be undertaken on an activity basis. The entire concept of a broad stress assessment on an activity-by-activity basis is an important area of follow-up research.

While an overall stress-assessment has never been completed, society is moving towards one on a number of fronts. The current focus is on loadings of contaminants and waste generation. Around the Great Lakes, a large number of comprehensive studies of pollution have been completed, some aimed at specific Areas of Concern and others aimed at larger study areas. As these investigations have evolved closer and closer to action plans, more and more data have been gathered that are activity and establishment specific.[18]

A more comprehensive approach to pollution has been taken in the United States with the creation in 1986 of the Toxics Release Inventory (TRI), a computerized tracking system of the release of 328 chemicals from manufacturing plants throughout the country. These facilities are required by law to report all releases directly to air, water, or land or that are transported to off-site facilities. The entire inventory, from facility-specific data to country aggregations, is available to the public in a computerized database.[19] All data are classified by the Standard Industrial Classification but are limited to the "manufacturing" line item in the tables of Appendix IX. In Canada a similar database, the National Pollutant Release Inventory (NPRI), is now under development. It is currently (1994) in its first year of data gathering.

The direct tie to human activities through the use of the standard industrial classification is an important characteristic of both TRI and NPRI. It is this simple step that will ultimately make possible a comprehensive accounting for any given activity, of imposed environmental stress in a manner that facilitates its comparison to economic benefits.

TRI and NPRI are far from comprehensive. They deal only with a limited set of chemical stresses and a limited number of human activities. In spite of these limitations, they represent a beginning and they set a very clear direction for future effort.

Human Activities That Restore Ecosystem Well-being

The concept of ecosystem restoration as a science (and art) is in its infancy.[20] Certain actions such as the setting aside of land for parks and protected areas, reforestation, providing fish-ladders around channel blockages, restoring fish spawning grounds, restoring migratory bird staging and nesting habitat, and restoring water and air quality all qualify as restoration activities.

In 1946, the Ontario Legislature passed the ***Conservation Authorities Act*** (R.S.O. 1946, Chapter 133) creating the Conservation Authorities Program. Thirty-eight watershed-based Conservation Authorities have since been created, largely located in southern Ontario and containing 90 percent of the population of Ontario. From their beginning, these have been seen as a mechanism to enable comprehensive water management and provide "a new approach to conservation planning" (Shrubsole 1989, 8). There is no equivalent mechanism in the eight Great Lakes states.

Concern for conservation and restoration, particularly of renewable resources, played a key role in the lead-up to and design of the ***Conservation Authorities Act*** (Shrubsole 1989, 105). However, there has never been an overall assessment of

Conservation Authority activities from the perspective of ecosystem restoration. In fact there is no centralized information system that facilitates a review of Conservation Authorities' activities.

Restoration has been formally entrenched in the Great Lakes Water Quality Agreement. Annex 2 of the amended Agreement (GLWQA, 1987) addresses Remedial Action Plans (RAPs) for the forty-three Areas of Concern (see Figure 10-1) and Lakewide Management Plans (LMPs). It states:

> (a) Remedial Action Plans and Lakewide Management Plans shall embody a systematic and comprehensive ecosystem approach to ***restoring and protecting beneficial uses*** in Areas of Concern or in open lake waters.
>
> (b) Such Plans shall provide a continuing historical record of the assessment of Areas of Concern or Critical Pollutants, proposed remedial actions and their method of implementation, as well as changes in environmental conditions that result from such actions, including significant milestones in ***restoring beneficial uses*** to Areas of Concern or open lake waters. They are to serve as an important step toward virtual elimination of perisistent toxic substances and toward ***restoring and maintaining the chemical, physical, and biological integrity*** of the Great Lakes Basin Ecosystem.
>
> (GLWQA 1987, 51; emphasis added)

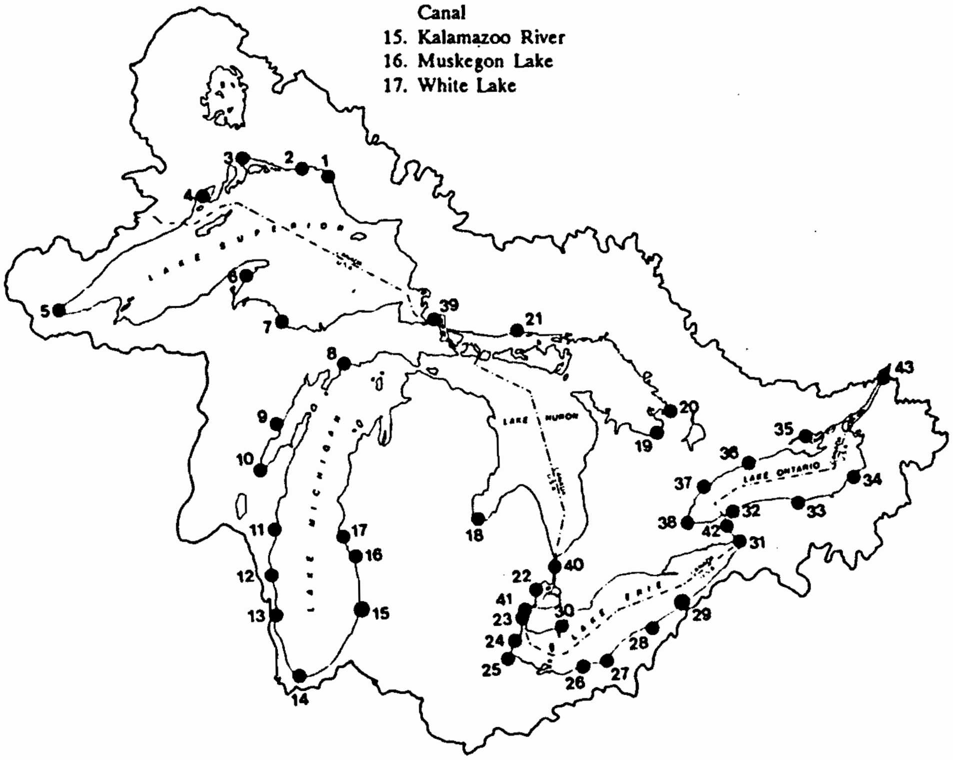
The intent of the Agreement is to protect human health and ecosystem integrity (GLWQB 1989, 61). Assessment of whether or not human health and ecosystem integrity is indeed being protected is tied to the concept of "impairment of beneficial use(s)." Impairment of beneficial uses are listed and defined below in Table 10-4.

From 1987 to 1991, the Great Lakes Water Quality Board maintained a responsibility for monitoring and reporting on progress in the development and implementation of the Remedial Action Plans (RAPs) and Lakewide Management Plans. Subsequently, that responsibility was returned to the Parties to the Agreement (GLWQB 1993, 1). Unfortunately, since that shift in roles occurred, no comprehensive reporting on progress has taken place. In its last RAP assessment, the Great Lakes Water Quality Board emphasized concern regarding the lack of progress in developing and implementing the Remedial Action Plans.

Lake Superior
1. Peninsula Harbour
2. Jackfish Bay
3. Nipigon Bay
4. Thunder Bay
5. St. Louis Bay/River
6. Torch Lake
7. Deer Lake/Carp Creek/River

Lake Michigan
8. Manistique River
9. Menominee River
10. Fox River/Southern Green Bay
11. Sheboygan River
12. Milwaukee Estuary
13. Waukegan Harbor
14. Grand Calumet River/Indiana Harbor Canal
15. Kalamazoo River
16. Muskegon Lake
17. White Lake

Lake Huron
18. Saginaw River/Saginaw Bay
19. Collingwood Harbour
20. Severn Sound
21. Spanish River Mouth



Lake Erie
22. Clinton River
23. Rouge River
24. River Raisin
25. Maumee River
26. Black River
27. Cuyahoga River
28. Ashtabula River
29. Presque Isle Bay
30. Wheatley Harbour

Lake Ontario
31. Buffalo River
32. Eighteen Mile Creek
33. Rochester Embayment
34. Oswego River
35. Bay of Quinte
36. Port Hope
37. Metro Toronto
38. Hamilton Harbour

Connecting Channels
39. St. Marys River
40. St. Clair River
41. Detroit River
42. Niagara River
43. St. Lawrence River (Cornwall/Massena)

Source: SAB 1993, 23

Figure 10-1. Forty-three Areas of Concern in the Great Lakes Basin.

TABLE 10-4. IMPAIRMENT OF BENEFICIAL USES AS DEFINED IN THE GREAT LAKES WATER QUALITY AGREEMENT.

"Impairment of beneficial use(s)" means a change in the chemical, physical, or biological integrity of the Great Lakes System sufficient to cause any of the following:

i. Restrictions on fish and wildlife consumption;
ii. Tainting of fish and wildlife flavour;
iii. Degradation of fish and wildlife populations;
iv. Fish tumours and other deformities;
v. Bird or animal deformities or reproduction problems;
vi. Degradation of benthos;
vii. Restrictions on dredging activities;
viii. Eutrophication or undesirable algae;
ix. Restrictions on drinking water consumption, or taste and odour problems;
x. Beach closings;
xi. Degradation of aesthetics;
xii. Added costs to agriculture or industry;
xiii. Degradation of phytoplankton and zooplankton populations; and
xiv. Loss of fish and wildlife habitat.

Source: GLWQA 1987, 49 - 50.

The above fragmented discussion of restoration reflects the lack of any overall inventory of restoration activities. On the other hand, public interest in restoration activities is growing and the number of restoration projects is increasing as communities move to rehabilitate degraded areas. These actions are motivated not only by aesthetics and the desire for an enhanced quality of life but also by the recognition that they are a seed to economic renewal as well.

In sum, restoration activities appear to be increasing but overall level of effort and success has never been inventoried and assessed. No system for tracking progress is in place. Together, these gaps represent important topics for follow-up research.

10.5 ASSESSMENT OF HUMAN-ECOSYSTEM INTERACTIONS IN THE GREAT LAKES BASIN ECOSYSTEM

Using the weight-of-evidence approach, conclusions can be drawn regarding the nature of human activities and the "value" they contribute to society - at least in economic terms. In the Great Lakes region, there is every reason to believe that ***human activities will be able to maintain or even increase their contribution to human well-being in an economic sense.*** Description, classification, and valuation of the broad range of monitored and non-monitored human activities using economic and other valuation approaches are all topics of current research.

Similarly, an overall conclusion can be drawn regarding the nature and extent of human-imposed stress on the ecosystem: ***imposed stress is likely on the increase.*** While this conclusion can be drawn by type of stress, the data are only beginning to be generated that link stresses to the human activities that impose them. Thus, the topic of activity-by-activity stress assessment emerges as a significant area of needed research.

An overall inventory and assessment of restoration activities in the Great Lakes Basin Ecosystem has never been undertaken. However, ***the number of restoration activities appears to be growing*** as public interest increases. Tracking and assessing restoration activities also emerges as an important area of needed research.

10.6 DOMAIN III — PEOPLE

> *DOMAIN DESCRIPTION: Data and information facilitating an assessment of the well-being of people and related decision-making including the range of physical, social, cultural and economic attributes.*
>
> *GOAL: To maintain or improve human well-being.*

The Domain III assessment includes consideration of the well-being of (1) individuals and families; (2) communities, and (3) institutions. Institutions include legislative, judicial, and corporate elements.[22] The assessment hierarchy shown in Figure 8-3 provides the organizational template.

While data are available for many of the most detailed topics found at the base of the indicator hierarchy shown in Figure 8-3, ***no systematic attempt has ever been made*** to bring this knowledge together and assess current, past, and anticipated future trends in human well-being across the Great Lakes Basin Ecosystem. Further, there are two significant gaps.

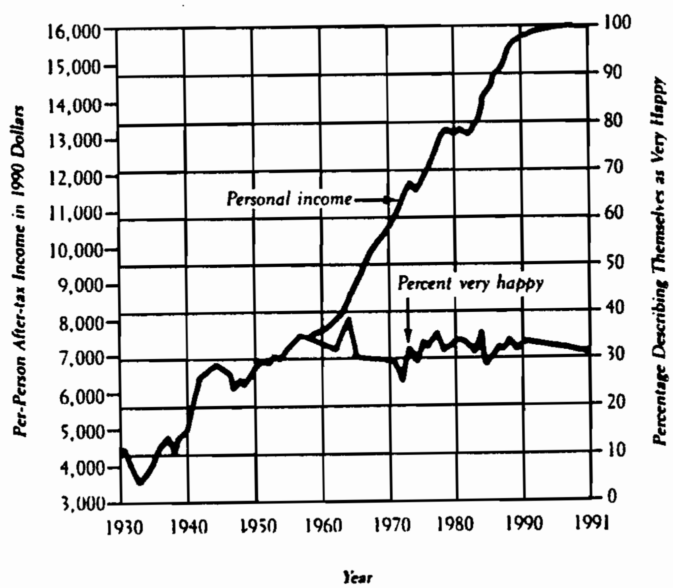
Remarkably, society has not developed an ongoing systematic approach to assessing the well-being of legislative and judicial institutions. From time-to-time relevant data are compiled that show, for example, that courts or penitentiaries are overcrowded or that respect for legislators has plummeted. The now defunct Law Reform Commission of Canada was periodically charged with examining some specific issue and Royal Commissions come and go. But no system has ever been established to set goals for our legislative and judicial institutions in terms of their effectiveness and subsequently develop measurable objectives that allow society to assess success. Such judgement is left to the election process and institutional weaknesses remain until either a crisis occurs to trigger some change or some champion appears with the resources necessary to lobby for change.

The required assessment of human well-being is complex and well beyond the limits of this case study. Not only do conditions and trends change over time, but also values change that influence both individual and collective interpretation of those conditions and trends. In spite of this difficulties, undertaking this task emerges as one of the most important recommendations for follow-up research.

Even though a systematic assessment has not been completed, two sets of observations are worthy of note. First, drawing from macroeconomic analyses, Testa points out that above average per-capita income persisted through the 1970s and "the region's intensive development provided a standard of living that had not been previously witnessed on so massive a scale" (1991, iv). This kind of observation suggests a high degree of human well-being.

However over the past several decades, a growing volume of literature has emerged that challenges the correlation that is made between material prosperity and overall well-being. Myers notes that between 1960 and 1990, after-tax income doubled in the United States while self-assessed "happiness" remained unchanged (see Figure 10-2 below). He also points out:

> Today's younger adults have grown up with more affluence, more depression, and more marital and family misery. They also know more of depression's consequences - suicide, alcoholism, and other forms of substance abuse.
>
> The same story holds true for the social well-being of adolescents. Between 1960 and the late 1980s, America's teens enjoyed the benefits of declining family poverty, smaller families, increased parental education, doubled per-pupil school expenditures (in constant dollars), double the number of teachers with advanced degrees, and an 11 percent drop in class size. Simultaneously, their delinquency rate doubled, their suicide rate tripled, their homicide rate tripled, and the birthrate of the unmarried nearly quadrupled. While standing tall during the 1980s believing a comfortable lie that all was well in a prosperous and militarily successful America, the uncomfortable truth was that social battles were being lost at home.
>
> (1992, 43)



Source: Myers 1992, 42.

Figure 10-2. After-tax income and happiness, 1930 - 1991.

10.7 ASSESSMENT OF HUMAN WELL-BEING IN THE GREAT LAKES BASIN ECOSYSTEM

These observations likely apply in the Great Lakes region as elsewhere. However, what is most important is that they challenge the commonly held concept that economic indicators of success always point to improved well-being. For this case study, they serve to bring emphasis to the need to undertake a systematic assessment of human well-being.

A second insight emerges from this Domain III assessment. It is that the natural boundary for Domain III analysis will almost inevitably be the secondary decision-making envelope rather than the primary ecosystem focus (see Figure 5-1). Data are compiled and emphasis for decision-making will be weighted on this basis. In a full Domain IV synthesis, this difference would have to be carefully weighed in the assessment process.

10.8 DOMAIN IV — SYNTHESIS

> ***DOMAIN DESCRIPTION:** Data and information facilitating an assessment of the whole: key linkages across the above three domains of data and information.*
>
> ***OVERALL GOAL:** To maintain or improve human and ecosystem well-being.*

The assessment hierarchy shown in Figure 8-4 provides the organizational template for undertaking the Domain IV synthesis. A summary of goals and principal conclusions drawn from the assessments for each of Domains I, II, and III is presented below in Table 10-5.

It is at this stage of the assessment process that the opportunity arises for identification of emergent properties that may not be evident from examination of any one of Domains I, II, or III on its own. Also, it is here that an integrated perspective can be achieved for decison-making and anticipatory analysis that spans the three previous Domains. And lastly, the stage is now set for addressing the inevitable situation in which the aggregated indicators of progress signal different trends in terms of progress toward sustainability.

TABLE 10-5. GOALS AND SUMMARY ASSESSMENTS, DOMAINS I, II, AND III.

goal	*assessment*
DOMAIN I - ECOSYSTEM	
1. ECOSYSTEM WELL-BEING: To maintain or improve ecosystem health and integrity.	While improvements have been achieved in a range of ecosystem characteristics over the past several decades, ecosystem well-being remains depressed. Current trends do not collectively signal that ecosystem health and integrity are being maintained or improved.
DOMAIN II - INTERACTION	
2. SUPPORT: To maintain or increase the ability of human activities to provide support for human well-being.	Human activities will be able to maintain or even increase their contribution to human well-being. Continued economic success as signalled by growth in value-added and employment can be expected.
3. STRESS: To reduce the physical, chemical, and biological stress imposed on the ecosystem by human activities.	The combined physical, chemical, and biological stress imposed on the ecosystem by human activities is likely on the increase.
4. RESTORATION: To increase the extent to which human activities restore ecosystem health and integrity.	Restoration activities are likely on the increase as public intrest grows. No overall inventory and assessment has been completed; no overall tracking system is in place to monitor and assess progress.
DOMAIN II - INTERACTION	
5. HUMAN WELL-BEING: To maintain or improve human well-being.	No systematic assessment of trends in human well-being in the Great Lakes region has been completed. A growing body of literature points out that once beyond poverty, further economic growth does not appreciably improve human moral. The International Joint Commission has repeatedly argued that human health is at risk from persistent toxic substances.

10.9 ASSESSMENT OF OVERALL PROGRESS TOWARD SUSTAINABILITY IN THE GREAT LAKES BASIN ECOSYSTEM

Five assessment elements are listed in Table 10-5. Together they amount to a shortlist of indicators of sustainability. Each is supported by a complex hierarchy of data and information that are scientifically defensible. In spite of limitations in current knowledge, the weight of evidence from these five indicators signals that ***the Great Lakes Basin Ecosystem is not currently on a path toward sustainability***. In particular, ecosystem health continues to deteriorate and imposed stress continues to grow. An overall assessment of trends in human well-being is lacking, not only in terms of individuals but also in terms of communities, and institutions. On the positive side, the ability of human activities to support human well-being from a material perspective appears to be growing and the number of initiatives aimed at ecosystem restoration is likely increasing.

It is essential that this kind of an assessment be put into a long-term historic context. For example, while (first order) trends in ecosystem conditions and imposed stress indicate movement away from sustainability, it is also apparent that many factors exhibit second order ***change*** that is positive. For example, the rate of waste generation may still be growing but at a rate that is slower than say three decades ago. In a comprehensive analysis these longer term characteristics would be carefully established and assessed.

Similarly, in a comprehensive analysis, the implications of current trends for future conditions would also be considered. For the very short term of a year or two this component of the analysis could contribute to predicting the requirements for say public expenditures on infrastructure. In the longer term, alternative scenarios might be constructed against which to test current public policy. Most powerfully, the anticipatory analysis can be used as a component of an exercise that designs needed present-day policies by starting with a future desired state and "backcasting" to current conditions.

While some scenario analysis has been completed for the Great Lakes Basin from time-to-time (for example, see Great Lakes Basin Commission, 1975) and backcasting has been specifically used as an approach to energy analysis for Ontario (see for example, Torrie, 1984) these approaches have not yet been applied to assessing progress toward sustainability in the Great Lakes Basin Ecosystem.

10.10 FOCUS ON ENERGY AND WATER

The preceding discussion serves to illustrate the general application of the proposed system of reporting on sustainability. It has focussed on the process of achieving a final integrated assessment of progress toward sustainability.

What remains is to demonstrate application at a more detailed level. To do so, two sub-systems will be examined, energy (production, transportation and use) and water.

END NOTES

1. The natural, modified, cultivated, built classification is proposed by Robert Prescott-Allan and is described in IUCN et al. 1991, 34.

2. The "tolerable loss rate" is defined as the maximum rate at which soil can be eroded and maintain productivity. There is much debate about whether or not this rate assures long-term productivity (see Colborn et al. 1990, 44).

3. Development Consulting House and Land Resource Research Institute 1986.

4. Colborn et al. 1990, 44.

5. Extreme cases of groundwater mining have taken place in the Chicago - Milwaukee area. The Lake Winnebago area and Green Bay, Wisconsin are other examples. It appears to be an emerging problem in growing suburban residential areas of southern Ontario (Hodge 1990, 451- 452).

6. In 1993, the Science Advisory Board of the International Joint Commission concluded that "after seven decades of initiatives to clean up toxic pollutants in the Great Lakes, there are insufficient data to measure past success and establish the benchmarks needed to direct future efforts. Available data do not substantiate success with these initiatives (SAB 1993, 9).

7. GLWQB 1991, 42.

8. Nonpoint or diffuse sources include contaminated aquatic sediments, urban runoff, the broad use of chemicals in agriculture, forestry, and transportation; vehicular emissions; and general contaminants in rain, snow, and dry atmospheric fallout from all sources.

9. Although data on spills are sketchy, there appears to be approximately 3,000 significant accidental releases of hazardous substances per year in the eight Great Lakes states and Ontario. These accidental releases may significantly exceed the impact of regulated point source discharges. One analysis of two styrene spills into the St. Clair River found them to be equivalent to the pollution loadings of 1,428 and 58 years of the respective point source discharges (SABTC 1988, 2-3).

10. Colborn et al. 1990, 60 - 66.

11. Colborn et al. 1990, 66 - 71.

12. Shands ed. 1988; Shands and Dawson 1985; Scarratt 1988.

13. The dramatic shift in attitude towards forests that occurred between about 1950 and 1980 is discussed by Hays, 1983. Thompson and Webb, 1994, document the results of a Forest Round Table that brought together industry, labour, environmental group, and community representatives from across Canada specifically aimed at dealing with alternative value sets regarding forests. This kind of bridging would never have occurred even ten years ago.

14. In 1985, the land value of commercial fishing in the Great Lakes was about $41 million while sport anglers were estimated to have spent $2 billion in the same year (Colborn et al. 1990, 150).

15. The Nature Conservancy 1994, 15 - 19.

16. Entry vectors of exotic species introduced in the Great Lakes since the late 1800s include:

vector	*number of exotic species introduced*
waterfowl, birds	8
range expansion	3
infected fish	2
fish stocking	11
canals	3
bait/culture	5
unknown	10
ship ballast water	27
TOTAL	69

Source: Dochoda, Hamilton, and Bandurski 1990, 24.

17. For example, the sea lamprey has devastated lake trout populations and annual direct expenditures on lamprey control now amount to $10 million. Costs of controlling the recently introduced zebra mussel may reach $100 million annually (IJC and GLFC 1990, 1 - 2).

18. Reports that include such data include the final report of the Niagara River Toxics Committee (1984), the Niagara River Toxics Management Plan (Niagara River Secretariat, 1988, 1990), the Lake Ontario Toxics Management Plan (Lake Ontario Toxics Committee, 1989), the final report of the Upper Great Lakes Connecting Channel Study (UGLCCS, 1988), many of the reports completed in development of the Remedial Action Plans for the 43 Areas of Concern in the Great Lakes basin, and the base data reports gathered in development of Ontario's Municipal-Industrial Strategy for Abatement or MISA program. Almost all of these focus on contaminant emissions to water.

19. USEPA, 1989.

20. The Society for Ecological Restoration held its first annual conference in 1989. It is committed to the development of ecological restoration as a science and art - a conservation strategy and a way of defining and celebrating a mutually beneficial relationship between human beings and the rest of nature. They publish a biannual journal, Restoration and Management Notes (1207 Seminole Highway, Madison, Wisconsin, 53711 USA). The topic was reviewed 9, 16 March, 1992 on CBC IDEAS.

21. Daly and Cobb point out that a group of people can be called a community if:

> a. membership in the group contributes to self- identification;
> b. there is extensive participation by its members in the decisions by which its life is governed;
> c. the group as a whole takes responsibility for its members; and
> d. this responsibility includes respect for the differences among these members.
>
> (1989, 49 and 172)

Using this definition, a community could be based on a range of motivating factors such as ethnicity, gender, religion, geography, politics or interest. However, typical community statistics are gathered, not on the basis of these factors but on the basis of a local government jurisdiction. Strictly speaking, such a local government is an incorporated institution. However, particularly in small communities, the local government reflects, at least to some extent, the local community as defined by Daly and Cobb above. Thus in this work and as an initial position, community and local government were treated as one. This topic requires further research.

22. Institutions include:

a. Lesislative: those that make the rules by which society governs itself;
b. Judicial: those that interpret and apply the rules;
c. Corporate: those that are formally incorporated under some piece of legislation including:

- for-profit businesses;
- not-for-profit voluntary organizations, churches, and trusts;
- professional associations;
- co-operatives;
- hospitals;
- unions; and
- universities, colleges, and community colleges.

Government functions both as a rule maker and a corporate entity. In the first of these functions, it must concern itself with the entire ecosystem, including people, within its boundaries. As a corporate entity it has internal responsibilities no different than any other corporation. These two functions are often confused, particularly from a reporting perspective. For example, from a financial perspective, the Federal Government must monitor itself as a corporate entity dealing with income, expenditures, deficits and so forth. This aspect of reporting is very different than reporting on the national economy in which the Federal government is only one player, albeit a significant player (see discussion in NRTEE 1983, 41-46).

CHAPTER ELEVEN.

ENERGY PRODUCTION, TRANSPORTATION, AND USE IN THE GREAT LAKES BASIN ECOSYSTEM

11.1 INTRODUCTION

Energy production, transportation, and use are obvious foci for assessing progress toward sustainability. They provide vital services and simultaneously, a high degree of stress is imposed on the ecosystem. There are a limited number of energy sources and forms and security of supply is both a national and regional concern.

In this case study, energy production, transportation, and use are included as examples of human activities within Domain II. They span monitored and non-monitored activities and thus show as "combinations" on the Domain II assessment hierarchy (Figure 8-2).

The set of three Domain II goals (Table 5-4) provide a general assessment framework. Re-stated in terms of energy, they are:

> (1) to maintain or increase the ability of energy production, transportation, and use to provide support for human well-being;
>
> (2) to reduce the physical, chemical, and biological stress imposed on the ecosystem by energy production, transportation, and use; and
>
> (3) to increase the extent to which energy production and transportation activities can be modified or directed to facilitate restoration of ecosystem health, integrity, and well-being.[1]

Any given activity uses energy both directly and indirectly and thus there are both direct and indirect environmental implications. Direct energy use encompasses energy consumed as part of any activity itself. In contrast, indirect energy use includes (1) energy consumed during prior contributing activities and (2) energy used in creation of the capital used in the current activity (see discussion in Brooks 1981, 278 - 279).

For example, direct energy used in agriculture would include farm heating, lighting, and equipment fuel while the energy used to manufacture the farm equipment and produce fertilizers and pesticides is considered indirect energy. Similarly, in automobile transport, the total energy use includes the "direct" consumption of gasoline as well as the "indirect" energy used to produce the car, highway, and materials of which they are made. Analysis of any activity should be sensitive to total energy use as part of full-cost accounting. However, only direct energy use is considered here. Inclusion of total energy use analysis (direct plus indirect) is beyond the scope of this case study.

11.2 TWO APPROACHES TO DEFINING "THE ENERGY PROBLEM"

Over the past two decades, a debate has developed regarding how to define "the energy problem" (Brooks et al. 1983, 2 - 3 give a useful summary). The more conventional and older approach focuses on ensuring that adequate supplies exist to meet present and future energy demands (for example, see EMR 1976, and Natural Resources Canada, 1993). This approach can be seen as a kind of "top-down" approach in which energy demand is considered a "given" driven the economy and demographic variables. This given must be satisfied by an adequate supply of energy. Analysis and policy are oriented around predicting most likely levels of future demand and establishing programs to ensure that sufficient supplies will be available when required.

The importance of estimating future energy needs is based on the long lead time required to design and construct major power generating facilities such as thermal generating plants (coal, oil, nuclear), and hydro-electric facilities. If needs are underestimated, industrial and commercial activity will be suppressed; if needs are overestimated, expensive capital facilities will lie idle and serve to further drain the economy.

In the late 1970s and motivated by both environmental and economic concerns, a second approach emerged that identifies ***both*** demand and supply as policy-determined variables (SAB 1982, 27). In simple terms, this perspective recognizes that reduction of demand can satisfy the demand - supply balance as well as increasing supply. Proponents recognize that:

> ...energy use is only a means to an end, not an end in itself, and that the purpose of energy use is to supply particular services, such as heat, motive power, and so on.
>
> (Brooks et al. 1983, 3)

In analysis, this second approach first emphasizes the consumption (demand) side of the equation rather than the production (supply) side of the equation. A detailed "bottom-up" disaggregation of the end-use tasks that energy must perform is completed first. Supply options are examined second. As much consideration is given to the potential for reducing the level of energy end-use as it is to supplying needs in the most appropriate manner.

An anticipatory stance is achieved, not by attempting to predict the future but rather by choosing desirable future characteristics (say greater efficiency, less environmental stress) and "backcasting" to the present to design and choose a suite of actions required to achieve that future (Robinson, 1982). Programs are aimed at (1) reducing demand and (2) matching end-use requirements to supply in an overall energy regime that is technically efficient, least cost, and imposes a minimum of stress on the ecosystem.

The energy supply mix that results is typically smaller scale, more decentralized, less technically complex, and more dependent on renewable forms of energy than those that result from the former analysis. As a result, this second kind of approach has come to be known as a "soft energy path analysis" (Lovins, 1979) in contrast to the conventional approach that has led to the large, highly centralized, complex, "hard" energy systems that have characterized industrialized nation development since World War II.[2]

These two approaches reflect different sets of underlying values. The value base of the earlier supply side approach is rooted in a kind of laissez-faire doctrine of consumer sovereignty (Brooks et al. 1983, 2 and Brooks 1981, Chapter 5). As a result, energy-related decision-making is driven by short-term economic implications of various supply options.

In contrast, a soft path analysis has at its foundation the very value set that underlies the concept of sustainability - a parallel concern and respect for the ecosystem and people within - not one or the other, not one more than the other, but both together.[3] As a result, in a soft-path approach, decision-making is driven by much broader technical, economic, social, and environmental implications of both energy end-use and the various supply options. The insights offered by the soft energy path approach are used in this case study.

11.3 ENERGY EFFICIENCY, QUANTITY, AND QUALITY

Energy cascades from being a primary source (e.g. coal and peat, natural gas, crude oil, hydro potential, nuclear fuel, sunlight, wind, biomass) to a secondary form (coal and peat, coke, coke oven gas, natural gas, refined petroleum products, active solar, biomass solids, methanol, vegetable oils, biogas and electricity), and a tertiary form which actually provides the desired services such as motion, light, or heat. Brooks points out:

> ...primary energy includes energy measured (by volume and by value) at the point of production whereas secondary energy includes energy measured at the point of consumption. . . Secondary energy is always less than primary for three reasons: (1) the energy-supply industry consumes or loses energy in processing and transportation; (2) some primary energy is used to make petrochemicals and other non-energy products; and (3) roughly three units of fossil-fuel energy must be consumed to obtain one unit of thermally-generated electricity ... Ideally, in studying the use of energy, one would work with what could be called "tertiary" energy, i.e., the energy that actually does work for us by moving wheels, providing lights, or keeping us warm. Tertiary energy would be still smaller than secondary because of inefficiencies in the consuming system, and it would vary with the form in which the energy is supplied. (Gas furnaces, for example, tend to be more efficient in use than oil furnaces; electricity is most efficient for lighting.) However, except in a few cases, as with different systems for space heating, data are not available to permit analysis in terms of tertiary energy.
>
> (1981, 271)

At each transformation point from primary to secondary to tertiary, some amount of energy is given up to the transforming process and a lesser amount is thus subsequently available for doing work. The energy given up goes to heat, noise, light, or some other form that can't be re-captured, but overall the amount of energy is always conserved. This principle of the conservation of energy is called the First Law of Thermodynamics.

The ratio of energy output to input through any process provides a measure of "First Law" efficiency. It is this measure of efficiency that is commonly understood when the issue of efficiency is addressed. From a societal perspective, the overall "First Law" efficiency of energy use depends on such factors as the nature of the processes that transform energy from primary source through secondary form to tertiary use, the effectiveness of transportation and transmission systems, and losses through accidents, spills, and poor insulation, (Torrie 1977, 6-11). Monitoring this "First Law" efficiency provides an important contribution to systematically assessing progress toward sustainability.

However, there is another aspect of efficiency that is not captured in the above. From the point of view of the energy user, a certain quantity of energy may be of differing value depending upon the amount of "useful work" that it can provide. For example, a unit of electricity can be used for many more things than a unit of energy produced by a living room fireplace - even though the quantity of energy is the same in both cases. This difference is embodied in the concept of "energy quality," a measure of the amount of "useful work" that can be extracted from the total energy contained in that form (Brooks et al. 1983, 3 and see also, Brooks, 1981, Appendix A and Lovins, 1977, Chapter 4).

The issue of energy quality is important because it introduces a notion of efficiency that is not captured in the "First Law" efficiency described previously. It recognizes that technical and economic efficiencies can be gained by matching end-uses with an appropriate quality of energy. This aspect of efficiency has come to be known as "Second Law" efficiency because of its link to the Second Law of Thermodynamics. Formally stated, this law is:

> A natural process that starts in one equilibrium state and ends in another will go in the direction that causes the entropy (or disorder) of the system plus environment to increase.
>
> (modified from Halliday and Resnick 1966, 638 - 642)

In rough terms and applied to energy production, it can be more simply expressed as "the quality of energy is *always diminished* (that is, becomes less valuable to us afterwards than it was before)" (Brooks 1981, 269).

The idea of calculating Second Law efficiency was first proposed in 1974 by the American Physical Society and the International Federation of Institutes of Advanced Study. They defined Second Law efficiency as the ratio of the least available work (energy) that could have done the job to the actual available work (energy) that was used to do the job (Torrie 1977, 6-12).

In principle, monitoring Second Law efficiency is as important to assessing progress toward sustainability as monitoring First Law efficiency. In reality, energy accounting systems are entirely geared to energy quantity and not quality. This is a serious limitation given that the largest gains in efficiency that remain are likely to be realized through (1) matching energy end uses to energy forms of appropriate quality and (2) by finding clever ways of doing things that create greater opportunities for being efficient (e.g. from prolonging the life of physical resources (through improved technology of materials use, increased product lifetimes, recycling)[4] and from increasing the efficiency of providing real services, not just energy, to users. (See discussion in Brooks 1981, 274 -5).

The only comprehensive study that has addressed both issues of quantity and quality in Canada is summarized by Brooks et al., 1983. This work starts with a 1978 data base and considers energy futures for the years 2000 and 2025. In their work, independent teams in each province and territory completed analyses that were then aggregated to national totals. Smith and Torrie provide a 1988 end-use analysis for Ontario at the sector level (1991, 7 - 18). No equivalent analysis has been completed for the United States as a whole or the eight Great Lakes states. In practice, no system exists that monitors Second Law efficiency throughout society.

11.4 END-USE ANALYSIS

Following the logic of the above discussion, the starting point for developing a system of monitoring and assessing energy production and use is appropriately a detailed end use analysis that considers both energy quantity and quality. Each of the residential, commercial, industrial, transportation, sectors are initially considered separately and subsequently aggregated. Sectors are disaggregated in a way that is as consistent as possible with the Standard Industrial Classification. Table 11-1 below lists a typical breakdown and Table 11-2 lists the four end-use categories that provide a rough link to energy quality. Table 11-3 provides the resulting end use analysis for Ontario.

TABLE 11-1. ENERGY END-USE ANALYSIS CATEGORIES.[5]

Residential	*Commercial*
single family detached	offices
single family attached	schools/universities
apartments	hospitals
mobile homes	stores/shops
	hotels/motels/restaurants
	government street light
Industrial	*Transportation*
agriculture	air
forestry	water
fishing, hunting, trapping	rail
iron mines	auto
other mining	truck
food processing	bus
pulp and paper	
iron and steel	
smelting and refining	
cement	
chemicals	
other manufacturing	
construction	

Source: Hodge and Ehrlich 1983, 4.

Table 11-1 demonstrates a critical link between this energy analysis and the Domain II analysis. The "standard activity classification" that builds on the standard industrial classification provides a common organizational format. In this case, the Residential sector has been added which provides a natural link with the "household" estimate of value-added listed in the Appendix I activity indicators. In addition, it is important in energy analysis to identify a "Commercial" category which is easily built from a number of elements of the standard industrial classification.

TABLE 11-2. END-USE CATEGORIES THAT REFLECT ENERGY QUALITY.

(1) **HEATING AND COOLING** (for warmth or comfort): mainly low-temperature heating and cooling of air and domestic hot water;

(2) **PROCESS HEAT**: heat used in industrial processes, either intermediate (100 to 260 C) or high (greater than 260 C);

(3) **LIQUID FUEL**: land, sea, and air transport, as well as other activities requiring portable energy;

(4) **ELECTRICITY SPECIFIC**: lighting, communications, stationary motors, and other activities requiring clean, high quality, highly controllable energy.

Source: Bott et al. 1983, 45 and 53.

TABLE 11-3. ENERGY END-USES IN ONTARIO, 1978. ALL FIGURES IN PETAJOULES.

	Coal & Peat	Natural Gas	RPP's	Electricity	Biomass Solids	Biomass Fluids	Active Solar	Total
Residential								
Heating & Cooling	--	183.90	172.00	50.60	5.00	--	--	411.50
Electricity Specific	--	--	--	60.30	--	--	--	60.30
Total	--	183.90	172.00	110.90	5.00	--	--	471.80
Commercial								
Heating & Cooling	--	130.10	69.37	2.27	--	--	--	201.74
Electricity Specific	--	--	--	93.63	--	--	--	93.63
Total	--	130.10	69.37	95.90	--	--	--	295.37
Industrial								
Heating & Cooling	--	22.40	--	--	--	--	--	22.40
Process Heat-Intermediate	--	181.00	48.80	--	--	--	--	229.80
Process Heat-High	128.40	114.10	69.30	46.60	--	--	--	358.40
Electricity Specific	--	--	--	74.40	--	--	--	74.40
Liquid Fuel	--	--	44.40	--	--	--	--	44.40
Total	128.40	317.50	162.50	121.00	--	--	--	729.40
Transportation								
Electricity Specific	--	--	--	0.70	--	--	--	0.70
Liquid Fuel	--	--	587.00	--	--	--	--	587.00
Total	--	--	587.00	0.70	--	--	--	587.70
Totals								
Heating & Cooling	--	336.40	241.37	52.87	5.00	--	--	635.64
Process Heat-Intermediate	--	101.00	48.00	--	--	--	--	229.00
Process Heat-High	128.40	114.10	69.30	46.60	--	--	--	358.40
Electricity Specific	--	--	--	229.03	--	--	--	229.03
Liquid Fuel	--	--	631.40	--	--	--	--	631.40
Total	128.40	631.50	990.87	328.50	5.00	--	--	2084.27

Source: Torrie 1984, 44.

11.5 BALANCING END-USE REQUIREMENTS WITH APPROPRIATE SECONDARY FORMS AND PRIMARY SOURCES

In a comprehensive energy review, the end-use compilation is followed with a supply analysis which draws on estimates of current and future prices and availability of the range of energy forms. Scale, proximity of source to use, and energy quality are all factors that are considered (Hodge and Ehrlich 1983, 4). Table 11-4 shows the production of primary sources and secondary forms for Ontario in 1978. It is the companion table to Table 11-3.

TABLE 11-4. PRODUCTION OF PRIMARY SOURCES AND SECONDARY FORMS IN ONTARIO IN 1978. ALL FIGURES IN PETAJOULES.

PRIMARY SOURCES					SECONDARY FORMS					
SOURCE	PRODUCTION	NET INFLOW	AVAILABILITY	ENERGY SUPPLY SECTOR	PRODUCTION	NET INFLOW	ENERGY SUPPLY SECTOR	NON-ENERGY USE	ENERGY USE	FORM
Coal & Peat	--	478.20	15.40	--	15.40	--	--	--	15.40	Coal & Peat
			142.80	12.20	130.60	(0.40)	--	60.30	69.90	Coke
			47.10	4.00	43.10	--	--	--	43.10	Coke Oven Gas
			272.90	175.70	97.20	*	*	*	*	Electricity
			--	--	--	--	--	--	--	Methanol
Natural Gas	11.60	702.50	678.70	--	678.70	--	25.30	21.90	631.50	Natural Gas
			35.40	19.60	15.80	*	*	*	*	Electricity
Crude	3.60	1222.17	1203.27	17.50	1185.77	81.40	114.70	161.60	990.87	RPP's
			22.50	15.00	7.50	*	*	*	*	Electricity
Uranium	353.20	--	353.20	247.20	106.00	*	*	*	*	Electricity
Hydro	141.00	--	141.00	--	141.00	*	*	*	*	Electricity
Active Solar	--	--	--	--	--	--	--	--	--	Active Solar
			--	--	--	*	*	*	*	Electricity
Wind	--	--	--	--	--	*	*	*	*	Electricity
Biomass	5.00	--	5.00	--	5.00	--	--	--	5.00	Biomass Solids
			--	--	--	--	--	--	--	Methanol
			--	--	--	--	--	--	--	Vegetable Oil
			--	--	--	--	--	--	--	Biogas
			--	--	--	*	*	*	*	Electricity
					[367.50]	(2.40)	36.60	--	328.50	Total Electricity
Total	514.40	2402.87	2917.27	491.20	2426.07	78.60	176.60	243.80	2084.27	Total

*All flows of secondary electricity are shown on the Total Electricity Line.

Source: Torrie 1984, 45.

11.6 MONITORING AND ASSESSING ENERGY PRODUCTION, TRANSPORTATION, AND USE

Building on the preceding discussion, a list of indicators can be developed that would effectively allow a given jurisdiction to monitor energy production, transportation, and use as a part of assessing progress toward sustainability. In Table 11-5, eleven indicators are identified, grouped into five categories:

I. Quantity and Quality of Energy Produced, Imported, and Used;
II. Efficiency of Transformation and Use;
III. Imposed Stress;
IV. Longevity of Energy Supply; and
V. Restoration.

A sixth category then similarly addresses energy for export and an additional five indicators are listed. The separate consideration of energy for domestic and export uses is necessary because of the very different policy considerations that are evoked by each.

In each case, a specific objective is first articulated that reflects the three Domain II goals. The list of sixteen indicators found in Table 11-5 is modified from Marbek Resource Consultants (1990). Their work follows closely from the Soft Energy Path analyses of the 1970s and 1980s from which the above discussion was drawn.

This approach to assessing energy production, transportation and use is mapped on the assessment hierarchy shown in Figure 11-1 As with the assessment hierarchies introduced in Figures 8-1 through 8-4, Figure 11-1 is intended as a kind of template to guide assessment. Specific indicators will be chosen depending on local conditions.

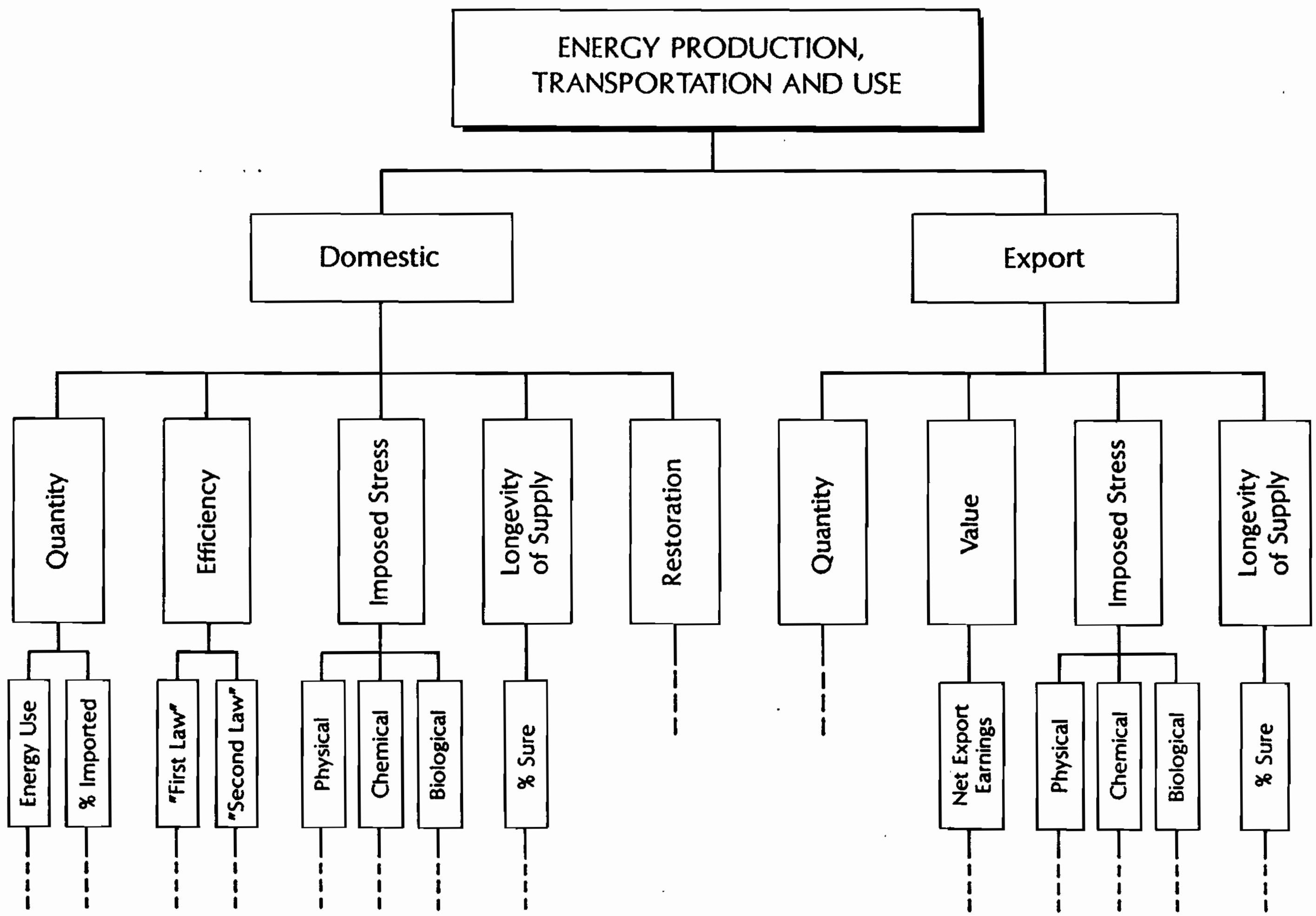


Figure 11-1. Assessment hierarchy for monitoring energy production, transportation, and use as a part of assessing progress toward sustainability.

TABLE 11-5. ENERGY INDICATOR DESCRIPTIONS.

I. ENERGY QUANTITY AND QUALITY (DOMESTIC)[6]

> ***Objective:*** *To reduce and minimize the quantity of energy produced, imported, and used for domestic purposes while maintaining or improving needed services.*

INDICATOR 1. SECONDARY ENERGY USE BY ACTIVITY AND QUALITY

- quantity by activity, quality, and form: national, province/state, region, and community, by subsector, sector, and total (gigajoules or equivalent per year)

INDICATOR 2. PROPORTION OF END USE MET WITH IMPORTED ENERGY

- national, province/state, region, and community, by subsector, sector, and total (percentage)

INDICATOR 3. SECONDARY ENERGY INTENSITY[7]

(energy use (gigajoules) per capita or some other variable such as passenger, floor area, or dollar of value-added)

- national, province/state, region, and community energy use per capita (gigajoules or equivalent per person)
- residential energy use per capita - total and by housing type (gigajoules per person)
- passenger transportation energy use per capita — total and by mode (gigajoules per person)[8]
- freight transportation energy use per tonne-kilometre of freight — total and by mode (gigajoules per tonne-kilometre)
- commercial energy use per area of floor space — total and by subsector (gigajoules per square meter of floor space)
- industrial energy use per dollar of value added — total and by subsector (gigajoules per dollar of value added)

II. ENERGY EFFICIENCY

Objective: To increase and maximize both the "First Law" and "Second Law" efficiencies of transformation from primary sources to secondary forms and tertiary services.

INDICATOR 4. "FIRST LAW" EFFICIENCY

- national, provincial/state, or regional secondary/primary ratio (dimensionless ratio or expressed as percentage) — total and by primary energy source

(Note: if data on tertiary energy use were available, a better indicator would be the tertiary/primary ratio.)

INDICATOR 5. "SECOND LAW" EFFICIENCY

- national, provincial/state, or regional ratio of the least available work (energy) that theoretically could provide the required services to the actual available work (energy) that was used to provide the required services (dimensionless ratio or expressed as percentage) — by subsector, sector, and total)

III. IMPOSED STRESS

Objective: To reduce and minimize the total and per unit of energy - imposed physical, chemical, and biological stress on the ecosystem.

INDICATOR 6. IMPOSED PHYSICAL STRESS AS A RESULT OF ENERGY PRODUCTION AND TRANSPORTATION - NATION, PROVINCE/STATE, REGION, COMMUNITY:

- land area affected[9] — total and per unit of energy (hectares per gigajoule)
- noise levels generated — total and per unit of energy (appropriate units)
- heat discharged — total and per unit of energy (appropriate units)
- solid waste generated — total and per unit of energy (appropriate units)

Indicator 7. Imposed Chemical Stress as a result of energy production and transportation — Nation, Province/State, Region, Community

- emissions of common and toxic contaminants to air, surface water, groundwater, and land — total and per unit of energy by contaminant species (tonnes per year and per gigajoule) — subsector, sector and total (could be grouped by issues of concern such as greenhouse gases, contributors to acid deposition, artificial estrogens, etc.)

Indicator 8. Imposed Biological Stress as a result of energy production and transportation — Nation, Province/State, Region, Community

- area of habitat degraded or lost (hectares)
- migration routes blocked or disrupted (streams or rivers blocked; hectares disrupted)
- introduction of exotic species; (numbers of species introduced)

IV. LONGEVITY OF DOMESTIC ENERGY SUPPLY[10]

Objective: *To ensure longevity of energy supply for domestic purposes.*

Indicator 9. Primary Energy Supply by Source

- annual primary energy supply by source — nation, province/state, region, community, sector, sub-sector (gigajoules per year and percentage of total)

Indicator 10. Proportion of Domestic Energy Use Met by Abundant Resources.

- proportion of resources that are renewable or have reserves adequate to meet current levels of Canadian use for more than (say) 50 years[11] — Nation, Province/State, Region, Community, sector, sub-sector (percentage)

V. RESTORATION

Objective: To ensure restoration efforts are a part of all energy production activities.

Indicator 11. Restoration Interest.

- proportion of energy producing facilities that include restoration as an explicit element of their corporate management strategy (percentage)[12]

VI. EXPORTS

Objectives:

1. Following provision of domestic needs in both the short and long term, to generate foreign earnings from the export of energy resources for the benefit of Canadians and investors;

2. To do so in a way that increases or maximizes both the "First Law" and "Second Law" efficiencies of transformation from primary sources to secondary forms and tertiary services.

3. To reduce and minimize the total and per unit of energy — imposed physical, chemical, and biological stress on the ecosystem.

Indicator 12. Net Energy Export

- quantity of net energy exports (gigajoules) - nation, province/state, region by energy source
- value of net energy exports (dollars) - nation, province/state, region by energy source[13]

Indicators 13, 14 and 15.

Imposed Stress - Total and Per Unit of Energy Produced or Used (Export)

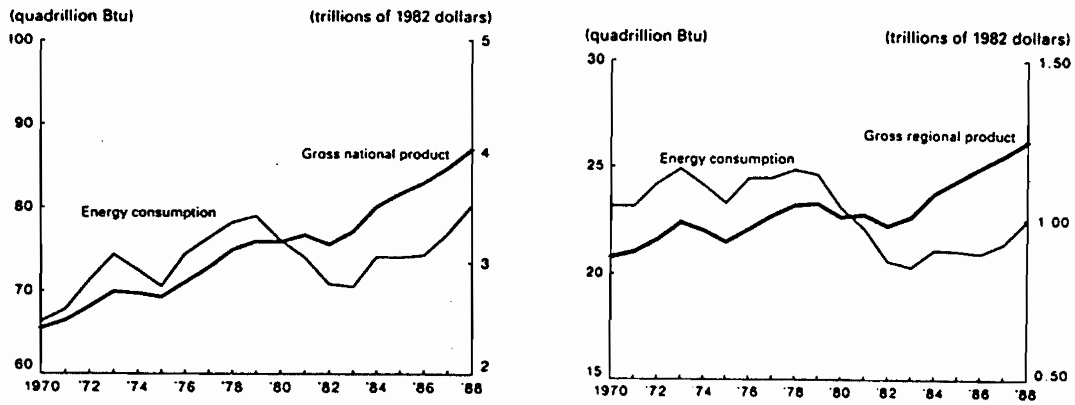
- PHYSICAL - see indicator 6
- CHEMICAL - see indicator 7
- BIOLOGICAL - see indicator 8

Indicator 16. Proportion of Energy Exports Met by Abundant Resources

- proportion of exports that are renewable or have abundant reserves - reserves adequate to meet say combined domestic and export demands over the next 50 years.

11.7 APPLICATION IN THE GREAT LAKES ECOSYSTEM

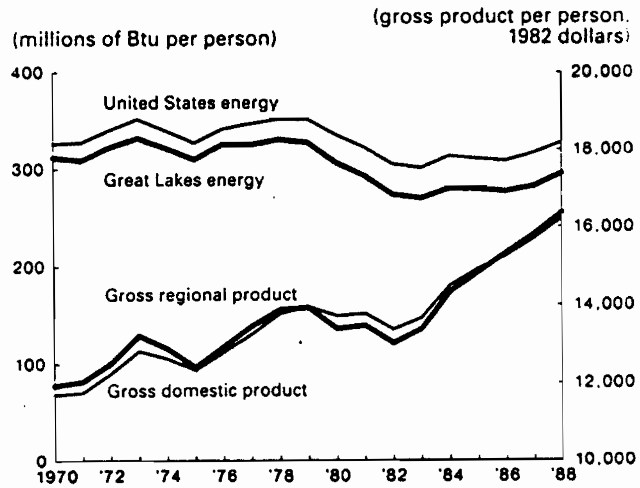
The only review of energy production, transportation and use that synthesizes data from the eight Great Lakes states and Ontario in an effort to consider the Great Lakes Ecosystem was completed by the Great Lakes Science Advisory Board (SAB, 1982). Bournakis and Hartnett provide a more recent review dealing with energy in the eight Great Lakes states (1991). Figures 11-2 through 11-8 illustrate typical indicators used to describe the energy regime.



a. United States b. Sum of Eight Great Lakes states.

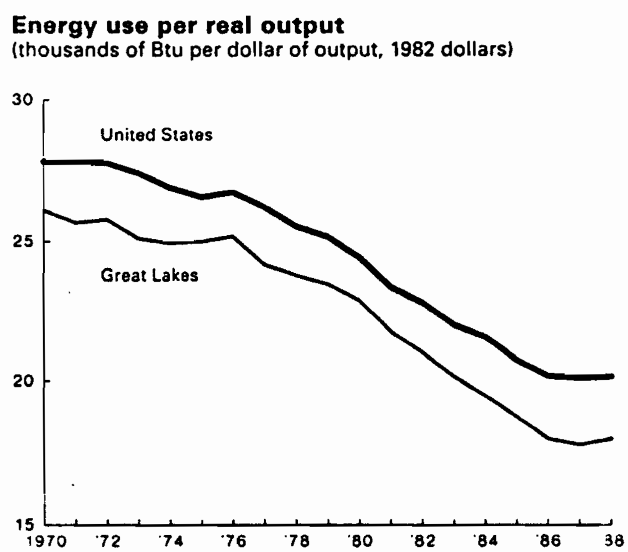
Source: Bournakis and Hartnett 1991, 72 - 73

Figure 11-2. Total energy use and gross national/regional for the United States and the eight Great Lakes states, 1970 to 1988.



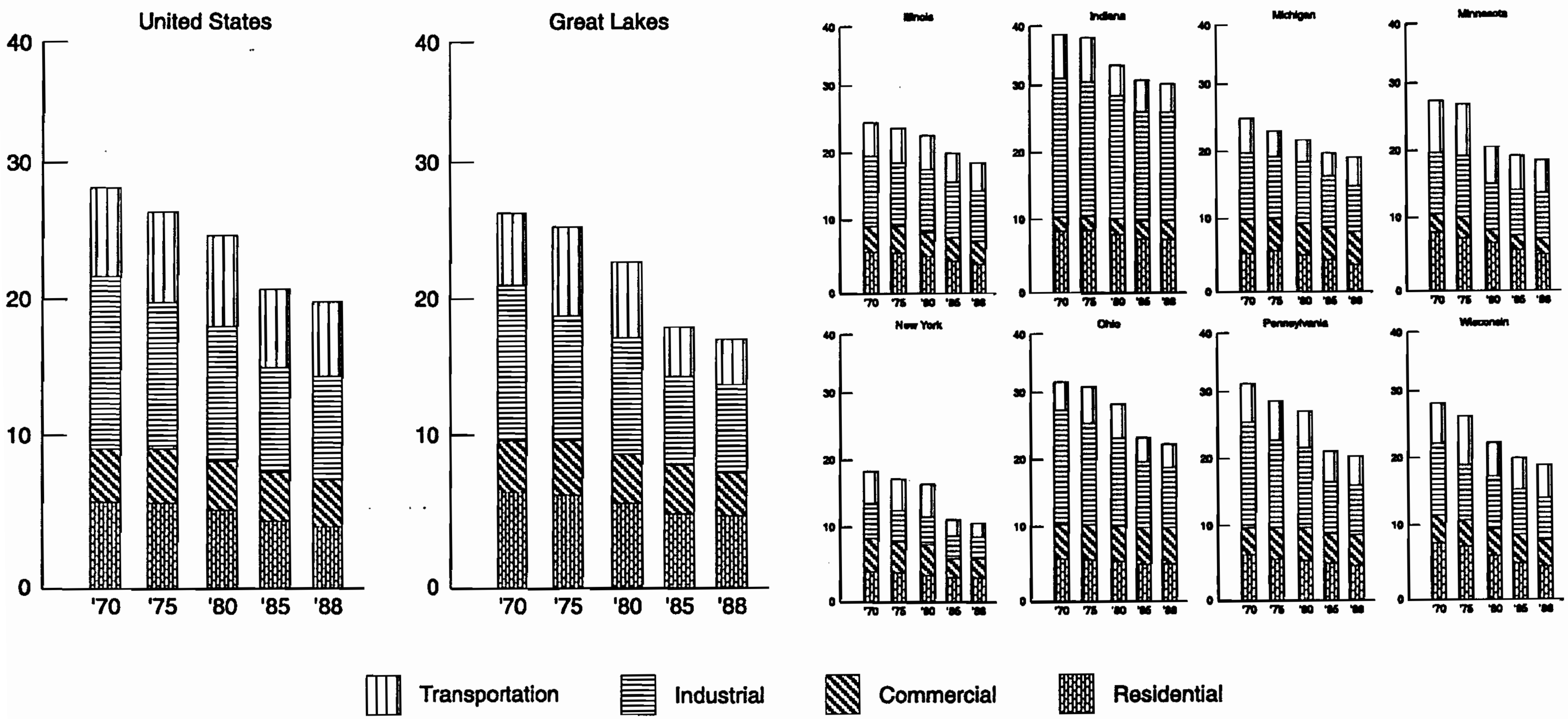
Source: Bournakis and Hartnett 1991, 74

Figure 11-3. Per capita energy use and per capita gross domestic and regional product for the United States and the eight Great Lakes states.



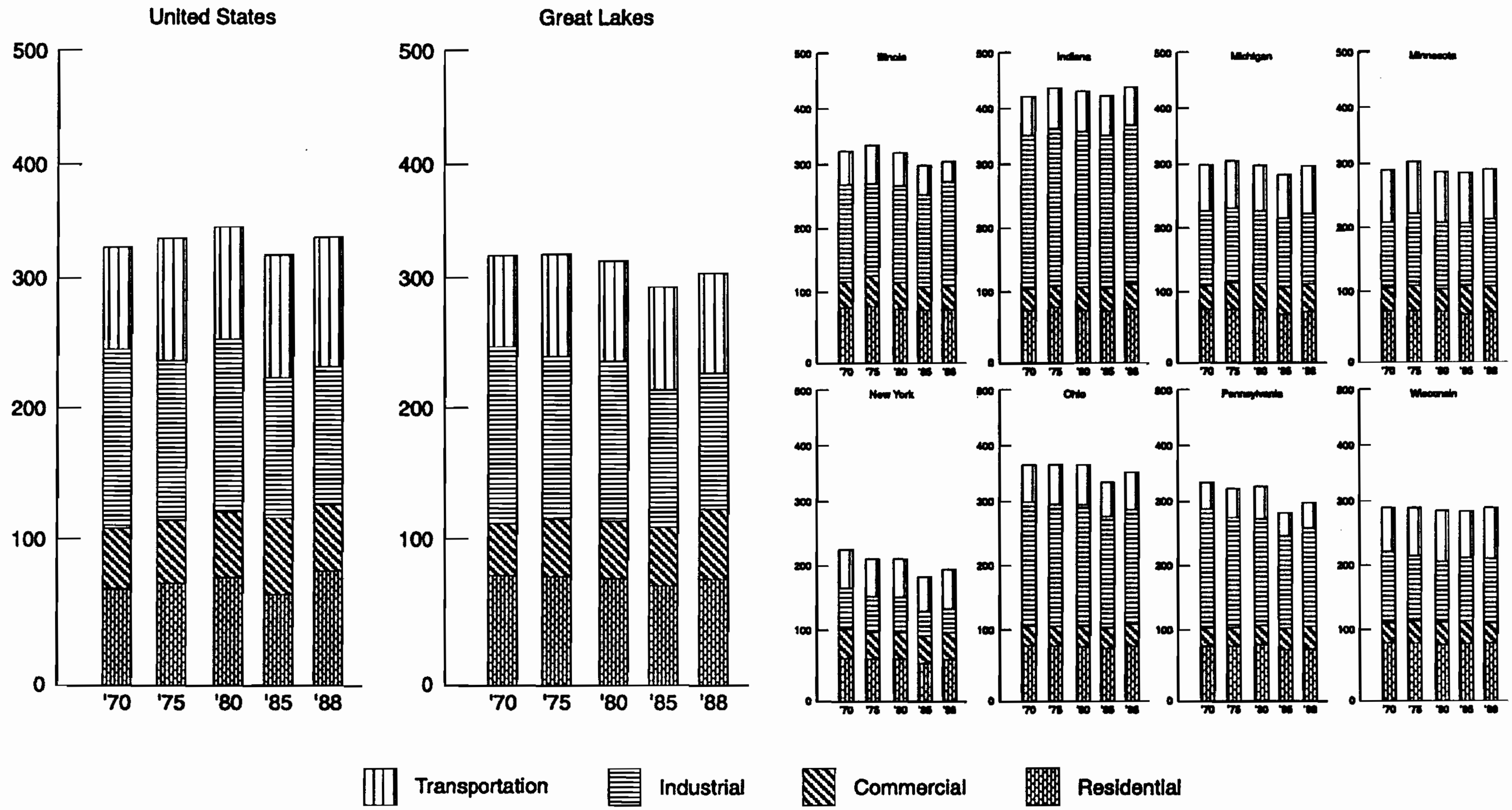
Source: Bournakis and Hartnett 1991, 74

Figure 11-4. Energy use per dollar of value-added, United States and sum of the eight Great Lakes states.



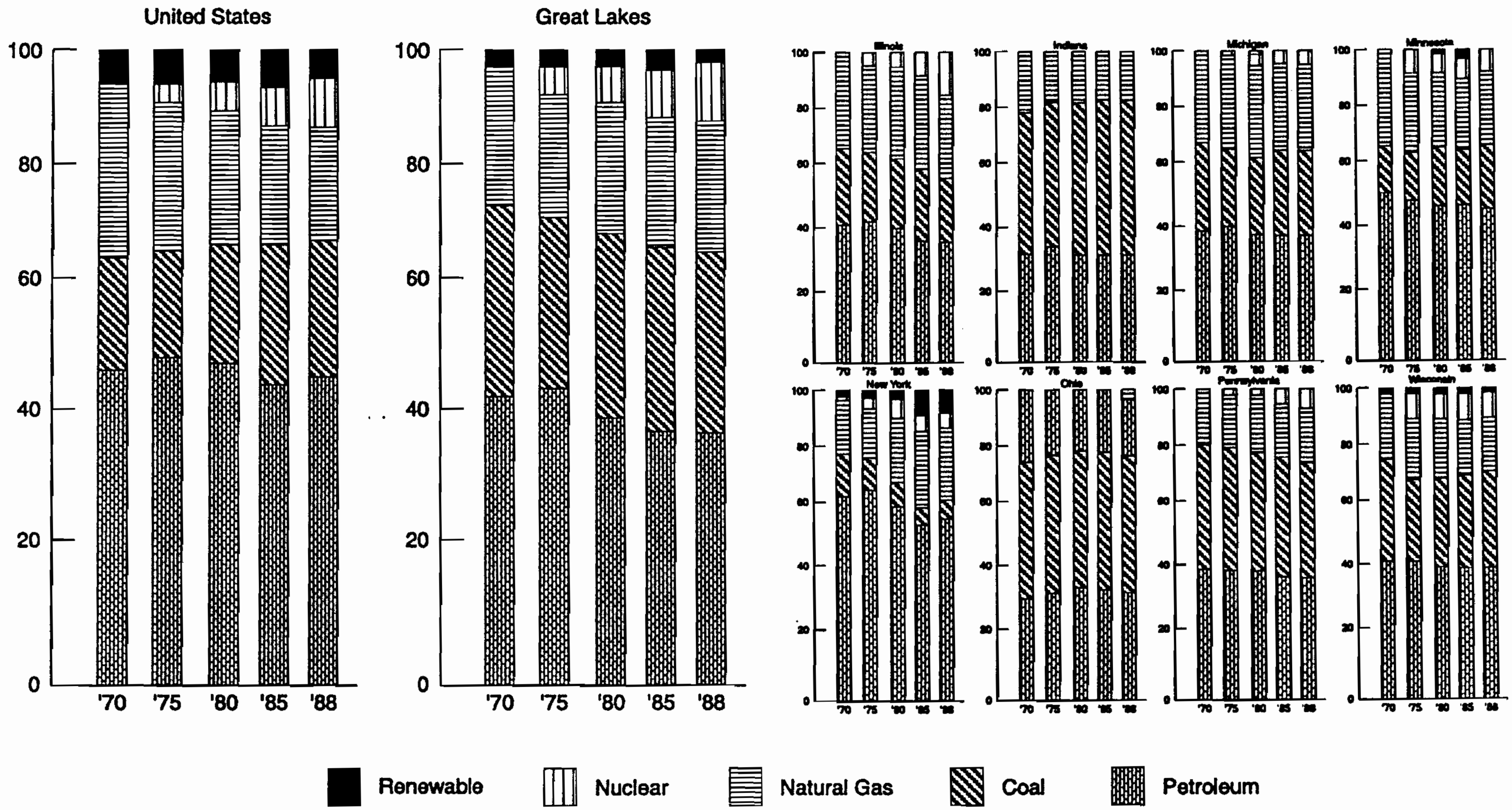
Source: Bournakis and Hartnett 1991, 77

Figure 11-5. Energy use per dollar of value added, United States, and the eight Great Lakes states by four major sectors. Thousands of Btu per dollar of value added, 1982 dollars.



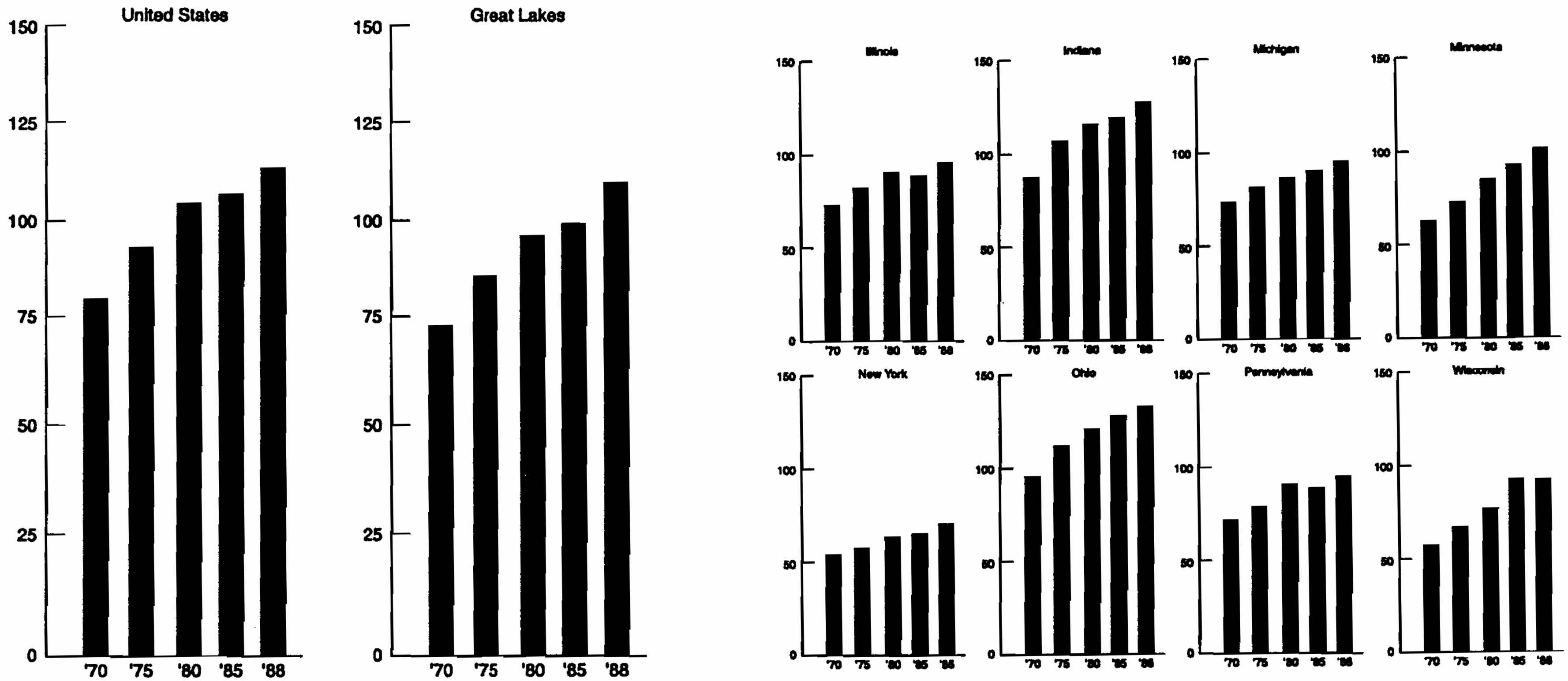
Source: Bournakis and Hartnett 1991, 76

Figure 11-6. Energy use per capita by major sector, United States and the eight Great Lakes states. Millions of Btu per person.



Source: Bournakis and Hartnett 1991, 78

Figure 11-7. Energy supply by fuel type, United States and the eight Great Lakes states. Percent of fuel type.



Source: Bournakis and Hartnett 1991, 79

Figure 11-8. Net electrical energy use per person, input to electricity. United States and the eight Great Lakes states. Millions of Btu per person.

In their discussion, Bournakis and Hartnett (1991) use the above indicators to address: (1) the increasing dependency of both the United States and the Great Lakes region on imported petroleum products; (2) the growing use of low-sulphur coal from outside the region to replace in-region high-sulphur reserves because of emissions problems; (3) the increasing pattern of electricity use per person and the implications of this growing demand for electricity on supply options (nuclear, coal, natural gas). In passing they raise a number of other energy-related issues including:

> ...alternative energy systems, solar and biomass (a major resource of the region); the future of regional transportation systems, including mass transportation, the railways, and the waterways; land-use planning and natural resources; automobile fuel economy standards, and priorities in energy research and development, to name a few.
>
> (Bournakis and Hartnett 1991, 84)

This list of issues and concerns demonstrates the potential breadth of energy as a topic of public policy. However, the aim of considering energy production and use as part of assessing progress toward sustainability is just that - to assess progress - not to address and resolve all current policy issues. As trite as this conclusion may seem, it is important for setting limits and maintaining a focus in the assessment process. The sixteen proposed indicators listed in Table 11-5 are linked by the objectives of each category to the goals of sustainability and provide the necessary input for making an initial assessment. Obviously, for any given policy issue, a much expanded set of indicators could be brought to bear.

A compilation that addresses the complete range of topics covered by the sixteen proposed indicators has never been attempted. Current practice is reflected in Figures 11-2 to 11-8 and a review of these in light of the proposed indicators leads to a number of observations and conclusions.

First, the dominant emphasis of current practice is on energy quantity, covered within Category I of the proposed indicators. Use of the term "energy consumption" implies secondary energy use. Total energy use (Figure 11-2) and two forms of energy intensity are used: energy use per capita (Figures 11-3 and 11-6 and energy use per dollar value-added (Figures 11-2 and 11-5)

Time series data on the proportion of energy imports are not presented raphically although Bournakis and Hartnett deal with the issue extensively in their text. The region continues to depend on imported natural gas, petroleum, and coal an issue that is of significant concern for policy makers.

These indicators of the quantity of energy used provide a useful first step. However, they do not address energy quality and no direct development of efficiency indicators (Category II) is undertaken. Instead, the reduction in total energy use per dollar of value-added (Figure 11-4) is used to imply improvements in the efficiency of industrial energy use. This may or may not be a fair conclusion.

While many industries undertook energy retrofits in response to the 1973 Arab oil embargo and the 1979 Iranian revolution, other factors changed as well. In particular, this same period has seen a significant restructuring of the economy with a shift away from many of the energy intensive heavy industries to services (Allardice and Testa 1991, 12). This shift is as significant to the reduction in energy use per dollar of value added as the introduction of energy efficient processes.

The power of using energy intensities such as energy used per dollar of value-added is more apparent at the sub-sector level than in the aggregated form shown in Figure 18. Goldemberg et al. use this approach to facilitate a comparison of the energy intensity achieved in different manufacturing activities in Sweden and the United States (1987, 45 - 46). For example, in 1978 the chemicals industry in the United States used 195 megajoules per dollar of value added ($1972) while the Swedish chemicals industry used 45. Even at this level, care must be taken to consider the nature of the industrial activities themselves to ensure they are comparable before drawing conclusions. To bring surety, a greater degree of internal stratification in data must be considered than is apparent from the term "chemical industries."

In any case, energy intensity remains only an indirect measurement of efficiency of end use. Direct monitoring is both preferable and entirely possible. Data are available to calculate "First Law Efficiencies" (Indicator 4) but not for calculating "Second Law Efficiencies" (Indicator 5). This issue should receive a high priority of effort from those concerned with assessing progress toward sustainability.

Category III indicators (imposed stress) are not covered at all. Bournakis and Hartnett make reference to a number of environmental concerns including the generation of urban smog, emissions contributing to acid deposition and global warming, toxic waste generation, and the implications of nuclear accidents (1991). A more extensive review of the environmental implications of energy production and use is provided by the Science Advisory Board (SAB 1982, 20 - 26). However, neither deal with the issue in any systematic way.

For their part, the Science Advisory Board recognized this deficiency and in particular, voiced concern that "no mechanism presently exists to anticipate problems in the Great Lakes basin ecosystem which may arise from (human) activities" (SAB 1982, 149). They suggested development of a computerized system that models the relationship between human activities and the generation of pollution. This at least would deal with chemical stress. While periodic interest in such an initiative has developed (for example, see Hoffman and McInnis, 1988 and Robert Associates, 1991) no ongoing support has been forthcoming from any level of government in either the United States or Canada. On the other hand, development of the Toxics Release Inventory (TRI) in the United States starting in 1987 and the National Pollutant Release Inventory (NPRI) in Canada starting in 1994 is generating the kind of data required to make ongoing monitoring of chemical stress a possibility.

Energy supply (Category IV indicators) is dealt with in terms of "relative energy share by fuel type" (Figure 11-7). These data provide a perspective that is similar to Indicator 9 (primary energy supply by source) but the next step to development of an indicator that addresses sustainability of supply (e.g. Indicator 10, proportion of domestic energy use met by abundant resources) has not been taken.

Bournakis and Hartnett also use figures for electrical energy use per person (Figure 11-8) in their discussion of the growing need for a supply of electrical energy. These figures too, should be used with great caution. The per capita indexing has the effect of hiding the exact source of the increase - for surely not everyone has used the same growing amount of electricity in the twenty year period covered in the time series. If the increase is due to structural change in the economy one might draw a different conclusion from these figures than if the increase is due to a conscious effort to reduce dependency on imported petroleum products. To be sure, a finer degree of disaggregation is required than is apparent from the data that are presented.

The issue of restoration (Category V) is not a subject that has been included in energy analyses to date.

11.8 ASSESSMENT OF ENERGY PRODUCTION, TRANSPORTATION, AND USE IN THE GREAT LAKES BASIN ECOSYSTEM

Available data show a recent reduction in energy use per dollar value added (Figures11-4 and 11-5). However, how much of this change is due structural adjustment in the economy and how much due to improved energy efficiency is unknown. Since 1985, energy use per capita appears to be increasing after dropping in the late 1970s and early 1980s (Figures 11-3 and 11-6). There is an ongoing vulnerability because of dependency on imported petroleum products and coal. Based on these three observations alone, a weak conclusion can be drawn that current trends do not signal overall progress toward sustainability.

However, in addition to the above assessment, two important conclusions can be drawn. First, current practice of energy analysis and energy-related data compilation in the Great Lakes (and elsewhere for that matter) are seriously deficient for effectively assessing progress toward sustainability. Only a minority of the indicators (1, 2, 3, and 7: per capita and total energy use, some emissions data) are available easily and in time series form. Indicators dealing with energy quality, efficiency, imposed stress, the longevity of supply, and restoration (4, 5, 6, 7, 8, 9, 10, 11) are not readily available although there is no technical reason to prevent their compilation. This situation is particularly alarming given the importance of energy to the sustainability equation (WCED 1987, Chapter 7 amongst many others).

Second, while it has not been possible within the limits of this study, to assess a broad number of human activities in a manner similar to the analysis of energy indicators, indicators related to other activities are likely limited in the same way as those for energy. Unfortunately, these are the data — on an activity-by-activity basis — that can help focus where action is required. Until the kinds of indicators suggested in this Case Study are being compiled and monitored on a systematic and consistent basis, solution building will continue to be adhoc and reactive to crises. Development and compilation of these indicators on an activity-by-activity basis must therefore be considered a high-priority research and development topic.

END NOTES

1. In their discussion of energy and sustainability, the Brundtland Commission identifies four "key elements" that require reconciliation (WCED 1987, 169). These elements are better seen as specific objectives that can be associated with the generic Domain II goals as follows:

   A. To maintain or increase human well-being:

   - by ensuring the growth of energy supplies to meet human needs;
   - by the maintenance of public health, recognizing the problems of risks to safety inherent in energy sources;

   B. To reduce stress on the environment:

   - by minimizing waste of primary resources with increasing energy efficiency and conservation measures
   - by ensuring overall protection of the biosphere and prevention of more localized forms of pollution.

   The Brundtland Commission does not deal with the complete range of physical, chemical, and biological stresses nor does it deal with restoration activities as an aspect of its energy discussion.

2. The use of the *soft* label may be unfortunate for it carries with it a connotation of fuzziness and lack of rigour. Horn (1993, 5) points out that concepts in the social sciences are called *soft* if they cannot be defined with the precision of terms used in the physical sciences. In fact from a technical perspective, the soft path approach is more precise, more demanding, and more sophisticated than the conventional approach in which demand management is not a policy-driven variable.

   There is an interesting parallel here to the hard/soft debate that emerged within the systems literature. As discussed in Appendix IV, the evolution of ideas in the last several years has led to hard systems being recognized as a subset of the more general soft system. This logic applies no less to the energy systems analysis addressed here.

3. The Brundtland Commission points out:

   > Energy is not so much a single product as a mix of products and services, a mix upon which the welfare of individuals, the sustainable development of nations, and the life-supporting capabilities of the global ecosystem depend. In the past, this mix has been allowed to flow together haphazardly, the proportions dictated by short-term

> pressures on and short-term goals of governments, institutions, and companies. Energy is too important for its development to continue in such a random manner. A safe, environmentally sound, and economically viable energy pathway that will sustain human progress into the distant future is clearly imperative.
>
> (WCED 1987, 202)

4. Use of scrap iron and steel instead of virgin material results in a 74 percent saving in energy; every tonne of glass recycled reduces the equivalent of 1,057 kg of carbon dioxide emissions; use of secondary paper resources instead of virgin materials results in a 74 percent reduction in air pollution, a 35 percent reduction in water pollution, and a 58 percent reduction in water use; for every ton of paper recycled, the equivalent of three barrels of oil are saved in energy use (Environment Canada 1994, 4).

5. The energy supply sector is categorized as mineral fuels, petroleum and biomass refining, pipeline transport, and utilities.

6. A decision must be made regarding the point of measurement - at primary source, secondary form, or tertiary use. Marbek (1990, 6) provide three arguments for using secondary energy throughout these indicators. as the dominant norm. First, energy at the point of use is likely to be most meaningful to users. Second, different workers use different methods in calculating primary energy. Although these inconsistencies can be resolved it adds a complication. And third, data are simply not available for monitoring tertiary energy use even though from a theoretical perspective measurement at this point would be most useful. Effort should be put to overcoming these deficiencies.

7. Significant care must be taken with analysis of energy intensities. While they provide another perspective on energy use, they also serve to average out data in a way that can mask important characteristics. For example, per capita figures provide no sense of distribution of use across a population. A second limitation is that they because they are dependent on several variables, they do not necessarily indicate change in the particular variable used to define the intensity.

8. Energy use per capita was chosen over energy use per passenger-kilometer because there is less opportunity for a mixed meaning. Changes in passenger-kilometer can be influenced as much by changes in technical efficiency of the system as by changes in ridership (Marbek 1990, 7). There is an analogy here to changes in energy use per dollar value added. Changes in this indicator can be generated by economic structural changes as much as by true improvements in the efficiency of energy use. Provided it is known that the macroeconomic structure has been

held constant, changes to energy use per dollar value added can be used as an indicator of changes in the efficiency of energy use. However, this is usually not the case. Both of these examples serve to highlight to limitations of using energy intensities.

9. Marbek suggest that a weighting scale be developed that captures the degree of imposed stress (and resulting degradation) and the sensitivity of the land where the stress is being imposed (1990, 9).

10. Marbek point out that long-term energy resource availability is a function of at least three variables:

    - current and future levels of energy consumption;
    - the renewable/non-renewable mix of energy sources;
    - the economically accessible reserves of each non-renewable resource, which in turn is dependent on physical reserves, current energy prices, and technology.

    (1990, 10)

    Decreasing energy consumption, increasing the proportion of renewable sources and increasing the stock of economically accessible non-renewable energy resources will all have the effect of increasing potential energy supply. To provide a conceptually simple indicator, Marbek propose an indicator that is based on an estimate of energy use met by abundant resources.

11. The 50 year time horizon is an arbitrary choice. Analysis may reveal that another figure is more appropriate. This is a topic for follow-up research.

12. This indicator is primitive. As restorative actions become more prominent, no doubt others will emerge to replace this one. At this stage the recognition that each facility has some responsibility for ecosystem restoration is what is most important.

13. Energy export is a delicate public policy issue. Theoretically it is undertaken to generate financial benefits for Canadians. On this basis, and assuming Canadian ownership of resources (which is not always the case) the higher the "value" of energy exports, the higher the financial benefits that can accrue to Canadians. As in other assessments of activities though, the assessment of value must be balanced against true full costs to Canada including those carried by people and the ecosystem. In addition, full cost analysis of energy exports should also include assessment of human and ecosystem implications to the recipient jurisdiction.

CHAPTER TWELVE.

SURFACE AND GROUNDWATER

IN THE GREAT LAKES BASIN ECOSYSTEM

12.1 INTRODUCTION

Water is a fundamental prerequisite for all life on earth. It is a critical ecosystem component and falls within the Domain I. The Domain I goal, re-stated in terms of water, is "to maintain or improve the health and integrity of the water subsystem."

In this case study, the focus is on the water and not on the biota that the water supports — the water subsystem, not the aquatic ecosystem. The abiotic water sub-system is a self-organizing entity, driven by gravity and the many factors controlling the hydrologic cycle. Even so, bioindicators must be used - for they have a significant role to play in facilitating an assessment of the water sub-system on its own.[1]

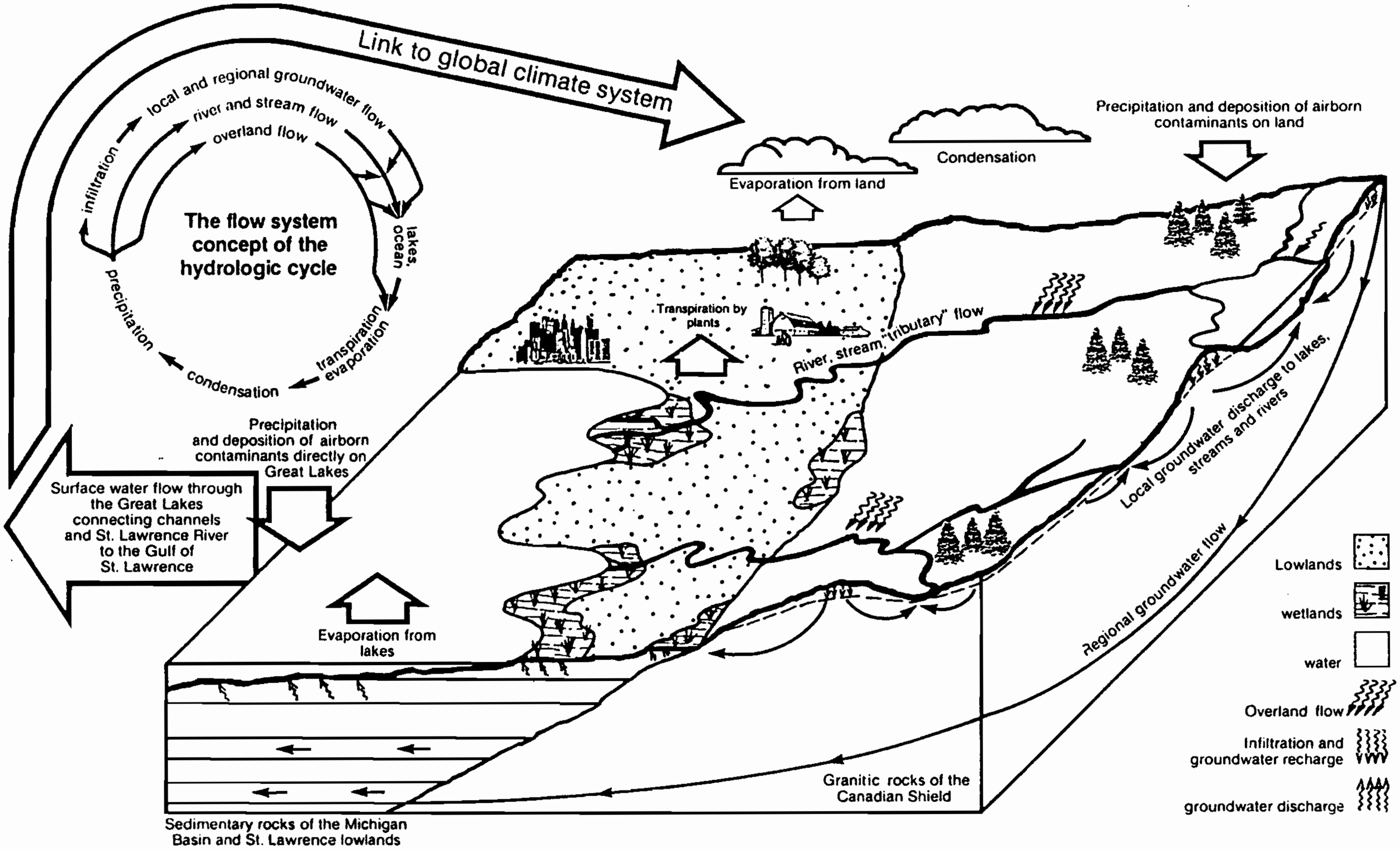
Organisms serve to integrate across stress types, through time, and spatially in a way that series of discrete physical and chemical measures cannot. Further, the potential may exist to identify bioindicators that reflect an ecosystem's ability to self-regulate. Because of the inevitability of surprise and the discontinuous path often followed by ecosystems under stress, such indicators are likely the key for understanding the effects of human imposed stress (see discussion in Kay and Schneider 1994). This issue is the subject of much current research and its resolution is well beyond this case study.

However, the discussion is important because it highlights the difficulty in identifying the best signals to measure and monitor. There is of course, no simple or single answer. What is clear from this work is that monitoring of progress toward sustainability requires a mix of physical, chemical, and biological measures and the best combination at any given time will vary depending on which specific objective is being addressed in the assessment process as well as ecosystem conditions.

For example, following the above line of thinking, bioindicators are obviously essential for assessing ecosystem health and integrity - including the water sub-system. But chemical and physical measures are equally important for monitoring imposed chemical and physical stress. If the objective being addressed is to maintain or increase the health and integrity of the aquatic ecosystem the set of chosen indicators will not be the same as those required to support assessment of an objective to reduce and minimize imposed stress on the ecosystem. These sets of data and information are closely related, but they are different.

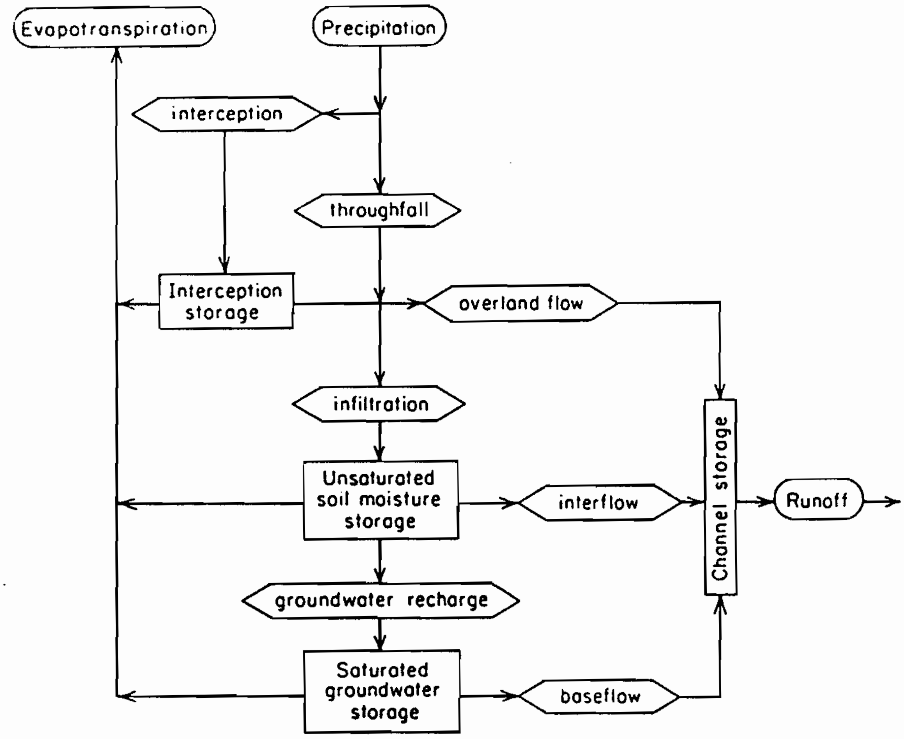
12.2 WATER AND THE HYDROLOGIC CYCLE

Figures 12-1 and 12-2 are complementary schematics of the hydrologic cycle. Figure 12-1 is a three-dimensional representation emphasizing the dynamic flow-system concept. Figure 12-2 is a "pot-and-pipeline" systems representation that does not capture a sense of system dynamics but is useful in differentiating factors that involve rates of movement or flows (hexagonal boxes) and those that involve storage or stocks (rectangular boxes) (Freeze and Cherry 1979, 4).



Source: Colborn et al. 1990, 76

Figure 12-1. Flow system concept of the hydrologic cycle applied to the Great Lakes.



Source: Freeze and Cherry 1979, 4. Copyright (C) 1979 by Prentice Hall Inc. Reprinted with permission of the publisher.

Figure 12-2. Systems representation of the hydrologic cycle

From a global perspective, the hydrologic cycle includes the nine elements listed in Table 12-1 which lists also the volume and proportion of water held in each as well as an estimate of residence time. The global water balance is dominated by oceans and seas which account for 94 percent of all water by volume. Of the remaining 6 percent, 2 percent is held in icecaps and glaciers. The remainder is almost entirely groundwater. However, if only the most "active" groundwater is considered (4 instead of 60 million km^3), the freshwater breakdown comes to: groundwater, 95 percent; lakes, swamps, reservoirs, and river channels, 3.5 percent; and soil moisture, 1.5 percent (Freeze and Cherry 1979, 5).

TABLE 12-1. COMPONENTS OF THE GLOBAL HYDROLOGIC CYCLE WITH AN APPROXIMATE WATER BALANCE.

component	volume (million km^3)	proportion (percent)	residence time
oceans and seas	1370	94	4000 years
groundwater	60	4	2 weeks - 50,000 years
icecaps and glaciers	30	2	10-10,000 years
surface freshwater:			
lakes and reservoirs	0.13	0.01	10 years
swamps and wetlands	0.01	0.01	1-10 years
river channels	0.01	0.01	2 weeks
soil moisture	0.07	0.01	2 weeks - 1 year
atmospheric water	0.01	0.01	10 days
biospheric water	0.01	0.01	1 week

Source: Nace 1971; Chapman (ed.) 1992, 2.

This quantitative perspective must be tempered by a sense of the residence time (and thus the response time) of each component which ranges from a few weeks for river water, a few weeks to a year for soil moisture, several thousand years for oceans and seas, and weeks to over 10,000 years for groundwater.

The above brief description helps in the identification of sub-system components that must be included in this assessment. Of the components listed in Table 12-1, atmospheric and biospheric water would be included in the air and climate designation of the Domain I assessment (see Figure 8-1) and soil moisture will be included as part of the unsaturated zone of the groundwater system.

In conventional analysis, groundwater and surface water are typically described and assessed in terms of quantity and quality. In fact there are physical, chemical, and biological characteristics that can help assess the state of each part of the water sub-system. Furthermore, there are direct and indirect indicators that can contribute. These factors are all mapped out together on the assessment hierarchy shown below in Figure 12-3. In the following Section, specific indicators are identified.

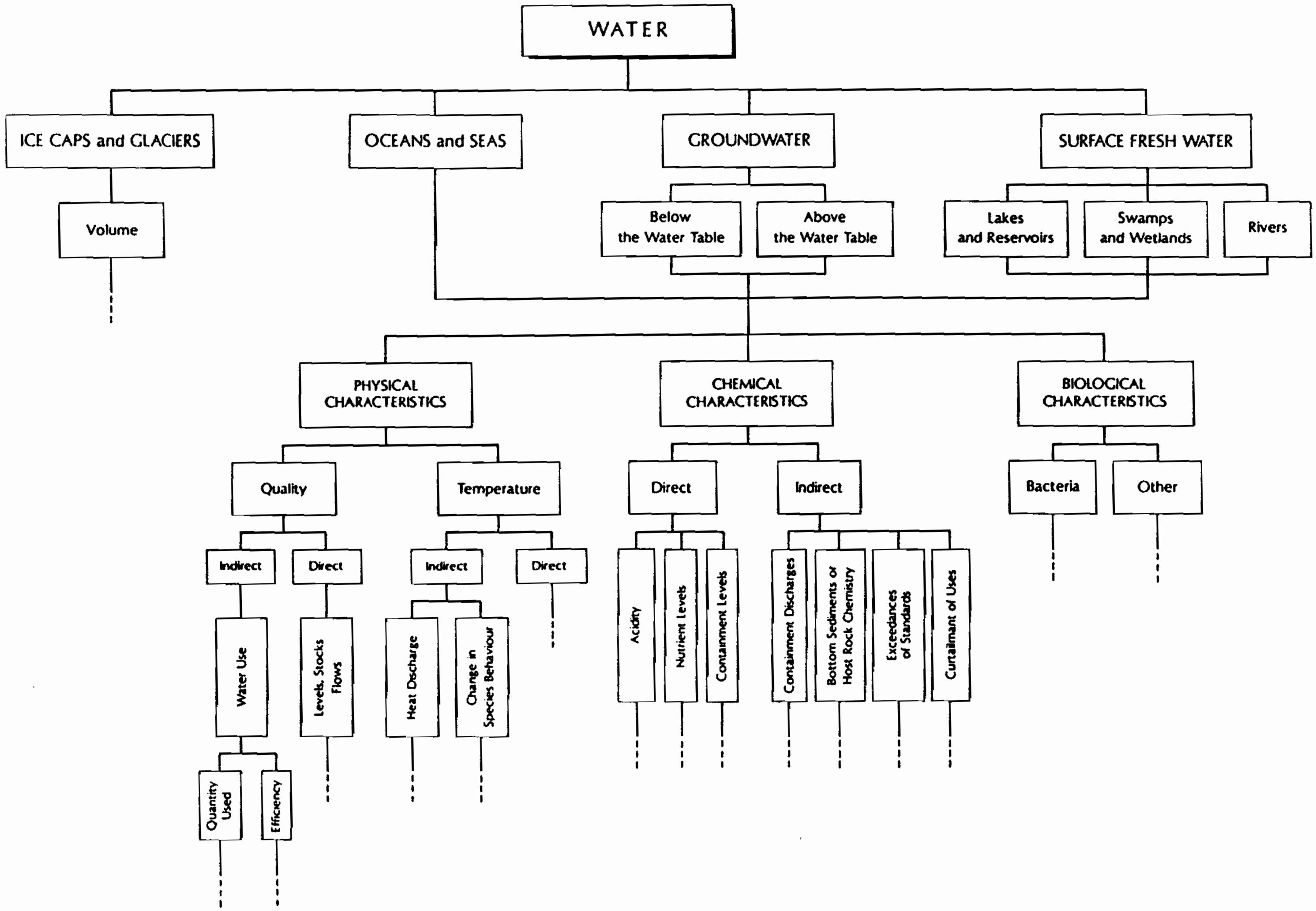


Figure 12-3. Assessment hierarchy for the water sub-system.

12.3 PROPOSED INDICATORS

Just as was done with energy, a set of indicators can be developed that would effectively allow a given jurisdiction to monitor the state of the water sub-system. Because the focus of this case study is on the Great Lakes Basin Ecosystem, two of the components of the water sub-system which are not directly relevant, (ice caps and glaciers; oceans and seas) will be set aside and not further considered. What remains are the groundwater and surface water components. Within each are physical, chemical, and biological characteristics that can be used in an assessment of sustainability.

The state of groundwater or surface water is assessed by hydrogeologists, hydrologists, chemists, engineers, and others who develop an understanding of the water sub-system drawing on a variety of specific measures that depend on local conditions and data availability. For example, the hydrogeologist will study the local topography, physical and chemical characteristics of host media, precipitation, evaporation, evapotranspiration and groundwater recharge mechanisms as much as the groundwater itself. These kinds of factors determine the nature of the groundwater flow system. Understanding them is essential for estimating any change to the groundwater flow system that might result from say well withdrawals or contaminant discharges.

A hydrologist will be similarly interested in precipitation, evaporation, evapotranspiration, stream gradients, channel characteristics, lake water dynamics and so forth as well as the actual chemistry, flow and volume of surface water. These are the factors that determine the nature of the hydrologic system.

Altogether, this body of knowledge is vast and an enormous number of specific physical, chemical, and biological measures are gathered in support of the variety of interested disciplines. To illustrate, Table 12-2 lists a typical selection of thirty-six variables that are used for assessment of water quality in relation to non-industrial uses. A number of the line items (for example, heavy metals, pesticides, and organic solvents) in turn, represent dozens of additional variables at a finer level of detail.

The task here is to distill from this body of knowledge, certain key factors that signal the state of the system. In taking this step, caution must always be exercised: once the indicators are isolated from the larger body of knowledge, they can be easily taken out of the context represented by that larger understanding.

TABLE 12-2. TYPICAL SELECTION WATER QUALITY ASSESSMENT VARIABLES.

	Background Monitoring	Aquatic Life and fisheries	Drinking Water sources	Recreation and health	Irrigation	Livestock watering
General variables						
Temperature	xxx	xxx		x		
Colour	xx		xx	xx		
Odour			xx	xx		
Suspended solids	xxx	xxx	xxx	xxx		
Turbidity/transparency	x	xx	xx	xx		
Conductivity	xx	x	x		x	
Total dissolved solids		x	x		xxx	x
pH	xxx	xx	x	x	xx	
Dissolved oxygen	xxx	xxx	x		x	
Hardness		x	xx			
Chlorophyll a	x	xx	xx	xx		
Nutrients						
Ammonia	x	xxx	x			
Nitrate/nitrite	xx	x	xxx			xxx
Phosphorous/phosphate	xx					
Organic Matter						
Total organic carbon	xx		x	x		
Chemical oxygen demand	xx	xx				
Biochemical oxygen demand	xxx	xxx	xx			
Major Ions						
Sodium	x		x		xxx	
Potassium	x					
Calcium	x				x	x
Magnesium	xx		x			
Chloride	xx		x		xxx	
Sulphate	x		x			x
Other Organic Variables						
Fluoride			xx		x	x
Boron					xx	x
Cyanide		x	x			
Trace Elements						
Heavy metals	xx	xxx		x	x	
Arsenic and selenium		xx	xx		x	x
Organic Contaminants						
Oil and hydrocarbons		x	xx	xx	x	x
Organic solvents		x	xxx			x
Phenols		x	xx			x
Pesticides		xx	xx			x
Surfactants		x	x	x		x
Microbiological Indicators						
Faecal coliforms			xxx	xxx	xxx	
Total coliforms			xxx	xxx	x	
Pathogens			xxx	xxx	x	xx

Key: likelihood that the concentration of the variable will be affected and the more important it is to include the variable in a monitoring program:

x — *low likelihood* xx — *medium likelihood* xxx — *high likelihood*

Notes: 1. Variables stipulated in local guidelines or standards for a specific water use should be included when monitoring for that specific use.
2. The selection of variables should only include those most appropriate to local conditions and it may be necessary to include other variables not indicated under the above headings.

Source: Chapman 1992, 106.

In practice, the choice of key indicators for monitoring and assessing the state of the water in any given ecosystem is best done following a comprehensive full-system assessment that provides an adequate foundation for that choice. This comprehensive assessment should be repeated periodically to allow for changing conditions.

The variables listed in Table 12-2 are organized by use. Six are listed: (1) background monitoring; (2) aquatic life and fisheries; (3) drinking water sources; (4) recreation and health; (5) irrigation; and (6) livestock watering. The need for a classifications of different water uses arose originally because regulatory regimes have designated different water quality requirements for different uses. For example, water used for industrial processes need not necessarily be the same quality as drinking water. From Table 12-2 it can be seen that the idea of use includes use by all aquatic biota as well as humans. Thus it can be seen as a kind of integrating idea.

Section 305b of the United States Clean Water Act requires the United States Environmental Protection Agency together with the states to prepare a nationwide inventory and assessment of water quality in all navigable waters. Reports must be filed every two years. These reports must:

> ...include an inventory of all point sources of discharge (based on a qualitative and quantitative analysis of discharges) of pollutants, into all navigable waters, and the waters of the contiguous zone; and
>
> ...identify specifically those navigable waters, the quality of which:
>
> (A) is adequate to provide for the protection and propagation of a balanced population of shellfish, fish, and wildlife and allow for recreation activities in and on the water;

(B) can reasonably be expected to attain such level by 1977, 1983; and

(C) can reasonably be expected to attain such level by any later date.

(Section 305b, The United States Clean Water Act of 1987)

The assessment criteria found in 3(A) above has come to be known as the "fishable and swimmable" use criteria of the Clean Water Act. In most states however, these criteria serve as a starting point for an expanded set that serve local purposes. For example, Ohio has developed the use designations listed in Table 12-3. Using both chemical and biological criteria, navigable courses and bodies of water are classified on the basis of uses being: (1) fully attained; (2) fully attained but threatened; (3) not attained; (4) partially attained, or (5) not assessed (see discussion in Rankin et al. 1990, 6-10).

TABLE 12-3. OHIO'S SURFACE WATER USE DESIGNATIONS.

Aquatic Life Uses

- warmwater habitat
- exceptional warmwater habitat
- coldwater habitat
- seasonal salmonid habitat
- limited resource water

Water Supply

- public water supply

Recreation

- primary contact
- secondary contact

State Resource Waters

- state resource waters
- outstanding resource waters

Source: Rankin et al. 1990, 6.

Yet another application of the idea of water use impairment is found in The Great Lakes Water Quality Agreement which lists fourteen "impairments of beneficial uses" (see Table 10--4). These impairments provide the framework for establishing criteria for listing and delisting a given degraded area in the Great Lakes as an official "Area of Concern" (see GLWQBb 1991, 10 - 14).

In an interesting piece of work, Rang et al., assess the impairment of uses in Lake Ontario. They use the above list of fourteen use impairments as the organizing framework for their study and in the process, test the applicability of the list to the Lake Ontario aquatic ecosystem. In summary, they point out that the list of fourteen use impairments in the Great Lakes Water Quality Agreement are really "routes by which contaminants may adversely affect ecosystem components" (Rang et al. 1992, 292).

They suggest alternative assessment criteria that focus directly on ecosystem components. Their list is provided below in Table 12-4. This list is consistent with Ohio's move to direct measures of the state of in-stream biological communities.

For assessing the water subsystem, water use is an indirect indicator: there is an assumed relationship between use and actual state of the water sub-system. However, both direct and indirect indicators can be helpful in assessment and both have an important role to play in communicating conditions to decision-makers. Further, water use is a direct indicator of human activity and provides a convenient linkage to Domain II analysis.

TABLE 12-4. CURRENT IMPAIRMENTS OF THE LAKE ONTARIO ECOSYSTEM.

IMPAIRMENT OF:

1. Aquatic Biota

- degradation of fish, phytoplankton, and zooplankton populations;
- fish tumors or other deformities;
- degradation of benthos;
- loss of habitat;
- presence of exotic species;
- changes in indicators of chemical stress (biomarkers).

2. Wildlife Dependent on Aquatic Biota

- degradation of bird and wildlife populations
- bird or animal deformities or reproductive problems;
- loss of habitat;
- changes in indicators of chemical stress (biomarkers).

3. Human Health

- restrictions on human consumption of fish and wildlife;
- restrictions on drinking water consumption, or tasteand odor;
- beach closings;
- degradation of aesthetics;
- congenital abnormalities, reproductive or developmental effects;
- psycho-social impacts.

4. Water Quality

- eutrophication or undesirable algae;
- beach closings;
- elevated water-column contaminant concentrations.

5. Sediment Quality

- degradation of benthos;
- restrictions on dredging activities;
- elevated sediment contaminant concentrations.

Source: Rang et al. 1992, 292.

In Table 12-5 below, twenty-three water subsystem indicators are identified. They are organized in the following four categories:

I. Groundwater — physical characteristics;
II. Groundwater — chemical characteristics;
III. Surface water — physical characteristics; and
IV. Surface water — chemical and biological characteristics.

For each category, specific objectives are articulated that reflect the Domain I goal. These are intended as generic suggestions - to serve as a kind of check list in the same way that the indicators for energy are intended (Table 11-5). In any given situation, local conditions might well lead to the choice of other specific indicators that are more useful for monitoring than those suggested here.

TABLE 12-5. SURFACE WATER AND GROUNDWATER INDICATORS.

I. GROUNDWATER — PHYSICAL CHARACTERISTICS

Objectives:

1. *Quantity. To maintain the groundwater flow system such that any withdrawals are within the natural annual re-charge;*

2. *Stress. To reduce and minimize the physical stress im posed on the groundwater flow system; and*

3. *Use Efficiency. To increase and maximize the efficiency of water use.*

DIRECT INDICATORS

INDICATOR 1. RATIO OF RECHARGE TO DISCHARGE

- direct measurement expressed as a dimensionless number or percent
- trends in the average annual position of the water table (elevation in metres or equivalent)

Indirect Indicators

Indicator 2. Groundwater Withdrawls

- withdrawals (volume per unit of time): national, province/state, region, and community by subsector, sector, and total

Indicator 3. Efficiency of Groundwater use

- ratio of the least necessary amount of groundwater required to provide a given service to the actual amount used (dimensionless ratio or expressed as percentage): national, province/state, region, or community by subsector, sector and total.

II. GROUNDWATER - CHEMICAL CHARACTERISTICS

Objectives:

1. ***Quality.*** *To maintain groundwater quality that is (a) within the range of natural ambient conditions for any given locale, or (b) characterized by elevated contaminant levels but only to a degree that can be attenuated by natural processes to "safe" levels (for any biota including humans) prior to discharge to wells,*[2] *and*

2. ***Stress.*** *To reduce and minimize the chemical stress imposed on the groundwater flow system.*

Direct Indicators

Indicator 4. Conentrations of Contaminants

- concentrations of contaminants by chemical species (mass per unit volume, e.g. mg/l)

Indirect Indicators

Indicator 5. Discharges of Contaminants to Groundwater

- discharges of contaminants by species (mass or volume per unit of time); national, province/state, region, and community by subsector, sector, and total

Indicator 6. Non-Compliance with Standards

- incidents of non-compliance per year related to contaminant discharges to groundwater (time exceeding standard combined with some assessment of seriousness of incident); national, province/state, region, and community by subsector, sector, and total.

Indicator 7. Use Curtailment

- incidences of curtailment of use (e.g. wells abandoned) as a result of contamination of groundwater; national, province/state, region, and community by subsector, sector, and total.

III. SURFACE WATER — PHYSICAL CHARACTERISTICS

Objectives:

1. ***Quantity.*** *To maintain surface water flows such that water level changes mirror natural seasonal changes in any given year and any withdrawals are within the natural annual recharge;*

2. ***Temperature.*** *To maintain surface water temperature such that any changes mirror natural seasonal changes and the range of any change with within the natural range.*

3. ***Stress.*** *To reduce and minimize the physical stress imposed on the surface water system;*

4. ***Use Efficiency.*** *To increase and maximize the efficiency of water use.*

Direct Indicators

Indicator 8. Flow Rate or Water Levels

- direct measurement of flow (volume per unit time) or level (height in metres above some datum)

Indicator 9. Temperature

- direct measurement of temperature (degrees centigrade)

Indicator 10. Water Course Continuity

- proportion of rivers and streams blocked by built infrastructure with water courses classified on the basis of their importance for human use and wildlife use

Indirect Indicators

Indicator 11. Surface Water Withdrawls Including Diversions

- withdrawals or diversions (volume per unit of time): national, province/ state, region, and community by subsector, sector, and total

Indicator 12. Efficiency of Surface Water Use

- ratio of the least necessary amount of surface water required to provide a given service to the actual amount used (dimensionless ratio or expressed as percentage): national, province/state, region, or community by subsector, sector and total

IV. SURFACE WATER — CHEMICAL AND BIOLOGICAL CHARACTERISTICS

> *Objectives:*
>
> *1.* ***Quality.*** *To maintain surface water quality that is within the range of natural ambient conditions for any given locale.*
>
> *2.* ***Stress.*** *To reduce and minimize the chemical and biological stress imposed on surface water.*

Direct Indicators

Indicator 13. Contaminant Levels[3]

- concentrations of contaminants by chemical species (mass per unit volume, e.g. mg/l);

Indicator 14. Nutrients Levels[4]

- concentrations of nutrients (nitrate plus nitrite, phosphorous) (mass per unit volume)

Indicator 15. Acidity[5]

- pH measurement

Indirect Indicators

Indicator 16. Contaminant Levels in Biota[6]

- concentrations of contaminants by chemical species in aquatic biota (for example, fish flesh) and other biota that depend on aquatic organisms for their diet (for example, fish eating birds) (mass per unit volume, mg/l)

Indicator 17. Bottom Sediment Geochemistry[7]

- contaminant content of bottom sediments (mass per unit volume)

Indicator 18. Discharges of Contaminants to Surface Water[8]

- discharges of contaminants by species (mass or volume per unit of time); national, province/state, region, and community by subsector, sector, and total

Indicator 19. Discharges of Nutrients to Surface Water

- discharges of nutrients by species (mass or volume per unit of time); national, province/state, region, and community by subsector, sector, and total

Indicator 20. Non-Compliance with Standards[9]

- incidents of non-compliance per year related to discharges of contaminants to surface water (time exceeding standard plus some measure of seriousness of incident); national, province/state, region, and community by subsector, sector, and total

Indicator 21. Use Curtailment

- incidences of curtailment of use (for example, use by aquatic biota and use by humans including drinking water limitations, beach closures, fishing closures and so on) as a result of contamination of surface water; national, province/state, region, and community by subsector, sector, and total.

Indicator 22. Bacterial Levels

- levels of bacteria (coliform count per unit volume)

Indicator 23. Other Bioindicators of the State of Surface Water

- species health (including humans), population health, biodiversity etc.
- biological indices such as the Index of Biotic Integrity (IBI, based on fish), the Modified Index of Well-being ((Iwb, fish) and the Invertebrate Community Index (ICI, macroinvertebrates)

12.4 APPLICATION IN THE GREAT LAKES ECOSYSTEM

There is a vast literature dealing with Great Lakes Ecosystem surface and groundwater that has been generated since the signing of the Boundary Waters Treaty in 1909. In the following discussion, an analysis is made of the water subsystem from the perspective of sustainability. An assessment is also provided of the adequacy of the data and information base.

GROUNDWATER — PHYSICAL CHARACTERISTICS

An overview of the state of understanding of groundwater in the Great Lakes Basin is provided by Hodge who points out that half of the residents in the eight Great Lakes states and Ontario depend on groundwater for their primary water supply (1990, 449). Hodge also describes a number of areas within the Great Lakes Basin where groundwater mining is occurring - where the amount extracted is more than the natural system can replenish. The result is a permanent lowering of the water table. The most extreme example is the Chicago-Milwaukee area where the groundwater system has been subject to withdrawals since the late 1800s:

> Continuous pumping since then has caused water levels in the Chicago area to drop, on average, 800 feet (244 m). One quarter of the fall has occurred since 1971. Water levels in some Chicago area wells are now 100 to 150 feet (30 - 46 m) below sea level and the growing cone of influence extends well beyond the boundaries of the Great Lakes hydrologic basin causing groundwater to flow northwest from Indiana, west from Lake Michigan, and south from Wisconsin. The withdrawal of water from Lake Michigan through the groundwater system is substantial enough to be included in Illinois' allocation of Lake Michigan water.
>
> Similar groundwater mining has been a concern, though not as extreme, in the Lake Winnebago area and in Green Bay Wisconsin. It appears to be an emerging problem in some growing suburban residential areas in southern Ontario.
>
> (Hodge 1990, 451 - 452)

The above kinds of data and information provide useful input for development of Indicator 1, Ratio of Recharge to Discharge (Table 47). Similarly, Hodge provides a summary of groundwater annual withdrawals by state/province and use (municipal, rural domestic, agriculture, and industrial self supply) that directly contributes to Indicator 2 (groundwater withdrawals). Trends in use over time are not available. No attempt has ever been made to quantify the efficiency of water use (groundwater or surface water) throughout the Great Lakes Basin (Indicator 3) although residential, commercial, and industrial activities in most of North America are extremely inefficient in water use, a characteristic brought about by the historic over-abundance of available water.

Overall, what little is known about the groundwater flow system suggests that in some areas, groundwater mining is seriously depleting the resource. However, the overall groundwater flow system in the Great Lakes Basin is ill-understood, a surprising conclusion given the proportion of people dependent upon it for their primary water supply.

Groundwater - Chemical Characteristics

Hodge also reviews groundwater quality in the Great Lakes basin and relates a number of cases where degraded groundwater quality is a significant concern (1990, 452-462). For example, groundwater-carried contaminants from buried hazardous waste are now likely the major single source of toxic contaminants to the Niagara River and Lake Ontario (458).

In 1975, the Great Lakes Basin Commission completed a review of groundwater in the eight Great Lakes states (GLBC, 1975) and groundwater quality is reviewed as part of the biennial reports to the United States Congress by states under Section 305b of the Clean Water Act. In Ontario, no overview of groundwater quality has ever been completed.

In short there is a serious lack of understanding of overall groundwater quality in the Great Lakes Basin that matches the lack of understanding of the physical groundwater flow regime. Concern caused by this conclusion led the Great Lakes Science Advisory Board to address groundwater contamination in their 1991 Report to the International Joint Commission:

> It has been ten years since the Commission alerted the Governments to the serious problem of toxic and hazardous substances in the Niagara River and the threat posed by contaminated groundwater from abandoned or improperly-operated hazardous waste facilities being release into the river. It has been eight years since the Science Advisory Board recommended increased attention to groundwater contamination and escalated the mapping of contaminants so that policy decisions on cleanup progress could be based on facts. These recommendations have not been implemented and the public remains in the dark on the basin-wide significance and ramifications of groundwater contamination.
>
> (SAB 1991, 57)

What is known is that localized groundwater problems are becoming more common as a result of a large variety of contaminant sources. Table 12-6 lists the dominant sources of groundwater contamination in the eight Great Lakes states and Ontario.

TABLE 12-6. DOMINANT SOURCES OF GROUNDWATER CONTAMINATION IN THE EIGHT GREAT LAKES STATES AND ONTARIO. THE BRACKETED FIGURE INDICATES THE PERCENTAGE OF THE POPULATION DEPENDENT ON GROUNDWATER AS THEIR PRIMARY WATER SUPPLY.

Pennsylvania (90%)

1. acid mine drainage
2. underground storage tanks
3. surface impoundments (excluding oil and gas brine pits)
4. on-site industrial landfills
5. septic tanks
6. abandoned hazardous waste sites
7. other: oil and gas brine pits, road salt, agricultural activities, land application of sewer sludge

Minnesota (75%)

1. industrial/manufacturing (on-site spills, illegal or uncontrolled disposal, industrial impoundments)
2. solid waste landfills and dumps
3. storage and transportation of petroleum and other products
4. agricultural activities
5. municipal impoundments and land treatment facilities
6. individual septic systems
7. road salt, salt storage

Wisconsin (67%)

1. agricultural activities
2. solid waste landfills
3. abandoned waste sites
4. underground storage tanks
5. spill incidents

Indiana (59%)

1. handling, storage, spillage, and eventual disposal of hazardous waste
2. mining
3. production of brines associated with oil and gas drilling
4. agricultural activities
5. underground storage tanks

Michigan (51%)

1. petroleum related
2. unknown
3. landfill
4. miscellaneous industrial products
5. metal plating and production
6. chemical production and manufacturing
7. salt storage
8. agriculture and food related
9. laundromats
10. hazardous waste handling

Ohio (50%)

1. hazardous waste
2. solid waste
3. leaks and spills

4. agriculture
5. household wastewater systems, especially septic tanks
6. mining, oil and gas extraction and associated waste disposal
7. improperly constructed and maintained water wells
8. road salt

Illinois (48%)

1. underground storage tanks
2. abandoned hazardous waste sites
3. municipal and industrial landfills
4. agricultural activities
5. production of brines associated with oil drilling
6. industrial activity (solvents, plating, metal finishing
7. road salt
8. coal mining and oil production
9. materials storage

New York (35%)

1. underground storage tanks
2. hazardous materials, leaks, and spills
3. abandoned hazardous waste sites
4. municipal and industrial wastewater treatment plant effluent and small leaks and spills associated with facility housekeeping
5. municipal landfills
6. agricultural activities
7. uncovered road salt piles

Ontario (23%)

1. improper construction of well and septic systems
2. road salt
3. gasoline or heating oil storage tanks
4. industrial leaks and spills
5. improper storage in waste disposal sites, particularly in older sites
6. abandoned coal-gassification plants
7. deep well disposal
8. agricultural activities
9. storage and disposal of radioactive waste
10. mine tailings

Source: Hodge 1990, 449 and 460 - 462.

1. Physical characteristics:

Direct Indicators

a. **Indicator 8, Flow Rate or Water Levels:** water flows maintain a rhythm and variation that mirror natural conditions;

b. **Indicator 9, Temperature:** with local exceptions adjacent to industrial and municipal facilities, water temperatures are within natural ranges;

c. **Indicator 10, Water Course Continuity:** while no comprehensive inventory has been compiled, the continuity of many inland rivers and streams is broken by built infrastructure. The complete range of ecosystem implications has not been established, nor has there been any attempt to balance these implications against the benefits achieved in terms of water supply, irrigation, power etc.;

Indirect Indicators

d. **Indicator 11, Withdrawals:** withdrawals and diversions are generally within the natural annual recharge;

e. **Indicator 12, Use Efficiency:** the efficiency of surface water use is far lower than is technically and economically possible.

2. Chemical and biological characteristics:

Direct Indicators

a. **Indicator 13, Contaminant Levels:** concentrations of most common and toxic contaminants in surface water have shown a significant improvement over the past fifteen years; concentrations at dozens of local areas remains elevated to the point of impairing some uses by humans and wildlife; although concentrations of some persistent toxic substances meet ambient water quality standards, the processes of bioaccumulation and biomagnification result in concentrations below water quality being still high enough to cause injury to fish, wildlife, and humans;

b. **Indicator 14, Nutrient Levels:** excess nutrient problems due to phosphorous in the Great Lakes proper have been greatly reduced although trophic conditions are still not at targeted levels in some areas (e.g. the bottom waters of Lake Erie). Eutrophication remains a significant problem in a number of nearshore areas and inland lakes. Increasing nitrate-plus-nitrite throughout the Great Lakes has been documented since the turn of the century and remains a concern particularly in terms of its potential impact on the lower trophic levels of the food web;

c. **Indicator 15, Acidity:** acidification remains a serious problem in many inland lakes;

INDIRECT INDICATORS

d. **Indicator 16, Contaminant Levels in Biota:** body burdens of persistent toxic substances in fish and wildlife have shown significant improvements since the early 1970s. However, since the late 1980s, trends are inconsistent with a number of contaminants showing either little further change or an increasing trend. For many substances, levels remain above objectives specified in the Great Lakes Water Quality Agreement or other guidelines and standards. Restrictions on fish consumption exist in certain areas around the Lakes. Continued high levels of substances whose use has been restricted signals (1) re-release of contaminants previously deposited in the ecosystem, (2) continued release from improper storage of waste and remaining stocks, or (3) continuing use in remote areas and subsequent transport into the basin;

e. **Indicator 17, Bottom Sediment Geochemistry:** contaminated lake or river bottom sediments remain a serious problem in 42 of 43 Areas of Concern. In general, recent deposition of sediments is less contaminant laden, is capping earlier deposits, and is thereby contributing to an improvement. However, at this stage, contaminated bottom sediments are a continuing source of contaminants and nutrients to the water column particularly in areas where storm action re-suspends bottom sediments;

f. **Indicator 18, Contaminant Discharges:** many industrial and municipal point source discharges of contaminants have achieved reductions over the past twenty years. However, the cumulative discharge from point sources in the Great Lakes system remains a serious concern. Both urban and

- Indicator 13: elevated contaminant levels in local areas;
- Indicator 14: eutrophication in a number of nearshore areas and inland lakes, increasing nitrate-plus-nitrate throughout;
- Indicator 15: ongoing acidification in inland lakes;
- Indicator 16: a stabilizing or even increasing trend in the body burdens of some persistent toxic contaminants;
- Indicator 17: contaminated bottom sediments in Areas of Concern;
- Indicator 18: ongoing cumulative discharge of contaminants from point sources and urban and rural nonpoint sources;
- Indicator 19: ongoing nutrient discharge from rural nonpoint sources;
- Indicator 23: ongoing population health problems for a range of fish and water dependent wildlife; growing concern that human health is threatened.

SUMMARY

In spite of the documented improvements in a number of factors, the number and seriousness of these concerns combined with the conclusions reached regarding groundwater signal that the water subsystem of the Great Lakes Basin Ecosystem is not yet on a path towards sustainability.

END NOTES

1. Through the last decade there has been an active debate about the relative merits of measures of water column chemistry as opposed to direct measures of the state of in-stream biological communities for assessing use impairments, particularly use as aquatic habitat. Rankin and Yoder point out that historically, reliance on chemical-specific criteria has come about because:

> (1) past efforts in water pollution control have focused, almost exclusively, on point sources of pollution (municipal waste water treatment plants and industry) where ambient chemical criteria are translated directly to discharge limits;
>
> (2) analytical and field survey techniques for biological community data were not well refined;
>
> (3) a working definition of "biological integrity" was not forthcoming;
>
> (4) biosurvey data had an unfortunate reputation of being too expensive, variable, or imprecise; and
>
> (5) chemical methods were thought to be more "precise" than biological assessments.
>
> (1990, I-2)

However, reliance on chemical monitoring alone may overlook the fact that:

> (1) pollution is often episodic and might be missed by typical monitoring programs;
>
> (2) some chemical parameters that cause degradation may not be measured or easily identified; and
>
> (3) degradation to stream resources may also be caused by nonpoint pollution and habitat destruction, variables that most chemical monitoring programs cannot easily consider.
>
> (Rankin et al. 1991, 4)

In Ohio, between 1986 and 1988, a change was made from assessment based on chemical surrogates and biological narrative descriptions to one based on ecoregion-based biological criteria integrated with various chemical and physical data (Rankin and Yoder, 1991). As a result, the proportion of Ohio's rivers and streams attaining aquatic uses dropped from sixty-one percent to 25 percent of those monitored. Subsequent analysis suggested that:

> ...over-reliance on a simple water chemistry approach seriously underestimates the extent of impairment of a state's waters and provides a potentially biased view of the important causes of impairment.
>
> (Rankin and Yoder 1990, I-9)

As a result of their experience, Ohio has assumed a leadership role in the use of three biological indices for quantitatively monitoring and assessing impairment of aquatic habitat:

- the Index of Biotic Integrity (IBI, based on fish);
- the Invertebrate Community Index (ICI, macroinvertebrates); and
- the Index of well-being (Iwb, fish).

(see discussion Rankin ed. 1988, 3 and Rankin et al. 1991, 4-5)

These direct measures of the state of the aquatic biota are now used as primary indicators in Ohio's water assessments while water chemistry and contaminant source data are used in a supporting role. However, in their assessments, they emphasize the need for an integrated chemical, physical, and biological assessment of a water resource (Rankin and Yoder 1990, I-3).

2. The concept of "safe" levels requires comment for it introduces the notion that for individual contaminants and groups of contaminants, some level can indeed be established that is "safe." Such a concept underlies the idea of standards which are often given the weight of law through their use in regulations attached to legislation.

In principle, the best knowledge available is applied and an appropriate standard is established. Theoretically, when new knowledge appears, the standard is accordingly adjusted. There is a significant limitation associated with this process. Both the development of new knowledge and the values that society uses to weigh the significance of that new knowledge are dynamic. Unfortunately, there is often a significant time delay between the development of new knowledge or a shift in societal values and the adjustment of standards. Hodge and Roman discuss groundwater and the nature of change in public policy pointing out that:

> For any human activity and related field of inquiry, understanding of technical issues grows with time, both through experience and directed research. As this understanding is fed back to society at large, it contributes to shifting societal values and attitudes. After a time lag, these values are reflected in the legislated rules used to govern our society. Inevitably, as Freeze and Cherry point out, "legislation changes . . . and what is an acceptable corporate environmental achievement one year . . . can be unacceptable the next."
>
> (Hodge and Roman 1990, 490)

As a result of these shifts, the use of legal standards to assess "safety" must be done so with caution. Standards do, however, provide a useful benchmark for comparison purposes.

Experience in the Great Lakes provides a useful illustration. Standards originally established for governing concentrations of organic compounds were set without an assessment of the possibility of bioaccumulation and biomagnification in the food web. Thus for example, early water quality standards may have been adequate for drinking water but were not adequate for protection of aquatic organisms. Recent developments that have identified the possibility of some of these contaminants (many of which have hazardous waste site - groundwater origins) functioning as artificial estrogens (see Chapter Twelve) add an entirely new perspective on establishing what might be considered "safe" and the adequacy of standards established a decade ago are now being seriously questioned.

3. Contaminants range from conventional types such as salt (sodium chloride) to radioactivity and persistent toxic contaminants that include heavy metals and a range of organic compounds. This one indicator is both complex and critical.

4. Excessive nutrients lead to massive growth of algae at the bottom of the food web. As these algae die and decompose, oxygen is consumed. Depletion of oxygen then threatens other biota. This process is called eutrophication. It occurs naturally in nutrient rich, productive lakes. But in many parts of the world, human generated nutrients, for example from sewage and agriculture chemicals, have caused serious degradation of water supplies.

5. Measurement of acidity responds to the problem of acid deposition, also a serious problem in many parts of the world.

6. Indicator 16 addresses contaminant levels in biota. It is an indirect indicator of water chemistry. Contaminants found in aquatic biota most likely have an origin in the water although in some cases, they may come from bottom sediments. Contaminants found in non-aquatic biota that feed on aquatic organisms may well signal contaminants in water but this relationship is complicated by the potential for the origin to be from the air. The processes of bioaccumulation and biomagnification add an additional dimension and in particular, extend the time horizon that must be considered. A good summary discussion of food webs, biomagnification, and bioaccumulation is found in Colborn et al. 1990, 16 - 20. The possibility exists for the contaminants to be out of the water column but still residing in the biota and being passed along in the food web.

7. Bottom sediments may be a result of the settling of suspended particles (that could be abiotic or biotic in origin) or chemical precipitation. Depending on the geochemistry, bottom sediments can act as either a sink or source of contaminants. In either case, they can often be used as an indirect indicator of water chemistry.

8. Discharges of contaminants and nutrients (Indicators 18 and 19) also provide an indirect indicator of water quality. However, the more important use of this indicator is in facilitating an assessment of imposed chemical stress, an issue dealt with as a Domain II topic.

9. Compliance with standards is a weak indirect indicator of surface water chemistry. See discussion, Footnote 2 above.

CHAPTER THIRTEEN

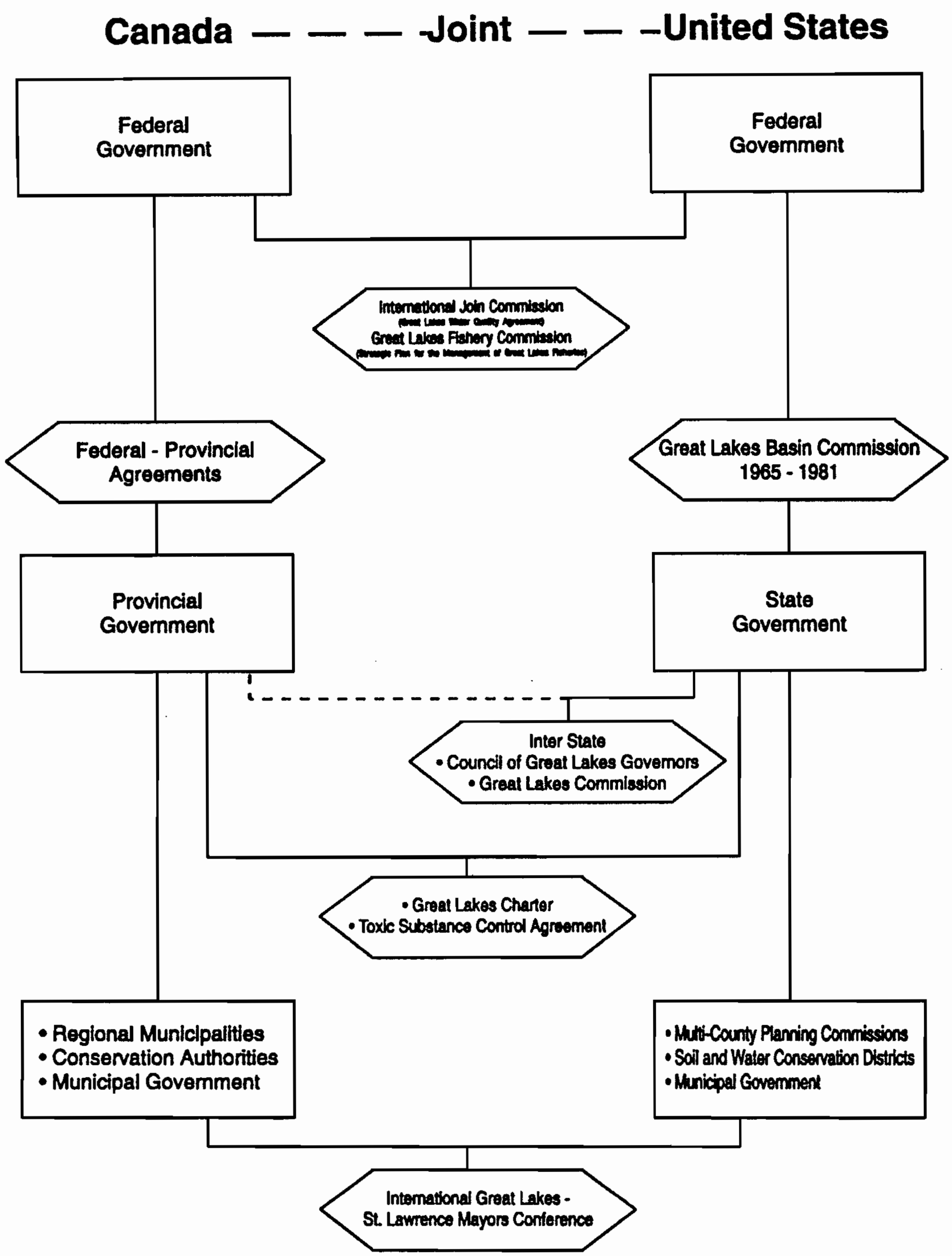
GREAT LAKES CASE STUDY 5

INSTITUTIONS AND IMPLEMENTATION

This Case Study has addressed assessment of sustainability in the Great Lakes Basin Ecosystem. It has explicitly taken the perspective of the ecosystem and decision-makers concerned with the region as an entity. It has done so recognizing that the ecosystem spans political jurisdictions and thus, after the primary ecosystem focus defined by the drainage basin, the secondary decision-making envelope includes eight Great Lakes states and Ontario.

Within the Case Study area, there is an immensely complex web of institutions with responsibilities related to the sustainability question. Within the Toronto area alone, the Crombie Commission identified dozens of institutional actors with some responsibility related just to surface waters (Barrett and Kidd 1991, 102).

In spite of this maze of institutional players, the basic structure of governance for the Great Lakes Basin is relatively simple. It is shown below in Figure 13-1. This figure helps to point to where within the institutional web, the responsibility for monitoring, assessing, and reporting on progress toward sustainability ***for the region*** could and should be lodged.



Source: modified from Francis 1989, 361.

Figure 13-1. Governance framework for the Great Lakes Basin Ecosystem.

The eight Great Lakes states and Ontario have a clear mandate for assessing and reporting on progress toward sustainability within their jurisdictional boundaries. More locally, counties, regional districts, municipalities, Conservation Authorities, and individual communities all have an important role to play within their jurisdiction. However, assessment and reporting on progress toward sustainability for a transboundary, multi-jurisdictional region is a more complex issue.

Ultimate responsibility for this issue lies with the federal governments of the United States and Canada who must agree between themselves on an appropriate mechanism. Resolution of this question has not been a major focus of this case study. However through the course of this work, the following fundamental criteria have become apparent that must be met by the office or institution that is assigned this responsibility if it is to be effective in discharging the task. The office or institution must have:

1. the freedom and resources to function independently;
2. the stature and capability to be able to link successfully with any required element of the existing institutional web;
3. assured longevity of existence to ensure that an institutionalized memory is created and assessment is undertaken periodically.
4. the mandate to report directly and publicly to the body vested with the responsibility and authority to make decisions and act on the results of the reporting.

(modified from NRTEE 1993, 44)

The only mechanism that potentially comes near to meeting these criteria is the International Joint Commission. To activate such an initiative would require a joint reference from the Governments of the United States and Canada.

A comprehensive review of institutions and implementation in the Great Lakes Basin Ecosystem is outside the scope of this dissertation. The subject area is a priority topic for follow-up research.

CHAPTER FOURTEEN.

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

14.1 INTRODUCTION

This dissertation describes the development of a systematic approach to assessing and reporting on progress toward sustainability. It is motivated by the belief that society's current way of assessing and reporting on change is deficient.

14.2 THE PURPOSE OF REPORTING

The overall purpose of assessing and reporting on progress toward sustainability is to improve the way society makes decisions -- to support informed and responsible decision-making and decision-making processes. Specific tasks include:

1. communicating key signals to targeted decision-makers, in particular to give early-warning signals for required policy, institutional, and/or behavioural change;
2. monitoring accountability;
3. encouraging initiative by giving credit where credit is due;
4. identifying knowledge gaps and providing rationales for giving priority to filling these gaps; and
5. providing a systematic framework for designing and staffing research in support of assessing progress toward sustainability and ultimately, determining the organization and content of the final assessment report.

14.3 SYSTEM DEVELOPMENT

Initial research focussed on a review of the literature related to indicators. Almost immediately, it became evident that concern regarding this issue has a long history. No less than six earlier phases of activity aimed at development of improved indicators of progress have occurred during the last fifty years. A dominant concern throughout is a perceived over-emphasis on economic indicators. However, none of these initiatives appears to have had a significant and lasting impact.

As a result of this conclusion, effort in this project was directed away from the choice of specific measures to the development of a systemic framework that could serve as an organizing template for assessing and reporting on progress toward sustainability. With such a framework in place indicators will emerge naturally, appropriately honed to the needs of a given locale or a given set of decision-makers, underlies this shift. Without such an approach, choice of indicators will continue to be ad hoc, reactive to current concerns, and unlikely to cause a change in current practice.

Definitions

First, the concepts of sustainability and sustainable development are carefully described. Sustainability is defined as ***the persistence over an apparently indefinite future of certain necessary and desired characteristics of both the ecosystem and the human subsystem within*** (modified from Robinson et al. 1990). It is a normative concept. Thus, the choice and the degree to which specific characteristics are to be sustained will depend on the operating set of values.

The sustainability of development (sustainable development) is the anthropocentric sub-component and is defined by the Brundtland Commission as ***development which meets the needs of the present without compromising the ability of future generations to meet their own needs*** (WCED 1987, 8).

The term development is taken to mean ***to expand or realize the potentialities of; bring gradually to a fuller, greater, or better state*** (Daly 1989, 4). It has both qualitative and quantitative characteristics and is to be differentiated from growth which applies to a quantitative increase in the physical dimensions of the subject (NRTEE 1993, 10).

Strictly speaking, it would be possible to differentiate a system of reporting on sustainable development from a system of reporting on sustainability. However, because people are part of the ecosystem, it makes little sense to do so.

Values, Goals, and Value-driven System Characteristics

Second, drawing from the review of a large related literature, an operating value base is identified. It is best described as a parallel concern and respect for the ecosystem and people within — not one or the other, not one more than the other, but both together. This value set enables articulation of an overall goal for achieving progress toward sustainability is articulated: to maintain or improve human and ecosystem well-being.

A number of value-driven characteristics that serve as design criteria for the whole reporting system can be identified. For example, the system should focus on:

I. RESPECT AND CONCERN FOR THE ECOSYSTEM - BY

1. using a time horizon in the reporting system that captures both human (short) and ecosystem (short and long-term) time scales;
2. adopting a spatial frame of reference for assessing actions and decisions that extends beyond political and other boundaries to encompass the full extent of affected ecosystems;
3. analyzing individual ecosystem components (e.g. air, groundwater, surface water, soil, fauna, flora etc.) within the context of the connected ecosystem;

II. THE INTERACTION BETWEEN PEOPLE AND THE ECOSYSTEM - BY

4. being sensitive to the complete range of chemical, physical and biological stress on the ecosystem — including that occurring naturally and that imposed by human activities;
5. adopting an anticipatory perspective when dealing with the manner in which indicators, time-horizons and analyses are expressed, so that in the reporting process there will be a forward-looking thrust instead of just a description of past and current conditions;
6. recognizing and accepting uncertainty as an inevitable occurrence instead of an impediment to good decision-making;

III. RESPECT AND CONCERN FOR PEOPLE - BY

7. using assessment criteria that respect the existence of alternative and changing values when evaluating progress;

8. assessing the distribution of environmental, economic, social, and cultural costs and benefits by examining their impacts on different social groups;

9. the inclusion of ways to measure participation and control in decision-making; and
10. using both quantitative and qualitative measures that draw on both objective data and information as well as subjective information such as intuitive understanding based on experience of everyday life, including experience gained from subsistence and traditional life styles.

Conceptual Framework

The conceptual framework proposed in this dissertation reflects the underlying value base, is consistent with systems theory, and draws on insights from state-of-environment reporting, macroeconomics, and roughly thirty theoretical treatments of the human-ecosystem relationship.

Systems theory is seen to have evolved significantly over the past forty years. Earlier work tended to emphasize the definition of objectives and the optimization of approaches to achieve those objectives. The development of techniques to incorporate a range of alternative values in decision-making systems and the emergence of the "ecosystem approach" to human-environment relationships are two important sets of contributions that have served to enrich systems thinking in ways probably not envisioned by early systems workers.

In recent years, there has been a change in systems thinking from optimization of systems to an emphasis on systemic processes of learning related to problems or issues with ill-defined objectives (Checkland and Scholes 1990, 277). This shift has facilitated the use of systems thinking to deal with many ill-defined, real-world situations. The issue of assessing and reporting on progress toward sustainability falls within the bounds of this latter category of problems.

Throughout the evolution of systems ideas, a core element has been a commitment to the idea of the "whole" system which can respond to stress and survive in a changing environment. Such systems are characterized by (1) ***emergent properties*** which are critical for understanding the whole but may have little or no meaning in terms of constituent parts; (2) ***a hierarchical structure*** in which systems are nested within other systems; and (3) ***processes of communication, feedback, and control*** that allow adjustment and adaptation in the face of stress.

Systems thinking involves the use of conceptual models to link components to the "whole" and the identification of controls and feedback loops. It is in the need to assess the state or performance of the constituent parts, controls, feedback loops, and the whole system, that indicators or performance measures arise. However, without the conceptual framework and the related value structure, the choice of indicators occurs in a vacuum.

The use of conceptual models provides a mechanism against which the real world can be set to facilitate learning. This comparison often leads to constructive tension, debate, and hopefully to the accommodation of different interests and values. The desired result is improved decision-making. However, the models themselves must not be thought of as truly capturing the real world, the complexity of which is beyond current knowledge.

All of the above systems ideas apply to a system of reporting on sustainability which is best seen as a system nested within a decision-making system.

The review of state-of-environment (SOE) reports serves to emphasize the richness of data and information that is now being compiled through this mechanism. However, although SOE reporting provides a systematic analysis of environmental conditions and trends, there is no common set of goals and objectives, no accepted norm, no common conceptual framework and no common report format. Further, SOE reporting does not link effectively to decision-making, is rarely anticipatory, and is particularly weak in dealing with human conditions. Thus, SOE reporting does not offer an overall guide for reporting on sustainability.

However, within the SOE literature lies a key conceptual contribution. It is the realization and documentation by David Rapport and Anthony Friend that imposed environmental stress is multifaceted and includes:

(1) physical restructuring;

(2) the addition or loading of substances, heat, radionuclides etc.;

(3) the harvesting or extraction of renewable resources;

(4) the extraction of non-renewable resources; and

(5) the introduction of non-native species and genetic manipulation.

(Rapport and Friend 1979)

Rapport and Friend's contribution serves to shatter the concept of the human-ecosystem relationship that has emerged through economic thought. Economics derived models have evolved from a conventional circular model involving a flow of money matched by an opposite flow of goods and services through a material-energy balance model to a depletion- pollution model.

In this now popular depletion-pollution model, the environment is seen as an "asset" that provides material, energy, and aesthetic resources to drive production and consumption activities within the economic system. As a result of these activities, waste products are formed that are then returned to the environment as pollution. The model thus leads to an interpretation of the environmental "problem" as having two components, one dealing with resource use (or misuse, depletion, and scarcity) and one dealing with pollution or generation of waste residuals. Following this logic, resolution of the "environmental problem" can be attained through (1) appropriate or wise resource use and (2) reduction of pollution. While these are very important steps, they are far from encompassing and do not deal with the range of stress that Rapport and Friend's work identifies. Further, this model's portrayal of the nature and role of the ecosystem itself is far from complete.

The review of the economist's perception of the human-ecosystem relationship is part of an examination of thirty such theoretical treatments. Included are twelve variations of the three-part "social-economic-environment" model, three models drawn from economics literature, three models that stem from Rapport and Friend's stress-response ideas, two general ecological systems models, the model reflected by AGENDA 21, and nine additional models that are found scattered in the literature related to sustainability, conservation, planning, and development.

This review did not reveal an existing model that could serve as a framework for reporting on sustainability. However, as is apparent from the review of SOE reports, the related literature is rich in ideas that contribute to the conceptual approach taken in this work.

The review of these contributions was motivated by a belief that any successful conceptual approach would have to be built on the common insights of many others. As such, this aspect of the project is an attempt to apply Rawls' idea of "overlapping consensus" (1987). Rawls points out that a consensus affirmed by opposing theoretical, religious, philosophical and moral doctrines is likely to be both just and resilient. Public policy based on such an overlapping consensus is therefore more likely to thrive over generations.

In this review, the idea of overlapping consensus is applied by seeking common elements in the conceptual approaches that various workers from a variety of disciplines have used in examining human-ecosystem interaction. Many of these workers are isolated within their disciplines and enjoy little or no interdisciplinary dialogue.

Drawing from all of the above leads to a systemic conceptual framework that includes the enveloping ecosystem, the human subsystem, the interaction between people and the ecosystem, and the related human decision-making processes. From this framework, four strategic elements emerge that serve as areas of diagnosis or indicator domains in the reporting system. They are:

I. Ecosystem

Data and information facilitating an assessment of the integrity and health of the ecosystem;

II. Interaction

Data and information facilitating an assessment of the interaction between people and the ecosystem: how and to what extent human activities contribute to provision of basic needs and the quality of life; how these activities are valued; how these actions stress, or contribute to restoring the ecosystem; and how successful we have been at meeting the goals and objectives of policies, regulations and legislation.

III. People

Data and information that facilite an assessment of the well-being of people including the range of physical, social, cultural and economic attributes.

IV. Synthesis

Data and information that facilitate the recognition of emergent system properties and provide an integrated perspective for decision-making and anticipatory analysis that spans Domains I, II, and III.

Each domain spans a complex set of data and information. Together they provide a template to be applied in support of different decision-making groups in society (including individuals, communities, corporations, regions, provinces/states, nation, other decision-making groups). These domains provide an effective organizing template because:

(1) in concept they are simple, clear, and understandable;

(2) they reflect the system being considered;

(3) they keep the focus where it needs to be - on people and the ecosystem;

(4) they reflect traditional areas of knowledge that can be respectfully brought to bear;

(5) they link easily to government; and

(6) they allow a degree of "compartmentalizing" that is useful for strategic thinking but only within the concept of the whole system.

Linking the Overall Goal to the Framework

In practical application, the assessment of progress toward sustainability must begin with the definition of general goals that provide a framework for subsequent identification of specific measurable objectives. The following goals result when the overall goal is expressed in terms of the four domains of the reporting system:

DOMAIN I GOAL

1. To maintain or improve ecosystem health and integrity;

DOMAIN II GOALS

2. To increase the ability of human activities to contribute to all aspects of human well-being including economic, physical, social, and cultural attributes.

3. To reduce the physical, chemical, and biological stress imposed on the ecosystem by human activities;

4. To increase the extent to which human activities restore ecosystem health and integrity;

DOMAIN III GOAL

5. To maintain or improve human well-being;

DOMAIN IV GOAL (OVERALL)

6. To maintain or improve human and ecosystem well-being.

The above goals are supported by a large number of specific measurable objectives that apply to each system component.

14.4 INDICATORS AND ASSESSMENT

The following definitions emerge from the relevant literature and are used in this dissertation:

INDICATOR:

a measurable descriptor, quantitative or qualitative, of normative interest which facilitates assessment of the past, current, or future state or performance of system constituent parts, controls, and feedback loops as well as the system as a whole.

INDICATORS OF SUSTAINABILITY:

indicators (as above) which:

- reflect a parallel care and respect for people and the enveloping ecosystem now and in the future (the normative interest);
- facilitate assessment (past, current, future) of the sustainability of the system that spans the ecosystem, interactions, people and the related decision-making system (Figure 5-1) using the goals listed in Table 5-4.

In addition, a set of desirable indicator characteristics are identified for use as indicator selection criteria. Indicators of sustainability should:

1. link directly to specific objectives which in turn are nested within general goals motivated by the concept of sustainability;
2. accurately and unambiguously reflect the degree to which the system component being measured meets the related objective;
3. be measurable and based on data which are either available or easily obtainable with a reasonable degree of accuracy;
4. facilitate forward, anticipatory application as well as historic and current analysis;

5. be sensitive to changes over time, space and in the case of the human subsystem, be sensitive to differences between sub-populations;

6. facilitate comparison between like system components being assessed; and

7. facilitate action needed to both reinforce positive results and correct negative ones.

The actual process of assessment is then addressed. While the goals and specific objectives provide the overall framework for assessment, standards and criteria provide the comparative mechanism for assessing any given indicator at the most detailed level. A standard usually enjoys some elevated status: if incorporated within a formal regulation it can have the weight of law. A standard sets a minimum or maximum value that must be achieved.

Criteria are not entrenched in law but can carry significant weight. They are usually expressed as a minimum or maximum that is desirable. A hierarchy of potential criteria exists including: state — point in time; change-of-state — trend; and rate of change-of-state — change in trend.

The setting of standards and criteria is dynamic. As values change and as scientific knowledge increases, assessment standards and criteria inevitably evolve also.

Few indicators have established standards or criteria although these are desirable. Therefore, recourse must be taken to an interpreted sense of goals and objectives. Thus, assessments must depend on judgements based on the best available data, information, experience, and frequently, intuition. Under these circumstances, it is one's operating value set that imputes assessment criteria.

Understanding the larger assessment process is of equal significance to the assessment of individual indicators. Indicators are after all, simply an assessment tool. To make an assessment of progress related to any one of the four domains of the reporting system, a hierarchy of factors must be considered. Thus the concept of an assessment hierarchy emerges.

For each of the four strategic elements a generic assessment hierarchy is developed. Subsequently, the same approach is taken in the Case Study for the more detailed examination of the energy and water subsystems.

Assessment hierarchies range from the most general category at the apex through a progressively finer level of detail towards the bottom. Specific measures are located at the very bottom. They provide a map of the assessment process which builds from specific measures to the apex, drawing on the best available knowledge.

In theory, a comprehensive assessment would methodically address each cell in each hierarchy moving up and down between more and less aggregated levels. In practice, some cells will receive greater emphasis than others, some may not be addressed at all. This emphasis will depend on local knowledge, conditions, operating values, and to some extent, the current issues of concern.

Each Domain assessment emerges as a product of aggregation leading to judgement. While it might be possible to apply numerical analysis in the aggregation process it would be both difficult to do and the results suspect: insights are brought to bear not only from ***measurement*** of state, trends, and changes in trends where possible but also from ***intuitive knowledge and professional judgement***. Further, elements contributing to the aggregation process are rarely compatible in terms of units and an exact weighting relationship is rarely agreed upon.

From a statistical perspective, these aggregations involve not only apples and oranges, but a large variety of vegetables and soil as well. However, they all contribute to assessing conditions and trends in the garden. This approach is an ***application of the "weight-of-evidence" approach***, pioneered in ecosystem analysis by the International Joint Commission in its work on the Great Lakes Ecosystem (IJC 1992, 12) and in use every day in the common law process of our court system.

14.5 GREAT LAKES CASE STUDY

Empirical testing of the proposed reporting system is undertaken with a case study of the Great Lakes Basin Ecosystem. The case study is intended to be illustrative, not definitive. It is a demonstration of how existing data and information can be organized using the proposed conceptual framework as a template and how a systemic assessment of progress toward sustainability can be made that is based on weighing conflicting information in order to determine where the preponderance of evidence points.

The case study assumes a transboundary regional perspective and focuses on regional decision-making. It does not attempt to deal with other decision-making groups such as individuals and households, corporations, state, provincial, and federal governments.

The Great Lakes region may well be at a critical juncture in its evolution. The continuous population growth and economic expansion through the last century may be coming to an end. At the same time, there is a growing realization that the hidden costs of this success in terms of human life and ecosystem degradation must now be accounted for. Re-establishing an enhanced quality of life through ecosystem restoration is emerging as a key to economic renewal. The region is now poised to move into a phase of overall decline or to change its direction to achieve long term stability in terms of both human and ecosystem well-being. In sum, the Great Lakes Basin Ecosystem together with the secondary decision-making envelope provided by the aerial extent of Ontario and the eight Great Lakes states provides an ideal test case for the proposed system of reporting on sustainability.

The proposed systemic assessment process is both practical and feasible. Even with the limitations of current knowledge, a well-founded assessment of progress toward sustainability can be made. In this example, based on the weight-of-evidence, it is apparent that ***the Great Lakes Basin Ecosystem is not currently on a path toward sustainability***.

In particular, ecosystem health continues to deteriorate and imposed stress continues to grow. An overall assessment of trends in human well-being is lacking, not only in terms of individuals but also in terms of communities and institutions. On the positive side, the ability of human activities to support human well-being from a material perspective appears to be growing and the number of initiatives aimed at ecosystem restoration is likely increasing.

Second, the methodology is useful in identifying some significant gaps in data and information. The following gaps are identified:

Domain I: Ecosystem

1. systemic analytic techniques that encourage assessment of ecosystem components within the context of the whole ecosystem;

2. data describing: toxic contaminants in air; surface water quality of inland rivers, lakes, and streams; physical and chemical characteristics of the groundwater flow system; the state of built infrastructure; the population health status of wide range of organisms; aquatic and terrestrial habitat; forest ecosystem health and integrity; human health and well-being (as an indicator of ecosystem health and integrity).

Domain II: Interaction

1. data, information, and analytic techniques that would facilitate an analysis of the imposed physical chemical, and biological stress caused by individual human activities;
2. data, information, and analytic techniques that would facilitate analysis of restorative actions and opportunities;
3. data describing: imposed physical and biological stress; activity-by-activity imposed physical, chemical, and biological stress; restoration actions and opportunities.

Domain III: People

1. data, information, and analytic techniques that would facilitate an assessment of overall human well-being;
2. data, information, and analytic techniques that would facilitate a systemic assessment of the well-being of corporate, judicial, and legislative institutions;

Domain IV: Synthesis

1. historical data and information and a compilation of older knowledge that would facilitate assessment of not only current state and change in state (first order change) but also change in the rate of change (second order change);
2. techniques for identification of emergent system properties; and
3. techniques for integrated decision-making and anticipatory analysis.

The methodology is effective at the subsystem level. Two subsystems are examined: (1) energy production, transportation, and use (an example from Domain II) and (2) surface water and groundwater (an example from Domain I).

In assessing the energy sub-system, care is first taken to define both energy demand and energy supply as important policy-driven variables. This approach is that of soft energy path analysis. Application of the proposed methodology leads to the identification of sixteen required indicators that group in the following five categories:

1. Quantity and Quality of Energy Produced, Imported, and Used;
2. Efficiency of Transformation and Use;
3. Imposed Stress;
4. Longevity of Energy Supply; and
5. Restoration.

A weak conclusion is drawn that current trends do not signal overall progress toward sustainability. Available data show a recent reduction in energy use per dollar value added. However, how much of this change is due to structural adjustment in the economy and how much due to improved energy efficiency is unknown. Since 1985, energy use per capita appears to be increasing after dropping in the late 1970s and early 1980s. There is an ongoing vulnerability because of dependency on imported petroleum products and coal.

Current practice of energy analysis and energy-related data compilation is seriously deficient for rigorously assessing progress toward sustainability. Only a minority of these indicators dealing with per capita and total energy use and some emissions data are easily available. Indicators dealing with energy quality, efficiency, imposed stress, the longevity of supply, and restoration are not readily available although there is no technical reason to prevent their compilation. As a result, while general observations can be made about energy and progress toward sustainability, the specific actions that can be initiated on an activity-by-activity basis cannot be identified. This situation is particularly alarming given the importance of energy to the sustainability equation.

The water subsystem of the Great Lakes Basin Ecosystem is carefully defined to focus on the water itself, not the aquatic ecosystem. It is no less important to focus on the aquatic ecosystem but that is a different analysis.

Twenty-three indicators are identified that group into four categories:

1. Groundwater — physical characteristics;
2. Groundwater — chemical characteristics;
3. Surface water — physical characteristics; and
4. Surface water — chemical and biological characteristics.

The conclusion is reached that in spite of documented improvements in a number of factors, the number and seriousness of identified concerns indicate that the water subsystem of the Great Lakes Basin Ecosystem is not yet on a path towards sustainability.

It is apparent, that data and information describing groundwater flow systems and chemistry are seriously deficient. This deficiency represents a serious gap in knowledge.

In contrast, surface water has benefited from the longest attention of any ecosystem component and is relatively well understood. The only areas where data are seriously deficient are water course continuity, water use efficiency and curtailments, and rural and urban nonpoint sources.

14.6 CONCLUSIONS REGARDING METHODOLOGY

A number of overall conclusions regarding the methodology can be drawn. First, the proposed methodology facilitates a systematic choice of indicators, be they specific measures or aggregations.

Second, the assessment hierarchies provide a powerful tool not only for mapping the process but also as a check template for identifying gaps and emerging issues. It is important to periodically revisit the broader framework to test current ideas, identify potential concerns, and assess their implications. It is in this revisiting that often missed, overarching and anticipatory thinking demonstrates the greatest usefulness of the conceptual framework and assessment hierarchies.

Third, data supporting Domains I, II, and III are not typically compiled on the same spatial basis. Domain I is relatively easily compiled on an ecosystem basis in spite of data gathering by agencies and individuals from many different local, state/province, and regional agencies. Data for Domain III describing human well-being are generally available by community or state/province. Data describing human activities, Domain II, are more easily available at the state/province level of aggregation but are sometimes available on a drainage basin basis as well. These boundary differences are currently unavoidable and complicate but do not prevent the overall Synthesis that is developed as Domain IV. It was not possible within the scope of this project to fully explore the Domain IV analysis.

Fourth, in general terms, the approach taken in this case study includes two steps. It begins with an examination of the development history of the Great Lakes Basin Ecosystem through the past century. Telling this story facilitates the identification of a number of overall trends important to the sustainability question. A second step then involves the formal assessment of progress toward sustainability moving from the general to the more specific and back again. Each element of assessment involves judgement that weighs knowns against unknowns, searches for patterns and trends, and balances probabilities in a process that draws inspiration from our system of common law. In spite of data and knowledge limitations, this approach facilitates a well-founded judgement -- one that can always be improved with better data and knowledge.

Fifth, the proposed system can be viewed as built on earlier contributions including input-output ideas of early systems thinking, the stress-response ideas of Rapport and Friend, and the three-part environment-economic-social natural resource use model. For example, Domain II can be thought of as input and Domains I and III as outputs. Domain II is the stress and Domains I and III are the response.

However the labels of earlier work (along with significant definitional limitations) have been discarded in favour of those that are consistent with systems theory and reflective of the underlying value base (ecosystem, interaction, people). Most importantly, the Domain IV synthesis has been introduced. The development and balancing of aggregated indicators is facilitated here. Without this synthesis, components remain isolated and emergent properties relating to the whole system will not be recognized.

Sixth, the Domain IV analysis results in a short list of five aggregated indicators. They deal with assessments of:

DOMAIN I: ECOSYSTEM

1. overall ecosystem well-being;

DOMAIN II: INTERACTION

2. the success of human activity in providing support for human well-being;
3. the extent of stress imposed by human activity on the ecosystem;
4. the extent to which human activities contribute to restoration of ecosystem health and integrity; and

DOMAIN III: PEOPLE

5. overall human well-being.

Each of these is a complex aggregate occupying a position high up on the assessment hierarchies and supported by a large number of often conflicting data sets. But, in turn, the result of each assessment serves as an indicator contributing to the even more aggregated assessment of progress toward sustainability that is completed in the final Domain IV synthesis. Together they are a powerful set of indicators of sustainability. Each is a complex aggregate, occupying a position high up on the assessment hierarchy — at the top of each of Domains I, II, and III — and supported by a large number of often times conflicting data sets.

Much of the recent interest in indicators has been motivated by a desire to identify a small group of key indicators that could be monitored to effectively assess progress. This interest is subject to a long-standing policy - science debate. Policy analysts, faced with the challenge of accounting to the public for government activity, argue that simple indicators, few in number are required to monitor and communicate progress on public policy issues. Scientists, understanding the complexity of the processes and systems being monitored are reluctant to build simple indicators on assumed causal relationships that are not well established. Further, the process of peer review, engrained in every scientist, demands a transparency in data measurement and interpretation that is often side-stepped in "nutshell" information sought by policy makers.

The issue is complicated by the fact that the ecosystem, including the human sub-system, is dynamic. What is considered a critical concern today in terms of sustainability will inevitably give way to other issues and concerns tomorrow. That is the nature of our evolving knowledge and values.

In a given political jurisdiction and at a given point in time, certain key issues must inevitably dominate public policy. Such issues are appropriately tracked with a few simple indicators. An example is the ongoing monitoring of emissions contributing to acid deposition. These kinds of indicators fall towards the bottom of the assessment hierarchies developed in this dissertation (see Figures 8-1 through 8-4). On their own, dependency on such a short list of specific measures can lock perspective to current concerns and inhibit anticipatory thinking.

In contrast, the short list of five indicators listed above are aggregates occupying the apex of each assessment hierarchy. It is at this level within the system that a practical short list of indicators would be expected to emerge. However, indicators involving a greater degree of aggregation inevitably must depend on a greater amount of applied judgement than at the base where specific measures yield trends that are clear. Resolution of this dilemma lies in establishing a rigorous process of judgement for use in developing these aggregates.

14.7 IMPLEMENTATION IN THE GREAT LAKES

A final comment regarding implementation of a reporting system for the Great Lakes Basin Ecosystem is appropriate. The issue of implementation is important and a top priority for follow-up research.

In spite of the immensely complex web of institutions with responsibilities related to the sustainability question, the basic structure of regional governance is relatively simple. And while analysis of this institutional maze is not a major focus of this case study, three criteria have emerged in the course of this work that must be met for an office or institution to be able to effectively assume the responsibility for assessing and reporting on progress toward sustainability in the Great Lakes Basin Ecosystem. The required office or institution must have:

1. the freedom and resources to function independently;
2. the stature and capability to be able to link successfully with any required element of the existing institutional web;
3. assured longevity to ensure that an institutionalized memory is created and assessment is undertaken periodically; and
4. the mandate to report directly and publicly to the body vested with the responsibility and authority to make decisions and act on the results of the reporting.

The only mechanism that comes near to potentially meeting these criteria is the International Joint Commission.

14.8 RECOMMENDATIONS FOR FUTURE RESEARCH

This work is characterized as much by breadth as depth. As a result, in the course of its completion, a large number of topics requiring attention emerged. The following eight topics are deserving of the highest priority.

1. **FURTHER SYSTEM TESTING AND PARTICIPATORY ACTION RESEARCH.** The completed case study provides a general assessment of the ecosystem-defined region from the perspective of regional decision-making. It then looks in greater detail at the energy and water subsystems. Further testing focusing on different decision-making groups (individual/household, community, corporate, province/state, federal) and differently bounded regions (different ecosystem units, different political jurisdictions ranging from community to nation) should be undertaken. An important aspect of this work is to expand the circle of discussion drawing on the experience of a broad range of decision-makers in a program of participatory action research.

2. SUB-SYSTEM ANALYSIS. Systematic analysis of the energy and water sub-systems led easily to the identification of required data sets and indicators. Similar analyses should be completed for other sub-system components especially:

a. the various ecosystem components of Domain I, including air and climate, land and biota;

b. the various human activities of Domain II, their value, the stress they impose, and the potential contribution each can make to restoration;

c. the various components of human well-being found in Domain III particularly the institutional component.

Use of formal modelling techniques should be explored for application at the sub-system level particularly for analysis of human activities (b. above).

3. DOMAIN IV ANALYSIS. It is within Domain IV analysis that emergent properties can be identified that are not apparent from considering any one of Domains I, II, or III. Further, it is here that an integrated perspective can be achieved to serve as a basis for decision-making and anticipatory analysis that is truly rooted in the bridging concept of sustainability. Research is required to examine the applicabilty of existing techniques and develop new approaches to undertaking Domain IV analysis.

4. THE USE OF NARRATION. The field of hermeneutics or interpretation and the use of narration as a technique in policy analysis and planning is receiving renewed interest. Its application as a formal aspect of reporting on sustainability has not been studied to date. Because of its potential for making a significant contribution to the assessment process, it should be assigned a high priority for follow-up research.

5. VALUING HUMAN ACTIVITY. Different approaches to valuing human activity including money-based, time-based, land-based, and energy -based alternatives require careful examination.

6. FORMALIZING THE JUDGEMENT PROCESS. This work makes it very clear that a critical element of the reporting system is the actual judgement process required to deal with a range of system components as well as the system as a whole. Inevitably data sets must be used with contradictory states and trends. Overall, few of these data sets employ rigorous standards and criteria to provide the comparative framework for assessment. And while it might be possible in certain instances to use schemes of numerical weighting and aggregation to assist the assessment process, it is often not possible to do so. This situation has led the International Joint Commission to use a "weight of evidence" approach. This approach is no different than that of the judgement process used in courts of law. This kind of assessment process requires a comprehensive and public "reasons for decision" if it is to be effective and fair. This entire topic is worthy of in-depth review.

7. IMPLEMENTATION. Implementing the proposed system of reporting is a critical topic for follow-up research. This issue will have a particular resolution in any given political jurisdiction or with any particular decision-making group. However, given that there has been no successful application of reporting on sustainability to date, the topic is worthy of examination in order to establish needed generic characteristics of the implementing process and agency.

8. GREAT LAKES CASE STUDY FOLLOW-UP. The Great Lakes Case Study resulted in the identification of some significant gaps in regional syntheses of data and information. Filling these gaps would greatly strengthen the assessment of progress toward sustainability. Included are regional syntheses of the following sixteen data and information sets:

a. toxic contaminants in air;

b. surface water quality of inland rivers, lakes, and streams;

c. water course continuity;

d. water use efficiency and curtailments;

e. the extent of urban and rural nonpoint sources of contaminants to surface and groundwater;

f. physical and chemical characteristics of the groundwater flow system;

g. the state of built infrastructure;

h. the population health status of a wide range of organisms;

i. the status of aquatic and terrestrial habitat;

j. forest ecosystem health and integrity;

k. human health and well-being;

l. activity-by-activity imposed physical, chemical, and biological stress;

m. activity-by-activity restoration actions and opportunities;

n. the quality and efficiency of energy use;

o. the imposed stress resulting from energy production and transportation; and

p. the longevity of energy supply.

The issue of assessing and reporting on progress toward sustainability is central to facilitating action. Without systematic reporting, society cannot know if progress is being made, it cannot know to change policies or behaviour, it cannot build on its own history, it cannot anticipate the implications of its own actions in order to prevent the repetition of mistakes previously made.

In spite of this motivation, the interdisciplinary issue of assessing and reporting on progress toward sustainability has not previously received in-depth research attention. The work documented in this dissertation is an early step in that direction. The need for follow-up is paramount.

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APPENDIX I

SUSTAINABILITY, SUSTAINABLE DEVELOPMENT AND VALUES

1. CONCEPT ORIGINS

The roots of the concept of sustainability lie in the mythology of North American Indians (Dorcey 1991a, 3) as well as in legends of the ancient Greeks who linked their version of "Gaia", the Goddess of the Earth, with natural replenishment (Hughes 1983, 55). Peter Jacobs et al. suggest that two closely-related Western paradigms of conservation are seminal:

> The first evolved from the perception that nature should be preserved; it was a reaction against the *laissez-faire* economic theory that considered living resources as free goods, external to the development process, essentially infinite and inexhaustible ... The second was derived from the moral injunction to act as a steward of the landscape ...
>
> (Jacobs et al. 1987, 18)

William Rees (forthcoming 1993, 2) and Partha Dasgupta (1991, 26) identify contributing ideas from the early part of this century, the former linking sustainability to the theory of renewable resource management and the latter pointing out that the "greening" of economics dates at least to Pigou's (1920) development of the concept of *externalities* and his differentiation of *private* and *social* costs.

Contemporary discussion of sustainability has been prompted by the notion of 'sustainable development' popularized in 1987 by the publication of *Our Common Future*, the World Commission on Environment and Development or Brundtland Commission's report (WCED 1987).

The 1972 United Nations Conference on the Human Environment held in Stockholm is usually credited with the origin of the term 'sustainable development' (Barbier 1987, 102). However, Lynton Caldwell suggests it probably originated in 1968 at The Biosphere Conference in Paris and Ecological Aspects of International Development Conference held in Washington (1984).

In 1972, publication of the Club of Rome's report, *Limits to Growth*, provided startling and controversial projections suggesting that absolute limits to natural resources available for human support would be reached if current practices of resource use were continued (Meadows et. al. 1972). As if on cue, 1973 brought the Arab-Israeli war, the Arab oil boycott, the subsequent coordinated action by OPEC to raise oil prices, and the first world energy crisis, cementing awareness that the period of relatively inexpensive and apparently unlimited fuel resources was rapidly coming to an end (SCC 1977, 13).

Simultaneously, the United Nations embarked on a new experiment. The 1972 World Conference on the Human Environment was held in Stockholm. Its was organized to facilitate interdisciplinary discussion that cut across traditional barriers and bring governments, international and national agencies, and non-government organizations together. At this conference, concerns for the natural environment were place on the international agenda for the first time. Recognizing that urbanization and industrialization were dominant sources of stress on the environment, a second international conference focussing on Human Settlements, Habitat '76, was held in Vancouver in 1976 (Oberlander 1989, personal communication).

In Canada, work by the Science Council (SCC) led to the concept of the "Conserver Society" (SCC 1973, 47; 1977). This concept is rooted in a concern for future generations. It recognizes that human cycles which were once well integrated with nature, are no longer synchronized with natural life cycles. And importantly, it is based on principles that would "reconcile our environment with our economy; our ends with our means" (Solomon 1978, 2). Such a society would:

- promote economy of design of all systems, that is, "doing more with less;"
- favour re-use or recycling and, wherever possible, reduction at source;
- question the ever-growing per capita demand for consumer goods, artificially encouraged by modern marketing techniques; and
- recognize that a diversity of solutions in many systems such as energy and transportation might in effect increase their overall economy, stability, and resiliency.

> In a Conserver Society, the pricing mechanism should reflect not just the private cost, but as much as possible the total cost to society, including energy and materials used, ecological impact, and social considerations. This will permit the market system to allocate resources in a manner that more closely reflects societal needs, both immediate and long term.
>
> (SCC 1977, 13)

The concept was explored by the Montreal based research group GAMMA, who listed three successively more radical scenarios: expansion with efficiency (*doing more with less*), a stable industrial state (*doing the same with less*), and a "Buddhist" scenario (*doing less with less*) (Valiskakis et al. 1975, 1976, 1979).

While interest in the Conserver Society waned in the early 1980s, many of its seminal ideas re-emerged under the aegis of sustainable development (for a discussion, see Robinson, 1989). In the 1970s however, the ideas of the Conserver Society caught and nourished a rising tide of public concern for the environment, much as the Brundtland Commission Report, *Our Common Future* (WCED, 1987) would do a decade later in 1987.

On the international stage, the United Nations called for a new "International Development Strategy" in 1979. It was intended to:

> (a) redress the inequities in the relations between richer and poorer nations;
>
> (b) establish a more dynamic, more stable, and less vulnerable world economy, in which all countries have opportunities o participate on a fuller and more equal basis;
>
> (c) stimulate accelerated economic growth in the poorer countries of the world; and
>
> (d) reduce and eventually overcome the worst aspects of poverty by improving the lot of hundreds of millions of people now living in abject poverty and despair.
>
> (IUCN et al. 1980, Section 20)

In 1980, the International Union for Conservation of Nature and Natural Resources (IUCN), the United Nations Environment Programme (UNEP) and the World Wildlife Fund (WWF) published the first World Conservation Strategy. They called for "equitable, sustainable development" that would combine the objectives of the new International Development Strategy described above with the following objectives of the World Conservation Strategy:

(a) maintenance of essential ecological processes and life-support systems;

(b) preservation of genetic diversity; and

(c) sustainable utilization of species and ecosystems.

(IUCN et al. 1980)

However, it was not until the 1987 publication of *Our Common Future* that the idea of sustainable development caught hold. *Our Common Future* combined elements of the International Development Strategy and the World Conservation Strategy. It was seen as "a third and compelling call for political action" (WCED 1987, x) following on the work of the Brandt Commission on North-South Issues (*Programme for Survival*, 1980; *Common Crisis*, 1983) and that of the Palme Commission on Security and Disarmament (*Common Security*, 1982)

With completion of the work of the World Commission on Environment and Development, the United Nations initiated a third international conference following from Stockholm '72 and Habitat '76. The themes of human environment and human settlement were brought together in The World Conference on Environment and Development or "Earth Summit" held in Rio de Janeiro, Brazil in 1992. At this meeting sustainable development was considered the principle integrating idea.

2. DEFINITIONS AND VALUES

The Brundtland Commission calls for a new world order that recognizes environmental values while working to overcome vast social and economic inequities. Their concern stems from recognition of both the inequities that currently exist between developed and developing parts of the world, as well as from those that would inevitably exist between this and future generations unless major changes in policy development and decision-making were introduced.

The Brundtland Commission defines sustainable development as that which "meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED 1987. 8). The general nature of this definition has sparked heated debate and in particular, how to translate such generalities into specific actions. If development is to be sustainable, what is development? If development means continued economic growth in the style of the current western market system, what level of activity is to be sustained, and over what time period? And of paramount importance, is continued economic growth of this sort possible without destruction of the ecosystem?

William Rees states rather cynically, "in light of worsening global environmental trends, any concept that implies we can eat our development cake and have the environment too, is bound to have a certain popular appeal" (Rees 1989, 1)· Some suggest that unless it is more clearly defined, the term sustainable development would surely be relegated to a simple catch phrase for politicians, business people, and economists (McLaren 1990). Others have pointed out the bridging capability of the current terminology: the ideas of sustainability acts as a mediating term acceptable to both developers and environmentalists, although both 'sides' are able to use the term to their own advantage (O'Riordan 1988, 29).

An alternative reaction to the definitional debate is provided by Herman Daly who suggests that the lack of a precise definition of sustainable development has led to an important international debate. This debate has engendered an overall consensus that: (1) "it is both morally and economically wrong to treat the world as a business in liquidation;" (2) patterns of development must hold good for many future generations as well as the present one; and (3) the Brundtland Commission was "wise not to foreclose the emergence of this vague but important consensus by insisting on a precise analytic definition from the outset" (Daly 1989, 16, 18).

Daly also makes an important contribution by uncoupling the concepts of development and growth. Growth is a term he applies to "the quantitative scale of the physical dimensions of the economy" (Daly 1989, 4). In contrast, he links development with a qualitative improvement. He notes that "to develop means to expand or realize the potentialities of; bring gradually to a fuller, greater, or better state" (Daly 1989, 4). It is this qualitative sense of development that will be used throughout this dissertation.

The authors of *World Resources 1992-93* point out that to bring a focus to the definitional debate, some authors have limited their concern to the physical aspects of sustainable development (WRI et al. 1992, 2). For example, Goodland and Ledec (1987, 36) and Pearce et al. (1988, 6) emphasize the use of renewable resources in a way that does not eliminate or degrade them or otherwise diminish their "renewable" usefulness for future generations while maintaining effectively constant stocks of natural resources such as soil, groundwater, and biomass. Non-renewable mineral resources have received much less attention in the sustainable development literature. Barbier concentrates on "maximizing the net benefits of economic development, subject to maintaining the services and quality of natural resources" (1989, 185).

A broader context is provided by Anil Markandya and David Pearce who link sustainable development to the idea that "the use of resources today should not reduce real incomes in the future" (1988b, 11). And Robert Repetto argues that:

> ...current decisions should not impair the prospects for maintaining or improving future living standards ... This implies that our economic systems should be managed so that we live off the dividend of our resources, maintaining and improving the asset base.
>
> (1986, 15 - 16).

Building on the concern for future generations articulated by the World Commission on Environment and Development, Pearce et al. examine sustainable development first as a concept of non-declining wealth and secondly as a concept of non-declining *natural* wealth (1989, 34 - 49). In the former, the overall aggregate of natural and man-made capital is held constant from one generation to the next. This approach assumes that man-made and natural capital are substitutes, and as long as the aggregate is constant, the stock of natural assets can decline because the growth of man-made assets will forever compensate.

However, they go on to cite four factors that significantly undermine such a "constant wealth" concept of sustainable development:

1. the weakness of the substitutability assumption (e.g. humankind cannot recreate the earth's protective ozone layer);

2. the limit to human understanding of ecosystem functions; uncertainty in knowing our dependency on the ecosystem for survival; the related uncertainty in also assuming technological advances will forever be able to compensate for destruction of natural assets;

3. the irreversibility of ecosystem damage (e.g. once lost, species cannot be recreated); and

4. the complications of the current and ongoing lack of equity in global distribution of technological benefits and environmental damage.

(Pearce et al. 1989, 34 - 49).

As a result of these factors, the constant wealth criteria has been labelled a "weak" criteria.

Pearce and co-workers then propose a "non-declining *natural* wealth" concept of sustainable development, a criteria labelled "strong." Overall, they conclude that a constant or rising natural resource stock (rate unspecified) is most likely to serve the goal of intergenerational equity.

David Pearce and Kerry Turner suggest that sustainable development "involves maximizing the net benefits of economic development, subject to maintaining the services and quality of natural resources over time" (1990, 24). They interpret economic development as a broad concept that includes not only increases in real per capita incomes, but also other elements of social welfare. Further, they would govern the maintenance of services and quality of natural resources by two rules: (1) the use of renewable resources only on a sustainable yield basis; and (2) the use of non-renewable resources only at "optimal" efficiency subject to substitutability between resources and technological progress.

In addition to approaching the sustainable development definitional debate from its role as an influence on economic theory, a number of contributors have found it useful to start with the identification of general principles to guide their work. For example, Pearce et al. list three such principles that they suggest frame the idea of sustainable development:

> 1. a substantially increased emphasis on the value of natural, built and cultural environments relative to that accorded historically;
>
> 2. a concern both with the short- to medium- term horizons, say the 5 to 10 years over which a political party might plan and implement its manifesto, and with the longer-run future to be inherited by our grandchildren and perhaps beyond;
>
> 3. emphasis on providing for the needs of the least advantaged in society ("intragenerational equity"), and on a fair treatment for future generations ("intergenerational equity").
>
> (Pearce et al 1989, 2)

Similarly, Michael Jacobs argues that although there is disagreement on exactly what sustainable development entails, there is a core meaning that includes (1) the entrenchment of environmental considerations in economic policy-making; (2) a commitment to social equity; and (3) recognition that development implies qualitative as well as quantitative improvement (Jacobs 1991).

In their second World Conservation Strategy, IUCN et al. point out that much of the definitional confusion is a result of interchangeable use of such terms as sustainable development, sustainable growth, and sustainable use, as if their meanings were the same. They argue:

They are not. "Sustainable growth" is a contradiction in terms: nothing can grow indefinitely. "Sustainable use" is applicable to renewable resources: it means using them at rates within their capacity for renewal.

"Sustainable Development" is used in this Strategy to mean: improving the quality of human life while living within the carrying capacity of supporting ecosystems.

> A "sustainable economy" is the product of sustainable development. It maintains its natural resource base. It can continue to develop by adapting, and through improvements in knowledge, organization, technical efficiency, and wisdom.
>
> A "sustainable society" lives by ... nine principles ...
>
> (IUCN et al. 1991, 9 - 12)

Their nine principles are listed in Table 1.

TABLE 1. NINE PRINCIPLES OF A SUSTAINABLE SOCIETY

1. maintaining respect and care for the community of life;
2. choosing as the aim of development, the improvement of the quality of human life;
3. conserving life support systems, biodiversity, and ensuring that the uses of renewable resources are sustainable;
4. minimizing the depletion of non-renewable resources;
5. keeping within the Earth's carrying capacity;
6. assuming personal attitudes (values) and practices that support the new ethic;
7. enabling communities to care for their own environments;
8. providing a national framework for integrating development and conservation; and
9. creating a global alliance of all countries to pursue worldwide sustainability together.

Source: IUCN et al., 1991, 9 - 12.

These later contributions reflect an important characteristic of the definitional debate. Rather than attempting to provide an air-tight definition, the aforementioned contributors have articulated an expression of underlying values. In 1988, the Dutch economist Johannes Opschoor suggested that to address the sustainability issue,

> ...one cannot escape the need to specify an ethical point of departure [that includes] "sustainability" of resource utilization, "justice" in the distribution of the fruits thereof, and partial "responsibility" for the continued evolution of all life forms [as] ethically defendable human values . . .
>
> (Opschoor, 1988)

Pearce et al. explicitly state that development is a normative or value-laden issue and that achieving economic development has something to do with achieving a set of social goals that may change over time (1989, 29). They further suggest that economic development would likely include three elements: (1) advance in the "utility" experienced by individuals; (2) preservation of existing freedoms or advances in freedoms where existing ones are inadequate; and (3) increased self-esteem and self respect. By "utility" they mean "satisfaction" or "well-being" and caution that equity must be considered: average societal well-being must not be attained at the expense of those most disadvantaged.

In an insightful contribution, John Robinson et al. also point out that sustainability is a "normative ethical principle" and thus precise definition will depend on any society's operative set of values (1990). They relate sustainability to "the persistence over an apparently indefinite future of certain necessary and desired characteristics of the socio-political system and its natural environment" and identify the seven characteristics of sustainability listed in Table 2.

Robinson et al.'s. description is important for a second reason. In describing sustainability in terms of "the socio-political system and its environment" they take a tentative step towards a systems description of the issue.

This same systems theme is strongly emphasized in the "working definition" of sustainability proposed by Robert Costanza et al. who suggest:

> *Sustainability* is a relationship between dynamic human economic systems and the larger dynamic, but normally slower-changing ecological systems, in which (1) human life can continue indefinitely, (2) human individuals can flourish, and (3) human cultures can develop; but in which effects of human activities remain within bounds, so as not to destroy the diversity, complexity, and function of the ecological life support system.
>
> (Costanza et al. 1991, 8)

Costanza et al.'s use of such value-laden words as "flourish" and their use of "develop" as a qualitative modifier of culture serves to underline the normative nature of the idea of sustainability.

TABLE 2. SEVEN IMPORTANT CHARACTERISTICS OF SUSTAINABILITY.

1. What is most important is preserving ***capacity to change***. Persistence of a system itself in perpetuity is not required.

2. Increasing the sustainability of a system is not necessarily equivalent to preserving the system in its current form. Increased ***resilience*** (capacity to recover from disturbance) is the appropriate goal rather than increased ***reliability*** (resistance to breakdown).

3. Both ***necessary and desirable characteristics*** should be considered.

4. The value-laden nature of this definition makes essential consideration of ***who is to decide*** what the necessary and desirable characteristics are ***and on what basis*** such decisions are made. Thus, social/political dimensions of sustainability are equally as important as environmental/ecological dimensions.

5. Because the definition is value-laden, there will be ***no single precise definition*** of sustainability.

6. Is is not meaningful to measure the absolute sustainability of a society at any one point in time. Sustainability will change as values change.

7. Applying this concept of sustainability, it is more meaningful to pursue a goal of ***"sustainable society"*** rather than ***"sustainable development"***.

Source: Robinson et al., 1990 (emphasis added).

Anthony Dorcey describes sustainable development as an evolving ethic (1991a, 4) and Susan Holtz offers an observation that emphasizes the value base of the term "sustainable development" (1992, 3). Also building on the qualitative sense of the term 'development', she links the concept of sustainable development to "the continuance of progressive social change" within constraints imposed by the enveloping ecosystem. Defining and assessing the "progressive" nature of this change is obviously a value-driven exercise.

Recognizing that the idea of sustainability is value-laden as explicitly stated by Opschoor (1988), Pearce et al. (1989), Robinson et al. (1990), Dorcey (1991), and implied by Costanza et al. (1991) and Holtz (1992), renders unnecessary the establishment of a single and rigorous ***end-point*** definition of sustainable development. Instead, effort can be made to (1) identify and express the (evolving) values that drive the concept of sustainability, (2) define the goals that reflect these values and provide an overall framework for achieving progress toward sustainability, (3) define a practical system for reporting on sustainability that is linked to these goals through measurable objectives, and (4) identify key signals (indicators, indices, measures of effectiveness, or other instruments) within that system that must be monitored and assessed to provide the best possible input to decision-making for both current and future generations. These steps are exactly those followed in this dissertation.

3. SUMMARY

The various elements of these ideas must be analyzed in relationship to one another to clarify the use of the terms "sustainable development" and "sustainability" in this dissertation.

To start with, both terms are normative. Thus, practical application is value-driven. This work is therefore explicitly value-based. It uses as its foundation, a value set based on a parallel care and respect for people and for the enveloping ecosystem - not one or the other, not one more than the other, but both together as one. The discussions found in Appendices II, III, and IV all contribute to derivation of this value set.

The term "development" is used in the sense introduced by Daly: to expand or realize the potentialities of; bring gradually to a fuller, greater, or better state. (1989, 4). Sustainable development is used as a term to describe qualitative growth of human society bounded by the same linked concern for human and ecosystem well-being. It is driven by the belief that current needs should be met without compromising the ability of future generations to meet their own needs within their own set of potentially different values.

This approach to describing sustainable development is particularly useful because it helps to focus on managing human activities while abandoning all pretence of trying to "manage" the environment. Policies, decisions, and regulations cannot "manage" the environment; all they can do is regulate human activity as it affects the environment (NRTEE 1993, 9-10).

Sustainable development is thus taken as an anthropocentric concept. The terms "environmentally sustainable economic development" (Goodland et al. 1992), "environmentally sustainable socio-economic development" (Dorcey 1991a, 4), "ecologically sustainable economic development" (Braat and Steetskamp 1991, 271), and "ecologically sustainable development" (Potvin 1991a; Victor et al. 1991, and Ruitenbeek 1991), are all consistent anthropocentric modifications of the more simply stated sustainable development.

There are many practical implications that must be taken into account when considering how best to draw support from the ecosystem for human activities. A good example is the suggested move to renewable resource use that ensures maintenance or improvement of the "asset base" (Repetto 1986, 15 - 16) or that overall, a state of "non-declining natural wealth" is sought (Pearce et al. 1989, 37). These are necessary concerns of sustainable development.

However, the underlying value set of care and respect for people and the enveloping ecosystem pushes well beyond an anthropocentric, resource use focus. It is for this reason that the concept of sustainabilty is seen as one that is broader than sustainable development.

In this dissertation, sustainability is used as a term that describes the persistence over an apparently indefinite future of certain necessary and desired characteristics of both the human subsystem and the enveloping ecosystem (modified from Robinson et al. 1990). This definition signals the normative nature of the concept, is consistent with the underlying value set, and appropriately hints at the nature of the system that must be considered.

In addressing the issue of monitoring, assessing, and reporting, this disseration therefore deals not only with the sustainability of human development and aspects of the ecosystem that can support human activity (the subject of sustainable development), but also with the sustainability of the ecosystem and ecosystem components in their own right. The system receiving attention includes the enveloping ecosystem, the human subsystem and in particular, the interaction between the two. Thus, "reporting on sustainability" is defined to encompass a broader universe than "reporting on sustainable development" which is included as the anthropocentric sub-component.

APPENDIX II

WELTANSCHAUUNG

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APPENDIX II.

WELTANSCHAUUNG

> ...value systems, far from being "subjective," "peripheral" (merely because they are inconveniently unquantifiable), are the dominant, driving variables in all economic and technological systems.
>
> Hazel Henderson 1981, xv

1. INTRODUCTION

Because the concept of sustainability is a normative concept, values play a primary role in defining the systemic framework for monitoring, assessing and reporting on progress toward sustainability. Values are "one's life code - - the building blocks of acceptable and unacceptable ideas and behaviour" (Nitken and Powell 1993, 57). Or, as Chadwick expresses it:

> A value is something which is prized as of great worth and desirability: that which is respected and which motivates action; the completed action may not be successful, valuation occurs whether or not the value is attained. In its usage here, values will be taken as meaning broader, more abstract concepts which motivate actors in a general way to more specific goals
>
> (1978, 125).

The purpose of this Appendix is to draw these ideas together within a discussion of "***WELTANSCHAUUNG***" a German word that in simplistic terms, translates to "world view". A proposed value set that underlies the concept of sustainability is described and in turn, the value set is used to develop a set of characteristics necessary for any system of reporting on sustainability.

2. DEFINING "*WELTANSCHAUUNG*"

Some 50 years ago, anthropologist Bronislaw Malinowski raised the concept of ***Weltanschauung***:

> What interests me really in the study of the native is his outlook on things, his ***Weltanschauung*** ... Every human culture gives its members a definite vision of the world.
>
> (Jones 1972, 92)

In synthesizing the results of a major conference on world views, W. Jones proposes that any individual's world view is comprised of a set of attitudes that:

- are learned early in life and are not readily changed;
- have a determinate influence on much of his/her observable behaviour, both verbal and nonverbal;
- are seldom or are never explicitly verbalized; and
- are constantly conveyed implicitly as latent meanings.

(Jones 1972, 83)

Tuan describes world view as conceptualized experience: "... it is partly personal, largely social ... it is an attitude or belief system" (1974, 4). Drawing on the work of the philosophers Hegel and Kant, Bennett and Chorley describe ***Weltanschauung*** as an "image of the world" or "the way of viewing the entire system" (1978, 10). They suggest that the philosophies of Hegel and Kant demand the linking of ***Weltanschauung*** with a deep conviction as to the operation of the real world as a necessary stage of inquiry into reality.

Thomas Kuhn has popularized the related concept of "paradigm":

> A paradigm is a set of basic ideas, thoughts or beliefs about the nature of reality. These beliefs serve as a lens through which we filter day-to-day perceptions of the world.
>
> (Korten 1990, 35)

And physicist/philosopher Fritjof Capra, in his *Turning Point* calls for "a new 'paradigm' - a new vision of reality; a fundamental change in our thoughts, perceptions, and values" (Capra 1982, 16).

Thus, a sense of ***Weltanschauung*** as a deeply held set of attitudes and values that govern each individual's sense of how the world is and how it operates emerges. It is the lens through which we filter and organize signals received through all of the senses. Description of such a filter in a complete way for any individual, community, or culture, is likely impossible. However, identification of gross elements of such an attitudinal/value framework is possible, particularly when a shift in ***Weltanschauung*** is discernable.

3. FACTORS CONTRIBUTING TO CURRENT WORLD VIEWS

Over three centuries ago, Sir Francis Bacon (1561 - 1626) proposed that the purpose of science was to secure power over nature (Anderson 1962, 273; and see also Leiss 1972, 45 - 71):

> Natural inquiry ... is both sanctioned and required by God of men for the exercise of their dominion over the lower creatures, a dominion granted them by the Creator at Creation.
>
> (Anderson 1962, 273)

In 1859, Charles Darwin published his Origin of Species, entrenching a sense of evolution that has humankind at the pinnacle of a great pyramid of life on earth (see discussion, Hodge and Roman 1990, 503). Together, these sets of ideas served to reinforce the biblical interpretation that man was given "dominion . . . over all the earth" and that God said to man "replenish the earth and subdue it" (Gen. 1. 26,28).

A particularly powerful challenge to the idea that humankind is, or should be considered, all powerful came from C. S. Lewis (1898 - 1963), a professor at Cambridge University. He suggests that what we call "man's" control over nature is, in fact, a power exercised by some men over all that follow, with nature as the instrument (Lewis, 1944). Lewis reflects on the entire life span of humanity from its beginning to its end — several hundred thousand years. He argues that decisions of one generation that force a succeeding generation to conform would inevitably result in a loss of choice. Carrying the argument to its logical end, he points out that the last of the human race would be the least powerful — controlled by the dead hands of the "great conditioners and planners" from all ages before.

Similar ideas are explored by Fritjof Capra. He identifies three phases of evolution in the world view that lies at the base of our culture (Capra, 1982). A first phase can be identified as dominant prior to about 1500. This phase he labels "organic":

> People lived in small, cohesive communities and experienced nature in terms of organic relationships, characterized by the interdependence of spiritual and material phenomena and the subordination of individual needs to those of the community ... The scientific framework rested on two authorities - Aristotle and the Church ... medieval science ... was based on both reason and faith and its main goal was to understand the meaning and significance of things, rather than prediction and control. Medieval scientists ... considered questions relating to God, the human soul, and ethics to be of the highest significance.
>
> (1982, 53)

A startlingly different, second world view emerged from the scientific revolution that occurred in the 16th and 17th centuries, driven by the work of Copernicus, Kepler, Galileo, Bacon, Descartes, and Newton:

> The notion of an organic, living, and spiritual universe was replaced by that of the world as a machine, and the world-machine became the dominant metaphor of the modern era.
>
> Since Bacon, the goal of science has been knowledge that can be used to dominate and control nature, and today both science and technology are used predominantly for purposes that are profoundly antiecological.
>
> The Cartesian view of the universe as a mechanical system provided a "scientific" sanction for the manipulation and exploitation of nature that has become typical of Western culture.
>
> (1982, 54, 56, 61)

Capra traces the influence of this mechanical conception of the world to current thought and identifies an emerging but not yet dominant third world view. In this phase, attitudes are drawing again from the "organic" pre-1500 world view and a holistic, ecologic sense of the world is developing based on a systems view of life:

> The new vision of reality ... is based on awareness of the essential interrelatedness of all phenomena - physical, biological, psychological, social, and cultural. It transcends current disciplinary and conceptual boundaries and will be pursued within new institutions. At present there is no well-established framework, either conceptual or institutional, that would accommodate the formulation of the new paradigm, but the outlines of such a framework are already being shaped by many individuals, communities, and networks ... In this situation it would seem that a bootstrap approach, similar to the one that contemporary physics has developed, may be most fruitful (p. 265).
>
> ... the "new physics," especially its bootstrap approach, is very close to general systems theory. It emphasizes relationships rather than isolated entities and, like the systems view, perceives these relationships as being inherently dynamic. Systems thinking is process thinking; form becomes associated with process, interrelation with interaction, and opposites are unified through oscillation (p. 267).
>
> (1982, 265, 267)

William Catton draws on parallel ideas and identifies two alternative world views. One, he suggests is based on the following four assumptions:

1. People are masters of their own destiny; they are essentially different from all other creatures, over which they have dominion.
2. People can learn to do anything.
3. People can always change when they have to.
4. People can always improve things; the history of mankind is a history of progress; for every problem there is a solution, and progress need never cease.

He contrasts this world view with an alternative "ecological paradigm" which is based upon the following ideas:

1. Human beings are just one species among many species that are independently involved in biotic communities.

2. Human social life is shaped by intricate linkages of cause and effect (and feedback) in the web of nature, and because of these, purposive human actions have many unintended consequences.

3. The world we live in is finite, so there are potential physical and biological limits constraining economic growth, social progress, and other aspects of human living.

4. However much the inventiveness of *Homo sapiens* or the power of *Homo colossus* may seem for a while to transcend carrying capacity limits, nature has the last word.

(1980, 238 - 239)

In a foreshadowing of the concept of sustainability, he pleads for restraint in consumption and a kind of "ecological modesty" and suggests that:

> History will record the period of global dominance by *Homo colossus* as a brief interlude. Our most urgent task is to develop policies designed not to prolong that dominance, but to ensure that the successor to *Homos colossus* will be, after all, *Homo sapiens*.

(1980, 266)

John Peet identifies and discusses a "political-economic world view" (1992, Ch. 4) and contrasts it to a "biophysical systems world view" (Ch. 6). His alternatives resemble those of Catton in substance, although in the former he draws heavily on macroeconomic theory and its use of dollars as currency while in the latter he examines the physical activities that underpin the social system using energy as currency.

Additional pairs of opposing world views are aired by Cotgrove and Duff (1980), who compare the "dominant social paradigm" with an "alternative environmental paradigm" (Table 1) and Milbraith (1989) who similarly describes a "dominant social paradigm" as well as a "new environmental paradigm" (Table 2). Similarly, Colby (1989) contrasts a "dominant economic world view" with a "deep ecology world view" (Table 3), and Taylor (1992) draws on many of the same ideas and provides a historic perspective for the competing "expansionist" and "ecological" world views.

TABLE 1. COTROVE AND DUFF'S DOMINANT SOCIAL PARADIGM VS. ALTERNATIVE ENVIRONMENTAL PARADIGM.

Competing Social Paradigms

	Dominant Social Paradigm	*Alternative Environmental Paradigm*
CORE VALUES	Material (economic growth) Natural environment valued as resource Domination over nature	Non-material (self-actualization) Natural environment intrinsically valued Harmony with nature
ECONOMY	Market forces Risk and reward Rewards for achievement Differentials Individual self-help	Public interest Safety Incomes related to need Egalitarian Collective/social provision
POLITY	Authoritative structures (experts influential) Hierarchical Law and order	Participative structures (citizen/worker involvement) Non-hierarchical Liberation
SOCIETY	Centralized Large-scale Associational Ordered	Decentralized Small-scale Communal Flexible
NATURE	Ample reserves Nature hostile/neutral Environment controllable	Earth's resources limited Nature benign Nature delicately balanced
KNOWLEDGE	Confidence in science and technology Rationality of means Separation of fact/value, thought/feeling	Limits to science Rationality of ends Integration of fact/value, thought/feeling

Source: Cotrove and Duff 1980, 341.

TABLE 2. MILBRAITH'S DOMINANT SOCIAL PARADIGM VS. NEW ENVIRONMENTAL PARADIGM.

NEW ENVIRONMENTAL PARADIGM	DOMINANT SOCIAL PARADIGM
I. High valuation on nature	I. Lower valuation on nature
A. Nature for its own sake—worshipful love of nature	A. Use of nature to produce goods
B. Wholistic—relationship between humans and nature	B. Human domination of nature
C. Environmental protection over economic growth	C. Economic growth over environmental protection
II. Generalized compassion toward	II. Compassion only for those near and dear
A. Other species	A. Exploitation of other species for human needs
B. Other peoples	B. Lack of concern for other people
C. Other generations	C. Concern for this generation only
III. Careful plans and actions to avoid risk	III. Risk acceptable in order to maximize wealth
A. Science and technology not always good	A. Science and technology a great boon to humans
B. Halt to further development of nuclear power	B. Swift development of nuclear power
C. Development and use of soft technology	C. Emphasis on hard technology
D. Government regulation to protect nature and humans	D. Deemphasis on regulation—use of the market—individual responsibility for risk
IV. Limits to growth	IV. No limits to growth
A. Resource shortages	A. No resource shortages
B. Increased needs of an exploding population	B. No problem with population
C. Conservation	C. Production and consumption
V. Completely new society	V. Present society OK
A. Serious damage by humans to nature and themselves	A. No serious damage to nature by humans
B. Openness and participation	B. Hierarchy and efficiency
C. Emphasis on public goods	C. Emphasis on market
D. Cooperation	D. Competition
E. Simple life-styles	E. Complex and fast life-styles
F. Emphasis on worker satisfaction	F. Emphasis on jobs for economic needs
VI. New politics	VI. Old politics
A. Consultation and participation	A. Determination by experts
D. New party structure along a new axis	D. Left-right party axis—argument over ownership of means of production
C. Willingness to use direct action	C. Opposition to direct action—use of normal channels
B. Emphasis on foresight and planning	B. Emphasis on market control

Source: Milbraith 1989.

TABLE 3. COLBY'S DOMINANT ECONOMIC WORLD VIEW VS. DEEP ECOLOGY WORLD VIEW.

Dominant Economic Worldview	vs. Deep Ecology Worldview
Dominance over Nature	Harmony with nature; symbiosis
Natural environment is a resource for humans	All nature has intrinsic worth; biospecies equality
Material/economic growth for growing human population	Simple material needs, serving a larger goal of self-realization
Belief in ample resource reserves	Earth "supplies" limited
High technological progress and solutions	Appropriate technology; non-dominating science
Consumerism, Growth in consumption	Do with enough; recycling
National/centralized community	Minority traditions/ bioregions

Source: Colby 1989.

Robert Costanza et al. examine the differences and similarities in the world views of "conventional economics," "conventional ecology," and "ecological economics" (1991, 2 - 7). Key elements of their comparison are summarized in Table 4. They define ecological economics as a trans-disciplinary field of study that "addresses the relationships between ecosystems and economic systems in the broadest sense". Their goal is "ecological economic system sustainability" although they point out that "no discipline has intellectual precedence in an endeavor as important as achieving sustainability" (1991, 3).

TABLE 4. COMPARISON OF "WORLD VIEW" CHARACTERISTICS OF CONVENTIONAL ECONOMICS, CONVENTIONAL ECOLOGY, AND ECOLOGICAL ECONOMICS.

	"Conventional" Economics	"Conventional" Ecology	Ecological Economics
Basic World View	**Mechanistic, Static, Atomistic** Individual tastes and preferences taken as given and the dominant force. The resource base viewed as essentially limitless due to technical progress and infinite substitutability	**Evolutionary, Atomistic** Evolution acting at the genetic level viewed as the dominant force. The resource base is limited. Humans are just another species but are rarely studied.	**Dynamic, Systems, Evolutionary** Human preferences, understanding, technology and organization co-evolve to reflect broad ecological opportunities and constraints. Humans are responsible for understanding their role in the larger system and managing it sustainably
Time Frame	**Short** 50 yrs max, 1-4 yrs. usual	**Multiscale** Days to eons, but time scales often define non-communicating sub-disciplines	**Multi-Scale** Days to eons, multiscale synthesis
Space Frame	**Local to International** Framework invarient at increasing spatial scale, basic units change from individuals to firms to countries	**Local to Regional** Most research has focused on smaller research sites in one ecosystems, but larger scales have become more important	**Local to Global** Hierarchy of scales
Species Frame	**Humans Only** Plants and animals only rarely included for contributary value	**Non-Humans Only** Attempts to find "pristine" ecosystems untouched by humans	**Whole Ecosystem Including Humans** Acknowledges interconnections between humans and rest of nature
***Primary* Macro Goal**	**Growth of National Economy**	**Survival of Species**	**Ecological Economic System Sustainability**
***Primary* Micro Goal**	**Max Profits (firms) Max Utility (indivs)** All agents following micro goals leads to macro goal being fulfilled. External costs and benefits given lip service but usually ignored	**Max Reproductive Success** All agents following micro goals leads to macro goal being fulfilled.	**Must Be Adjusted to Reflect System Goals** Social organization and cultural institutions at higher levels of the space/time hierarchy ameliorate conflicts produced by myopic pursuit of micro goals at lower levels
Assumptions About Technical Progress	**Very Optimistic**	**Pessimistic or No Opinion**	**Prudently Skeptical**
Academic Stance	**Disciplinary** Monistic, focus on mathematical tools	**Disciplinary** More pluralistic than economics, but still focused on tools and techniques. Few rewards for integrative work.	**Transdisciplinary** Pluralistic, focus on problems

Source: Costanza et al. 1991, 5. Copyright (C) 1991 by Columbia University Press. Reprinted with permission of the publisher.

Almost all of the above sets of world views are set up as either opposites, mirror images, or in competition with one another. Duncan Taylor cautions that in doing so, the proposed new or emerging world view often "falls into its own form of dualistic thinking as well as remaining subject to the contradictions and inadequacies of the world view it opposes" (1992, 31) .

In contrast, Charles Taylor examines the evolution of two competing world views but completes his analysis with the recognition that clinically pure forms of each are unlikely to be found. Rather, elements of both world views are found in everyone of us (1985, Chapter 10).

In Charles Taylor's version 1, reason and control are what matter:

> ... the rational identification of desire, and the rational fulfillment; and the control to do both. The latter branch of rationality is what we call instrumental rationality, and this became for many thinkers in the modern world synonymous with rationality itself.
>
> (1985, 265 - 266)

Control of self and the environment in this version is important because it makes us able to effect our desires. In addition to the fulfillment of desires, this ability to get things done (efficacy) is "also valued as a sign of spirituality, of the correct stance of disenchantment to the world" (1985, 267). He points out that:

> ... in the context of this outlook, it is quite rational and understandable that the instrumental stance to nature ... should also pay off in happiness and prosperity ... The chief sign of goodness is success.
>
> (1985, 267)

The lifting of the moral limits on accumulation is thus quite understandable:

> Modern man accumulates through productive labour. And this labour is the result of discipline and control, the discipline of an instrumental stance towards the world. In producing, we are not only meeting our needs, but we are also realizing our status as autonomous, rational agents. We

> are affirming ourselves spiritually, and not just fulfilling our material needs - using this term 'spiritual' again to designate the goals and aspirations which we recognize not only as ours *de facto*, but as having an intrinsic worth in our lives.
>
> (1985, 268)

In this world view, the accumulation of goods through productive activity is seen as an exercise of our spiritual capacity which has intrinsic worth. As a result, the Platonic critique that a life of endless accumulation is one of vice because it represents a kind of slavery — an obsessive craving for what is purely material, leaving no place for what has higher, intrinsic value — is undermined. In sum, it can be said:

> Continued accumulation bespeaks consistent, disciplined maintenance of the instrumental stance; hence is not a deviation, or a form of decadence, but a realization of man's spiritual dimension. Far from being an obsession with things, or a sort of entrapment in them, it is an affirmation of our autonomy: that our purposes are not imposed on us by the supposed order of things, but we develop them ourselves through our discernment of nature. The instrumental stance towards nature is a spiritual declaration of independence from it.
>
> (1985, 268)

Taylor points out that the contemporary world view described above has roots in the 16th and 17th centuries, while in the 18th century a second world view influential in contemporary thinking emerged. In this version:

> ... human excellence does not lie in the autonomy and rationality with which men discern and fulfil desires ... rather it lies in the tender and noble sentiments which he has, which flow from an undistorted or unsullied nature. It is not calculating reason which tells him that he ought not to harm his fellow man, or that he must be industrious and sober, but the voice of nature, a pure unsullied impulse which carries him towards benevolence, industry, sobriety, frugality, the enjoyment of simple pleasures ...
>
> (1985, 269)

This second world view involves identifying true sentiments and setting aside false passions. It requires, "a kind of intuition, of attunement" and is based on a "form of rationality which can grasp intrinsic value" rather than instrumental reason (1985, 270). The yearning is for intrinsic good, not for *de facto* goods that satisfy our *de facto* desires and further:

> ... from this perspective, the striving after control and efficacy, that is, the domination of nature, can seem like a willful refusal to listen, a kind of flight forward, an attempt to still with material success the demand for an insightful reflection on the intrinsic value of one's ends
>
> (1985, 270 - 271).

Taylor sees both world views interwoven in contemporary ideals and to a greater or lesser extent present in each and every one of us. Inevitably, they evoke tension and lead to some of "our most profound divergences in social outlook" (1985, 273). He points out that "much of human behaviour will be understandable and explicable only in a language which characterizes motivation in a fashion which marks qualitative contrasts and which is therefore not morally neutral" (1985, 243). And thus, he warns:

> It is this dimension of qualitative contrast in our moral sensibility and thinking that gets short shrift in the utilitarian and formalist reductions. One of the main points of utilitarianism was to do away with this and reduce all judgements of ethical preference to quantitative form in a single dimension.
>
> (1985, 240)

The above survey of various author's identification and interpretation of changing and competing world views is summarized below in Table 5. While the various proposed world views differ in fine detail, and important common element is evident: all of these authors identify a shift from an earlier but still dominant world view that is human centred, cartesian/mechanical, utilitarian, expansionist and the motivation of conventional economics to one that is whole, biophysical, environmental, or ecological in context.

TABLE 5. WORLD VIEW SHIFTS.

SHIFT IDENTIFIED/DESCRIBED			REFERENCE
	human-centred	ecological	Catton 1980
	dominant social	alternative environmental	Cotrove and Duff 1980
organic	cartesian/mechnical	whole systems	Capra 1982
	instrumental rationality	intrinsic rationality	C. Taylor 1985
	dominant social	new environmental	Milbraith 1989
	dominant economic	deep ecology	Colby 1989
conventional economics	conventional ecology	ecological economics	Costanza et al. 1991
	expansionist	ecological	D. Taylor 1992
	political-economic	biophysical	Peet 1992

Duncan Taylor's warning of the dangers of dualistic thinking is an important insight (1992, 31). So too is Charles Taylor's recognition that such competing world views do not exist in clinically pure forms in any given individual (1985, Chapter 10). Rather, the differences evoke tensions in each and everyone of us and give rise to the broad divergences in social outlook that exist today.

Charles Taylor's observation that use of the earlier (but still dominant) utilitarian world view would lead to the deemphasis and even exclusion of some types of data and information in decision-making is an important observation for this dissertation (1985, 240). However, equally important is his comment that "the modern dispute about utilitarianism is not about whether it occupies some of the space of moral reason, but whether it fills the whole space" (1985, 235).

In this dissertation, a conscious choice is made to use a value base that is influenced but not dominated by the earlier utilitarian world view. Rather, a systemic, ecological perspective, is assumed and used to guide development of the reporting system. The very roots of the concept of sustainability are drawn from such a value set.

4. *WELTANSCHAUUNG*, VALUES AND THEIR INFLUENCE ON REPORTING SYSTEM CHARACTERISTICS

The National Round Table on the Environment and the Economy points out:

> Decisions are based on values. A decision seeks a result and that result is desired because it is seen to be a beneficial thing. And it is seen as beneficial because the decision-maker has rated it according to his or her value system and has said it rates high enough to want.
>
> (NRTEE 1993, 13)

A persons world view and values are closely linked as has been seen previously.

At the core of the concept of sustainability is the realization that the well-being of people is dependent on the health and integrity of the ecosystem; that people are a sub-system of the ecosystem. This realization translates to a value set that is best expressed as a parallel care and respect for people and for the enveloping ecosystem — not one or the other, not one more than the other, but both together.

Specific implications of this value set will vary for any group of decision-makers. However, when the value set is applied to reporting (a subsystem of the decision-making process), it will channel attention in certain ways — ensuring that chosen strategic directions and related indicators reflect the parallel care and respect described above.

Many initiatives have grappled with this issue in considering how best to transform the values of sustainable development and sustainability to specific actions to be taken by governments, corporations, or individuals. Often the result is a listing of "principles" or "strategic imperatives."

In an attempt to identify common elements, a review was undertaken of twenty relevant contributions. Early in this review it became evident that the concept of "principles" had no common meaning. Some principles were in fact general goals, some were measurable objectives, some were actions to achieve objectives, some were statements of values.

In time it became evident that to translate underlying values to action relative to a reporting system, two practical expressions of those values were required. Firstly, values are expressed in terms of general goals that are subsequently supported by a series of measurable objectives. This is a well understood process.

However, an equally important second step is the expression of values that occurs through identification of desirable reporting system characteristics that stand as a kind of "design criteria." Such a set is offered in Table 6 below. Both singularly and together, these design criteria control the form and the substance of the proposed reporting system.

TABLE 6. VALUE-DRIVEN CHARACTERISTICS OF A SYSTEM OF REPORTING ON SUSTAINABILITY.

A SYSTEM OF REPORTING ON SUSTAINABILITY
SHOULD FOCUS ON:

I. RESPECT AND CONCERN FOR THE ECOSYSTEM - BY

- using a time horizon in the reporting system that captures both human (short) and ecosystem (short and long-term) time scales;
- adopting a spatial frame of reference for assessing actions and decisions that extends beyond political and other boundaries to encompass the full extent of affected ecosystems; and
- analyzing individual ecosystem components (e.g. air, groundwater, surface water, soil, fauna, flora etc.) within the context of the connected ecosystem.

II. THE INTERACTION BETWEEN PEOPLE AND
THE ECOSYSTEM - BY

- being sensitive to the complete range of chemical, physical and biological stress on the ecosystem —including that occurring naturally and that imposed by human activities ;
- adopting an anticipatory perspective when dealing with the manner in which indicators, time-horizons and analyses are expressed, so that in the reporting process there will be a forward-looking thrust instead of just a description of past and current conditions;
- recognizing and accepting uncertainty as an inevitable occurrence instead of an impediment to good decision-making.

III. RESPECT AND CONCERN FOR PEOPLE - BY

- using assessment criteria that respect the existence of alternative and changing values when evaluating progress;
- assessing the distribution of environmental, economic, social, and cultural costs and benefits by examining their impacts on different social groups;
- including of ways to measure participation and control in decision-making; and
- using both quantitative and qualitative measures that include both objective data and information and subjective information such as intuitive understanding based on experience of everyday life, including experience gained from subsistence and traditional life styles.

Sources: See End Note 1.

END NOTES

1. Earlier versions of this table are found in Hodge and Taggart (1992, 19 - 20) and Hodge (1991, 78 -79). It is influenced by the entire literature and experiential base of this dissertation. However, in particular, the following inputs were influential:

    - the report of the World Commission on Environment and Development (WCED 1987);
    - the Canadian reaction to WCED (1987) as articulated by the National Task Force on Environment and Development (NTFEE 1987);
    - the original objectives for sustainable development proposed by the National Round Table (NRTEE1990, 7);
    - the Strategic Planning Report of the National Round Table developed at the Montebello Plenary, 14-15 November 91 and presented at the Aylmer Plenary, 20-21 Feb 92 (NRTEE 1992);
    - the mission statement of the National Round Table as stated in Article 4 of *Bill C-72, An Act to Establish the National Round Table on the Environment and the Economy;*
    - results of YUKON 2000, a multistakeholder process undertaken between 1986 and 1988 which resulted in development of a long term Yukon Economic Strategy (YTG 1988);
    - the Yukon Conservation Strategy (YTG 1990);
    - the World Conservation Strategies I (IUCN et al.1980) and II (IUCN et al. 1991);
    - ideas developed through the Canadian Environmental Advisory Committee and synthesized by Ruitenbeek (1991 a and b);

- the Challenge Paper of the Ontario Round Table on Environment and Economy (ORT 1991);

- work of the Goals Committee (Work Group 3) of the Ontario Premier's Council on Health Strategy (OCHS 1993);

- the Conservation Council of Ontario (1989) discussion of an Environmental Strategy for Ontario;

- MacNeill et al.'s (1991), *Beyond Interdependence* (especially their strategic imperatives);

- Gardner and Roseland, 1989. Part I - Thinking Globally, The Role of Social Equity in Sustainable Development; Part II - Acting Locally, Community Strategies for Equitable Sustainable Development.

- Goldberg's (1989) *On Systemic Balance;*

- Capra's (1982) *Turning Point;*

- Holling's (1978) *Adaptive Environmental Assessment and Management;*

- Schumacher's (1973) *Small is Beautiful;*

- Kidder, R., Personal Communication, 1993. President, The Institute for Global Ethics, Washington D.C.; and

- BCRTEE 1993 a, b, and c.

APPENDIX III

CONCEPTS OF TIME: CARING FOR GENERATIONS NOT YET BORN

CONTENTS

TABLES

APPENDIX III

CONCEPTS OF TIME:

CARING FOR GENERATIONS NOT YET BORN

1. INTRODUCTION

Concern for the living conditions and rights of future generations is a central element of sustainability. Current practice in western industrialized society, the former eastern block communist countries, and most developing regions of the world is in direct contradiction to such long-term thinking. Industry generally operates in terms of a fiscal year or two, the political arm of democratic government an election cycle of four or five years at most. A 20-year time frame is typical in community planning with 5-year revisions to allow for adjustments and most individuals function from day-to-day (G. Hodge 1991, 207).

These practices are reflected in our administrative, legal and economic systems, none of which are currently designed to deal with time horizons and cyclic rhythms that govern ecosystem functions. This human-ecosystem time discrepancy is one of the most significant challenges to be overcome in bringing the ideas of sustainability from theory to practice in contemporary decision-making. With this motivation, an early phase of this study involved an examination of current and historic practices and attitudes regarding the concept of time.

2. DEALING WITH TIME: DISCOUNT RATES, TIME HORIZONS AND THE ECOSYSTEM

In ethical, economic and legal terms, the issue of time is expressed as a distributional concern between today's and future generations. In economic analysis, the link to the future is captured through (1) the use of a discount rate (a factor that accounts both for inflation and the changing cost of money) to bring future to present values and (2) the choice of a specific time horizon over which the discount rate is applied.

In a study of decision-making related to the design of waste management facilities that have the potential to contaminate groundwater, Freeze considers the alternative choices of discount rate and time horizon that might be chosen by an owner/operator, a regulator, and the property owner or an environmental interest group (1987). These alternatives are listed in Table 1 and demonstrate one interpretation of the wide variation in approach to the time dimension that alternative values generate.

The decision criteria listed in Table 1 reflect a commonly held perception that the greater the positive discount rate that is used, the more decisions or projects with short-term benefits and long-term costs are encouraged. This essentially removes long-term environmental and social costs from the decision-making process. This assumption has been challenged in more recent work motivated by the ideas of sustainability. Pearce and Turner point out that although high discount rates may shift a cost burden forward to future generations, they might also slow the demand for natural resources by curbing investment (1990, 224). Thus capital intensive projects such as large dams or nuclear power stations may be discouraged. This dichotomy has been labelled the "conservationist's dilemma" — both high and low discount rates can favour conservation interests (Norgaard and Howarth 1991, 90 - 92).

TABLE 1. ALTERNATIVE DECISION CRITERIA FOR SITING AND DESIGN OF WASTE MANAGEMENT FACILITIES THAT HAVE THE POTENTIAL TO CONTAMINATE GROUNDWATER.

PARTY	TIME DIMENSION OF DECISION-MAKING AS DEFINED BY: DISCOUNT RATE	TIME HORIZON
owner/operator	5 to 10 percent: market interest rate	10 to 50 years: standard engineering time horizon (facility service life)
regulatory agency	2 to 5 percent: social discount rate	100 to 200 years: social time horizon
property owner or environmental interest group	0 percent: environmental discount rate	200 to 10,000 years: environmental time horizon

Source: Freeze 1987, 34. Copyright (C) 1987 by the University of Waterloo Press. Reprinted with permission of the publisher.

There is a vast literature dealing with the choice of appropriate discount rate (for example, see Lind et al. 1982, Pearce and Turner 1990, 211 - 225, Norgard and Howarth 1991). In the following discussion, a review of some of the key ideas is provided.

Pearce and Turner point out that the choice of a positive interest rate for discounting arises for two reasons, one related to a ***time preference*** and one related to the ***productivity of capital*** (1990, 213). People's preference for receiving benefits now as opposed to later combined with the value judgement in welfare economics that people's preferences matter results in the ***time preference***. The second factor arises from recognizing that allocation of some resources to savings and investment (capital formation) rather than current consumption offers the possibility of a higher level of consumption at some later period.

Some economists argue that individuals naturally discount the future because their own lives are finite, while societies are quasi-mortal and some decisions made on behalf of society should therefore be made with a very low or zero discount rate (Pigou 1920, 191 - 203; I. Pearce 1975, 200 - 203; Kay and Mirrlees 1975, 166; Lind 1982 a and b; Streeten, 1986). Another school of thought sees an "intergenerational invisible hand" that assures greater wealth for future generations:

> By devoting itself to improving the lot of the living, therefore, each generation whether recognizing the future oriented obligation to do so or not, transmits a more productive world to those who follow.
>
> (Barnett and Morse 1963, 249)

Therefore it is seen as only fair for present generations to discount the future at a high rate.

Similarly, Dasgupta and Heal suggest that "as long as the mutual concern that each of every two successive generations displays towards the other is adequate, a competitive environment can in principle handle the issue of intergenerational distribution of welfare adequately" (1979, 257). However, they further caution that "there are many reasons why a decentralized economy may sustain an unpalatable distribution of welfare among generations."

In any case, the preferences and circumstances of future generations remain unknown and, as Randall points out:

> ...in intertemporal resource-allocation problems, where the opportunities of many generations are at stake, the endowments, at any given time, are all in the hands of living generations. Thus, viewed from the theories of social choice and distributive justice, the discount rate that is determined entirely by living generations is, when used as the basis for a decision rule to adjudicate conflicts between living and unborn generations, ***dictatorial***.
>
> (1981, 241, emphasis added)

In theory, the use of any particular discount rate involves a normative judgement expressed in mathematical terms that sets the relative importance of the present and the future. However, in spite of significant efforts to develop a sound theoretical basis for choosing appropriate discount rates (see, for example, Lind et al. 1982 and Norgaard and Howarth 1991), in practice, discount rates are estimated largely on an ad-hoc basis and do not accurately reflect our relative valuation of present and future (Goodland and Ledec 1987, 33). Furthermore, acceptance of the sustainability of development as a priority indicates the demise of two centuries of faith in the idea that current progress will take care of future posterity (Norgaard and Howarth 1991, 92).

In suggesting a way past this dilemma, Norgaard and Howarth argue the need for distinguishing between decisions concerning the efficient use of this generation's resources (an efficiency issue) and decisions concerning the reassignment of resource rights to future generations (an equity issue) (1991). They suggest that discounting is appropriate for assessing the efficiency of use of this generation's resources, but is inappropriate for dealing with the redistribution of resource rights to future generations. Finally, they endorse what they describe as an "emerging consensus within academic economics" that separate criteria should be established for sustainability and that economic and sustainability criteria need to be used together in project analysis (see also Tietenberg, 1988; Batie 1989; Pearce and Turner 1990, and Markandya and Pearce 1988a).

These sustainability criteria are equity decisions that need to be resolved politically. Such criteria should themselves frame the efficient allocation of resources from generation to generation and determine the discount rate and other prices and quantities relevant to applying conventional benefit-cost analysis. This approach is the exact opposite of past and current practice which inappropriately uses the discount rate as a decision-rule for governing intergenerational transfers.

The debate regarding discount rates and intergenerational equity will likely continue. However, the trends in ideas discussed above indicate a shift in time perception, a lengthening of the time-horizon, and a change in values. Together these reflect a growing concern for future generations — even if agreed upon methodologies for dealing with this issue remain moot.

This shift in time perception is being pushed along by a shift in the understanding of the long-term consequences of human activity. And it is in the application of law that some of the best illustrations can be found.

There are severe limitations on the ability of economic analyses to deal with anything more than a time-horizon of a decade or two. Our system of law is also affected. In fact, the issue puts into question one of the fundamental principles of the legal system: that it is possible to identify all consequences of current human action and fairly distribute those consequences amongst those responsible (A. J. Roman 1992, personal communication).

A good example is the migration of contaminants through the groundwater system from waste buried decades before. Resolution of how to deal in law with the distribution of responsibility today for the costs of actions taken long ago is not clear. Resolution of how to deal in law with the distribution of responsibility today for costs that will be borne many years hence is even less clear. Elizabeth Brown Weiss points out that what "little intertemporal doctrine that does exist relates the present to the past" (1990, 8). The degree of uncertainty these examples have introduced into legal process has not yet been resolved.

Some technical analysts are beginning to recognize the differences of time scale evoked by different components of the ecosystem. For example, Hufschmidt et al. examine different time rates of response of natural systems to residuals discharge (1983, 118 - 120). Table 2 is a list of a number of human actions, ecosystem response mechanisms, final system state, and an estimate of time elapsed from action to final state.

TABLE 2. EXAMPLES OF HUMAN ACTIONS AND DIFFERENT TIME RATES OF RESPONSE OF NATURAL SYSTEMS TO RESIDUALS DISCHARGES

human action	**ecosystem response mechanism**	**final ecosystem state**	**time from action to final state**
Spill or leak of oil or chemical substance	flow through porous media	eventual contamination of aquifer	several decades
Pumping from aquifer with hydraulic connection to the ocean	gradual encroachment of seawater	salination of aquifer	several decades
Construction of major dam	degradation immediately downstream from dam, aggradation in reaches further downstream	channel modification with more flooding in some locations more phreatophyte growth	1-3 decades
Time pattern of pesticide application	uptake by and accumulation in some bird species	demise of bird species in region because of reproductive failure	1 decade
Discharge of sewage effluent into lake	increased production of algae	accelerated eutrophication	few years
Tussock moth control program with pesticides	modification of moth population, other insect or bird populations increased wood growth per acre	reduction in non-target species	1-3 years
spill of acid into well-mixed estuary	mixing by turbulence and tidal action	increase in acidity	few days

Source: Hufschmidt et al. 1983, 119.

Hufschmidt et al. recognize a variation from a few days to several decades in the time interval from "action to final state". In practice, their approach is useful in extending the time horizon of current economic analyses. However, their time-horizon maximum does not correspond to ecosystem characteristics, and their labelling of a "final state" implies a static end point that simply does not exist in the dynamic world.

While the economic and legal systems struggle to deal with long-term "ecosystem" time horizons in an equitable way, earth scientists and engineers must deal with long-term time horizons through analyses of natural systems and application of related design criteria. Table 3 is a list of the components of the hydrologic cycle, and a qualitative assessment linked to human decision-making describing the space and time dimensions of each.

Of the four system components, inland surface water operates within the space and time dimensions most compatible to those governing human decision-making. Interestingly, it is this component that has probably received the greatest attention over the longest time in terms of policy development and law attempting to deal with environmental degradation. At the other end of the spectrum, the incompatibility of the long time dimension of the groundwater system with the very short time dimension of most current decision-making is the root cause of much of the current waste management crisis (Hodge and Roman 1990, 499-500).

Design criteria of some major civil works such as water and mine tailings dams and a variety of waste disposal facilities can (but do not always) include allowance for one-in-one-thousand or one-in-ten-thousand year floods and earthquakes. Some geotechnical engineers urge the use of a general design life of 10,000 years for uranium mine tailings management facilities (Meneley 1979, 3). Others argue that long-term principles of geomorphology should be given greater emphasis in design of hazardous waste disposal sites (see Nasmith 1980 and BCRCUM 1980, Vol. 1, 121).

Detailed study of the crystal structure of minerals is now being used to project the condition of high-level radioactive waste ceramic containment vessels during the period 10,000 to 100,000 years after the initiation of storage (Ewing, 1989). This kind of time criteria applied to human activities is certainly without precedent in modern society although it has been suggested that the Egyptian pharaohs may have thought in such terms for construction of the pyramids (J. A. Caldwell 1989).

TABLE 3. COMPONENTS OF THE HYDROLOGIC CYCLE AND A QUALITATIVE ASSESSMENT LINKED TO HUMAN DECISION-MAKING OF THE SPACE AND TIME DIMENSIONS OF EACH.

TIME / SPACE DIMENSION	LINKS TO DECISION-MAKING
AIR	
Short time dimension, global space dimension. Air moves rapidly covering several thousand kilometers per day. Contaminant residence time is days to weeks.	Reaction to perturbation is rapid and within the human time-frame. Spatial dimension is greater than that of most current decision-makers.
INLAND SURFACE WATER	
Medium time and spatial dimensions which are both consistent with human perceptions. Contaminant residence time is weeks to years.	Reaction to perturbation is consistent with human perceptions, a situation that facilitates appropriate decision-making
MARINE WATER	
Medium to long time frame and global spatial dimension. Long history of ocean travel has brought the time and spatial dimensions of oceans within general human understanding. Contaminant residence time is centuries to millennia.	Much greater space and time dimensions of the oceans relative to most human perceptions makes this component more difficult for most decision-makers to handle
GROUNDWATER	
Long time dimension: often in terms of centuries or longer. Local spatial dimension is most common. Contaminant residence time is weeks to millennia.	Long time dimension is incompatible with current short-term human decision-making. Spatial dimension is within the perceptions of decision-makers but the subsurface location has led to "out of sight, out of mind" mentality.

3. CHANGING PERCEPTIONS OF TIME

The origins of current perceptions of time is a topic that has been explored piecemeal by researchers in a wide variety of fields including history, geography, anthropology, sociology, physics, and mathematics. The literature of human/cultural geography serves to integrate many of these ideas and it is from this literature that most of the following thoughts are drawn.

Alternative ideas of time are described in the early environmental perception literature. Tuan discusses concepts of cyclical and linear time noting:

> The ancients believed that movement in nature was disposed towards the circular path . . . Time is commonly modelled on the recurrent phases of nature, those of the stars or those of the earth in rotation and revolution. Modern man recognizes these recurrent phases but for him they are little more than waves in the directional time stream. Time for him has direction, change is progressive . . . the medieval man's sense of time, mirroring his vertical and rotary cosmos, was essentially cyclical. Not until the eighteenth century did the linear, directional concept of time become important.
>
> (1974, 148)

Similarly, Buttimer suggests that life world experiences are best examined through understanding rhythms of time-space and that neither geodesic space nor linear clock/calendar time is appropriate for the measurement of experience (1976).

A comprehensive examination of time perception covering the period 1300 to 1880 was undertaken by Thrift (1981). He suggests that three distinct phases of time-consciousness can be identified. These are summarized in Table 4.

In the initial phase, time-consciousness was characterized by an extremely short time horizon. At the same time, however, individuals maintained control over time, living a life governed by response to need and seasonal rhythms rather than to mechanical clocks. During the second phase, clocks were introduced as was the idea of work (owner's) time and leisure (own) time. However, seasonal rhythms retained their dominance for a majority of people largely following agrarian pursuits. The third phase was marked by the industrial revolution. Watches and clocks became fetishes and clock-time enslaved society. Commercial activity has led to a lengthening of the time-horizon because time in both the future as well as in the present is recognized to have monetary value.

TABLE 4. THRIFT'S THREE PRE-20TH CENTURY PERIODS OF TIME CONSCIOUSNESS.

PERIOD I. 1330 TO 1550. ISLANDS OF TIMEKEEPING IN A SEA OF TIMELESSNESS.

Daily activities were task oriented and temporally flexible. Seasonal rhythms dominated, the week was not a common unit. The calendar was not formal but rather was an assemblage of different but inter-related religious, secular, and agricultural practices and traditions. The perception of past and future was probably truncated or blurred, history was almost unknown; the future would be simply the model of existing society, as would the past. Monasteries and towns, driven by religious and commercial enclosed units, would be islands of more exact timekeeping: self-enclosed units rather than segments of a continuous line. Thus there would have been an uneven quality of time, punctuality would have been unknown. Lewis Mumford notes that by 1370, a "modern" clock had been built by Heinrich von Wyck at Paris (1934, 325).

PERIOD II. 1550 TO 1750. TRANSITION

The proliferation of clocks; the Puritans were successful in having society adopt a six-day work-week followed by rest on the seventh day. Work (owner's) time as something different from leisure (own) time was introduced. However, seasonal rhythms still dominated and workers still left work when they had earned enough money for the week.

PERIOD III. 1750 TO 1880. THE IMPRISONING

Introduction of the Gregorian calendar in 1751. In the early to mid-1800s clocks and watches proliferated and became the first consumer item. Clock time became a fetish. The industrial revolution demanded greater synchronization of labour. Task-oriented piece work became less common, weekly wage labour more-so. Time became a measurable commodity. Clock time "colonized" interactions, work-time became the reference point for life. Elementary and Sunday schools aimed at inculcating the habit of time discipline in children. Scheduled trains began in 1825. Consumer demand became a popular concept and as a result, a new importance was associated with regular wages and planning ahead. Not only present time, but also future time became equated with money.

Source: summarized from Thrift, 1981.

A similar interpretation of the shift in time perception and the key role played by the introduction of the mechanical clock was earlier proposed by Lewis Mumford. He notes that:

> ... the application of quantitative methods of thought to the study of nature had its first manifestation in the regular measurement of time; and the new mechanical conception of time arose in part out of the routine of the monastery ...the clock is not merely a means of keeping track of the hours, but of synchronizing the actions of men ... early time-keeping evolved into time-serving and time accounting and time-rationing.
>
> (1934, 324)

Mumford links the change in time perception to a parallel shift in the conception of space: "space as a hierarchy of values was replaced by space as a system of magnitudes" (330). He also notes that all events were then seen within the context of this new ideal structure of space and time and "the most satisfactory event within this system was uniform motion in a straight line, for such motion lent itself to accurate representation within the system of spatial and temporal coordinates" (330). And Mumford concludes:

> The new attitude toward time and space infected the workshop and the countinghouse, the army and the city. The tempo became faster; the magnitudes became greater; conceptually, modern culture launched itself into space and gave itself over to movement. What Max Weber called the "romanticism of numbers" grew naturally out of this interest. In time-keeping, in trading, in fighting, men counted numbers; and finally, as the habit grew, only numbers counted.
>
> (1934, 332)

The linear interpretation of time has been further entrenched with recourse to the second law of thermodynamics — the entropy law: "all physical processes proceed in such a way that the availability of the energy involved decreases" (Peet 1992, 36, 41 - 42). Rifkin points out:

> Time goes forward because energy itself is always moving from an available to an unavailable state... To say the world is running out of time, then, is to say the world is running out of usable energy. In the words of Sir Arthur Eddington, "Entropy is time's arrow".
>
> (1980, 49)

However, Rifkin also recognizes that

> While entropy tells us the direction of time, it does not tell us the speed. The fact is, the entropy process is constantly changing speed.
>
> (1980, 50)

More recently, Boulding picks up this same theme and notes:

> ... we can certainly detect a "time's arrow" in the evolution of the universe in terms of complexity, both chemical and biological, and also in terms of knowledge and control. Sustainability here presumably means continuing to follow the "time's arrow" of the universe ... "time's arrow," however, especially in biological evolution on earth, is by no means a simple steady process.
>
> (1992, 23)

In Rifkin's view, the current world paradigm of Newtonian mechanics that began with Descarte's suggestion that there is total separation between people and nature has led to an "illusion that time is an autonomous process in the world, independent of the workings of nature" (1980, 49). This he links to the heart of the scientific method and its dependence on:

> ... the establishment of complete neutrality between the observer and the observed, so that nature could be manipulated and used to advance the material interest of humankind.
>
> Having hit upon a method of organizing the world that effectively separated people from nature, the true relationship between life, time, and the entropy process was severed from people's consciousness.
>
> (1980, 49).

Rifkin's conclusion is extremely important to this dissertation which posits people as an integral part of nature. This configuration emerges through application of systems theory which requires inclusion of people as a sub-system of the ecosystem.

The concept of time and its interrelationships with space are examined by Walter Isard in the fourth of his volumes dealing with regional science and urban economics (Isard and Liossatos 1979, 9 - 32). Isard discusses different notions of time including universe, calendar, geological, macro, micro, life-cycle, and seasonal. In simpler language, these notions translate to time horizons of varying length. Isard also points out the need to use some kind of "potential concept" to relate past and future events to the point in time when a decision is to be reached or an action taken. For this he draws on economics nomenclature calling for a "time discount (upcount) factor." In practice, he recognizes the need to be able to deal analytically with a large number of different time horizons which operate simultaneously (21 - 24). He proposes a mathematical treatment of this problem which utilizes ideas of a time vector, a time trajectory, a real-time differential, a generalized space-time, and effective time.

Isard describes this exploration as early and speculative. Further, his fundamental model of time is linear in nature - he defines "the unit of time as that which elapses between . . . two strong memorable sensations" (10). And for Isard:

> The concept of time is useful only because it allows us to study processes effectively - processes that require inputs and yield outputs (tangible or intangible), some of which have value. Viewed another way, our interest is in the innumerable real social and physical processes and their interrelationships. Through the use of one or more notions of and metrics of time, we can sift out processes and interrelationships to be studied intensively and relegate less urgent ones to the background.
>
> (1979, 10)

In spite of these self-articulated limitations, Isard's treatment of time touches on three of the key time-related issues important in this dissertation: varying perceptions of time, use of different time horizons, and linking past and future to present with some kind of discounting (upcounting) function. In particular, Isard recognizes that regional analysis requires special care to:

> ...be able to use the several models of time concomitantly and effectively in order to understand the ongoing processes, not only individually but also in combination, and in particular as they affect one another and lead to a synthesis resulting in behaviour (decision and action).
>
> (1979, 10)

This conclusion is also fundamental to monitoring, assessing, and reporting on sustainability.

4. SUMMARY

This discussion was motivated by the observation that a large discrepancy exists between the time perception typically factored into current decision-making processes and the time dimension governing many ecosystem functions. This discrepancy is one of the most significant problems to be overcome in bringing the ideas of sustainability from theory to practice.

In economic theory, the normative judgement of the relative importance of the present and the future is captured in the use of a discount rate and a particular time horizon. While there is much literature attempting to deal systematically with the choice of an appropriate discount rate, in practice the process is ad-hoc. Further, some workers are now suggesting that the discounting process should be limited to establishing the most efficient use of this generation's resources. Assessments that amount to reassigning the rights of resources to future generations are dealing with an intergenerational equity issue and should be dealt with using politically-established criteria.

While economists and lawyers are pursuing these conceptual issues, others such as earth scientists and engineers are being forced to deal with a growing number of technical issues that reflect recognition of much greater extent of long-term implications of human activities than was understood even a decade ago. All of these developments are contributing to a shift in society's time perception.

Drawing on Thrift's analysis, it appears that society, motivated by heightened environmental awareness, is moving towards a fourth stage of time consciousness. In this stage, clock/calendar time is no longer the single master. Natural rhythms are once again recognized and honoured, and a time horizon that captures the long-term dimension of the natural ecosystem is utilized. It is this sense of time that is governing the approach to reporting on sustainability developed in this dissertation.

END NOTES

1. The earlier three volumes are Isard, 1956, 1960, and 1969.

APPENDIX IV

DRAWING FROM SYSTEMS THEORY

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APPENDIX IV.

DRAWING FROM SYSTEMS THEORY

1. ORIGINS, INSIGHTS FROM PLANNING, AND THE ECOSYSTEM APPROACH

Over the past fifty years, systems ideas have been formalized and applied to a large number of issues throughout pure and applied social and natural sciences. While the roots of these ideas lie in antiquity, biologist Ludwig von Bertalanffy (1901 - 1972) is credited with first establishing systems thinking as a significant conceptual approach.

Bennett and Chorley provide a review of many systems ideas from a historical perspective and including those until the late 1970s. They point out:

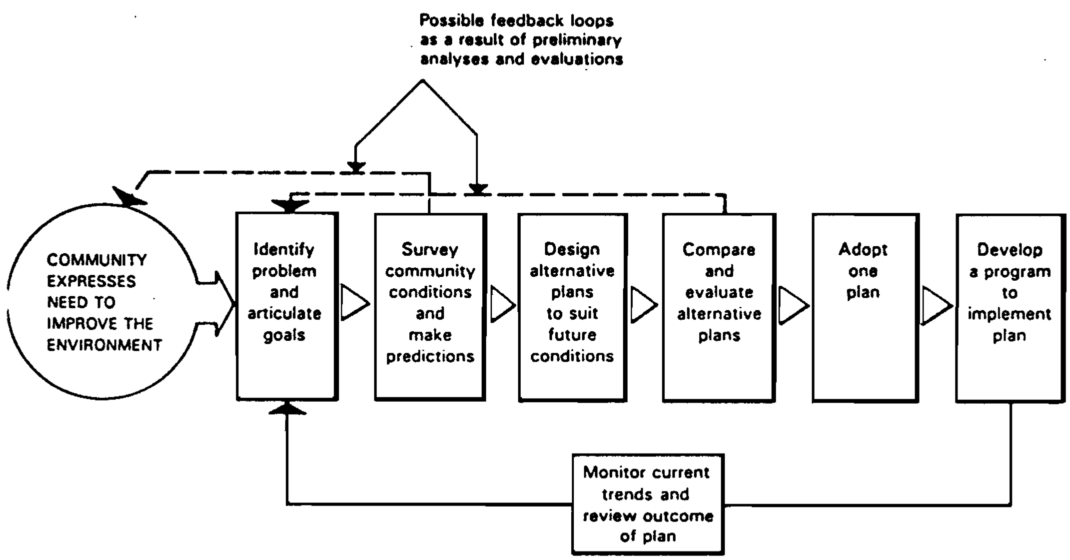
> The systems approach has been greeted by some as a universal panacea for our philosophical and technical problems, by others as a jargon-ridden overstatement of the obvious - it is neither.
>
> (1978, 541)

Lilienfeld (1978) is particularly severe in his ideological critique of systems theory and its proponents. He suggests that von Bertalanffy and colleagues articulate their ideas as though they were missionaries "convinced that the discoveries and concepts they have developed are of major philosophical, societal, and even religious significance" (1978, 2). He advances the thesis that systems theory is a reworking of old ideas and is better seen as an ideology with authoritarian tendencies that would have elite systems scientists at the apex of societal control.

Lilienfeld's concerns have not been borne out. Rather, systems ideas have continued to evolve, particularly in ways that contribute to the resolution of his primary concern regarding social control. For example, the emergence of the systematic rationalist approach to planning in the 1950s and since has provided a formalized approach to dealing with a range of citizen's values in decision-making.

Secondly, the emergence of the "ecosystem" approach to the human - environment relationship as enshrined in the Great Lakes Water Quality Agreement of 1978 has added a perspective that sheds new light on peoples' relationship with the surrounding world. Both of these developments have served to enrich systems thinking in ways likely not envisioned by von Bertalanffy and other early contributors.

The principal threads of contemporary planning theory are sketched by Jeanne Wolfe (1989). She concludes that in spite of those who would have it otherwise, contemporary planning continues to be based on a systemic "rational-comprehensive" process. The origins of this process lie in the early part of this century, although the development of a more systematic approach is attributed to Meyerson and Banfield (1955, 312 - 322). Important adaptations of their approach are made by I. M. Robinson (1972, 27 - 28). One representation of the rational planning process is depicted below in Figure 1.



Source: G. Hodge, 1991, 173. Copyright (C) 1991 by Nelson Canada. Reprinted with permission of the publisher.

Figure 1. General model of the "rational-comprehensive" process of planning.

Planners have been struggling with many of the key process issues that have been raised within the sustainable development debate for at least the past forty years. The recognition that contemporary planning practioners have long grappled with the problem of integrating alternative value sets in decision-making is of particular significance to this review.

Wolfe proposes a classification of planning theory that includes three groups: (1) substantive theory relating to design and policy in urban planning; (2) theories of explanation of urban phenomena; and (3) theories of process dealing with the nature of decision-making (Wolfe, 1989). Theories of process are used to explore "methods by which plans are formulated, how decisions are made, how conflicts are resolved, how policies, plans and programmes are implemented and how they are or should be evaluated" (Wolfe 1989, 68). And it is from this third group that the more formalized systemic rational planning process previously described has emerged. This process begins with a goal statement that ideally reflects a community or regional consensus on values.

In *Methods of Regional Analysis,* Walter Isard presents five alternative "channels" for synthesizing regional planning analysis (1960, Chapter 12). The first three depend on optimizing regional systems using a variety of methodologies including inter-regional flow analysis, industrial location analysis, inter-regional and regional input-output techniques, industrial complex analysis, inter-regional linear programming, and gravity, potential, and spatial interaction models.

The fourth "channel" is a conceptual approach driven by culturally-based values that lead to a definition of goals (political, social, and economic) which in turn govern the design of "social accounts." Isard points out that in 1960, the process by which goals were established by the social system was not well understood. As a result, he identifies a need for greatly improved sociological, psychological, and anthropological theory and methods. He also emphasizes the need for significant advances in political theory and administrative analysis before progress is possible using this value-based approach.

In his fifth "channel," he reverts to an optimization approach while attempting to factor in at least the values and goals that are subject to approximate quantitative representation. Isard's early attempts to factor values and goals into a formal and sophisticated systems approach to regional analysis is noteworthy.

In the intervening thirty years, significant progress has been made in grappling with "the process by which goals are established by the social system." Gerald Hodge identifies three determinants to land use decision-making in any community: economic determinants, social determinants, and public-interest determinants (1991, 174 - 178). The framing of a community plan, he suggests, is largely a process of sorting out values and attitudes related to each of these three determinants and establishing a commitment to a future in which various interests can act in harmony. Thus the entire contemporary (rational) planning process is value driven and its fundamental commitment to public participation and collective articulation of goals and objectives provides ideally, at least a counterweight to Lilienfeld's concern regarding excessive control by elite systems scientists.

Checkland and Scholes recent systems work emerges from management science literature and also builds on the value context of decision-making through the explicit articulation of the operating "***Weltanschauung***" or worldview (1990). The operating ***Weltanschauung*** provides the context for the transformation process(es) at work in the system being considered.

Christie et al. describe the key elements of the ecosystem approach as it emerged in the Great Lakes basin in the 1970s. Firstly, they note that ***ecosystems*** are :

> ...natural or artificial subdivisions of the biosphere with boundaries arbitrarily defined to suit particular purposes. It is possible to speak of your personal ecosystem (you and the environment on which you depend for sunshine, air, water, food, and friends), the Great Lakes basin as an ecosystem (interacting communities of living and non-living things in the basin) . . .
>
> (1986, 4)

Secondly, echoing an assertion commonly attributed to John Muir from early this century that "when we try to pick out anything by itself, we find it attached to everything else in the universe," they describe how:

> The ecosystem concept recognizes that you are new, yet not new. The molecules in your body have been parts of other organisms and will travel to other destinations in the future. Right now, in your lungs, there is likely to be at least one molecule from the breath of every adult being who has lived in the past 3000 years; the air around you will be used tomorrow by deer, lake trout, mosquitoes, and maple trees. The same is true of water, sunshine, and minerals. Everything in the biosphere is shared . . . There is something very strange, deep, and mysterious about the way the building blocks of life are arranged as wholes that are in turn parts of larger wholes. Everything from atoms to galaxies.
>
> (1986, 4)

Thirdly, they carefully outline the difference between "environment" and "ecosystem":

> The notion of environment is like that of *house* - something external and detached. In contrast, ecosystem implies *home* - something that we feel part of and see ourselves in even when we are not there.
>
> (1986, 4)

Fourthly, they trace a historical succession of management approaches in the Great Lakes basin from "egocentric to piecemeal to environmental and now to an ecosystem approach". This later emerged partly as a result of the discovery of toxic chemicals in human food chains, something that showed "people and environments can only be managed effectively in relation to ecosystems of which they are parts" (1986, 4).

Lastly and most importantly, they link the above ideas in their description of an ecosystem approach:

> The essence of an ecosystem approach is that it relates wholes at different levels of integration (us and ecosystems containing us) rather than interdependent parts (us and our environments).
>
> (1986, 4)

In operationalizing this approach, they identify a need for both a people-oriented perspective (may be through the eyes of a person, corporation, voluntary association, professional discipline, government, or nation) as well as an ecosystem perspective that looks at people and their operational environment as a whole. This concept of the ecosystem approach is fundamental to this dissertation.

2. KEY SYSTEMS DEFINITIONS AND IDEAS

The fundamental starting point for all systems thinking lies in the simple assertion that the whole has properties that are in addition to those exhibited by its parts. Or, the whole is potentially quite different than the sum of its parts. Bennett and Chorley apply this idea and offer the following definition of a system:

> ...a set of logical operations acting upon, and acted upon by, one or more ***inputs***. These inputs lead to the production of ***outputs*** from the system and this process of ***throughput*** is capable of either sustaining the operational structure of the system, or of transforming it, perhaps catastrophically.
>
> (Bennett and Chorley 1978, 1)

According to Checkland and Scholes, in early applications of systems ideas, analysts such as systems engineers worked primarily to understand systems in these terms and if working in a design capacity, they attempted to optimize such systems so that more could be achieved with less (1990, 17).

An alternative and somewhat pragmatic articulation of systems thinking is provided by Armstrong:

> The systems approach uses two basic ideas. First, one should examine objectives before considering ways of solving a problem; and, second, one should begin by describing the system in general terms before proceeding to the specific.
>
> (1985, 14)

Armstrong outlines four steps that serve to operationalize a systems approach: (1) identify objectives; (2) develop indicators of success; (3) generate alternative strategies; and (4) develop and select programs (1985, 13 - 22).

More recently, the basis of systems thinking has been extended to include the three sets of principles listed in Table 1 below.

TABLE 1. FUNDAMENTAL PRINCIPLES OF A SYSTEMS APPROACH.

1. **WHOLENESS, EMERGENT PROPERTIES AND SYNERGY.** There are aspects of the whole which cannot be described or dealt with by analyzing the parts. Systems do not necessarily behave simply as the sum of their individual parts. Further, the behaviour of the parts does not allow the behaviour of the whole to be predicted. Rather, the complex whole may have so-called ***emergent properties*** which are critical for understanding and describing the whole but may have little or no meaning in terms of individual constituent parts. The components and the whole must be taken into account as well as the relationship and mutual effects of the parts on each other and to the whole.

2. **HIERARCHY.** The concept of emergent properties implies a view of reality as existing in the layers of a (perhaps multi-dimensional) hierarchy; systems will be found nested within systems.

3. **FEEDBACK, COMMUNICATION AND CONTROL.** Processes of communication and control (e.g. feedback mechanisms) exist within the hierarchically organized whole that allow adjustment and adaptation in the face of stress.

Sources: modified from Goldberg, 1989; Atkinson and Checkland, 1988; Project Management Team, 1989, and Checkland and Scholes 1990.

Checkland and Scholes note by way of summation that:

> These ideas together generate the image or metaphor of the adaptive whole which may be able to survive in a changing environment. To make mental use of that image is to do systems thinking.
>
> (1990, 19)

In application, models or paradigms are used that provide a conceptual framework for organizing the constituent parts and identifying controls and feedback loops. It is the assessment of the state or performance of these parts, controls and feedback loops as well as the whole that give rise to indicators or performance measures. Without the conceptual framework, however, the choice of indicators occurs in a vacuum. Indicators are one part of a system description and cannot usefully be regarded in isolation (Checkland and Scholes 1990, 112).

Chadwick suggests that "a model of a system is a representation of that system by another system" (1978, 189). Checkland and Scholes emphasize that it is inappropriate to claim that any model truly captures the real world because its complexities are well beyond our understanding (1990, Chapter 2). Rather, learning and better decisions can result from setting the perceived world against the systemic model. This comparison often leads to necessary debate and, ultimately, an accommodation between different interests may prove possible.

A great many organizing models which reflect attempts to bring the general concepts of sustainability to practical application from general notions are now emerging in the literature. None of these are appropriately judged in terms of being right or wrong. They obviously work for those who have created them. Rather, they represent a richness of ideas from which it may be possible to identify common elements with which to build a bridging conceptual approach to reporting on sutainability.

It is important to clarify what is meant by the terms "hard," "soft," "subjective" and "objective." Bennett and Chorley describe hard systems as "those capable of specification, analysis, and manipulation in a more or less rigorous and quantitative manner" (1978, 25). In a similar vein, Horn suggests that concepts in the social sciences are called "soft" if they cannot be defined with the precision of terms used in the physical sciences (1993, p. 5). Thus, according to Checkland and Scholes, 'hard' systems engineering is the task of engineering a well-defined system to achieve its objectives (1990, 16). In contrast, a soft system according to Bennett and Chorley is one which is not tractable by mathematical methods even though it may be an identifiable part of the real world that is able to maintain its identity in spite of internal change. (1978, 223). The designations "hard" and "soft" therefore can be seen to be related to the clarity of definition: hard systems are well-defined, soft systems are not.

Checkland and Scholes argue quite convincingly that in spite of the seeming technical sophistication and rigour of methodological approaches applied to hard systems analysis, hard systems are best described as a special case (characterized by well defined objectives) of the more general soft systems universe (1990, 17 - 18).

Schon articulates a similar conclusion pointing out that neatly defined problems solvable with sophisticated techniques are the exception. The greatest concerns of the real world are usually not amenable to such crisp analysis:

> Unfortunately, although there is a 'high, hard ground where practitioners can make effective use of research-based theory and technique', there is also a swamp lower down in which lie the 'confusing "messes" incapable of technical solution'; and it is in the swamp that we find 'the problems of greatest human concern'
>
> (1983, 42).

The issue of sustainability encompasses components that are both 'hard' and 'soft' in the sense described above. Because there is often confusion, it is important to differentiate these ideas with those related to the labels "objective" and "subjective."

The terms "subjective" and "objective" are usually applied to different modes of assessment. Robert Horn points out that:

> The term 'objective' is usually applied to the mode of assessment that is based on external evidence that is independent of the reporter, such as the series published by official statistical agencies where objectivity becomes identified with factual evidence. Subjective indicators are judgmental, often in mode and in concept, and reflect perceptions or opinions.
>
> (1993, 8)

In their work on systems, Checkland and Scholes state that an important aim:

> ...is to take seriously the subjectivity which is the crucial characteristic of human affairs and to treat this subjectivity, if not exactly scientifically, at least in a way characterized by intellectual rigour.
>
> (1990, 30)

They caution however, that although subjectivity:

> ...is never a problem for those whose inclinations are towards the arts and humanities, it can be difficult for numerate

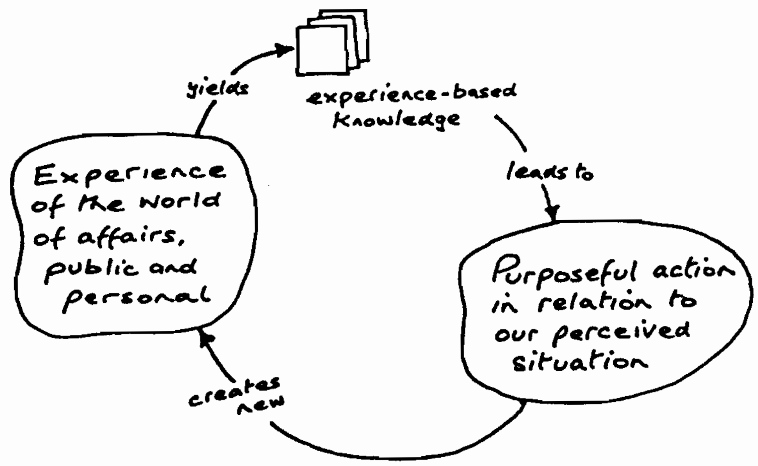
> scientists and engineers whose training has not always prepared them for the mixed drama, tragedy and farce of the social process.
>
> (1990, 31)

From the above, it falls that both subjective and objective modes of assessment are important to systematically assessing progress toward sustainability.

In introducing their particular approach to systems methodology, Checkland and Scholes point out that:

> To 'manage' anything in everyday life is to try to cope with a flux of interacting events and ideas which unrolls through time. The 'manager' tries to 'improve' situations which are seen as problematic — or at least as less than perfect — and the job is never done (ask the single parent!) because as the situation evolves new aspects calling for attention emerge, and yesterday's 'solutions' may now be seen as today's 'problems.'
>
> (1990, 1).

They suggest that systems thinking is simply a consciously organized thought process "of or concerning a system as a whole" (1990, 1). For anyone, especially managers, its power lies in providing "an organized way of tackling messy situations in the real world" (1990, 18). By taking a more formalized systems approach, the opportunities for learning and developing "experience-based knowledge" are heightened and as a result, more effective "purposeful action" aimed at constructively changing real situations is possible (1990, 3-5). This simple experience - action cycle is illustrated below in Figure 2.



Source: Checkland and Scholes 1990, 3. Copyright (C) 1990 by John Wiley & Sons Ltd. Reprinted with permission of the publisher.

Figure 2. The experience - action cycle.

The idea of a messy or complex situation in the real world is a rather apt description of dealing with the multi-faceted issue of sustainability. Furthermore, the concept of a learning-motivated approach leading to constructive change provides an appealing starting point for dealing with the complex and dynamic reporting problem. As will be seen below, this approach represents a significant historic shift in systems thinking from one aimed at optimizing a system with crisply defined objectives to an approach based on articulating and enacting a systemic process of learning related to an issue that has ill-defined objectives, as well as a variety of options forachieving them. Thus, as Checkland and Scholes state, "systemicity is shifted from the world to the process of enquiry into the world" (1990, 277).

3. SYSTEMS AND ANTICIPATION

With publication of the work by the World Commission on Environment and Development (WCED) in 1987 came a plea for a shift in perspective for policy development and decision-making from "react and cure" to one of "anticipate and prevent" (WCED 1987, 10, 365; NTFEE 1987, 3). This anticipatory stance is essential to the reporting system being proposed in this dissertation.

The principal definitions of "report" (verb) provided in *The Oxford English Dictionary* (1989) are:

> (1) To relate, narrate, tell, give an account of (a fact, event, person, etc.); (2) to carry, convey, or repeat (something said, heard, a message, etc.) to another; to take down in writing; to prepare a written account of (any meeting, event, etc.); (3) to give in or render in a formal account or statement of or concerning (some matter or thing); as the result of special observation or investigation;
>
> Similarly, "report" (noun) is defined as:
>
> (1) rumour, common talk; (2) an account brought be one person to another, especially on some matter specially investigated; a formal statement of the results of an investigation, or of any matter on which definite information is required; a teacher's official statement in writing about the work and behaviour of a pupil at school; (3) a statement made by a person; an account, more or less formal, of some person or thing; an account, more or less complete, of the statements made by a speaker or speakers of the proceedings at a meeting, or of any occurrence or event; weather report; (4) the act of saying or uttering; (5) in music, a response, a note or part answering to or repeating another; (6) a resounding noise, especially that caused by the discharge of fire-arms or explosives.

Both of these sets of definitions tend to place emphasis in the past and a retrospective viewpoint that documents events, utterances, or observations after the fact. Indeed, this conception of reporting is commonly held. In fact, some argue that the nature of current scientific thought with its emphasis on demonstrated cause-effect relationships forces a reactive stance and discriminates against anticipatory modes of thought.

For example, Rosen, investigating anticipation from a systems perspective, suggests that under current thinking:

> ...it is forbidden to allow present change of state to depend upon future states. Past states perhaps, in systems with "memory"; present state certainly; but never future states
>
> (1985, 9)

> ...as such, anticipation has routinely been excluded from any kind of systematic study, on the ground that it violates the causal foundation on which all of theoretical science must rest
>
> (1985, v)

By this logic, current systems analysis and related decision-making based on science is driven by a "reactive paradigm". Drawing heavily from biological analogies, he proposes as an alternative, the recognition of the "anticipatory system," one in which present change of state depends upon future circumstances:

> ...those systems which contain internal predictive models of themselves and/or their environment, and which utilize the predictions of their models to control their present behaviour.
>
> (1985, vii)

In subsequent investigations, Rosen has found many biological instances of control of behaviour through the use of predictive models. For example, he recognizes that:

> ...a prominent if not overwhelming part of our own everyday behaviour is based on the tacit employment of predictive models ... if I am walking in the woods, and I see a bear appear on the path ahead of me, I will immediately tend to vacate the premises. Why? I would argue: because I *foresee* a variety of unpleasant consequences arising from failing to do so. The stimulus for my action is not *just* the sight of the bear, but rather the output of the model through which I predict the consequences of direct interaction with the bear. I thus change my *present* course of action, in accordance with my model's prediction. Or, to put it another way, my present behaviour is not simply *reactive*, but rather *anticipatory*.
>
> (1985, 7)

Rosen goes on to examine the concept of prediction and the nature and use of models. He explores the coupling of predictive models with models of current state in such a way that predictive models influence and even direct current state.

It is exactly the kind of predictive modelling coupled to decision-making described above that is entrenched in the rational planning process described previously in Figure 1. The very activity of planning is described by Chadwick as:

> ...preparing for future actions, thus anticipating future states; it is the choice of those future states of a system which are thought to yield optimum conditions, as described by reference to criteria derived from the goals of the system.
>
> (1978, 155)

Many of the forecasting-prediction (the two terms are interchangeable, see Armstrong 1985, 5) and related techniques of anticipatory thinking have been most rigorously and enthusiastically explored and used within business administration and economics, particularly related to marketing, financial, and strategic corporate planning.

It is useful to differentiate three distinct approaches that contribute to anticipatory thinking: (1) forecasting or prediction; (2) scenario building; and (3) backcasting. Each of these approaches serves a different purpose and each is to some extent, applicable over different time horizons.

Forecasting is concerned with determining what the future ***will*** look like, not what it ***should*** look like. This latter determination is included in the broader purview of planning (Armstrong 1985, 6). A list of forecasting methodology in current practice is given in Table 2.

TABLE 2. CLASSIFICATION OF FORECASTING METHODS.

A. DESCRIPTIVE JUDGMENTAL METHODS

- interviews: personal, telephone
- mail questionnaires
- Delphi (a repetitive technique based on a statistical analysis of anonymous questionnaires to experts)
- meetings: traditional, structured
- group depth interviews (focus group)
- role playing, games

B. THEORETICAL MODELS

- trend extrapolation
- input-output models
- linear models
- combinations

C. OTHER SIMULATION MODELS

- mechanical analogs (for example, wind tunnel)
- metaphorical analogs (for example, tree: city)

D. VARIOUS COMBINATIONS OF THE ABOVE

Source: modified from Armstrong, 1985.

Unlike forecasting, scenario building is the art of developing a tool for helping current decision-makers take a long view in a world of great uncertainty. In a recent treatment of this topic, Schwartz points out that:

> The name comes from the theatrical term "scenario" - the script for a film or play. Scenarios are stories about the way the world might turn out tomorrow, stories that can help us recognize and adapt to changing aspects of our present environment. They form a method for articulating the different pathways that might exist for you tomorrow, and finding your appropriate movements down each of those possible paths. Scenario planning is about making choices today with an understanding of how they might turn out.

> In this context the precise definition of "scenario" is: a tool for ordering one's perceptions about alternative future environments in which one's decisions might be played out. Alternatively: a set of organized ways for us to dream effectively about our own future. . . This approach is more a disciplined way of thinking than a formal methodology.
>
> (1991, 3-4)

Backcasting provides yet another approach to anticipatory thinking. Using backcasting techniques, a desired future state is identified and described in terms of measurable objectives (for example, increased efficiency of energy use, reduction of chemical emissions etc.) and a suite of current policy options are then designed and chosen to achieve these goals. Robinson describes this approach and provides an application related to energy planning (1982).

From this discussion it is apparent that at least amongst community, corporate, and planning practioners, a relatively formalized anticipatory approach is well entrenched. It is equally apparent as the Brundtland Commission (WCED, 1987) and many others before and since have warned that contemporary policy development and decision-making continues in practice to be much more "react and cure" than "anticipate and prevent."

It is important to recognize that a system of reporting is a component, but only a component, of a decision-making process. It is itself a system nested within another system. The degree of anticipation is dependent, in the first instance, on the broader decision-making system and the perspective and wisdom of decision-makers. However, in addition to a commitment to the use of a **time horizon** that spans the long-term ecosystem dimension as well as the short-term human dimension (see Appendix III), there are two important features that emerge from this discussion that can be built into a system of reporting on sustainability to enhance its anticipatory capability and thus contribute to more anticipatory policy development and decision-making. First, a **formalized anticipatory component** should be included (could be some mix of the techniques described above) that examines and assesses implications of current trends as well as explores optional preferred futures and policy paths for attaining them. Second, as discussed by Jack Ruitenbeek, indicators that are chosen to monitor and assess progress should be those that allow forward-looking applications as well as description or past or current conditions (1991b).

4. SUMMARY

Starting with a brief sketch of the historic evolution of systems thinking, this chapter has provided a number of insights. While systems thinking is not a panacea, it provides a particularly effective structure for dealing with messy situations in the real world. The sought-after result is ongoing learning and growth of experience-based knowledge leading to purposeful action and constructive change.

General systems theory is evolving. While it has always been built on the need to consider the whole system and not merely its component parts, earlier work has tended to emphasize the definition of objectives and the optimization of approaches to achieve those objectives (as in critical path programming). The most successful early applications were in fact amenable to the crisp definition of objectives. Such applications are best described as "hard" systems.

The development of techniques to incorporate a range of alternative values in decision-making systems and the emergence of the "ecosystem approach" to man-environment relationships are two important developments that have served to enrich systems thinking in ways probably not envisioned by early systems workers.

In recent years, there has been a recognizable shift in systems thinking from optimization of systems to an emphasis on systemic processes of learning related to problems or issues with ill-defined objectives. This shift has facilitated the use of systems thinking to deal with many ill-defined, real-world situations. Information describing such systems is often "soft" and subjective in nature. Care must be taken to treat such subjectivity with intellectual rigour. Reporting on sustainability must deal with both "hard" and "soft" components.

Throughout the evolution of systems ideas, a core element has been a commitment to the idea of the "whole" system which can respond to stress and survive in a changing environment. Such systems are characterized by (1) **emergent properties** which are critical for understanding the whole but may have little or no meaning in terms of constituent parts; (2) a **hierarchical structure** in which systems are nested within other systems; and (3) processes of **communication, feedback, and control** that allow adjustment and adaptation in the face of stress.

Systems thinking involves the use of conceptual models to link components to the "whole" and the identification of controls and feedback loops. Assessing the state or performance of the constituent parts, controls, feedback loops, and the whole system, gives rise to indicators or performance measures. Without the conceptual framework and the related value structure, the choice of indicators occurs in a vacuum. Such indicators are only a part of the needed system description and cannot usefully be regarded in isolation.

The use of the conceptual models provides a mechanism against which the real world can be set to facilitate learning. This comparison often leads to constructive tension, debate, and hopefully to the accommodation of different interests and values. The sought-after result is improved decision-making. However, the models themselves must not be thought of as truly capturing the real world, the complexity of which is beyond current knowledge.

A system of reporting on sustainability is best seen as a system nested within a decision-making system. A variety of systems practioners have insights to offer in terms of enhancing the anticipatory capabilities of the reporting system, recognizing that it is the broader decision-making system which ultimately must invoke anticipatory thinking.

While anticipatory thinking is used to some extent on a daily basis, the concept of sustainability demands its application within an extended time horizon that respects ecosystem as well as human processes. Formalized techniques for anticipatory thinking include (1) forecasting or prediction, (2) scenario building, and (3) backcasting.

Lastly, two important features that can serve to enhance the reporting system's anticipatory capability and thus contribute to more anticipatory policy development and decision-making are identified: (1) including a **formalized anticipatory reporting component** (could be one or a combination of the three techniques noted above); and (2) use of **indicators** that allow forward-looking applications.

END NOTES

1. Many authors attest to von Bertalanffy's contribution including Lilienfeld 1978, 16; Checkland and Scholes 1990, 21 - 22; Chadwick 1978, 37. In addition to a large number of elements of applied mathematics (e.g. compartment, set, graph, and net theory), Von Bertalanffy included as special cases of general systems theory the disciplines of:

   - applied systems research including systems engineering, operational research, linear and non-linear programming;
   - cybernetics, the theory of control mechanisms based on communication (transfer of information) between system and environment and within the system, and control (feedback) of the system's function in regard to the environment
   - computerization and simulation; and
   - a variety of formalized theories related to information, games, and decision-making.

   (1968, 19 - 23)

2. The need to deal formally with the kind of ill-specified systems described here has led to the development of "fuzzy set theory" in applied mathematics. Zadeh's 1965 paper is seminal. The works by Kaufman (1975), Yager et al. (1987) and Novak (1989) provide useful overviews. Smithson's *Fuzzy Set Theory for Behavioral and Social Sciences* is particularly germain to the ideas discussed in this dissertation.

APPENDIX V

REVIEW OF STATE OF ENVIRONMENT REPORTS

CONTENTS

TABLE

APPENDIX V

REVIEW OF STATE OF ENVIRONMENT REPORTS

1. INTRODUCTION

Two purposes motivated this review: (1) to gain insight into alternative conceptual approaches for assessing and reporting on environmental and related conditions; and (2) to establish whether or not a conceptual approach is available from the state of environment reporting literature that is appropriate for guiding reporting on sustainability.

A total of two-hundred and twenty state of environment reports from eight categories were examined: global (23 examples); international (9); non-U.S. national reports (68 reports from 54 countries); U.S. national reports (23); provincial/regional (23 from 14 regions); municipal (9 from 4 municipalities); ecosystem component (e.g. air, water, forests, oceans) (47); and company or industry (18).

Macelli (1977, 1) pointed out the inevitable link between the conceptual approach taken in any project and the format of the final report. Drawing on this link and to facilitate a comparison, a summary outline of the substantive components of each report was prepared, using a common format. The majority of these summaries (144) are found in Hodge 1991, Appendices II through IX. In Sections 2 through 9 below, observations are drawn from each category. A summary of key conclusions is presented in Section 10 and a complete bibliography of the reports included in the review is provided in Section 11.

2. GLOBAL SOE REPORTS

These reports fall into two groups: (1) broad global environmental assessments (Barney 1980; Brown et al. 1986 - 1993; Brown et al. 1992b; Durell 1986; King 1980; UNEP 1982, 1987, 1989, 1992; World Resources Institute and IIED 1986 - 1989; World Resources Institute, UNEP and INDP 1990, 1992) and (2) reports addressing specific themes on a global scale such as environment and health (UNEP

1986), people and the environment (UNEP 1988), and children and the environment (UNEP 1990).

An important characteristic that can be drawn from this category and is reflected again at the national, regional and municipal levels, is that while the vast majority of these reviews stem from work undertaken by government, some of the most insightful work is the result of efforts by the private sector, in particular, non-profit or academic organizations (for example, see the World Resources Institute and Worldwatch Institute reports in this category; the Centre for Science and Environment, (India 1982 and 1985), Environmental Problems Foundation of Turkey 1981 and The Conservation Foundation (1982, 1984, 1987) in the National category; Colborn et al. 1990 at the regional level (Great Lakes); and Barnhizer 1990 (Cleveland) and Elkin 1987 (Waterloo) at the municipal level. It is apparent that there is an important role to play for both the public and private sectors in SOE reporting.

3. INTERNATIONAL SOE REPORTS

A small group of reports are included in this category from two multi-national organizations: the Commission of the European Communities (1977, 1978, 1986) and the Organization for Economic Co-operation and Development (1979, 1985, 1987a, 1987b, 1991). The influence of the stress-response approach can be seen with the OECD reports. For example, in their 1979 report, the OECD use a three part approach including human activities and their impacts (the stresses), environmental conditions, and policy responses (stress alleviation). The two most recent of these reports, Commission of the European Communities 1986, and OECD 1991 both show a marked shift to including a substantive discussion of environment — economy linkages although no systematic approach is utilized.

4. NON-U.S. NATIONAL SOE REPORTS

National SOE Reports are by far the most numerous, representing two-thirds of all those reviewed. In total, 68 reports from 54 countries were reviewed. The split between non-United States national reports and United States reports is one of convenience and motivated simply by the large number of reports that focus on the

U.S. relative to any other single country.

U.S. researchers and consultants have had a significant influence on SOE Reporting in other countries. Many of the national reports included in this review are draft environmental profiles of developing countries completed with support from the U.S. Agency for International Development (U.S.A.I.D.) and a number of these are based solely on literature surveys. However, exceptions to this generalization are the SOE Reports for Australia (Commonwealth of Australia 1985a, 1985b, 1987); Canada (Bird and Rapport 1986; Structural Analysis Division 1986; Environment and Wealth Accounts Division 1991; and Canada 1991); France (Ministere de l'Environnement et du Cadre de Vie 1981, 1987a, 1987b); India (Centre for Science and Environment 1982, 1985); Israel (Whitman 1988); Japan (Environment Agency 1977, 1979, 1982, 1986, 1988); Netherlands (National Institute of Public Health and Environmental Health 1988 and 1991); Thailand (Thailand Development Research Institute 1987); and Turkey (Environmental Problems Foundation of Turkey 1981).

Most SOE reports address their subject through the four perspectives listed in Table 1. All of these perspectives can be found in the reports in this category.

TABLE 1. PERSPECTIVES TAKEN BY SOE REPORTS.

1. ISSUES of concern (e.g., urban air quality, acid rain, drinking water quality, accidents and spills, natural disasters, etc.)

2. INDUSTRIAL SECTORS and related environmental impacts (e.g., energy, transportation, mining, agriculture, forestry, etc.)

3. ECOSYSTEM COMPONENTS (e.g., air, land, water and the aquatic ecosystem, wetlands, biota: mammals, migratory waterfowl, fish, forests, insects, etc.)

4. Some COMBINATION of the above either in a haphazard manner or within some more formalized structure such as the Canadian devalued stress-response framework

Source: modified from Sheehy, 1989.

Regardless of the specific objectives defined for any particular SOE assessment, of great import is the link between environmental conditions and the policy and decision-making system. Thus a critical aspect of SOE reporting should be a description of the system of governance, the related regulatory regime, and the enforcement and compliance record. In their discussion of "Pollution and Countermeasures Taken," the Japanese SOE reports (Environment Agency 1977, 1979, 1982, 1986, 1988) are illustrative in this regard. In terms of institutional description, the Israeli SOE report (Whitman 1988) provides a good example. However, overall, attempts to link to systems of policy development and decision-making are weak at best.

Difficult topics that must be dealt with explicitly are the social, cultural and economic implications of any measures taken (or not taken) in the public or private (corporate, not-for-profit, individual) domains to reduce environmental stress. The environmental profile of Honduras (JRB Associates 1982) specifically mentions social and cultural issues. The special role of women is highlighted in the 1984-85 India SOE report (Centre for Science and Environment 1985) a report which also discusses the topic of "agents of change" assessing both government and non-government organizations. The United Nations Environmental Programme's 1988 global scale report (UNEP 1988) focuses on "people and the environment" and also highlights the special role of women. Environmental education is a critical topic to be addressed and is done so in several reports of which the Israel SOE report (Whitman 1988) is a good example.

A common concern in SOE reporting is the issue of human health, but almost always in terms of its link to chemical contaminants. This topic is dealt with in the global scale United Nations Environment Programme 1986 theme report (UNEP 1986) as well as the UNEP world reviews (UNEP 1982, 1986, 1987, 1989, and 1992) and a large number of national level reports. No SOE report was found that attempts a link to an overall assessment of human well-being.

Reporting on the cultural, social, and economic implications to aboriginal peoples of environmental conditions is rare and always only as a minor component. There is a marked absence of the perspective of "traditional" (aboriginal) and/or "country" (non-aboriginal subsistence) perspectives on environmental conditions.

Assessment of social and cultural implications lags far behind assessment of economic implications. A noteworthy report dealing with the economic "cost" topic is the French assessment of "economic statistics of the environment" (Ministere de l'Environnement 1987b).

5. U. S. NATIONAL SOE REPORTS.

National level SOE reporting for the U.S. is unequaled in the world. A total of 23 reports were reviewed in three groups: 19 reports from the Council of Environmental Quality, three from the Conservation Foundation, a not-for-profit environmental research group, and one set from the National Wildlife Federation, a not-for-profit environmental public interest group. There is some similarity in approach between the CEQ and the Conservation Foundation reports, a result of key people moving from one organization to the other (Liroff 1990, personal communication).

The Council of Environmental Quality was established in 1970 in the President's Office with the National Environmental Policy Act (NEPA). Under NEPA, the President is required to file with the Congress an annual Environmental Quality Report setting forth the status and conditions of the Nation's environment. The report was to trace current environmental trends, assess the adequacy of natural resources to fulfill human and economic needs, review and assess activities effecting the environment, and suggest ways of remedying program deficiencies (CEQ 1970).

The CEQ was established under President Nixon and has continued ever since through Ford, Carter, Reagan, Bush and now Clinton presidencies. Staff and financial resources were stripped from the CEQ in the early 1980s by the Reagan administration and in the last half of the 1980s, the annual reporting requirement was not met. By 1990, the Bush administration was considering re-injection of resources into the CEQ but the momentum of the first decade of CEQ activities has never been re-gained (Liroff 1990, personal communication).

A standard format for CEQ reports has never been established. Through the 1970s and in particular, the earlier years, specific technical problems were dealt with at a state-of-the-art level. Examples include land use (CEQ 1970, 1974), the inner city environment (CEQ 1971), environmental indices (CEQ 1972), the law and the environment (CEQ 1971), the economy and the environment (CEQ 1971), the costs and economic impacts of environmental improvement (CEQ 1972), economics and environmental management (CEQ 1973), environmental economics (CEQ 1975, 1982), economics (CEQ 1978), forecasting (CEQ 1972), local governments (CEQ 1972), human settlements (CEQ 1972, 1978, 1980), environmental impact assessment (CEQ 1976), carcinogens and the environment (CEQ 1975), and ecology and living resources, biological diversity (CEQ 1978, 1979, 1980).

In the CEQ reports there is somewhat of a pattern established by reporting first on "events" of the reporting year (often split on the basis of federal, state, and private activities) followed by "conditions and trends." All of the perspective listed in Table 1 are found scattered through the CEQ reports and there is no apparent organization indicating an underlying conceptual framework. Through out the CEQ reports, treatment of enforcement and compliance issues is erratic, likely a reflection of the political sensitivity of the topic.

Like the CEQ reports, those of The Conservation Foundation do not follow a set format, dealing sometimes with issues, sometimes with particular resource sectors, sometimes with ecosystem components. There is somewhat of an emphasis on contaminant related topics and indeed, one of the major contributions of The Conservation Foundation has been the recognition of the significance of cross-media movement of contaminants and the need for an integrated air-water-land approach to contaminant regulation. The independent position of the Conservation Foundation has allowed it to speak out explicitly (and often critically) on shifts in government policies as reflected in expenditures on environmental protection and related actions.

Since 1966, The National Wildlife Federation has prepared an annual assessment of environmental conditions in the U.S. based on a simple, subjective evaluation of the state of seven items: wildlife, air, water, forests, energy, soil, and quality of life. Though lacking a profound technical and scientific base, the subjective approach taken is analogous to the "expert or focus" group approach very commonly used in policy assessment and planning. For example, Southam News (Ottawa Citizen supplement, Saturday, October 20, 1990) commissioned an eight-person panel of experts to review the environmental performance of the provinces and territories in five areas - energy, waste, resources, conservation and political will. Similarly, the approach played a central role in the work of the Citizen's Forum on the Future of Canada (Spicer Commission). This kind of process will probably play a significant role in assessing and reporting progress toward sustainability.

6. PROVINCIAL/REGIONAL SOE REPORTS

In this category, 23 reports were reviewed from such diverse locations as the Arctic (Canada 1991, Chapter 15), Atlantic Canada (Wilson et al. 1979; Eaton et al. 1986), British Columbia (BCMOE 1993; Canada 1991, Chapter 16; Dorcey 1991; Regional Consulting Ltd. and Quadra Planning Consultants Ltd. 1990a, 1990b); the Gulf of Maine (Van Dusen and Hayden 1989), the Great Lakes Region (Canada 1991, Chapter 18; Colborn et al. 1990, Council of Environmental Quality 1990), Manitoba (Manitoba Environment, 1991); the prairie ecozone in Canada (Canada 1991, Chapter 17), Quebec (Environnement Quebec 1988a and 1988b); Saskatchewan (Saskatchewan Environment and Public Safety 1991); Washington State (Washington Environment 2010 1989, Puget Sound Water Quality Authority and Entranco Engineers Inc. 1986), Victoria, Australia (Ministry for Planning and Environment 1986), and South Australia (Environmental Protection Council of South Australia 1988).

The provincial/regional scale of these reports allows review in greater detail than those discussed above in Sections 2 through 4. In several of the reports reviewed, study area definition was based on a physically defined ecosystem component such as a drainage basin (Great Lakes, Lower Fraser Basin), or distinct coastal feature (Gulf of Maine, Puget Sound).

There are few conceptual insights that emerge from these reports that have not already become apparent from those previously reviewed. However, a few highlights are worth noting. Human health plays a prominent role in about half of the reports. With the exception of the Quebec reports (Environnement Quebec 1988a and 1988b), and the Manitoba report (Manitoba Environment 1991), economic analysis is limited to review of some human activities (for example see Van Dusen and Hayden 1989, Chapter 2), and there is little effort extended to developing a regional economic picture integrated with environmental conditions. The Quebec SOE reports also highlight the environment-city issue, a topic not captured in standard sectoral analyses.

Two of these reports, Colborn et al. 1990 and Puget Sound Water Quality Authority and Entranco Engineers 1986 provide a long- term historic context that is particularly useful. In Colborn et al., the discussion of the difficulties faced in defining and measuring ecosystem health touches a very difficult and key topic. Their summary chapter of 15 indicators of ecosystem and economic well-being is also very useful for gaining an overall perspective.

The Lower Fraser River Basin discussions (Regional Consulting Ltd. and Quadra Planning Consultants Ltd. 1990) regarding sustaining air quality, sustaining water resources, sustaining land, sustaining fish and wildlife, and an overall sustainable environment are innovative extensions to more standard SOE approach. The protection of heritage resources discussed in the Victoria, Australia report (Ministry for Planning and Environment 1986) is a useful addition.

The trend assessment in the Manitoba report (Manitoba Environment 1991) in which a general "better - same - worse" label is attached to a broad number of concerns (e.g. supply of prime farmland - worse (see p. 105) is helpful but assessment criteria are not always made clear. In an earlier draft, attempts were made to identify future issues (Environmental Management Services, in preparation). The action priorities in the South Australia Report (Environmental Protection Council of South Australia 1988) also reflect an important anticipatory perspective that is too often missing.

7. MUNICIPAL SOE REPORTS

The municipal level of government (cities, towns, and settlements) has a critical role to play in SOE reporting. In the order of two-thirds of all government expenditures related to the environment occur at the municipal level. Municipalities are created to provide services to their residents. At the same time they are a focus of human-induced stress on the environment and it is here where much of the effective action can be taken to reduce environmental degradation. In spite of this realization, to date very few municipal governments or not-for-profit organizations at the municipal level have thought in terms of comprehensive SOE reporting.

In this review, work from four cities/municipalities was examined: Cleveland, Ohio (Barnhizer 1990), Hamilton-Wentworth (Planning and Development Department 1990), Waterloo (Elkin 1987), and Toronto (Macpherson 1988; Royal Commission on the Future of the Toronto Waterfront 1990, 1991, Barrett and Kidd 1991).

Barnhizer's 1990 work on Cleveland is a collection of issue papers written by students at the College of Law, Cleveland State University and compiled by the Dean of Law (Barnhizer). Though not intended as a formal SOE report, all of the

34 components could quite comfortably be included in an SOE report. Discussion of topics such as municipal infrastructure (section 31), illicit drugs and the urban environment (section 32), environmental education (section 33), and a guide to community action (section 34), all serve to signal topics.

The State of the Environment Report for the Regional Municipality of Waterloo (Elkin 1987) is a noteworthy example of a municipal level SOE report. In some ways it is one of the most comprehensive SOE reports included in this review. It draws on the stress-response model for conceptual insights but is organized in four parts including background, abiotic elements, biotic elements, and cultural elements. The later category includes detailed discussions of demography, institutional arrangements, the regional economy, recreation, land use, and municipal infrastructure.

Barrett and Kidd's 1991 report completed for the Royal Commission on the Future of the Toronto Waterfront provides a useful application of the "ecosystem approach", now the driving management principle throughout the Great Lakes Region. The report is an outstanding example of a synthesis that draws together technical information, values, decision-making and anticipatory thinking.

8. ECOSYSTEM COMPONENT SOE REPORTS

Forty-seven SOE assessments aimed at a defined ecosystem component were reviewed: air (3), water (42), forests (1) oceans (1).

Of the three air reports, one addresses air quality at the national (Canada) level (Hilborn and Still 1990), one at the state level (Alaska Department of Environmental Conservation 1990) and one at the municipal level (Vancouver Task Force on Atmospheric Change 1990). All focus on various types of emissions to air and programs for their reduction. None provide an explanation of the regional climatic system a context that is important to understand because of trans-regional and transboundary air movement. The discussion, in the Vancouver Task Force Report on "The City as Leader" provides an important guiding theme. Stillborn and Hill (1990) provide a useful overview of the effects of air pollution.

The 47 water reports include four groups, all of which contain useful insights:

(1) water quality:

- reports by the International Joint Commission and its Water Quality Board on Great Lakes Water Quality (8 reports);
- inland water quality assessments by the eight Great Lakes states and Alaska as required by Section 305B of the Clean Water Act (23 reports from 1986, 1988, and 1990);
- assessments of nonpoint source impacts from the eight Great Lakes states and Alaska (8 reports, mostly 1988);
- assessment of inland water quality from Victoria, Australia;

(2) water quantity

- reports on Great Lakes water levels by the Great Lakes Water Levels Project Management Team (interim and final reports);

(3) river basin assessment

- Yukon River Basin study report;

(4) ocean assessment

- state of Canada's oceans;

Of particular note, are the "urgent issues" identified by the International Joint Commission in their assessment of Great Lakes Water Quality (International Joint Commission 1982 - 1994); and the systems approach taken by the Great Lakes Water Levels Project Management Team (1989, 1993). Both of these sets of reports also reflect a continuing struggle regarding the balancing of values and interests within the Great Lakes Basin.

The 305B reports typically include sections on surface water quality, groundwater quality, and water pollution control activities. The assessment of surface water is based on the ability of a particular water body to support designated uses that are defined either through the U. S. Clean Water Act or parallel state legislation. Designated uses under the Clean Water act include "fishable" — protection and propagation of fish, shellfish, and wildlife, and "swimmable" - providing for recreation in, and on, the water (Michigan Department of Natural Resources 1990, 3). Designated uses under state water quality legislation include:

Illinois: general use, public and food processing water supply, Lake Michigan, secondary contact and indigenous aquatic life (Illinois Environmental Protection Agency 1986, 7);

Indiana: aquatic fish and wildlife, domestic water supply, recreation, agriculture, industrial, navigation, non-degradation, other, unclassified (Indiana Department of Environmental Management1988, 3)

Michigan: agriculture, industrial, and public water supply; navigation; body contact recreation; use by aquatic life and wildlife (Michigan Department of Natural Resources 1990, 3);

Minnesota: aquatic fish and wildlife, domestic water supply, recreation, agricultural, industrial, navigational, non-degradation, other-limited resource value waters (Minnesota Pollution Control Agency 1990, 5)

New York: no additional use designations

Ohio: aquatic life uses (seven designations); public water supply, recreation (primary, secondary), state resource waters, outstanding resource waters (Ohio Environmental Protection Agency 1990, 6);

Pennsylvania:fish and aquatic life; public, industrial, livestock, wildlife, and irrigation water supply; boating, fishing, water contact sports, and esthetics recreation uses; special protection (Pennsylvania Department of Environmental Resources 1990, 9-10)

Wisconsin: public supply of fresh water, commercial self-supply, domestic fresh water, industrial water use, thermal electric utility generation, mining, agriculture (non-irrigation), agriculture (irrigation), hydropower (Wisconsin Department of Natural Resources 1988, 11-12). In addition, classified uses are designated as fish and other aquatic life uses, outstanding resource waters, exceptional resource waters, recreational uses, public health and welfare, and wild and domestic animal uses (Wisconsin Department of Natural Resources 1992, 17-18).

In each case, some degree of impairment of designated uses is assessed on the basis of a variety of water quality criteria. Assessment criteria for the fishable, swimmable federal use designations are set in the Clean Water Act. Assessment criteria related to state designated uses vary from state-to-state. Reports also attempt to identify major sources of non-support of designated uses. The Michigan and Minnesota 1990 305b reports also identify and describe public health and aquatic life concerns, an assessment that goes well beyond the earlier methodology based on use impairments.

Different than the Great Lakes states, the Alaska 305b report (Alaska Department of Environmental Conservation 1990, 3) simply classifies waters as either impaired (water quality standards not met) or suspected of being impaired (based on professional judgement).

The concept of assessing surface water in terms of impairment of "uses" does not lend itself to an assessment of overall ecosystem integrity or well-being. Furthermore, variations in sampling frequency and distributions introduce a major degree of subjectivity in assessing a dynamic surface water system. In addition, state coverage is far from comprehensive.

Evaluation of groundwater conditions varies greatly from state to state depending on how much dependence there is on groundwater as a water supply. Quantity is clearly often as much an issue as quality. Assessment of both groundwater quality and quantity is limited to observations drawn from discrete point measurements; none reports address groundwater from a natural systems perspective.

In spite of significant limitations, the 305B reports do provide a starting point for periodic assessment of surface water conditions. There is no equivalent reporting mechanism in Canada.

In the report on Victoria's Inland Waters (Commissioner for the Environment 1988), the clear separation between (1) human activities and environmental stress, (2) environmental impacts - water quality indicators, and (3) environmental impacts - biological indicators is unique.

The Yukon River Basin Study (Yukon River Basin Committee 1984) was a joint Federal, provincial, territorial project initiated under provisions of the Canada Water Act. The final study report is organized very much like many SOE reports with a first part describing the state of various ecosystem components, a second part addressing human use of resources, a third part discussing management challenges, and a fourth part identifying transboundary considerations for water management.

9. CORPORATE OR INDUSTRY SOE REPORTS

Eighteen reports of this type were reviewed, covering chemicals/petrochemical; electrical utility; forestry; minerals/mining/metallurgy, pharmaceuticals, steel manufacturing; and transportation.

These reports represent a new and rapidly expanding element of SOE reporting. They reflect a recognition on the part of individual corporations sectoral associations, or government, of the need to undertake a periodic environmental performance report or "audit."

In each case, companies provide a self-assessment of their environmental policies, cost implications short and long-term, imposed environmental stress (almost entirely related to chemical emissions to water and air), programs for pollution reduction, records of achievement and compliance with regulations, implications for public and employee health and safety etc. Degree of coverage of these topics varies enormously.

No company has attempted to report on the integrity of the ecosystem or community with which its activities interact or provide an assessment of the role its activities have in influencing current conditions found in that ecosystem or community.

10. MAIN CONCLUSIONS

The following main conclusions emerged from this review. Previous versions of this list are found in Hodge and Taggart, 1991 and Hodge, 1993a.

1. RICH AND IMPORTANT SOURCE OF DATA AND INFORMATION. State of environment reports are a rich and important sources of data and information. The dominant focus is on ecosystem conditions. A secondary focus is on factors contributing to those conditions.

2. NO ACCEPTED FORMULA FOR SOE REPORTING. There is no common set of goals and objectives for SOE reporting, no accepted norm, no common conceptual framework and no common report format.

3. WEAK LINKS TO DECISION-MAKING. While the target audience for these reports is the educated public and decision-makers, few include description of the decision-making system: the role of different decision-makers in society, governance and institutions, the relevant regulatory regime, the enforcement and compliance record, use of market based incentives for action etc. Further, explicit understanding of the time and space characteristics that govern ecosystem conditions in comparison with the time and space characteristics that govern contemporary decision-making is rarely demonstrated. As a result, the link between SOE reporting and decision-making is weak at best.

4. INADEQUATE MODEL OF THE HUMAN-ECOSYSTEM INTERFACE. In spite of efforts to assume an "ecological" perspective, the vast majority of these reports are driven by a "world view" that is based in the materials-energy balance model of the human-environment relationship that has roots in economics literature. In this model, the environment is seen as an "asset" that provides material, energy, (and aesthetic) resources to drive production and consumption activities within the economic system. As a result of these activities, waste products are formed that are then returned to the environment as pollution. The environmental issue thus reduces to two components, one dealing with resource use (or misuse, depletion, and scarcity) and one dealing with pollution. In turn, the solution to the environmental problem becomes one based on wise resource use and reduction of pollution. The related reporting is then focussed on the stocks and flows of resources and levels of pollution. This model of the human-environment relationship is inadequate for resolution of the many linked human and ecosystem issues now requiring attention.

5. REPORTS ARE RARELY ANTICIPATORY. While often expressing an interest in assuming an anticipatory stance, the form and content of most SOE reports ensures a reactive stance based on current and historic concerns.

6. WEAK ENVIRONMENT-ECONOMY LINKAGES. More recent reports place greater emphasis on the linkage between economic activities (and the status of the economy) and ecosystem conditions. However, no report has demonstrated a fully satisfactory approach to describing this relationship.

7. LIMITED TREATMENT OF HUMAN CONDITIONS. Human conditions are dealt with erratically: in descending priority of treatment are treatments of health, social, culture and heritage. Reporting related to aboriginal peoples or other sub-populations that have a closer direct dependence on the natural ecosystem is rare. Nor is there treatment of disadvantaged populations such as the urban poor. The issue of equity is not a significant theme of SOE reports.

8. SOE REPORTING DOES NOT PROVIDE A MODEL FOR REPORTING ON SUSTAINABILITY. The insight into environmental conditions provided by SOE reporting is a critical component of reporting on sustainability. However, SOE reporting is not a sufficiently robust instrument for effectively dealing with the linked human and ecosystem issues that are critical to the concept of sustainability. Insights must also be drawn from a large number of reporting exercises including those focussed on the economy, health and welfare, quality of life, human development, and healthy communities. Each has something to offer and no one on its own can deal with the breadth of topics requiring attention.

9. NEED TO STRENGTHEN SOE REPORTING BY CONSCIOUSLY LIMITING. Lacking any formal conceptual approach, SOE reporting stands as an unbounded task carrying with it expectations and intentions the vary greatly depending on the interested party. Formally defining limits to its task would greatly strengthen its role and significance.

10. AUTHORSHIP. While the vast majority of these reports stem from work undertaken by government, some of the most insightful are the result of efforts by private, non-profit or academic organizations. The arms-length-from-government relationship facilitates a greater degree of assessment, critique, and consideration of non-status-quo problem solutions. Further, government initiated reporting has a tendency to assume a stance that is defensive of its various programs rather than critically objective in undertaking an assessment.

11. SOE REPORT LISTING

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WATER

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APPENDIX VI

A REVIEW OF
ALTERNATIVE MODELS THAT ADDRESS
THE HUMAN - ECOSYSTEM RELATIONSHIP

APPENDIX VI

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A REVIEW OF ALTERNATIVE MODELS THAT ADDRESS THE HUMAN - ECOSYSTEM RELATIONSHIP

1. INTRODUCTION

A large number of models have been developed over the years that in some way address the human-ecosystem interface. These models are found in the literature of a variety of interests and disciplines including: economics, geography, ecology, health, planning (community, urban, regional, water resources, etc.), resource management, and most recently the broad interest areas of sustainable development and sustainability.

This review has two purposes: (1) to scan the literature in search of a conceptual framework that would serve as a guide for reporting on sustainability or failing success in that quest, (2) to identify insights and common characteristics and elements with which the needed bridging conceptual "roadmap" can be built. Thirty different approaches to modeling the human-ecosystem interface are examined.

From the outset, this approach has been partly motivated by the idea of an "overlapping consensus", proposed by John Rawls (1987). Rawls points out that a consensus affirmed by opposing theoretical, religious, philosophical and moral doctrines is likely to be both just and resilient. Public policy based on such an "overlapping consensus" is therefore more likely to thrive over generations.

Young applies this idea in examination of sustainable investment and resource use. He points out that in practice, the search is for "clinical rules, judgements and advice" usually in the form of either constraints or prescriptions: constraints that if crossed impede sustainability or prescriptions that if adhered to make it easier to remain within the constraints to generate sustainability (1992, 14).

In this review, the idea of "overlapping consensus" is applied by seeking common elements in the conceptual approaches that various workers from a variety of disciplines have used in examining human-ecosystem interaction. Many of these workers are isolated within their disciplines and enjoy little or no trans-disciplinary dialogue.

The intent is not so much to judge the various models in terms of their being right or wrong. Most models work, at least for those who propose them. Rather, the hope is to identify fundamental elements that provide a common base.

Following the purposes state above, each model was examined for its appropriateness for guiding reporting on sustainability. Any useful characteristics or insights were identified in the process. In practical terms, the test for appropriateness amounted to assessing whether or not the model: (1) reflected the value set of sustainability (see Chapter Two and Appendices I, II, and III); (2) was based on systems theory (see Chapter Two and Appendix IV); and conceptually spanned the resulting system.

Mitchell reviews four groups of models drawn from ***resource analysis*** ("examination of phenomenon to determine their essential features") and ***resource management*** ("decisions concerning policy or practice regarding how resources are allocated and under what conditions resources may be developed"). He grouped his models as biophysical, economic, cultural, or integrative. Mitchell's work provided a useful point of departure for this review (Mitchell, 1980)[1].

Discussion in this Appendix is organized as follows. Immediately following the Introduction, Section 2 examines six contributions that utilize the common three-part "social, economic, and environmental" model. Five health-motivated variations are considered in Section 3. A summary discussion of these eleven models is then found in Section 4. Section 5 deals with variations of four models drawn from economics literature. Three approaches built on stress-response relationships are described in Section 6. In Sections 7, two "general ecological" models are reviewed. Four analyses specifically aimed at sustainability are described in Section 8. In Section 9, the macrostructure of AGENDA 21 is reviewed and Section 10 serves as a general grouping of five additional relevant models. Lastly, a summary of key conclusions is provided in Section 11.

2. THE COMMON "SOCIAL-ECONOMIC-ENVIRONMENT" MODEL

2.1 Firey's Theory of Natural Resource Use

Over thirty years ago, Walter Firey pointed out that three broad groupings of knowledge were pertinent to natural resource use: (1) ***ecological***, which takes the physical habitat as its point of departure; (2) ***ethnological***, which stems from the culture of human beings; and (3) ***economic***, which begins with the attribute of scarcity which attaches to human activities (1960, 20). He examines optimization of processes associated with each of these categories and tests the proposition that:

> The set of ecologically optimal resource processes
>
> *coincides with* —
>
> The set of ethnologically optimal resource processes
>
> *coincides with* —
>
> The set of economically optimal resource processes
>
> (39 - 53)

He concludes that the proposition ***cannot*** be sustained.

However, he further asserts that the only reasonable way for resource planning and policy making to proceed is to look for a way of balancing the criteria used in optimizing each of these three sets.

Firey's theory of resource use lies at the root of much of today's conceptualization of the human - ecosystem interface. His three-part model (ecologic, ethnologic, economic), and his assertion that a balancing of criteria drawn from each component is required in analysis of natural resource use is prevalent in contemporary through (Mitchell, 1991). In the 1990s, the three elements are often referred to as (1) ecological or environmental; (2) social or cultural, and (3) economic. In the late 1980s, Firey's three-part model was adopted by a number of workers attempting to operationalize the concept of sustainable development (Mitchell 1991, 268).

2.2 SADDLER'S WORK ON SUSTAINABLE DEVELOPMENT

Saddler (1988, 1990) addresses the integration of environmental, economic, and social concerns in articulating what he called "a systems perspective on sustainable development". He described sustainable development as a "commonwealth of values" lying at the intersection of environmental, economic, and social goals to give (1) conservation with equity; (2) environment-economy integration, and (3) community economics as if people mattered (Figure 1).

Source: Saddler 1988.

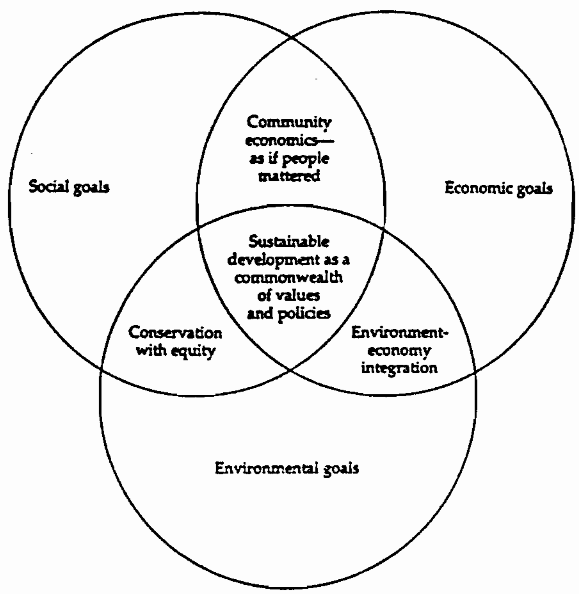
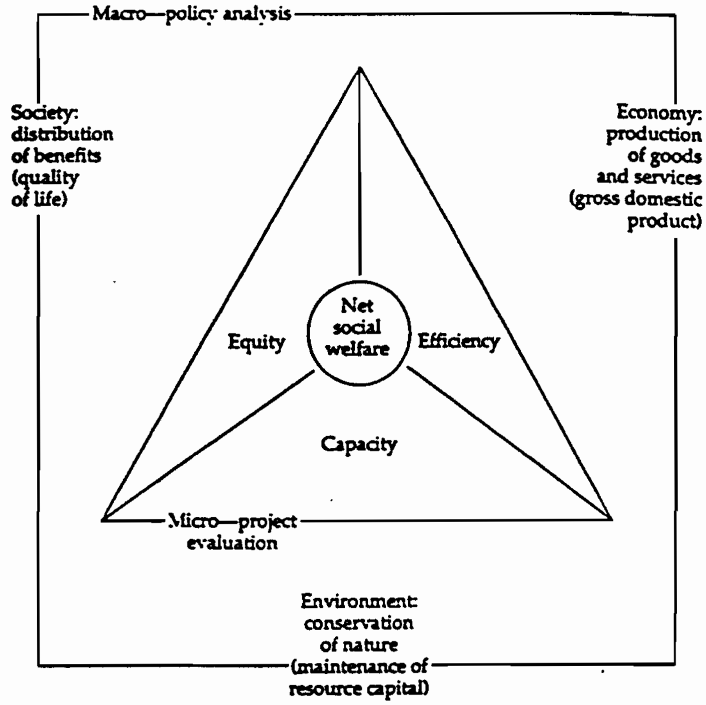


Figure 1. Saddler's systems perspective on sustainable development.

Echoing Firey's earlier work, Saddler also develops a conceptual approach to linking criteria and components of decision-making for sustainable development (Figure 2).



Source: Sadler, 1988.

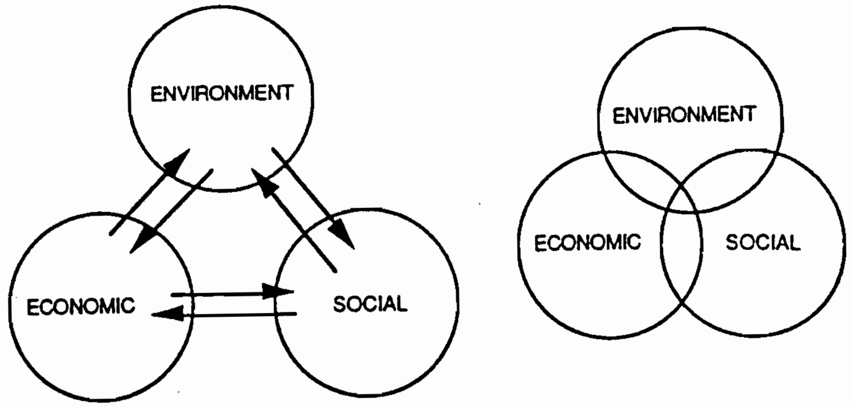
Figure 2. Criteria and components of decision-making for sustainable development

Saddler argues that decision-making for sustainable development ***macro-policy*** should include consideration of: (1) environment (conservation of nature, maintenance of resource capital); (2) economy (production of goods and services, gross domestic product); and (3) society (distribution of benefits, quality of life). He further opines that the ideas of sustainable development imply that ***micro-project*** evaluation (aimed at maximizing net social welfare) should include consideration of: (1) environmental capacity; (2) economic efficiency; and (3) social equity. Following these ideas through as a model for reporting on sustainability, these three categories would provide an organizational template for grouping indicators and related assessment.

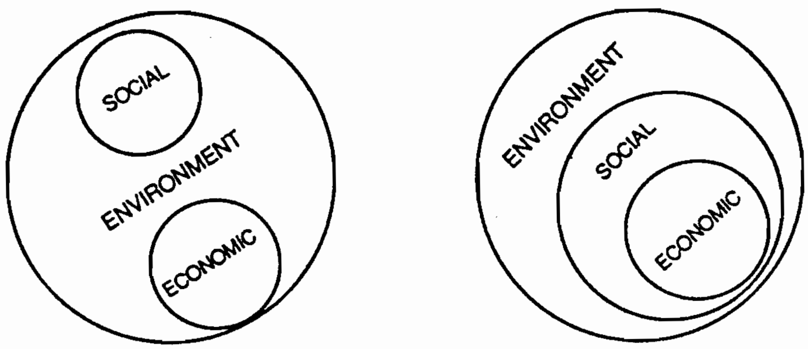
2.3 Dorcey's Work on Sustainable Development

Dorcey applies a similar three-part conceptual approach in study of British Columbia's Fraser River Basin (Dorcey, 1991a, b, and c). The evolution of his conceptual thinking is shown schematically in Figures 3a, b, and c. Building on these ideas, he proposed a "governance system in the analysis of sustainability" in application to the work on the Fraser River Basin (Figure 4).

His nesting of certain system elements within others implies a hierarchy of relationships that is an important advance. Because of the overlap he illustrates, it is not surprising that much confusion surrounds the definition of the elements in the three-part model. Further, his "governance system" model, no doubt in pursuit of definitional clarity, departs from the three-part model and in simple terms, reduces to a description of certain elements of the "human system" lying within the aquatic component of the "natural system". These system elements (the human subsystem within the ecosystem) along with the interface between the two, are the principal system components that emerge as necessary in a system of reporting on sustainability. This conclusion is reinforced throughout the literature reviewed in this Appendix.

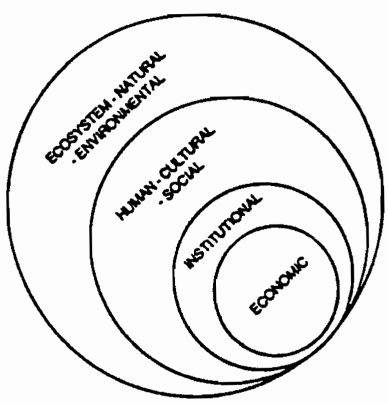


a. What systems should be considered in sustainable development?



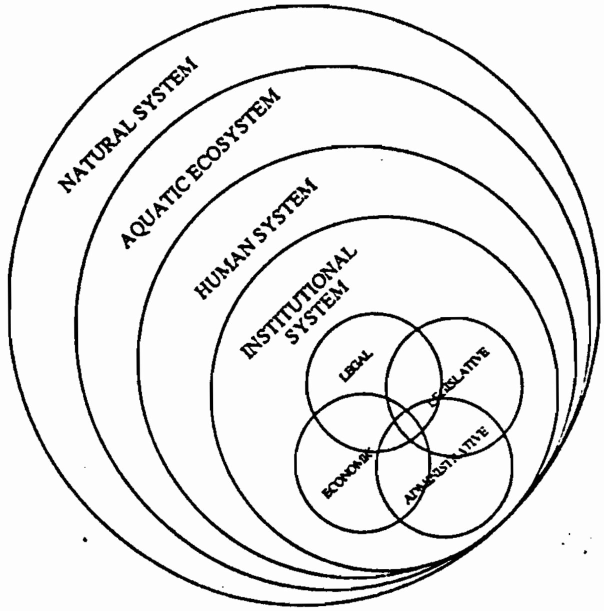
b. Are some of them sub-systems?

c. One way of conceptualizing the analysis of sustainable development.



Source: Dorcey 1991b, 550. Copyright (C) 1991 by the Westwater Research Centre. Reprinted with permission of the publisher.

Figure 3. Dorcey's systems analysis of sustainable development.



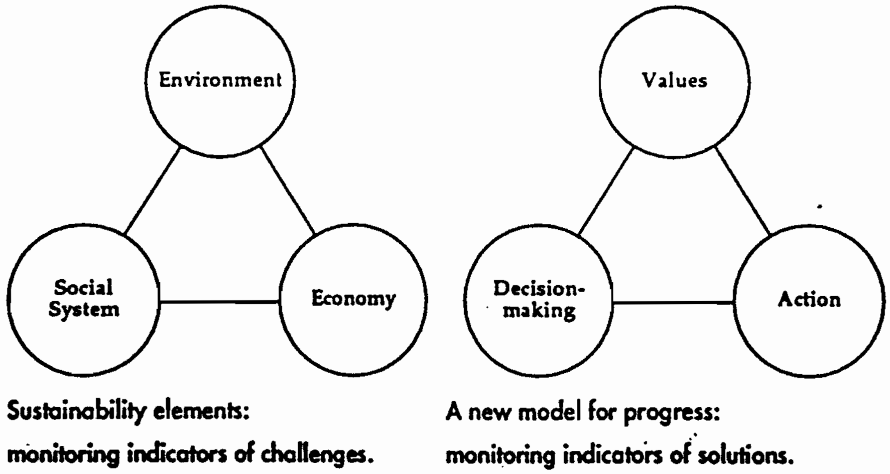
Source: Dorcey 1991b, 571. Copyright (C) 1991 by the Westwater Research Centre. Reprinted with permission of the publisher.

Figure 4. Dorcey's governance system in the analysis of sustainability.

2.4 The British Columbia Round Table's Approach to Reporting on Sustainability

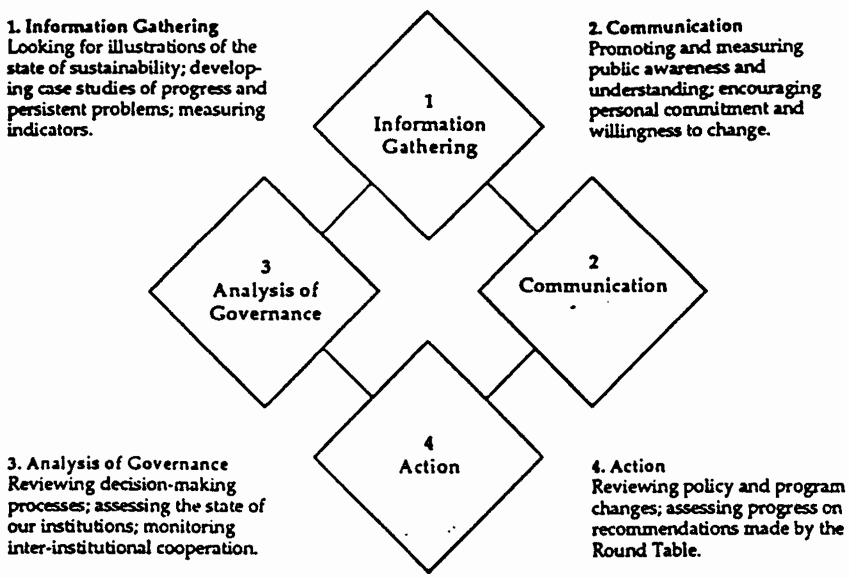
The British Columbia Round Table on the Environment and the Economy uses the three part environmental-social-economy conceptual approach for framing their "Strategy for Sustainability" (BCRTEE 1992, 14-15) and for organizing a system of monitoring progress towards sustainability (BCRTEE 1993, 38-44). They note that "sustainability is dependent upon the linkages between the environment, the economy, and the social system" (1993, 40). These three elements comprise what they label the "challenges" of sustainability. In addition to monitoring these challenges, that would monitor a second category of "solutions." These they see in terms of an interactive triangle comprised of decision-making, values, and action. Their conceptual approach to reporting would thus be organized on the basis of two sets of data and information (Figure 5).

In addition to their conceptual model, they describe a four-part reporting process model (Figure 6) that includes: (1) information gathering; (2) communication; (3) analysis of governance; and (4) action.



Source: BCRTEE 1993, 41.

Figure 5. The B. C. Round Table's conceptual approach to sustainability.



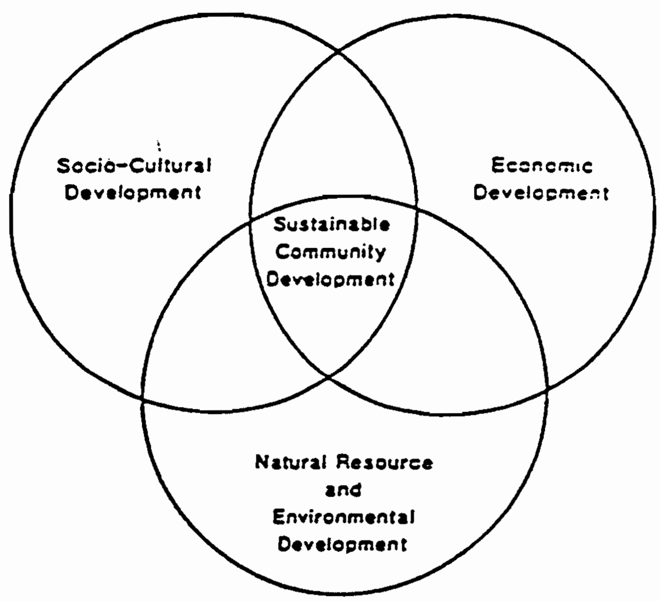
Source: BCRTEE 1993

Figure 6. The B. C. Round Table's process model for reporting on sustainability.

The B. C. Round Table uses "environment" to mean the bio-physical world. "Social" includes concerns regarding both the "social system" and "social well-being" (equity and provision of social services are key elements). And "economy" refers to the functioning of the traditional market economy (BCRTEE, 1993).

2.5 The Prairie Farm Rehabilitation Administration's Model of Sustainable Community Development

In an application of the three part model for development of a rural strategy, the Prairie Farm Rehabilitation Administration state that specific objectives must address three issues: the economy, society, and the environment (PFRA, 1992). Their model is shown in Figure 7.



Source: PFRA 1992, 3.

Figure 7. Dimensions of "Sustainable Community Development".

In this example of the three-part model, the three overlapping circles express aspects of "development": socio-cultural; economic; natural resource and environmental; and sustainable community development. They define the economic objective as the efficient use of land (natural resource base), labour and management (human capital) such that economic returns to industry and to society were maximized. Their primary objective is to provide an acceptable standard of living to all and to strive to improve or exceed this level. In "standard of living" they include access to health and education services, recreational activities, cultural events and many other goods and services that contribute to a modem life style. Their environmental objective is to protect or enhance the environment for future generations and thus ensure sustainability.

2.6 The Canadian International Development Agency's Framework for Sustainable DMevelopment

Lastly, a model developed by the Canadian International Development Agency is appropriately included in this Section (CIDA, 1991). It is built on five "pillars": (1) environmental sustainability; (2) economic sustainability; (3) political sustainability; (4) social sustainability; and (5) cultural sustainability. Table 1 lists and describes each of these five components.

This five-part CIDA model serves to illustrate one of the major drawbacks of the three-part model: while there is consistency in the use of the terms "environment" and "economy" there is little evidence of a common meaning for "social". This issue is further discussed in Section 4.

TABLE 1. CIDA'S FRAMEWORK FOR SUSTAINABLE DEVELOPMENT.

1. ENVIRONMENTAL SUSTAINABILITY

- ecosystem integrity
- biological diversity
- population

2. ECONOMIC SUSTAINABILITY

- appropriate economic policies
- efficient resource use
- more equitable access to resources including gender equity
- increasing productive capacity of the poor

. POLITICAL SUSTAINABILITY

- human rights
- democratic development
- good governance

SOCIAL SUSTAINABILITY

- improved income distribution
- gender equity
- investing in basic health and education
- emphasizing participation of the beneficiaries

5. CULTURAL SUSTAINABILITY

- sensitivity to cultural factors
- recognition of values that are conducive to development

Source: CIDA 1991, 7.

3. HEALTH VARIATIONS OF THE THREE-PART MODEL

3.1 Redefining Health

While considerable activity dealing with the human-ecosystem interface has been evident in environment and economy related disciplines, less recognition has been given to the high level of effort occurring within various "health" disciplines.

The 1970s saw a major rethinking of the concept of health. In 1974, the Lalonde Report (Health and Welfare Canada, 1974) recognized that the major determinants of health were much more than medical and hospital care and included environment, lifestyle and human biology.

In 1977, Canada along with 170 other nations at the World Health Assembly, made a commitment to achieving "Health for All by the Year 2000". This resolution was based on a World Health Organization definition that asserts that health is not just related to the absence of disease but is critically linked to the physical, social, and economic environment.

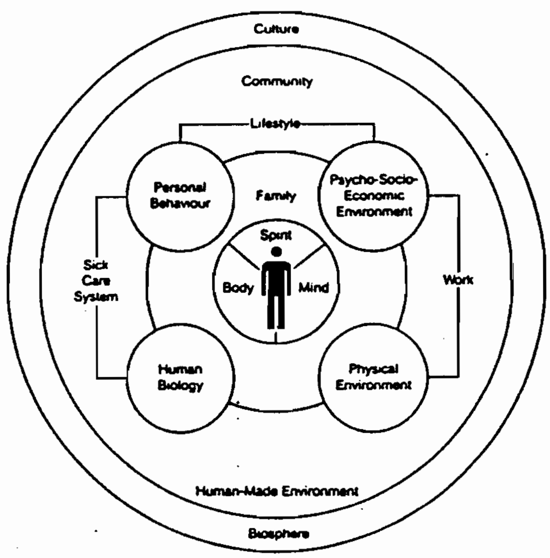
In 1986, the World Health Organization, Health and Welfare Canada, and the Canadian Public Health Association held a major international conference that resulted in the "Ottawa Charter for Health Promotion". The Charter recognizes that our ***physical*** environment is important to health, and points out the need for "a stable ecosystem and sustainable resources" (WHO et al., 1986, Health and Welfare Canada 1992, 114). Further, it notes that conserving natural resources throughout the world should be emphasized as "a global responsibility" and that protecting "the natural and built environments" and conserving natural resources must be part of any health promotion strategy (Hancock, 1989).

At this same conference, health promotion was established as the key to achieving health for all. Setting an important precedent, health promotion is defined in terms of empowerment: "the process of enabling people to increase control over and improve their health" (WHO et al. 1986; Health and Welfare Canada 1986). Since then, both WHO and Health and Welfare Canada have considered health as a positive concept, "a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity."

Five strategies were chosen to enact the Ottawa Charter: (1) building healthy public policies; (2) creating supportive environments; (3) strengthening community action; (4) developing personal skills for health; and (5) reorienting health services (as summarized by Hancock, 1990b). Application of these strategies at the local level led to a series of healthy city/community projects in Europe and Canada. As of May, 1991, over 100 Canadian communities had undertaken to participate while in Europe, 30 core project cities exist in 18 countries (CPHA et. al., 1991).

3.2 Hancock's Mandala of Health and Healthy Community Model

In an early contribution to the Healthy Communities movement, Trevor Hancock proposed an "ecological" or "socioecological" model of human health organized as a "mandala of health" and shown in Figure 8.

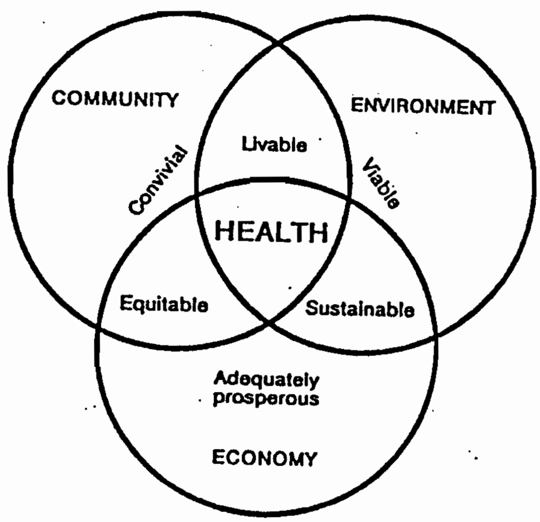


Source: Hancock, 1985; Hancock and Perkins, 1985.

Figure 8. Hancock's Mandala of Health.

Hancock's mandala is yet another conceptualization of the human-ecosystem interface. In this case, the individual is seen within family and community. People and their built environment together reflect culture all of which is enveloped by the biosphere. David Brown uses a modification of Hancock's mandala that encloses the entire human sub-system within a "political" sphere which in turn sits within the biosphere (1991, personal communication).

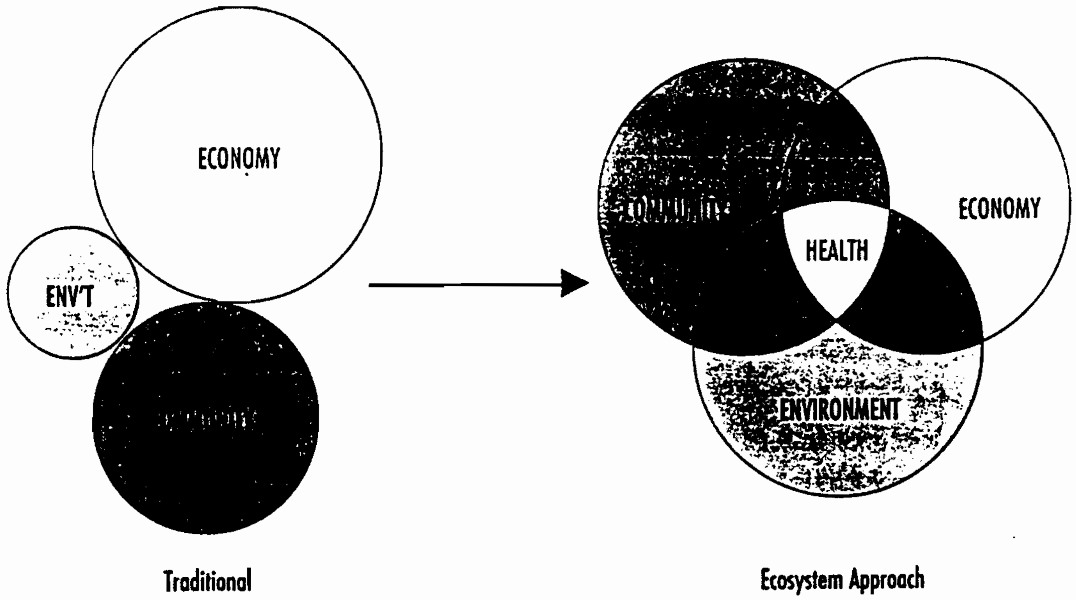
Hancock's work has greatly influence the development of the Healthy Communities Movement both in Canada and elsewhere. His widely used conceptual framework for the healthy community is shown in Figure 9. In his view, a "viable" environment, "prosperous" economy, and "convivial" community together lead to a "health" community (sustainable, livable, equitable).



Source: Hancock, 1989, 1990.

Figure 9. The Healthy Community conceptual framework.

The Royal Commission on the Future of Toronto's Waterfront suggests that Hancock's conceptual approach demonstrated a shift from traditionally separate concerns to linked analysis through an integrative ecosystem approach (Figure 10).



Source: Crombie 1991, 35.

Figure 10. A shift from traditional to ecosystem-based decision-making.

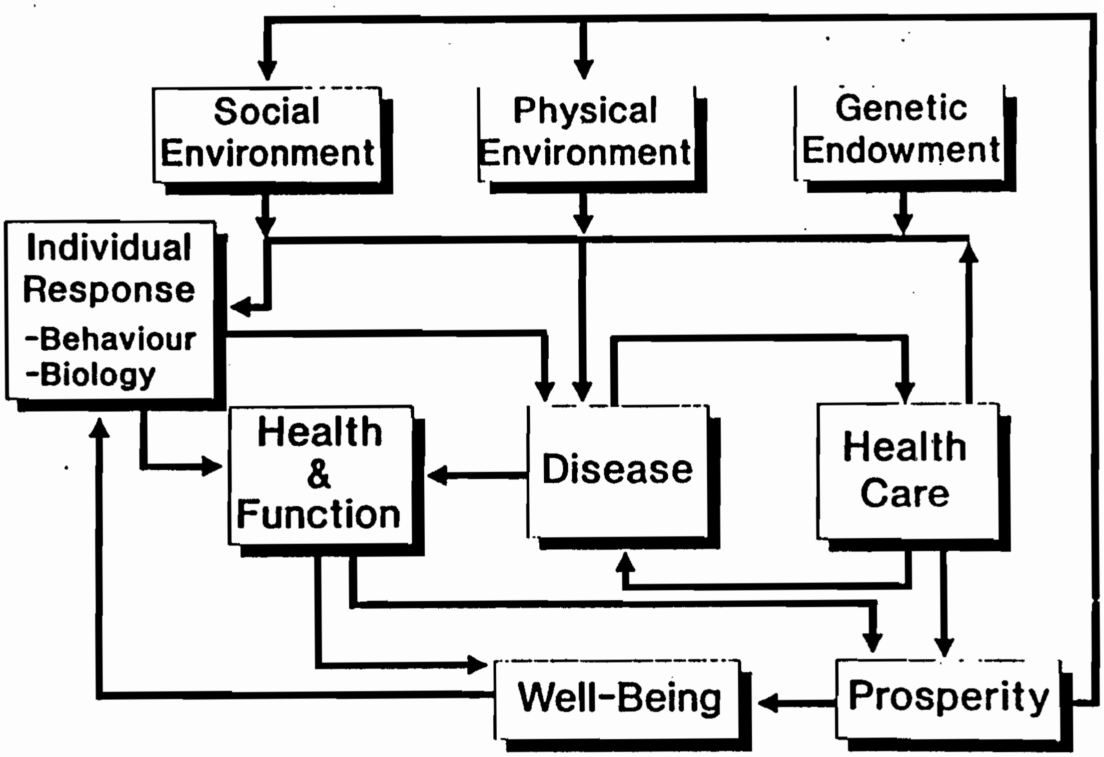
The roots of Hancock's model lie in a concern for the health of people (as opposed to use of natural resources). As with Firey's and Saddler's work, a balance of concerns is emphasized. However, the "social" element of the standard three-part model has been subsumed by a "community" element which includes the equity issue but goes well beyond. Hancock does not provide definitions of viable (environment), adequately prosperous (economy) and convivial (community) are not provided.

3.3 The Canadian Institute for Advanced Research's Model of the Determinants of Health

Yet another health-driven conceptualization of the human-ecosystem interface has come as a result of work initiated in the Population Health Program of the Canadian Institute for Advanced Research. The aim of this program is:

> ...to advance understanding of the factors influencing health status and function including social, economic, cultural, genetic, and health care factors and their complex inter-relationships.
>
> (Evans and Stoddart 1990, Preface)

Their working conceptual framework is shown in Figure 11. It shows interactive links between an individual's well-being and (1) the physical ***environment***; (2) an individual's level of prosperity ***(economy)***; (3) the ***social*** environment; and (4) a series of factors traditionally dealt with by medical sciences: genetic endowment, health care, disease, health and function, and an individual's particular response (behaviour and biology). Developmental work with this framework is ongoing, especially to add a dynamic time dimension (Evans, 1991, Personal Communication).



Source: Evans and Stoddart 1990, 51.

Figure 11. Conceptual framework identifying and showing the relationships between determinants of health.

Evans and Stoddart's "social environment" is based on a concern for lifestyle impacts on health but extends this initial concern recognizing that:

> Feelings of self-esteem and self-worth, or hierarchical position and control, or conversely powerlessness, similarly appear to have health implications quite independent of the conventional risk factors.
>
> (1990, 36)

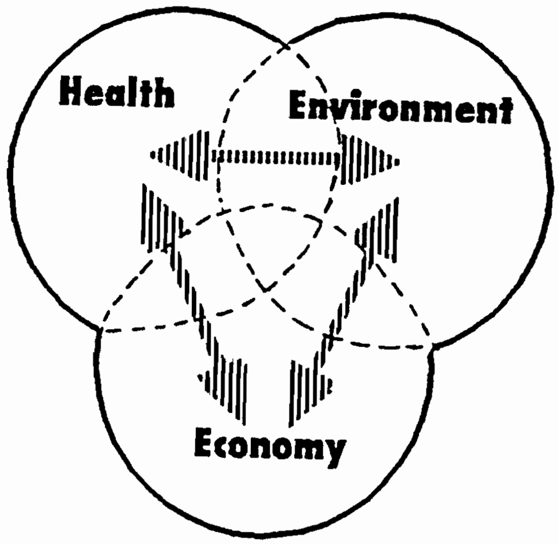
Their introduction of "well-being" as a category is important to underline. They define well-being as "sense of life-satisfaction of the individual" (40). This use of well-being amounts to a re-labelling of the broad World Health Organization's definition of "health". They argue that this broad sense of well-being should become the objective "not only of health policy, but of all human activity" (40).

3.4 The Canadian Medical Association's Model of Sustainable Development

In a related analysis, the Canadian Medical Association pointed out that while health was not specifically mentioned by the World Commission on Environment and Development's report Our Common Future, nor identified as an element of sustainable development, it is in fact, a critical partner in the environment-economy relationship:

> Any activity which impacts on a community's economic prosperity and/or the state of its environment, will also have an effect on the health of the community and it inhabitants.
>
> (CMA 1991, 6)

The CMA conceptualization of the health-environment-economy relationship is shown in Figure 12.



Source: CMA 1991, 7.

Figure 12. The Canadian Medical Association's linking of health, environment and economy.

3.5 System of Health Statistics for Canada

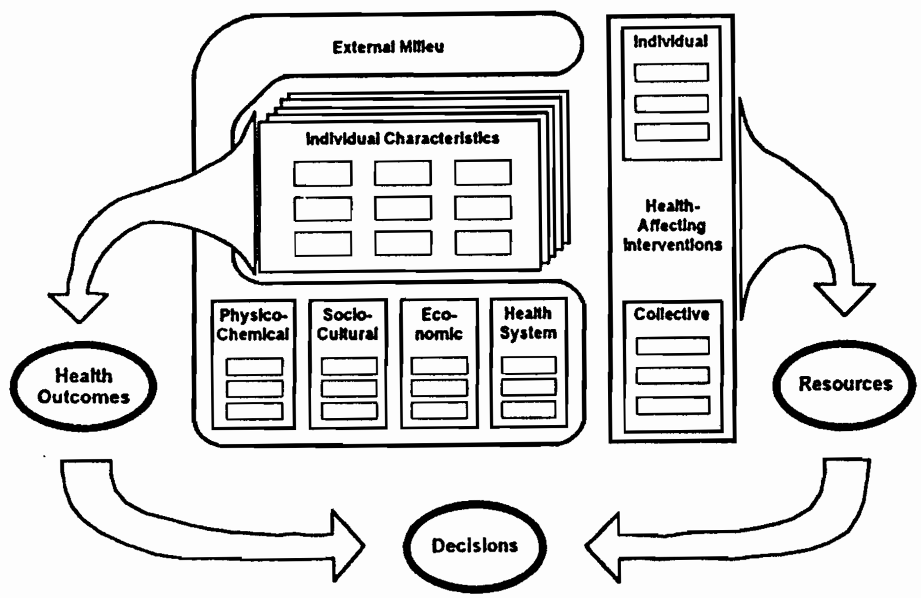
In June 1990 the National Task Force on Health Information was created as a result of a joint initiative of the National Health Information Council (NHIC), the Conference of Health Deputy Ministers, and Canada's Chief Statistician. In its final draft report, the Task Force concluded that health information in Canada is in a deplorable state (NTFHI, 1991).

Early in their work, the idea of development of "satellite accounts" (to Canada's System of National Accounts) for health statistics was considered and rejected. In their view, the term "satellite" inappropriately implied the subject matter (health) to be of lesser importance than and subordinate to economic conditions described by the System of National Accounts. Instead, they propose development of a parallel "System of Health Statistics (SHS)" (Wolfson, 1990). This recommendation is currently under consideration by the Conference of Health Deputy Ministers (Wolfson, 1992, Personal Communication).

The Task Force recognized the need for a conceptual framework to provide a coherent approach noting "the diversity of areas claimed to be part of the health field by various stakeholders is so broad that some sort of road map was needed . . ." (NTFHI 1991, 23-28). In response, they created the "Health Information Template". The template is built on three broad domains of information: (1) individual characteristics, (2) the external milieu, and (3) health-affecting interventions.

The micro-data foundation of the system is reflected in its focus on individuals. Thus, like the work of Evans and Stoddart and different from that of Hancock and the Canadian Medical Association, the concept of "community" is not explicitly recognized.

The external milieu includes four sub-domains: (1) the physio-chemical ***environment***; (2) the ***socio-cultural*** environment; (3) the ***economic*** environment; and (4) the ***health*** system environment. Health-affecting interventions include two broad groups: those directed to individuals and those operating on a collective level. The template is computerized and set up to handle any level of geographic and temporal scale. It is intended as a working, dynamic and interactive bridging tool. A schematic of the template is shown in Figure 13.



Source: NTFHI 1991, 29.

Figure 13. Organizing template for Canada's proposed system of Health Statistics.

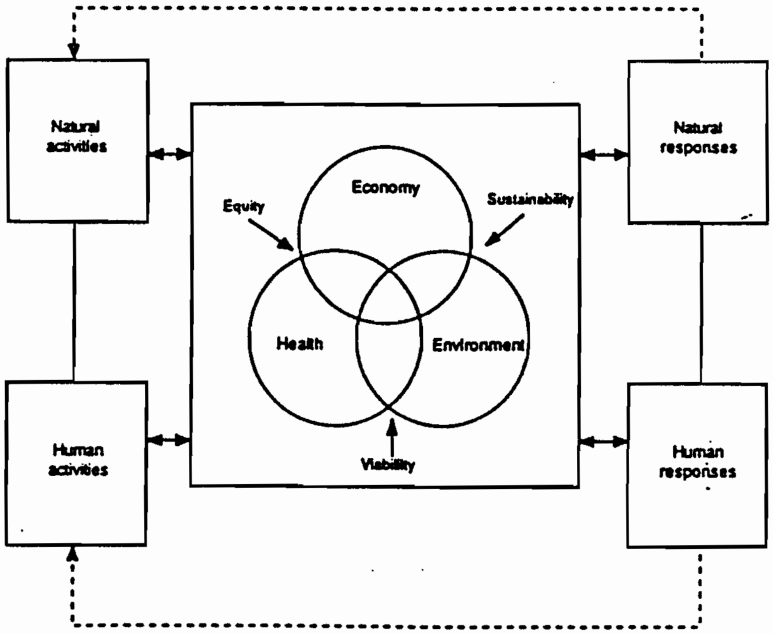
3.6 Steering Committee on Indicators for a Sustainable Society

In 1989, Health and Welfare Canada sponsored an Ottawa conference entitled "Health, Environment, and Economy". One outcome was the creation of a ***Steering Committee on Indicators for a Sustainable Society***. With support from both Health and Welfare Canada and Environment Canada the Committee set out to grapple with the issue of measuring and reporting progress toward a sustainable society. The results of their work are reported in detail in Gosselin et al. 1991 and summarized in Gosselin et al. 1993.

An important first step for this group is to place their set of indicators "within an organizational framework that would allow the reader to position these elements . . . within a more global vision" (Gosselin et al. 1991, 12). For their framework, they draw on concepts previously articulated by Hancock (1989) as well as the stress-response conceptual approach proposed some years earlier by Rapport and Friend (1979, and see discussion in Section 6 of this Appendix). In particular they recognize:

> Human activities and natural disturbances will act as stresses upon society and will alter relationships between environment, economy, health, and equity. These modifications ...elicit human and natural responses. These responses will in turn act upon the agents of stress and upon the state of the society.
>
> (1991, 13)

Their framework is shown below in Figure 14.



Source: Gosselin et al. 1991, 13.

Figure 14. Organizational framework for sustainable society indicators.

The Steering Committee identify a short list of 20 key indicators. Arguing the need to facilitate a pragmatic choice they group these indicators in four categories: (1) environment; (2) economy; (3) equity; and (4) health. This organization does not reflect the framework shown above in Figure 14. Rather, the effect is to create a new conceptual framework which extends slightly the common three-part model by splitting the social component into equity and health.

4. THE THREE-PART MODEL: DISCUSSION

Table 2 groups the contributions introduced in Sections 2 and 3 by each component of the three-part model.

TABLE 2. SUMMARY: THREE-PART MODEL.

component	*contributor*
1. ENVIRONMENT	
ecology:	Firey 1960
environment:	Saddler 1988, 1990; Dorcey 1991; BCRTEE 1992; Hancock 1989, 1990; CIDA 1991; CMA 1991; Gosselin et al. 1991, 1993
physical environment:	Evans and Stoddart 1990 natural resource and
environmental development:	PFRA 1992
physico-chemical (external milieu):	NTFHI 1991
2. ECONOMY	
economy:	Firey 1960; Saddler 1988, 1990; Dorcey 1991; BCRTEE 1992; Hancock 1989, 1990;CIDA 1991; CMA 1991; Gosselin et al. 1991, 1993; PFRA 1992; NTFHI 1991
physical prosperity:	Evans and Stoddart 1990
3. SOCIAL/CULTURAL/COMMUNITY/HEALTH	
ethnology (culture):	Firey 1960
social:	Saddler 1988, 1990; Dorcey 1991; CIDA 1991
social system:	BCRTEE 1992
social/cultural:	PFRA 1992; NTFHI 1991
cultural:	CIDA 1991
community:	Hancock 1989, 1990
health:	Hancock 1989, 1990; CMA 1991; NTFHI 1991; Gosselin et al. 1991, 1993
political:	CIDA 1991
equity:	Gosselin et al. 1991, 1993

The three-part model enjoys certain attributes that have contributed to its relatively broad appeal. However it also has some significant weaknesses that limit its use as an organizing framework for reporting on sustainability. These strengths and weaknesses are discussed below followed by a listing of seven useful insights that emerge from this body of literature.

The three-part model makes a significant contribution by clearly identifying the need to balance different sets of values and goals. This point is made by Firey (1960), emphasized by the Brundtland Commission (WCED, 1987) and reinforced by Saddler (1988, 1990), Hancock (1989, 1990) and Evans and Stoddart (1990). It is an important aspect of bringing the concept of sustainability from theory to practice.

A second usefulness of the three-part model is its recognition that this balancing is not simply a dipole situation — a black and white, economy verses the environment debate. It thus expands the frame of thinking to include factors that are often not simultaneously considered.

However, the three-part model is characterized by three conceptual deficiencies. First, the elements of the three-part model are not tightly defined. The different models are not always consistent in their usage of the same terms. For example, in some models, "social" is used to bring a focus to the equity issue (Saddler 1988) while for others broad social-cultural development is implied (PFRA 1992). Its relationship to "health" and "politics" is not always clear. These different nuances of meaning all contribute to a lack of clarity.

Second, applying systems theory to the idea of sustainability, the three-part model can be seen to be mixing unequal system parts. The "natural ***environment***" or "ecosystem" is comprised of a set of interacting physical components that can be identified and described in physical, chemical, and biological terms. Economics has come to mean the study of human activities arising from scarcity and the ***economy*** is the human created system used to make decisions about allocating certain resources (See Chapter Four). ***Health*** is a characteristic of people. ***Social*** is "concerned with the mutual relations of people or classes of people" (Oxford, 1989). People are linked through a wide range of ***socio-cultural*** relationships. Robert Horn cautions that what is considered "economic" overlaps with what is thought of as "social" because "social demands are subject to economic restraints and because economic processes are linked to their social and societal environment" (1993, 146).

While words like "social," "environment," and "economy" may well be appropriate for designating general categories of knowledge necessary in assessing wise natural resource use (Firey, 1960), concerns or goals (Saddler, 1988, 1990), aspects of development (PFRA, 1992), or challenges (BCRTEE, 1993), they do not describe a well-defined set of system components that systematically capture the human-ecosystem relationship.

Lastly, the three-part model does not adequately describe or bound the system that must be considered for assessing progress toward sustainability. In particular, the "economy" deals with human activities and related stocks and flows of materials that are transacted through the market system. It does not deal with housework and volunteer activity. And yet these two sets of activities contribute greatly to human well-being while creating significant environmental stress.

With its roots in the theory of resource use, it is not surprising that the three-part model is limited in dealing with the broader issue of reporting on sustainability. However, the related literature contains a number of useful insights.

Dorcey's use of the conceptually simple "human system" nested within the "natural system" points to resolution of some of the conceptual inconsistencies of the three-part model.

Evans and Stoddart's (1990) argument for human well-being as the objective of not only health policy but all human activity is important because it is fundamental — people do what they do to improve their lot. For example, it is not for the benefit of the economy that jobs are created - it is for the benefit of people and their well-being. These kinds of fundamental understandings often become hidden beneath secondary and tertiary concerns.

The key roles of community, health, and culture in determining human well-being (Hancock 1989, 1990; CMA 1991, PFRA 1992, and Gosselin et al. 1991) serve to highlight the need to include these factors in any assessment of progress toward sustainability.

Saddler's consideration of micro (individual project) analysis and lessons from the environmental and social impact assessment literature along with overall macro analysis provides an important linkage. Jacobs (1987) points out that further progress in project level environmental assessment awaits the evolution of a paradigm that "circumscribes the whole" and together, Saddler and Jacobs (1990) argue for development and use of "sustainable development assessments". This quest is no different than the very aim of this dissertation.

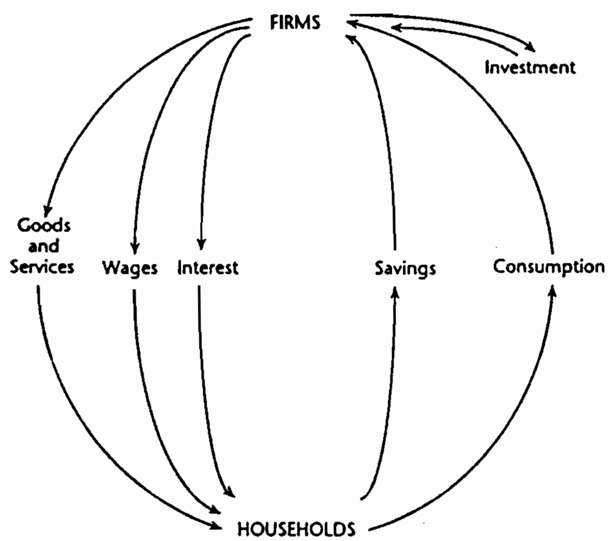
5. DRAWING FROM ECONOMICS

5.1 Clarifying the Meaning of Economics

In Chapter Four the dominant contemporary sense of economics is described as the study of allocating resources in a way that brings the greatest benefit to the most people. In turn, the economy is simply seen as a mechanism that allocates scarce resources amongst competing uses.

In a decentralized market economy, three groups of decision makers are typically included within the economy: households, firms, and governments. Factors of production include labour (brain- and muscle- power of human beings; land (natural resources of all kinds); and capital (all the equipment, buildings, tools, and other manufactured goods that can be used in production). Two mechanisms are used to achieve coordination of economic choices: command mechanisms and market mechanisms.

A conventional schematic of the idealized closed, market economy is shown in Figure 15. In reality, economies are open with links to other economies through imports and exports of goods and services. Further the regulatory role of government doesn't show in this figure but its presence would not change the basic pattern. Figure 15 shows a circular flow of money matched by an opposite flow of goods and services and productive factors between households (consumption) and firms (production).

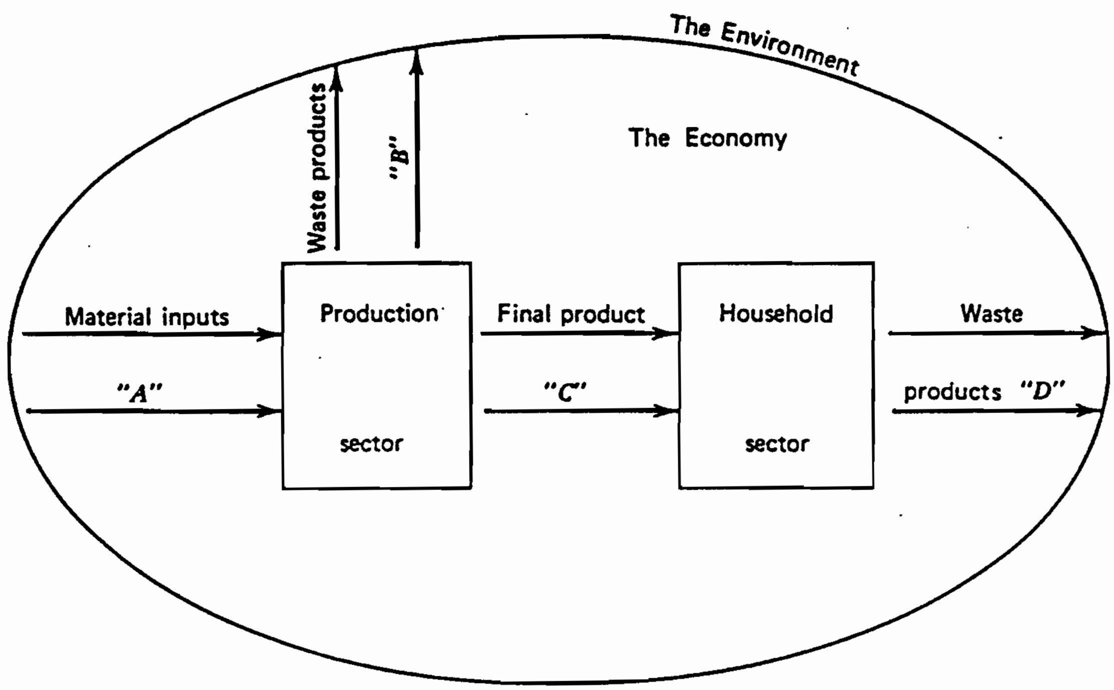


Source: Jacobs 1993, 13. Copyright (C) 1993 by UBC Press. Reprinted with permission of the publisher.

Figure 15. Conventional schematic of the economy.

5.2 The Materials - Energy Balance Model

Critics of this model argue that it ignores (1) energy and material flows, (2) the basic laws of physics governing these flows, and (3) backward linkages of resources to ecosystem structure or function (see for example, Georgescu-Roegen 1971 and 1975, Freeman et al. 1973, Underwood and King 1989, Rees 1993, and Jacobs 1993 amongst many others). Over twenty years ago, a materials/energy balance model linking the economy and the environment was proposed by Kneese et al. (1970) to overcome these deficiencies and is shown in simplified form in Figure 16.



Source: Freeman III et al. 1973, 12. Copyright (C) by John Wiley & Sons, Inc. Reprinted with permission of the publisher.

Figure 16. Materials balance and the economy. The materials balance (flows measured by mass) for: (1) the production sector (A = B + C); (2) the household sector (C = D); and (3) the economy (A = B + D).

Figure 16 also represents circular flow. However, instead of it being a circular flow of "money apparently unpowered by any external source of energy," it is "one of matter: taken from the environment, used in production and consumption and then returned to the environment as waste" (Jacobs 1993, 14).

5.3 The Pollution - Depletion Model

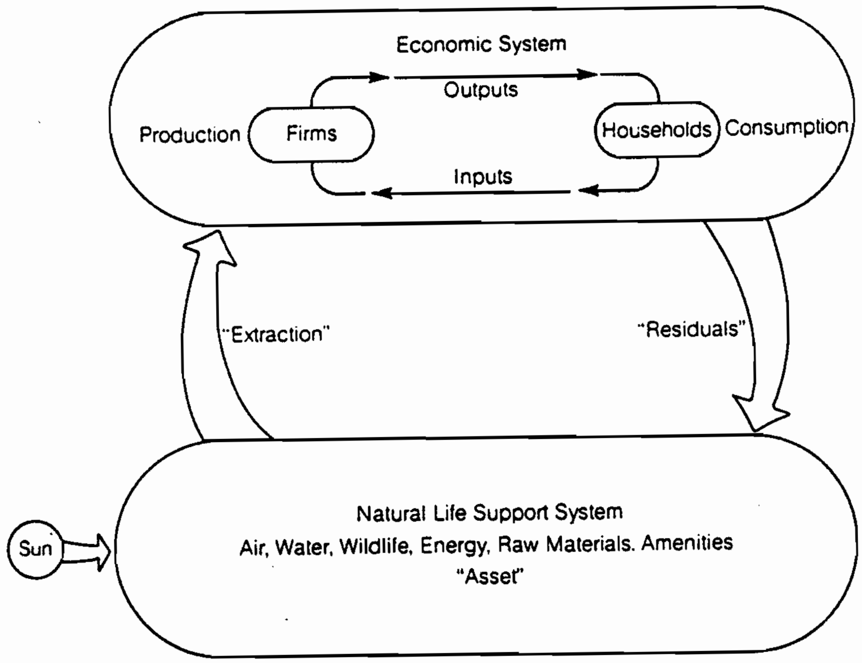
Tietenberg (amongst many others) has drawn on the ideas captured by Figures 15 and 16 noting that in economics, the environment is considered a ***composite asset*** that:

> (1) provides raw materials which are transformed into consumer products;
>
> (2) provides energy which fuels this transformation; and
>
> (3) provides a variety of services directly to consumers (e.g. air to breathe, nourishment, aesthetic amenities, etc.).
>
> (1992, 19)

Ultimately, the raw materials and energy return to the environment as waste products or residuals. In a similar vein, Siebert suggests that from an economic perspective, the environment has four functions:

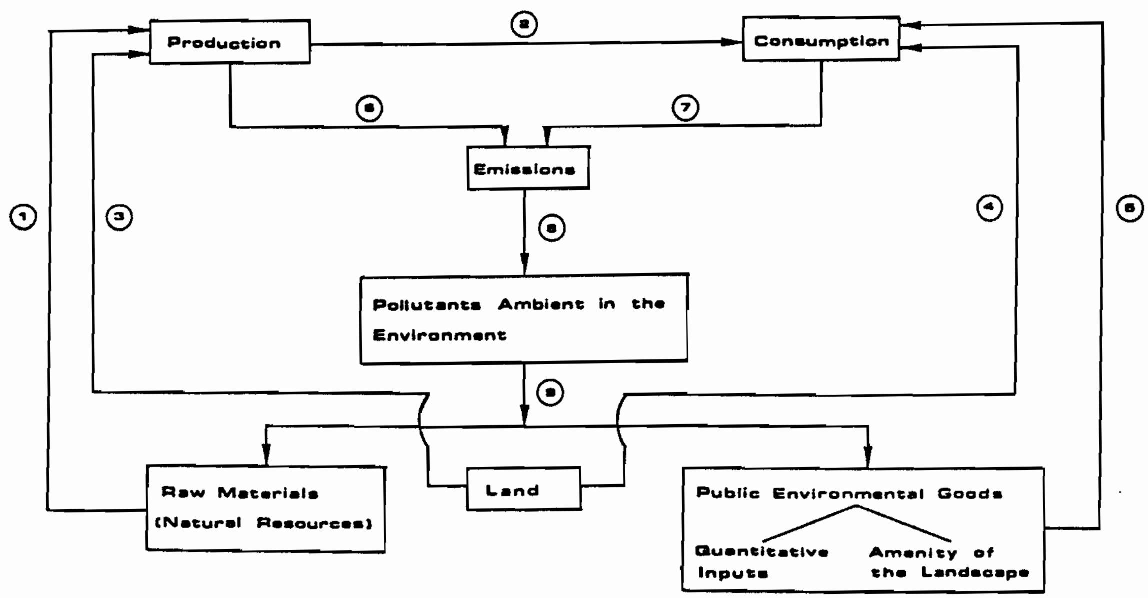
> (1) the provision of public goods such as air, water, the amenity of the landscape, and the recreational function of nature;
>
> (2) the provision of resources for inputs in production activities;
>
> (3) a receptacle of wastes;
>
> (4) provision of space for location of the economic system.
>
> (1982, 8 - 11)

Tietenberg's model of the economy-environment relationship is shown in Figure 17 and Siebert's in Figure 18. A third model that traces the circular flow of materials is shown in Figure 19. Kneese and Bower who designed this model point out that a parallel model could also be developed for energy flows (1979, 16).



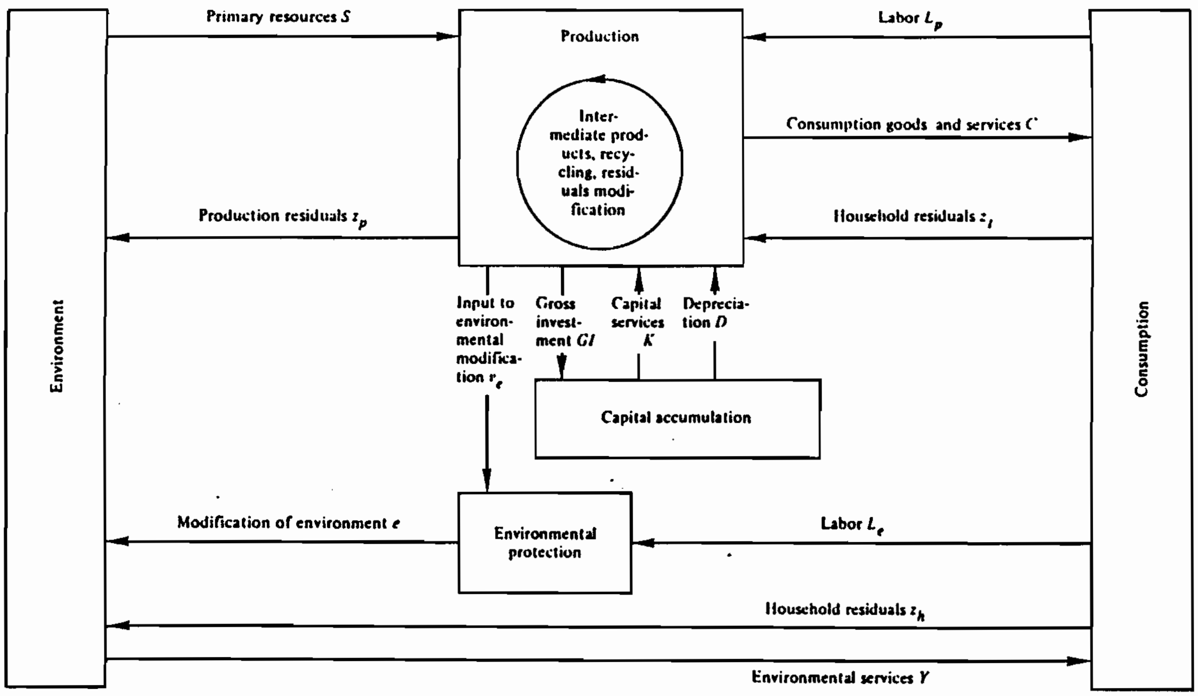
Source: Tietenberg 1992, 19. Copyright (C) 1992 by Harper Collins College Publishers. Reprinted with permission of the publisher.

Figure 17. Tietenberg's model of the economy-environment relationship



Source: Siebert 1981, 9.

Figure 18. Siebert's model of the economy-environment relationship



Source: Kneese and Bower 1979, 17.

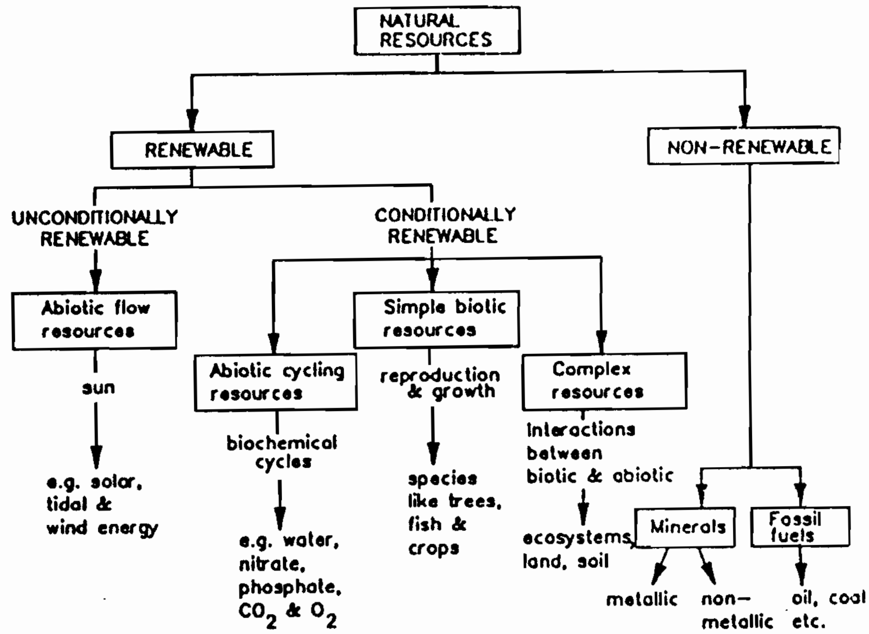
Figure 19. Kneese and Bower's model of the economy- environment relationship:

All of these models can be applied in a way that overcomes the three deficiencies of the conventional decentralized market economic model cited earlier. That is, (1) energy and material flows can be monitored to ensure that (2) governing laws of physics are adhered to and (3) backward linkages to ecosystem structure and function can be traced, monitored, and assessed (at least theoretically).

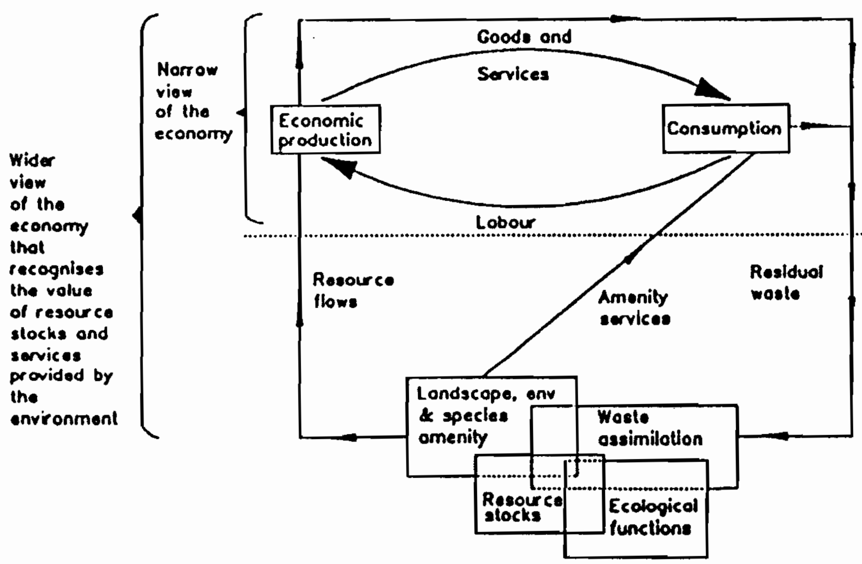
Together, the models shown in Figures 16 - 19 reflect a ***depletion/pollution*** conceptualization of the human-ecosystem relationship that is dominant in contemporary thought. Influence can be found through out contemporary literature from economics, ecology, geography, natural resources, planning, and most recently, sustainable development.

For example, Chiras (1991, 3 - 4) describes the environmental crisis as consisting of three categories: (1) overpopulation; (2) depletion of both renewable (e.g.. forests, fish) and non-renewable resources (e.g.. certain minerals); and (3) pollution. Establishing appropriate use rates for natural resources and coming to terms with pollution are both the subject of vast quantities of literature (economics, natural resources, environment).

Additional examples aimed at analysis of sustainable development and based on the depletion/pollution model are provided in Figures 20 through and 24.



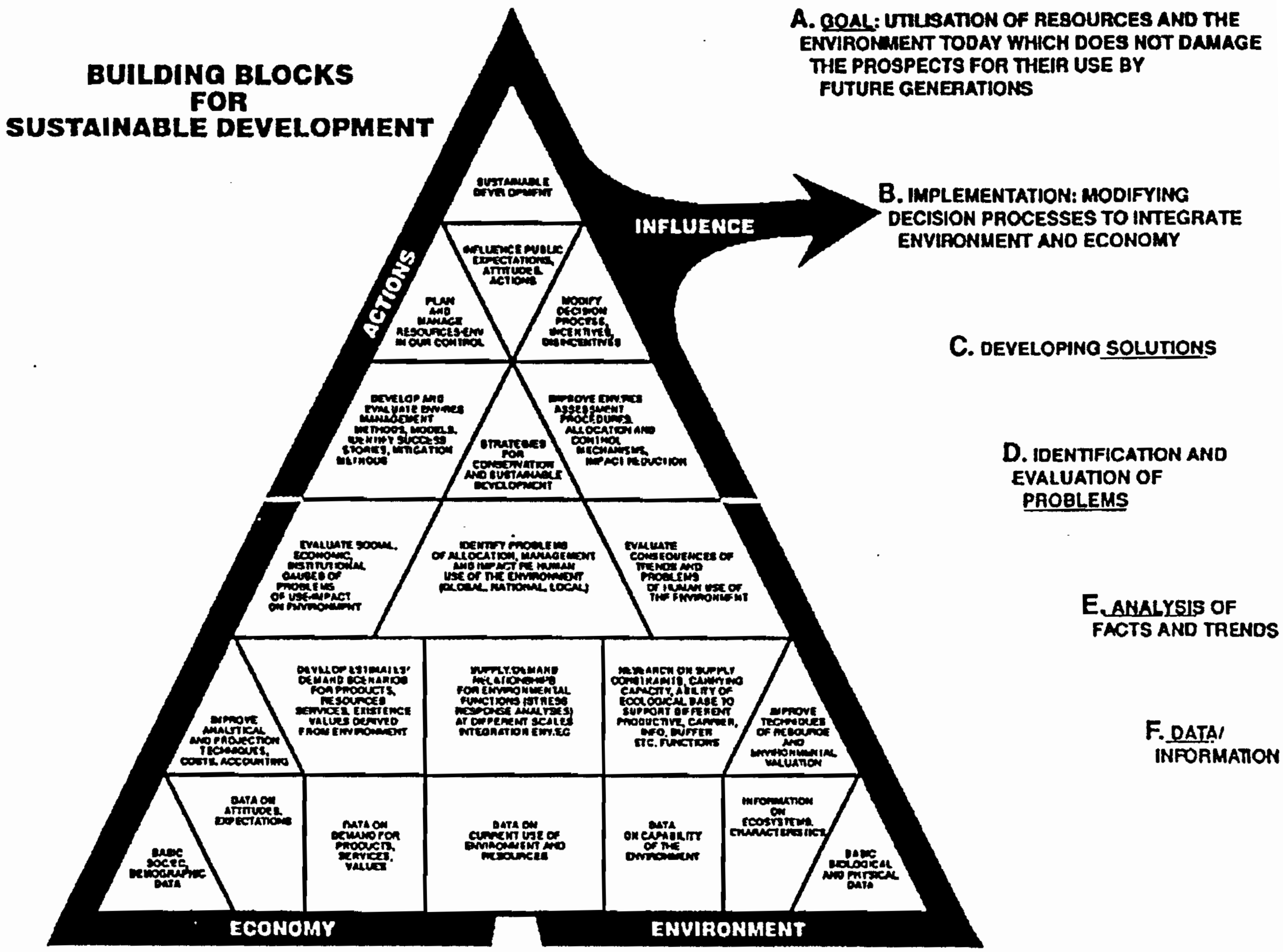
(a) description of the nature of natural resources



(b) the relationship between resource stocks, flows, and the economy.

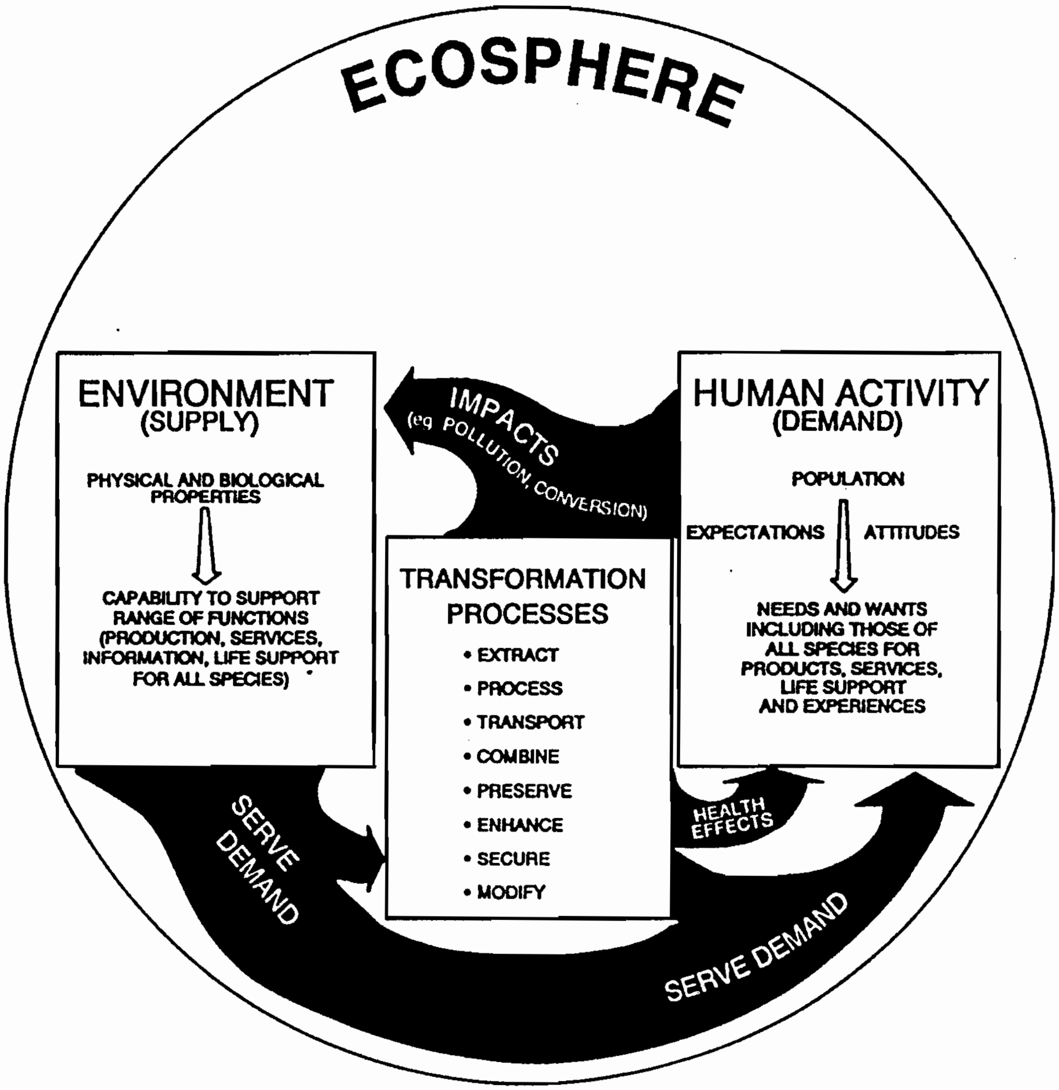
Source: Adapted by M. Young (1992, 9 - 10) from Gilbert et al. 1990. Copyright (C) 1992 by the United Nations Educational, Scientific, and Cultural Organization.

Figure 20. Young's (a) description of the nature of natural resources and (b) resource stocks, flows, and the economy.



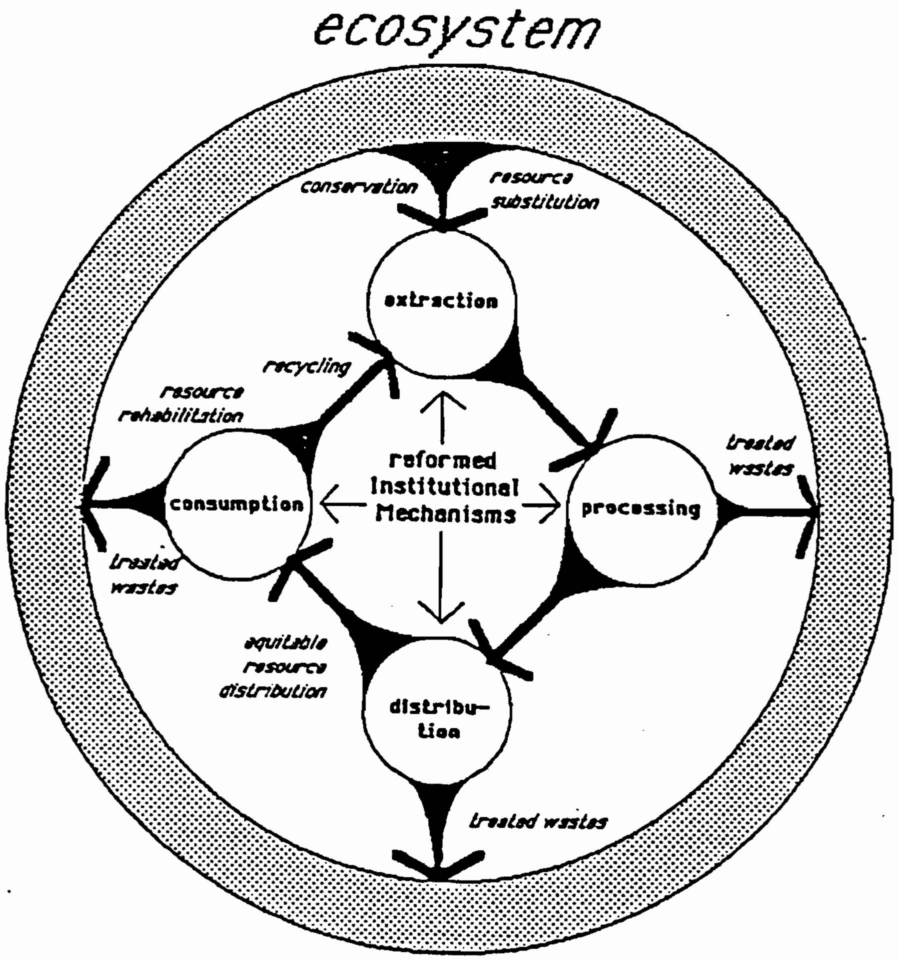
Source: Manning 1990, 294;

Figure 21. Manning's building blocks for sustainable development.



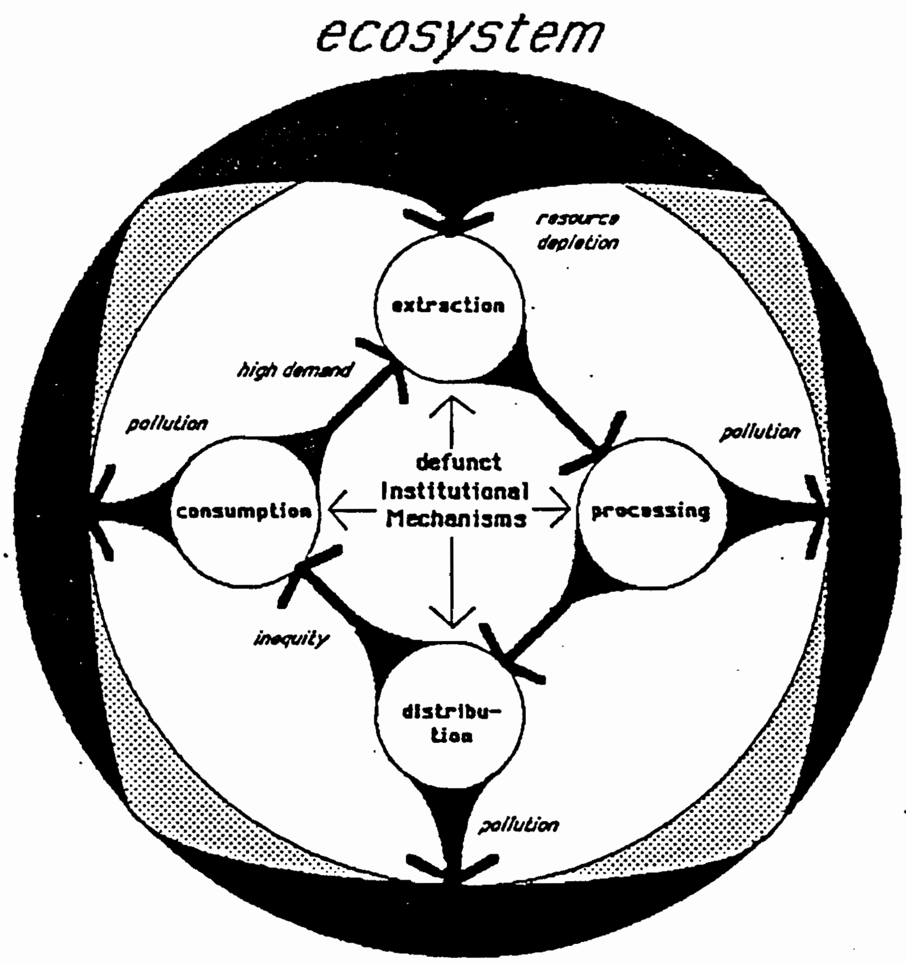
Source: Manning, personal communication

Figure 22. Manning's systems description for "a sustainable system"



Source: Leeman and Cox 1990, 5.

Figure 23. Leeman and Cox's schematic of sustainable development.



Source: Leeman and Cox 1990, 5 - 6.

Figure 24. Leeman and Cox's schematic unsustainable development.

However, the description of the human-ecosystem interface and the role that the ecosystem plays in sustaining life presented in these models is far from complete.

In each model the environment is seen as an "asset" that provides material, energy, (and aesthetic) resources to drive production and consumption activities within the economic system. As a result of these activities, waste products are formed that are then returned to the environment as pollution. The environmental "problem" (their model of human-ecosystem interface) thus reduces to two components, one dealing with resource use (or misuse, depletion, and scarcity) and one dealing with pollution or generation of waste residuals. Following this logic, resolution of the "environmental problem" can be attained through (1) appropriate or wise resource use and (2) reduction of pollution.

For many, including the authors of Figures 20 through 24, the depletion-pollution model has come to embody the concept of sustainability. Using this model, argument is provided that reporting on sustainability should be centered on resource use (or depletion) and pollution. However, more rigorous examination of human-ecosystem interaction reveals that the drawing of resources and the generation of waste emissions are only two of a much larger set of interactions.

5.4 The Population Economy Process (PEP) Model

Hamilton's Population Economy Process (PEP) Model recognizes this larger suite of interactions (1991). It was developed in response to the need for a conceptual framework to organize statistics describing the socioeconomic system and its relationship to the environment and natural resources. Hamilton subsequently applied it to organize Human Activity and the Environment (Statistics Canada, 1991), the statistical companion volume to the 1991 state-of-environment report for Canada (Canada, 1991).

PEP is based on the following five principles:

1. the **socioeconomic system** is an artificial system embedded in a natural environment;
2. the human-created and human-controlled processes within the socioeconomic system have **two types of direct impact** on the environment:
   (a) restructuring as a byproduct of production and consumption, and
   (b) extracting, harvesting, and using the natural en vironment as processes providing necessary re sources for the socioeconomic system;
3. **restructuring** includes three basic expressions:
   (a) **physical** (construction of dams, roads, power lines, mines, dump sites, and other changes to the natural landscape;

(b) **chemical** (release of pollutants and wastes into the environment); and

(c) **biological** (harvesting and the introduction of exotic species).

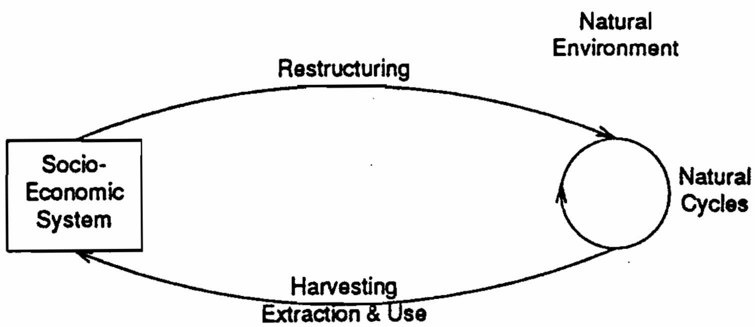
4. the **natural environment** is affected by the outputs and inputs to the socioeconomic system, and the state of the environment changes as a result;

5. the change in the state and quality of the environment, in turn, affects the quantity and quality of resources available to the socioeconomic system.

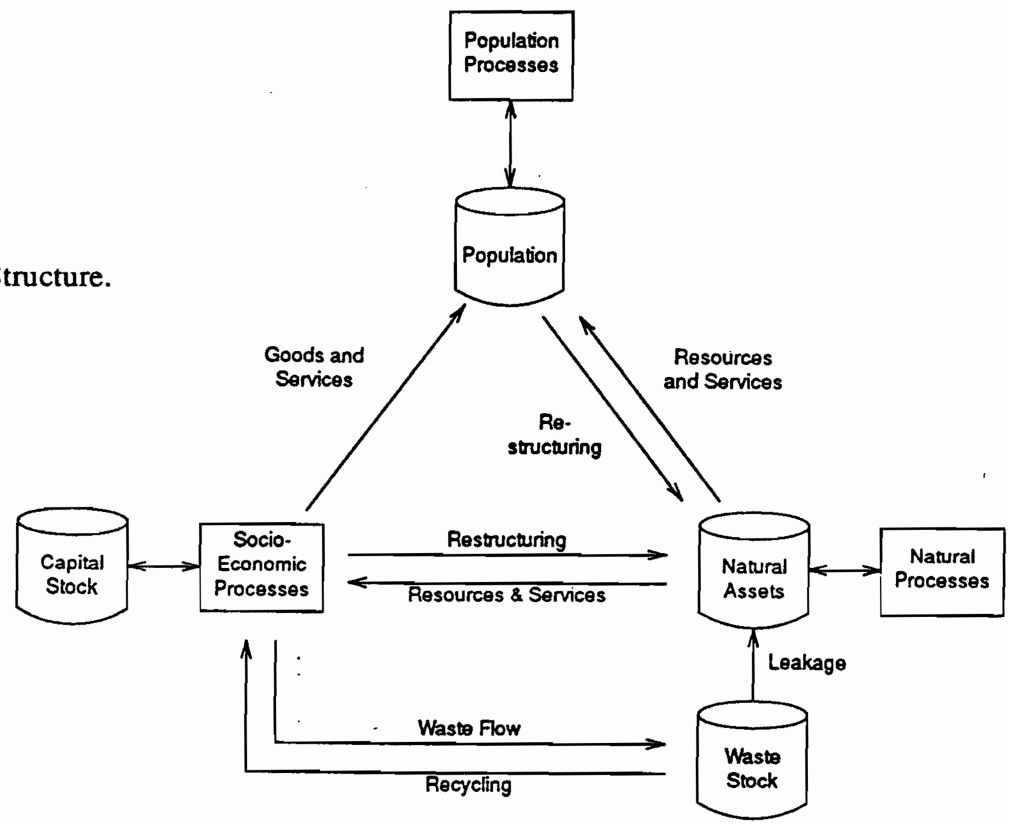
(Hamilton, 1991)

The model is shown graphically in Figure 25. By showing the by-products of socioeconomic activity as interacting with the environment to produce changes in the resources on which these activities depend, PEP forms an interactive closed loop. Hamilton's recognition that the human-ecosystem interface is influenced by what he calls: (1) physical, chemical, and biological restructuring; and (2) the drawing of resources for use by the socioeconomic system represents a significant conceptual advance from the earlier depletion/pollution model.

However, work completed more than a decade before, also at Statistics Canada, stands as the pioneer in this matter. This earlier work led to development of the stress-response model of the human-ecosystem interface and is described in the next section.



(a) Concept.



(b) Structure.

Source: Hamilton, 1991.

Figure 25. The Population-Economy-Process (PEP) model.

5.5 Discussion

Review of economics literature reveals a series of conceptual shifts over time regarding treatment of the human-ecosystem interface. The conventional definition of the economy simply sees a circular flow of money matched by an opposite flow of goods and services and productive factors (labour, land, capital). "Land" can be seen to include environment in its broad sense.

In the early 1970s, criticism that this simple circular model ignores (1) energy and material flows, (2) the basic laws of physics governing these flows, and (3) backward linkages of resources to ecosystem structure or function led to development of the material - energy balance model. This model addresses all three of these criticisms. The material - energy balance model has since evolved into a pollution - depletion model which is dominant in contemporary thinking.

However, a growing number of workers are recognizing that this conceptualization also is not complete. Human activities impose a range of stresses on the ecosystem, not simply the drawing of resources and the generation of pollution. In turn, the role of the ecosystem is far greater than merely the provider of energy and material resources.

6. STRESS-RESPONSE IDEAS

6.1 Stress on People from Natural Events

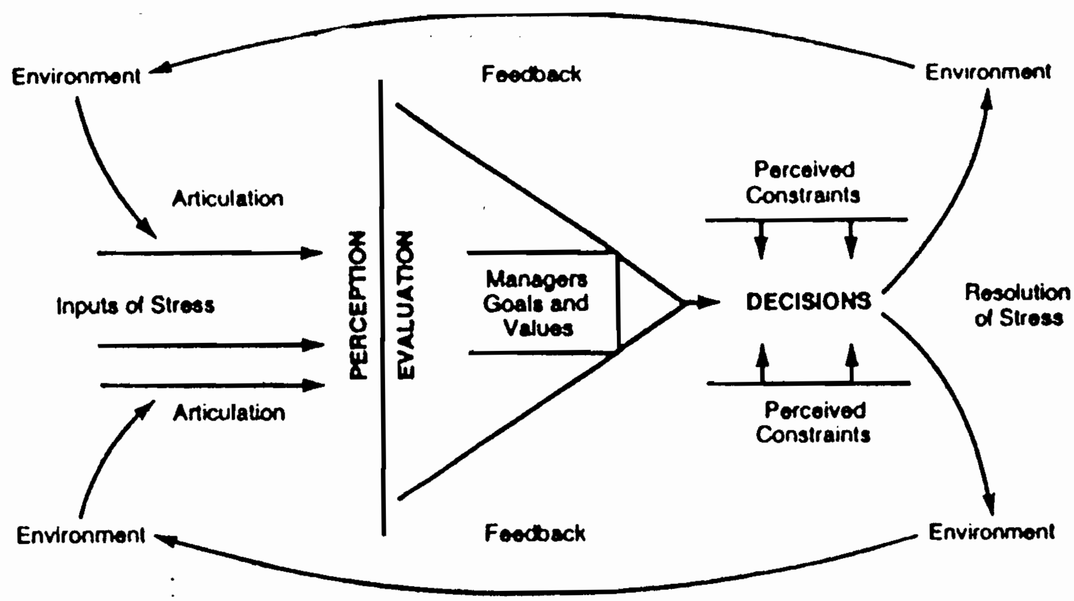
The concept of stress at the human-ecosystem interface was first introduced from a perspective of it being something acting on and influencing human well-being. Examples include disasters causing stress on people (Janis, 1954) or migration as an adjustment to environmental stress (Wolpert, 1966).

Recent work by the World Health Organization aimed at integrating environmental and health issues in decision-making process continues this approach (WHO, 1993). In their work, the World Health Organization defines ***environment*** as "the sum total of factors, whether natural or anthropocentric, influencing human health and overall well-being." ***Environmental health indicators*** are thus designed:

> to clarify environmental influences on human health and well-being ... to serve as an aid for decision making in environment and health management.
>
> (WHO 1993, 3)

These are not definitions used in this dissertation but they are important to note for interpretation of WHO documents.

Kasperson (1969) extends the earlier work on stress influencing people through examination of the broad influence of environmental stress on municipal decision-making. He developed the model of municipal stress management shown below in Figure 26 based on analysis of the drought and political decision-making process related to municipal water supply.



Source: Kasperson 1969, 485.

Figure 26. A general model of municipal stress management.

Kasperson defines stress as "noxious or potentially noxious environmental forces upon the individual" and strain as "the individual's perception, evaluation, and reaction to the stimulus" (1969, 484). He notes:

> ... managers of the political system cope with the diverse stresses according to goals and objectives which they bring to office and in order to play the game of politics within the rules and constraints of their particular roles. This analysis, then, views drought within the context of other stresses acting upon the city and the differing, shifting objectives of actors in the municipal political system.
>
> ... stress may arise as a result of gradual accumulation or by a precipitous change in the environmental framework in which the municipal political system operates. It may also be internal as well as external to the system. Stress, via strain, will become a "crisis" when the managers of the system view themselves or the system as being in a hazardous situation. In all cases, strain involves the notion of threat either to the actor or the political system as a whole.
>
> (1969, 484)

6.2 Rapport and Friend's Concept of Stress-Response

A major contribution was made by David Rapport and Anthony Friend and in the 1970s when the concept of stress was recognized to include both (1) stress imposed on the ecosystem as a result of human activities and (2) stress imposed on human beings by the environment. With this recognition, they argued that the subsequent responses, both human and environmental could also be recognized and that together, a stress-response conceptual approach should form the organizing framework for state-of-environment reporting and the supporting system of environmental statistics. The evolution of their work occurred as follows.

In the mid-1970s a formal program for the development of a broad environmental statistical framework was established by the Conference of European Statisticians of the Economic Commission for Europe in Geneva. About the same time, the United Nations' Statistical Office embarked on the development of a general framework of environmental statistics, emphasizing in particular, the needs of developing countries (Friend and Rapport 1989, 3).

As part of this work, a joint initiative between Statistics Canada and the UN Statistical Office was developing a "Material-Energy Balance Statistical System (MEBSS)" that could be considered a physical analogue to the System of National

Accounts (SNA) (Rapport and Friend, 1979). This work was led by the evolution of economics ideas described in the previous Section.

The MEBSS approach focuses on a structural model of human activity where "economic transactions" are seen as physical processes rather than "economic institutional transactions." It provides a basis for measurement of national wealth in terms of physical assets (accumulated infrastructure) and natural resources. This approach was championed by its proponents as a potential replacement methodology for construction of input/output models. In that it was to be based on actual physical flows rather than dollars, an accounting for natural resource depletion and waste residual generation would provide a direct link to environmental concerns.

After initial investigation, work on the joint U.N./Statistics Canada project was phased out. However, within Statistics Canada, the resulting modelling expertise was captured in development of a large scale simulation model labelled the "Socioeconomic Resource Framework" or "SERF". SERF has since been transferred to both the University of Waterloo and the University of British Columbia where ongoing development has proceeded. The originators of the model, Robert B. Hoffman and Bertram C. McInnis, formerly with Statistics Canada are also continuing developmental work in a wide range of applications, as private consultants[2].

A sub-set of the work on the proposed Material-Energy Balance Statistical System led Rapport, Friend and colleagues within Statistics Canada, to develop the "STress-Response Environmental Statistical System (STRESS)" (Rapport and Friend 1979; Friend and Rapport 1989). STRESS focuses on the interface between production-consumption activities of humans and the transformation of the state of the environment using concepts of environmental stress and response. Their examination and resulting description of the human-ecosystem interface stands as a remarkable and to this day, somewhat unheralded contribution.

Rapport and Friend identified three motivating concerns that underlay development of STRESS.

(1) stewardship: the need to protect and conserve environmental assets for future generations;

(2) environmental quality: the need to maintain and enhance the quality of the ambient environment for quality of life objectives; and

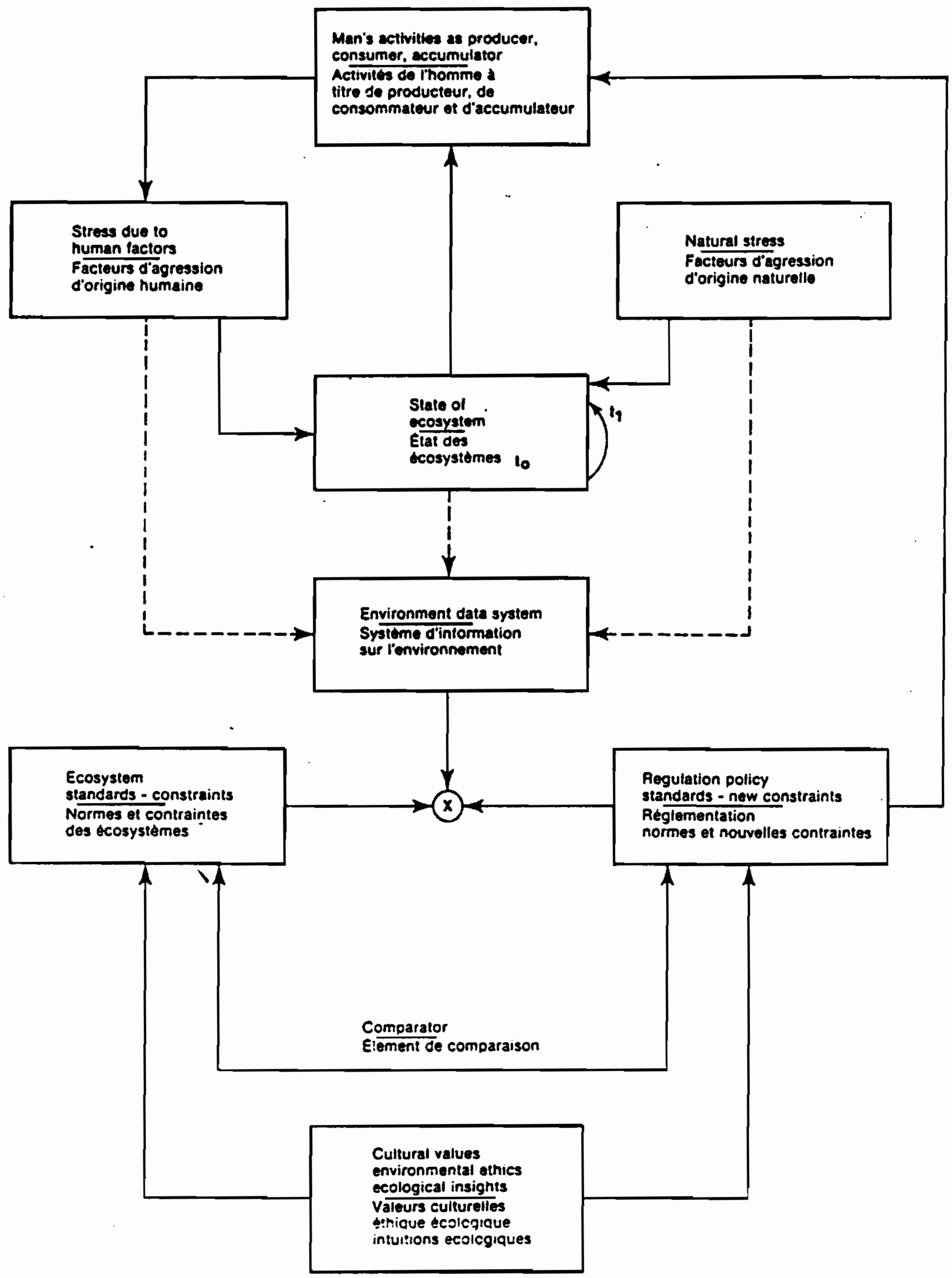
(3) irreversibility: the need to make explicit the closing of potential options by human-initiated permanent restructuring of the environment, i.e. ecosystem destruction.

(1979, 74)

Their overall conceptual framework links "transactions" between man and nature with the design of public policy. It is shown in Figure 27.

They identify four categories of statistics: (1) activity "**stressor**" statistics; (2) environmental "**stress**" statistics; (3) environmental "**response**" statistics; and (4) statistics on "**collective and individual human responses.**" These four categories are listed with examples in Table 3.

Friend and Rapport (1989) have since linked (1) indicators of environmental stress and response (through STRESS); (2) indicators of economic performance (through the SNA); and (3) indicators of demand and supply of natural resources (through satellite accounts) within a proposed "Information System for Sustainable Development" in support of environmental, socioeconomic, and natural resource policies. This is shown schematically in Figure 28.



Source: Rapport and Friend 1979, 64. Reprinted by authority of the Minister of Industry, 1994.

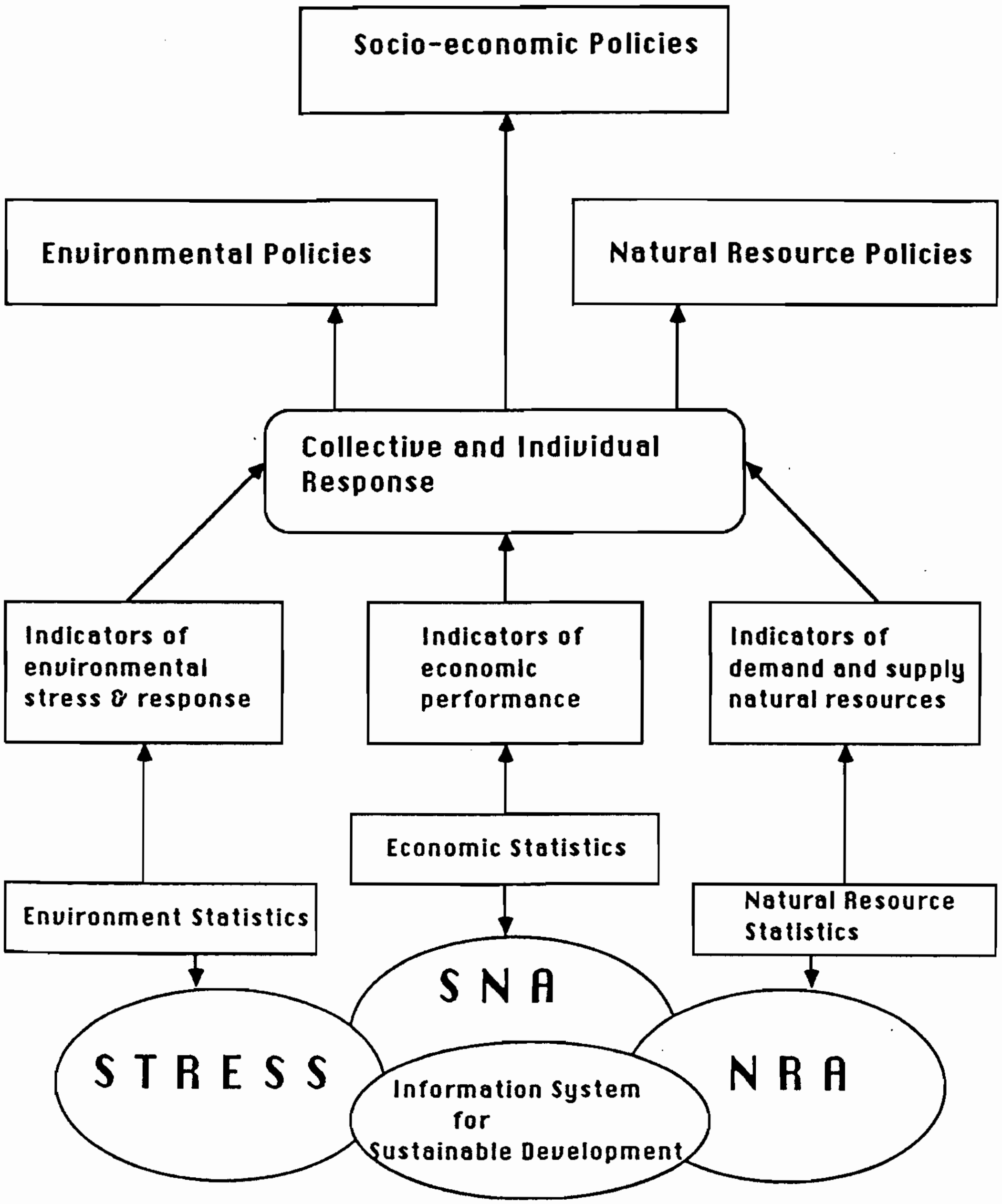
Figure 27. Monitoring the transactions between man and nature for the design of public policy.

TABLE 3. STRUCTURAL FRAMEWORK FOR THE STRESS-RESPONSE ENVIRONMENTAL STATISTICAL SYSTEM (STRESS) WITH TYPES OF STATISTICS LISTED BY ACTIVITY.

Activity Activité	Measures to reduce environmental stress Mesures destinées à réduire l'agression			Policy response Réaction administrative	Conservation measures Mesures de conservation
	A Stressors measures → Mesures des sources d'agression →	B Stress measures → Mesures des agressants →	Environmental response measures → Mesures des réactions de l'environnement →	Collective and individual response Réactions collectives et individuelles	C Inventory of stock measures Mesures des stocks
I. Genera ion of waste residuals. – Production de déchets.	Production and consumption. – Production et consommation.	Pollution loadings. – Charges de polluants.	Monitoring of environmental quality. – Surveillance de la qualité de l'environnement.	Abatemen expenditures and process change. – Dépenses de lutte contre la pollution et changement des procédés.	Capacity to abate pollution and recycling capacity. – Capacité de lutte contre la pollution et de recyclage.
II. Permanent environmental restructuring. – Restructuration permanente de l'environnement.	Construction and land use change. – Construction et changements dans l'utilisation des terrains.	Construction and land use change at local level. – Construction et changements dans l'utilisation des terrains à l'échelle locale.	Ecosystem transformation. – Transformation des écosystèmes.	Protection and conservation of environmental assets. Environmental impact assessment. – Protection de l'environnement. Évaluation des répercussions sur l'environnement.	Accumulated stock of man-made structures. Area of protected environmental. – Stock cumulatif de bâtiments. Zones d'environnement protégé.
III. Harvesting activity. – Récolte.	Production from renewable resources. – Production à partir de ressources renouvelables.	Over-production and technological stresses. – Surproduction et agressants technologiques.	Sustainable yield response. – Maintien du rendement.	Control of technology and establishment of quota systems. – Contrôle de la technologie et contingentement.	Stock of renewable resources. – Stock de ressources renouvelables.
IV. Extraction of non-renewable resources. – Extraction de ressources non renouvelables.	Production and consumption and alternative substitutes. – Production et consommation et substituts.	Same as I and II. – Comme en I et II.	Same as I and II. – Comme en I et II.	Conservation measure. – Mesures d'économie.	Stock of non-renewable resources. – Stock de ressources non renouvelables.
V. Production and consumption of potentially hazardous substances. – Production et consommation de substances dangereuses.	Production, disposition and disposal. – Production, utilisation et élimination.	Application of potentially hazardous substances and leakage. – Utilisation et fuites de substances dangereuses.	Level of contaminants in the environment. – Niveau des contaminants dans l'environnement.	Restrictions and control of use of potentially hazardous substances. – Restrictions et contrôle de l'utilisation des substances dangereuses.	Stock of potentially hazardous substances. – Stock de substances dangereuses.
VI. Production and consumption of energy. – Production et consommation d'énergie.	Production and use. – Production et utilisation.	Development of supporting infrastructure. Thermal loadings. Noise generations. – Infrastructure de soutien. Charges thermiques. Bruit.	Thermal pollution, (noise) nuisance. – Pollution thermique, nuisances (bruit).	Energy conservation. – Économie d'énergie.	Stock of energy resources. Capacity of energy production. – Stock de ressources énergétiques. Capacité de production d'énergie.
VII. Natural activity. – Activité naturelle.	Meteorological records and geo-physical events. – Dossiers météorologiques et phénomènes géophysiques.	Variation of climate and geo-physical events beyond normal range. – Variations anormales du climat et des phénomènes géophysiques.	Drought, flood, earthquakes and long-term biome change. – Sécheresse, inondations, séismes et changements à long terme des biomes.	Socio-enonomic response to natural activity – Réactions socio-économiques aux phénomènes naturels.	Mapping of climate and ecological zones. – Levés climatiques et ecologiques.
VIII. Population dynamics (human and other biological species). – Dynamique de la population (homme et autres espèces biologiques).	Population change on temporal and spatial dimensions. – Changement des populations sur les plans temporel et spatial.	Population in relation to carrying capacity. – La population par rapport à l'espace.	"Over use" of natural resources. Increase in mortality and morbidity. – "Sur-utilisation" des ressources naturelles. Accroissement de la mortalité et de la morbidité.	Control of population size and habitat expansion. – Limitation des populations et expansion des habitats.	Population count. – Dénombrement des populations.

A. Preventive actions (e.g., change in processes of production and consumption).
A. Mesures préventives (par ex., changement des processus de production et de consommation).
B. Curative actions (e.g., installation of pollution abatement equipment).
B. Mesures curatives (par ex., installation de matériel antipollution).
C. Conservation actions (e.g., policies to restrain the use of, and protect, environmental assets).
C. Mesures de conservation (par ex., décisions administratives limitant l'exploitation de l'environnement et le protégeant).

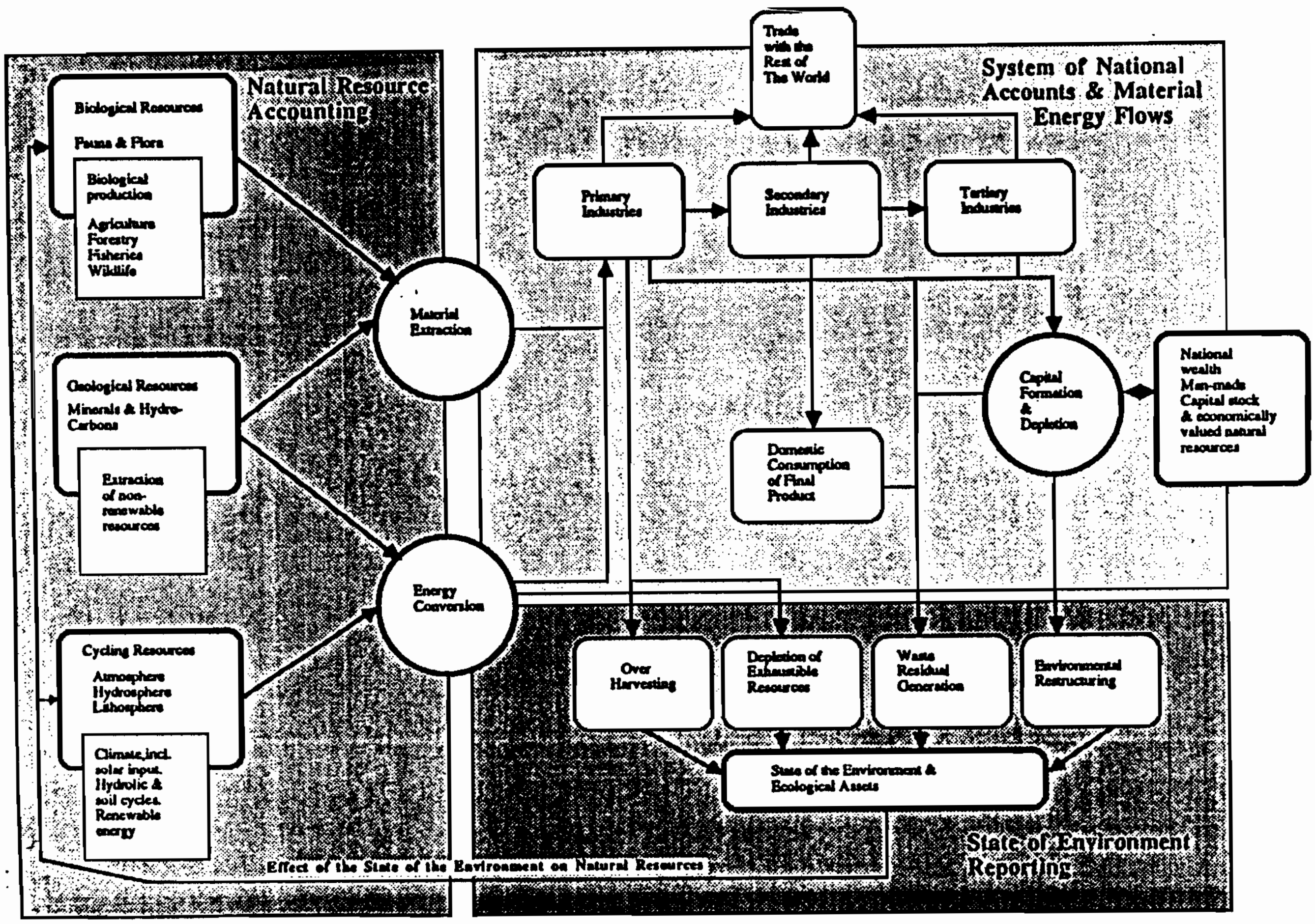
Source: Rapport and Friend 1979, 80. Reprinted by authority of the Minister of Industry, 1994.



Source: Friend and Rapport 1989, 20; Friend and Rapport 1990, 18.

Figure 28. Framework of an information system for sustainable development and environmental, socioeconomic and natural resource policies

In a further development, Friend argues for a "pluralistic" approach to national accounting that would have three equal elements: (1) natural resource accounting; (2) system of national accounts and material energy flows; and (3) state of environment reporting (1991). These three elements are integrated in Figure 29 which they describe as a schematic view of material-energy flows and feedback of environmental degradation on natural resource stocks.



Source: Friend 1991, 8.

Figure 29. Framework for a "pluralistic" approach to national accounting.

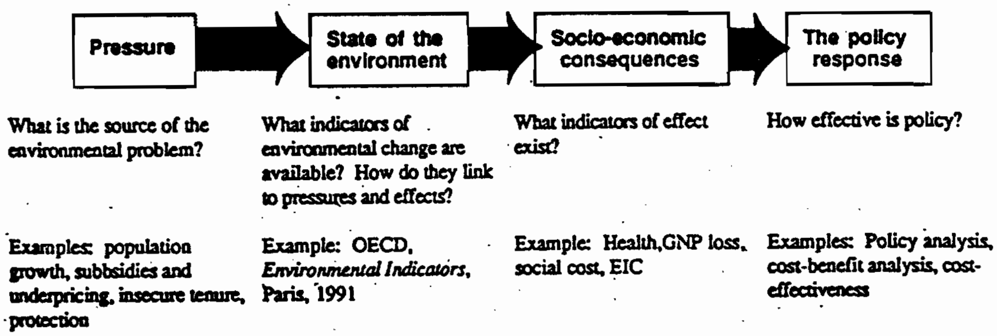
Friend and Rapport's use of the concept of stress imposed on the ecosystem from human activities (and vice verse) represents a major and critical advance beyond the older depletion/pollution model of the human-ecosystem interface. It is this concept that makes possible a more rigorous and systematic description of the human-ecosystem interface than was previously possible. Further, it is this part of the stress-response model that provides an important building block for the conceptual approach to reporting on sustainability proposed in this dissertation.

A number of limitations have emerged that have mitigated against use of the stress-response framework as an over-arching conceptual approach for reporting on sustainability. First, any given "environmental response" to a human-induced stress may, from another perspective, be itself a stress on another part of the ecosystem. This leads to a trickle-down effect that is inevitable in complex systems but is cause of much confusion. Second, while the concept of stress-response is intellectually appealing, it is rare that specific responses can be linked with specific stresses — the cause-effect relationships are not established. And lastly, the language of the stress-response approach has not facilitated smooth linking with public policy and decision-making.

In spite of these limitations, the stress-response concept has been very influential in many parts of the world. A specific application to the lower Great Lakes is described in Rapport (1983) and examples of SOE reports organized to some extent on the stress-response conceptual model include at the international level, OECD (1979, 1985); at the national level, Bird and Rapport (1986); at the regional level, Van Dusen and Hayden (Gulf of Main, 1989); and at the municipal level Elkin (Regional Municipality of Waterloo, 1987). Further, the roots of the current OECD approach to environmental policy analysis can be attributed to Friend and Rapport's work (Pearce and Freeman 1992, 63; and Comolet 1992, 4 - 5).

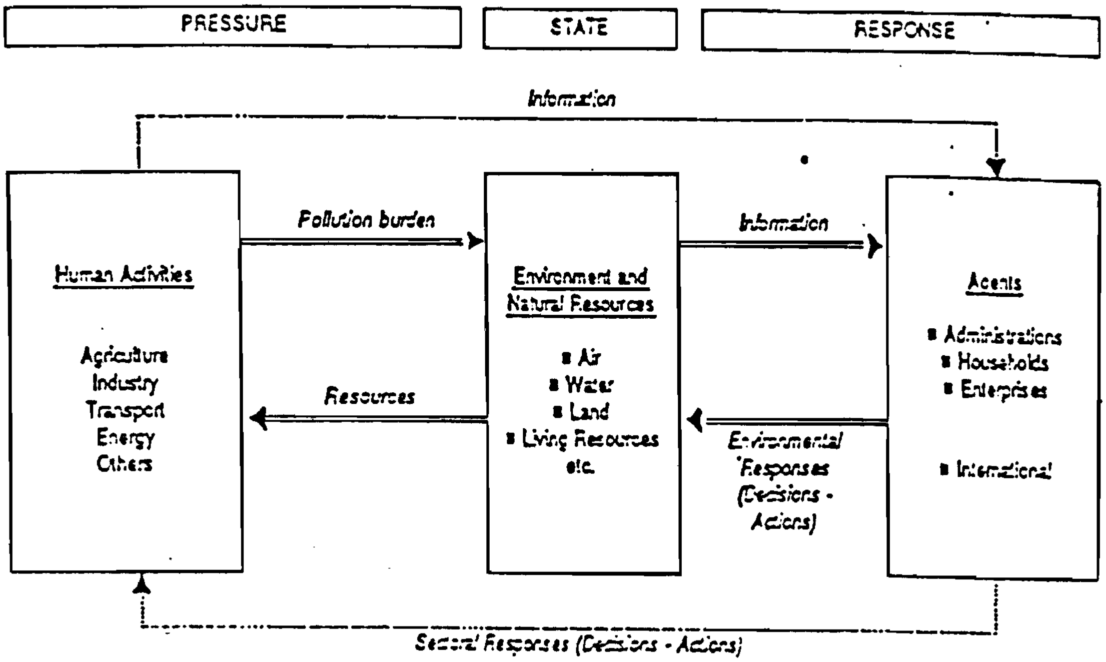
6.3 OECD'S PRESSURE-RESPONSE APPROACH

The OECD's analytic structure is shown in Figure 30 and the conceptual framework linked to environmental performance indicators in Figure 31. Unfortunately, the OECD framework has eliminated the stress concept proposed by Rapport and Friend and reverted to the old depletion/pollution model of the human-ecosystem interface.

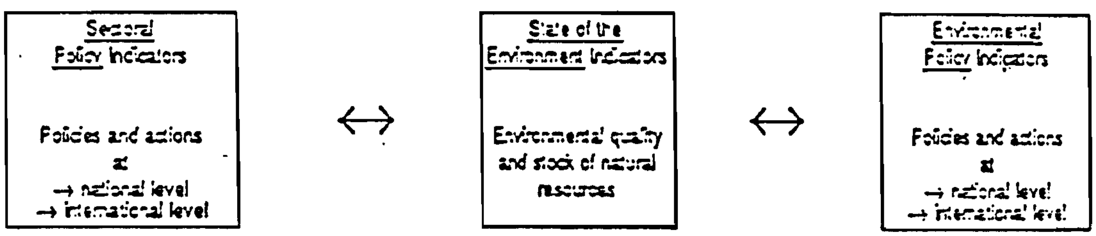


Source: Pearce and Freeman 1992, 63

Figure 30. OECD's analytic structure of policy-maker information.



a. Framework



b. Indicators

Source: OECD, 1993.

Figure 31. OECD's conceptual framework for environmental performance indicators. Environmental performance indicators will include: (1) state of environment indicators referring to sustainable development in terms of both pollution and natural resource issues; (b) environmental policy indicators; and (c) sectoral policy indicators.

6.4 Discussion

Rapport and Friend's stress-response ideas represent on of the most significant contributions reviewed in this Appendix. While the idea of response has not gained greater clarity over time, their recognition of the two-way nature of stress (on people and on the ecosystem) and their multifaceted categorization of stress on the environment have facilitated a significant growth in understanding of human-ecosystem interactions.

Friend and Rapport's more recent work aimed at developing an information system for sustainable development and Friend's pluralistic approach to national accounting provide useful systems based approaches to these issues. However, it is not apparent that these recent initiatives effectively build on the integrative power of the concept of sustainability while drawing on the really powerful elements of their own earlier work.

7. GENERAL ECOLOGICAL SYSTEMS

A different perspective on the human-ecosystem interface is provided by general ecological models. Two of these are described in this section, one proposed by Pierre Dansereau, and one by James Miller.

7.1 Dansereau's Ecosystem Model

Dansereau's now legendary work spans the past forty years. Near the centre point of this period, he developed a model of the ecosystem based on the identification of six "trophic levels". The ecosystem he defines as:

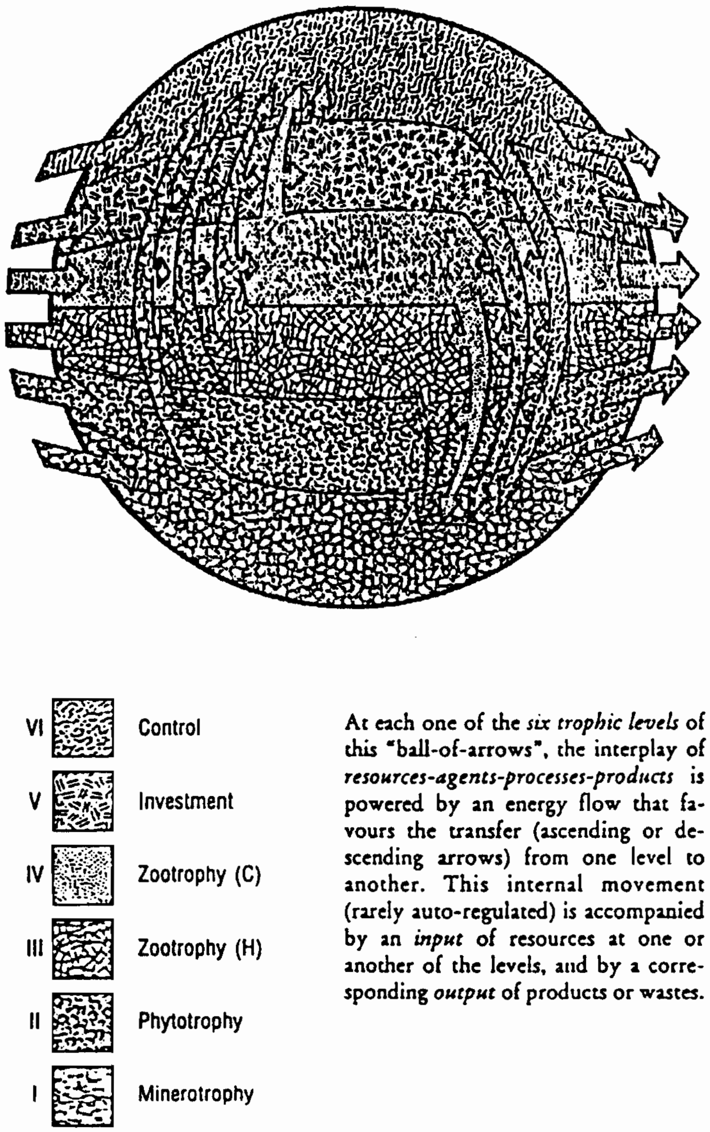
> ... a limited space where the cycling of resources through one or more tropic levels is effected by more or less fixed and numerous agents utilizing mutually compatible processes simultaneously and successively, which engender products that are useable on short or long term.
>
> (Dansereau 1990, 71)

He carefully adds the following additional definitions:

> ***Resources***: the elements which are variously fed into the cycling process, whether they be mineral, biological, or functional (iron, wheat, cattle, lumber, information);
>
> ***Agents***: elements or organisms capable of powering the various processes by absorption, transformation, storage, channeling, or transport of resources (wind, plant, animal, man, bank, State);
>
> ***Processes***: mechanisms whereby the resources undergo all and any kind of change, metabolism, or transformation; anabolic, metabolic, or catabolic, they all imply an energy flow (pedogenesis, photosynthesis, absorption, predation, damming, electricity transmission, marketing, stock exchange speculation, legislation);
>
> ***Products***: objects or services resulting from the processing of resources by agents; they are consumed, stored, lost, or reinvested for further cycling (humus, starch, flesh, automobile, poem). The product arising at a given level will thus become a resource at another level, or be stored, or even lost or transferred to another ecosystem;
>
> ***Trophic levels***: more or less determined stages which are stratified in time and space, wherein the cycling processes carry the resource from one state to another (for example, from mineral to animal). Each level is characterized by associated and more or less exclusive processes which make up a regime.
>
> (Dansereau 1990, 72).

Dansereau's ecosystem model is shown in Figure 32.

In an early application of this model, Dansereau demonstrates the need for interdisciplinary analysis. Table 4 lists each tropic level of his model, the relevant factors encompassed, the functions performed and the "competences" required for effective analysis.



At each one of the *six trophic levels* of this "ball-of-arrows", the interplay of *resources-agents-processes-products* is powered by an energy flow that favours the transfer (ascending or descending arrows) from one level to another. This internal movement (rarely auto-regulated) is accompanied by an *input* of resources at one or another of the levels, and by a corresponding *output* of products or wastes.

Source: Dansereau 1990, 91.

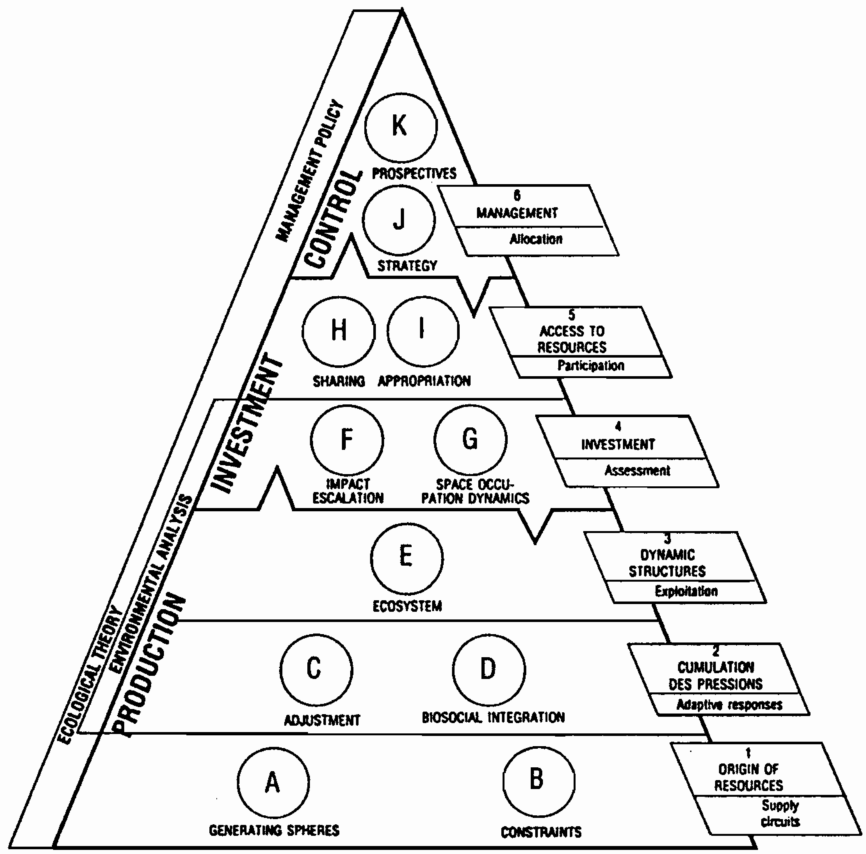
Figure 32. Dansereau's ecosystem model.

TABLE 4. DANSEREAU'S SIX TROPHIC LEVELS WITH FACTORS, FUNCTIONS, AND PROFESSIONAL COMPETENCES IMPLICATED.

Trophic level	Factor	Function	Competence	
VI Control	Recreation Culture Education Government Finance	Legislation Relocation Transfer Planning	Political science Law Economics Engineering Administration	VI VI V-VI V-VI V
V Investment	Work Habitation Construction Circulation	Regrouping Importation Substitution Succession	Geography Engineering Architecture Sociology Economics Psychology	I-VI V-VI V V V-VI VI
III-IV Zootrophic	Animals	Hazards Food Survival	Epidemiology Wildlife management Veterinary science Agronomy Animal ecology Zoology	VI III-V III-IV II-V III-IV III-IV
II Phytotrophic	Flora Vegetation	Hazards Food Substitution Succession Destruction	Design Agronomy Forestry Plant ecology Botany	VI II-V II-V II II
I Minerotrophic	Noise	Residence Work Transport	Medicine Sociology Engineering Physics	V-VI V V I
	Water	Drainage Evacuation Water level Supply	Engineering Agronomy Geography Geology	V-VI II-V I-VI I
	Rock Gravel Sand Minerals	Relief Transport Support	Economics Engineering Pedology Geology	V-VI I

Sources: Dansereau, 1975, 1976.

In a more recent piece of work, Dansereau places his model of the ecosystem (Figure 32) in the centre of what he calls the ecopyramid, "a general scheme of environmental relationships cast on the three basic operations: PRODUCTION, INVESTMENT, and CONTROL" (1990, 63). His ecopyramid is shown in Figure 33.



Source: Dansereau 1990, 63.

Figure 33. Dansereau's ecopyramid.

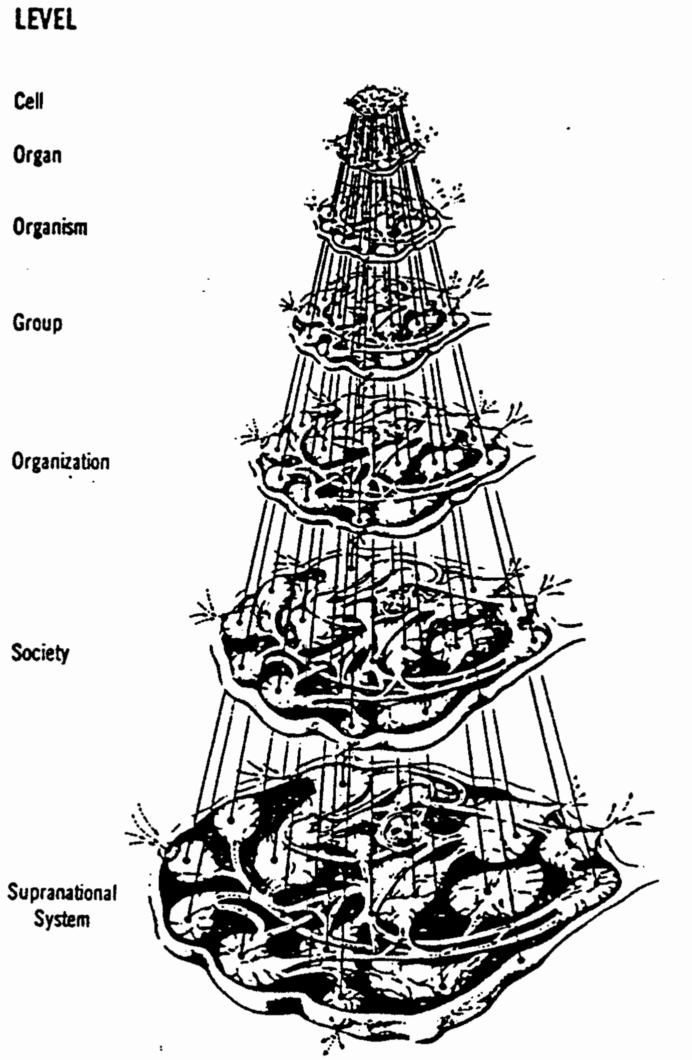
Dansereau bases all of his work on the belief in ecopolitics - "a set of decisional principles resulting from socioeconomic experiences and experiments geared to ecological priorities" (1990, 58). In elegant words he suggests (1990, 58):

> A philosophy of the "conserver society" (Valaskakis et al., 1979), of "small is beautiful" (Schumacher, 1973), of "joyous austerity (DansereauM, 1975) is offered as a grid upon which to project the image of "Only One Earth" (Ward and Dubos, 1972) as a means of insuring "Our Common Future."
>
> (WCED, 1987)

This sense of values is consistent with the value set outlined in Chapter Two (and see Appendices I, II, and III) as the foundation for the system of reporting on sustainability proposed in this dissertation.

7.2 MILLER'S GENERAL THEORY OF LIVING SYSTEMS

In 1978, James Miller proposed a "General Theory of Living Systems" (Miller, 1978). In his general theory, he identifies seven hierarchical levels - cell, organ, organism, group, organization, society, and supranational system. He considers each level to be an open system composed of subsystems which process inputs, throughputs, and outputs of various forms of matter, energy, and information. He identifies nineteen critical subsystems, common to each level, whose processes are critical for life. Miller's generalized living system is shown schematically in Figure 34 and the 19 critical subsystems are described in Table 5.



Source: Miller 1978, 4. Copyright (C) 1978 by McGraw-Hill, Inc. Reprinted with permission of the publisher.

Figure 34. Miller's generalized living system showing the seven levels and 19 critical subsystems.

Table 5. The 19 critical subsystems of a living system.

SUBSYSTEMS WHICH PROCESS BOTH MATTER-ENERGY AND INFORMATION

1. *Reproducer*, the subsystem which is capable of giving rise to other systems similar to the one it is in.

2. *Boundary*, the subsystem at the perimeter of a system that holds together the components which make up the system, protects them from environmental stresses, and excludes or permits entry to various sorts of matter-energy and information.

SUBSYSTEMS WHICH PROCESS MATTER-ENERGY	SUBSYSTEMS WHICH PROCESS INFORMATION
3. *Ingestor*, the subsystem which brings matter-energy across the system boundary from the environment.	11. *Input transducer*, the sensory subsystem which brings markers bearing information into the system, changing them to other matter-energy forms suitable for transmission within it. 12. *Internal transducer*, the sensory subsystem which receives, from subsystems or components within the system, markers bearing information about significant alterations in those subsystems or components, changing them to other matter-energy forms of a sort which can be transmitted within it.
4. *Distributor*, the subsystem which carries inputs from outside the system or outputs from its subsystems around the system to each component.	13. *Channel and net*, the subsystem composed of a single route in physical space, or multiple interconnected routes, by which markers bearing information are transmitted to all parts of the system.
5. *Converter*, the subsystem which changes certain inputs to the system into forms more useful for the special processes of that particular system.	14. *Decoder*, the subsystem which alters the code of information input to it through the input transducer or internal transducer into a "private" code that can be used internally by the system.
6. *Producer*, the subsystem which forms stable associations that endure for significant periods among matter-energy inputs to the system or outputs from its converter, the materials synthesized being for growth, damage repair, or replacement of components of the system, or for providing energy for moving or constituting the system's outputs of products or information markers to its suprasystem.	15. *Associator*, the subsystem which carries out the first stage of the learning process, forming enduring associations among items of information in the system.
7. *Matter-energy storage*, the subsystem which retains in the system, for different periods of time, deposits of various sorts of matter-energy.	16. *Memory*, the subsystem which carries out the second stage of the learning process, storing various sorts of information in the system for different periods of time. 17. *Decider*, the executive subsystem which receives information inputs from all other subsystems and transmits to them information outputs that control the entire system. 18. *Encoder*, the subsystem which alters the code of information input to it from other information processing subsystems, from a "private" code used internally by the system into a "public" code which can be interpreted by other systems in its environment.
8. *Extruder*, the subsystem which transmits matter-energy out of the system in the forms of products or wastes. 9. *Motor*, the subsystem which moves the system or parts of it in relation to part or all of its environment or moves components of its environment in relation to each other.	19. *Output transducer*, the subsystem which puts out markers bearing information from the system, changing markers within the system into other matter-energy forms which can be transmitted over channels in the system's environment.
10. *Supporter*, the subsystem which maintains the proper spatial relationships among components of the system, so that they can interact without weighting each other down or crowding each other.	

Source: Miller 1978, 3. Copyright (C) 1978 by McGraw-Hill, Inc. Reprinted with permission of the publisher.

Miller's work is an attempt to:

> ... integrate all the social, biological, and physical sciences that apply to structure or process of any of the seven levels. Physiology, biochemistry, genetics, pharmacology, medicine, economics, political science, anthropology, sociology, and psychology are all almost entirely relevant. Physical sciences and engineering also contribute. Logic, mathematics, and statistics yield methods, models, and simulations, including some involving the relatively new approaches of cybernetics and information theory.
>
> (1978, 4)

Miller's general theory provides a fascinating conceptualization of how the ecosystem functions. However two issues prevent its use as an organizing template for reporting on sustainability. First, the complexity of his seven levels and 19 critical subsystems makes his work very difficult to translate into practical terms for decision-makers. Second, he does not deal with abiotic system elements. The issue of sustainability is as much concerned with characteristics of the non-living world as it is with living systems.

7.3 Discussion

As an analytic tool, Dansereau's conceptual approach is powerful. However, as a model to provide structure to reporting on sutainability, it is difficult to apply. Neither the classification of six trophic levels of his ecosystem model, nor the classification of three basic operations identified in the ecopyramid provide an effective organizing template for organization of an assessment of progress toward sustainability. Furthermore, Dansereau's ecosystem model (Figure 30) is based on inputs of resources to each trophic level and corresponding outputs of products or wastes. Thus in function, it echoes the too limited depletion/pollution model discussed in Section 5.

Dansereau's work offers many insights into the nature of ecosystem relationships and the need to bring to bear a broad range of professionals to undertake effective analytic work. However, his approach and language do not lend themselves to easy application in the hands of contemporary decision-makers.

Miller's Theory of Living systems draws heavily on input-output ideas being pursued early in the evolution of systems ideas. His nineteen subsystems result in a degree of complexity which impedes easy application.

8. ADDITIONAL ANALYSES FOR SUSTAINABILITY

8.1 THE SUSTAINABLE SOCIETY PROJECT

In May, 1988, and following some four years of preparatory work, a team in the Department of Environment and Resource Studies at the University of Waterloo, led by Professor John B. Robinson, initiated the Sustainable Society Project (SSP). The project has since shifted to the Sustainable Development Research Institute at the University of British Columbia.

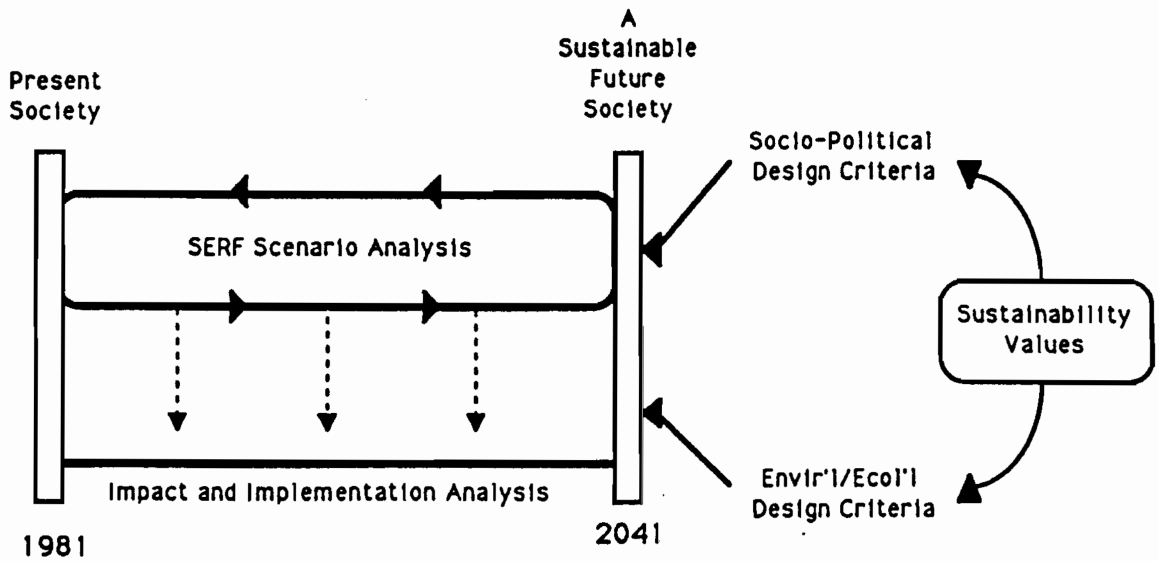
Robinson (1989) describes the project as an exploration of the resource requirements and socioeconomic impacts of a Sustainable Society scenario for Canada. It is national in scope, and is based on a 60 year time frame (1981 to 2041). It starts by postulating a desirable future which is to be evaluated in terms of feasibility and implications. It is thus an exercise in backcasting (see discussion APPENDIX IV).

The approach is explicitly normative and based on a belief that society should be involved in choosing and designing its future rather than merely responding to it as it unfolds. The governing values are reflected in an articulated belief in:

- environmental protection;
- sustainability of resource development;
- increased efficiency of resource and material use;
- social and environmental diversity, flexibility and responsibility;
- such socio-political values as equity, community, participation , and autonomy.

Because of its focus on backcasting, the SSP is not an attempt to predict the future but rather is an assessment of relative feasibility and identification of implications of a particular path of events towards a consciously chosen objective.

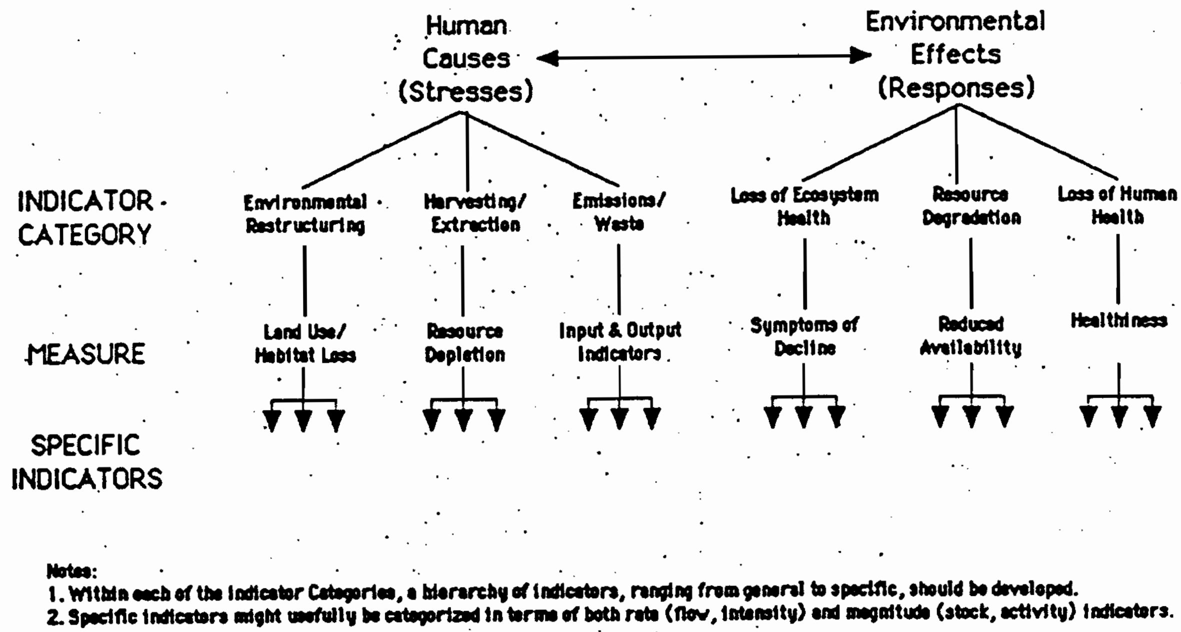
At the core of the project is the socioeconomic Resource Framework (SERF), referred to in Section 6, which provides a comprehensive description of the physical and technological state of the system for each year of the scenario evaluation. In this way, the nature of the interactions within and between human and natural systems over time can be assessed, as can the degree to which undesirable futures can be avoided or responded to, and desirable futures created. The conceptual framework for the project is shown in Figure 35.



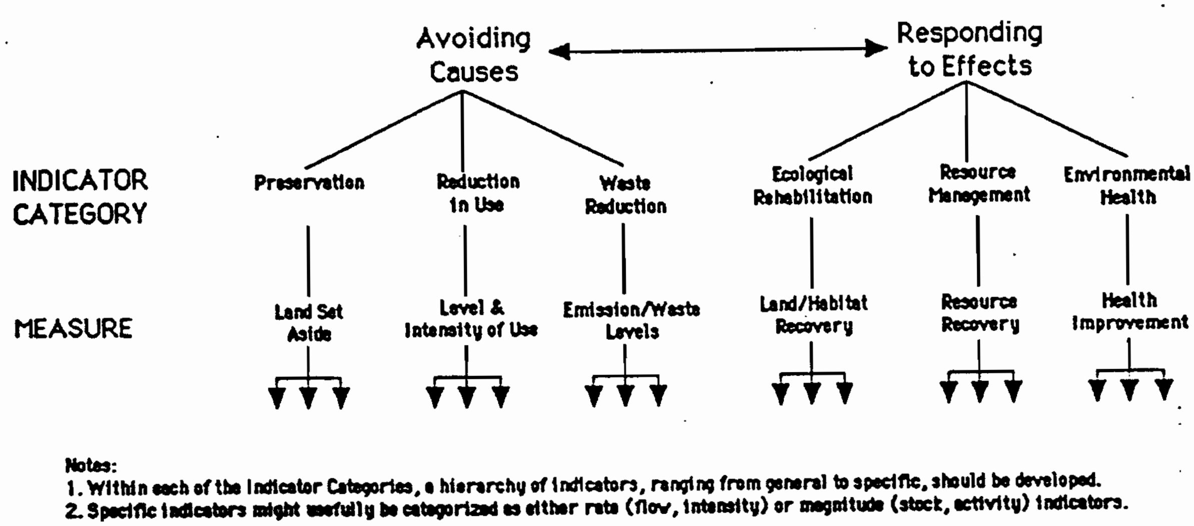
Source: Robinson, 1989.

Figure 35. Conceptual framework of the ustainable Society Project (SSP).

The project defines a sustainable society in terms of interrelated (1) socio-political, (2) environmental, and (3) technological "dimensions". Their "design criteria" (see Figure 35) imply definition of sets of indicators to be monitored in the subsequent assessment and analysis. Indeed, they have designed a systematic approach to indicators as shown in Figures 36 a and b. Their explicit recognition that values directly influence such design criteria is an important insight.



a. Indicators for a sustainable society: state of the environment



b. Indicators for a sustainable society: human responses to environmental decline

Source: Robinson, 1991

Figure 36. The Sustainable Society Project's (SSP's) Conceptual Framework for Indicator Development

Figures 36 a and b are based on a stress-response framework with three general stressor categories (harvesting/extracting, environmental restructuring, and waste generation) and three impact or response categories (ecosystem maintenance, sustainable resource use, and biotic diversity). These response categories reflect the objectives of the World Conservation Strategy (IUCN, 1980). Eventually, development of a hierarchy of indicators is envisioned with broad categories serving to group indicators sets.

8.2 World Conservation Strategies I and II

The first World Conservation Strategy (WCS-I) (IUCN et. al., 1980) was published in 1980 through a joint effort of the International Union for Conservation of Nature and Natural Resources, the United Nations Environment Programme, and the World Wildlife Fund. WCS-I specifically calls for acceptance of "equitable, sustainable development" (Section 20). Their strategy was built on the following three objectives:

- maintenance of essential ecological processes and life-support systems;
- preservation of genetic diversity;
- sustainable utilization of species and ecosystems.

(1980, vi)

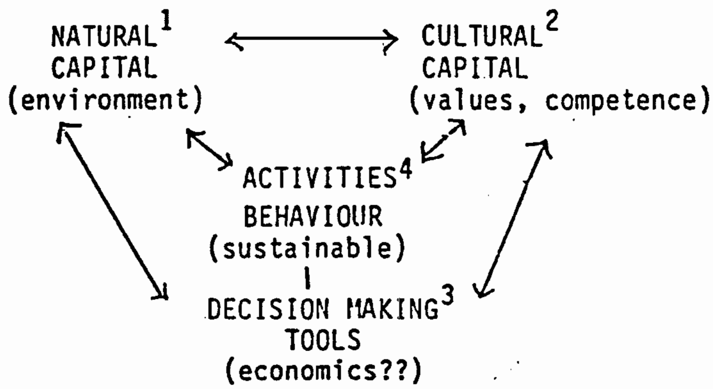
In 1991, publication of the Second World Conservation Strategy (WCS-II) (IUCN et al., 1991) marked a significant conceptual shift. In WCS-II, IUCN et al., recognize that measurement of progress toward a sustainable society included both a human and ecological dimension. For their human dimension they propose assessment of "quality of life" and for the ecological component they define "ecological sustainability" in terms that echo the objectives listed in WCS-I. In WCS-II, they suggest that a society is ecologically sustainable when it:

- conserves ecological life-support systems and biodiversity;
- ensures that uses of renewable resources are sustainable and minimizes the depletion of nonrenewable resources; and
- keeps within the carrying capacity of supporting ecosystems.

(1991, 198)

8.3 Hill's Model of the Theory and Practice of Sustainable Development

Over the past 20 years, Dr. Stuart Hill has been a major contributor to conceptual thinking related to "ecological" agriculture. With popularization of the ideas of sustainable development, many of his ideas have found broader application. In 1989, he proposed a pyramidal model to guide the theory and practice of sustainable development. At the apex of the pyramid he places behaviour and activities that would result in sustainable development. His model is shown below in Figure 37 and the expanded descriptions of each of the four corners are listed in Table 6.



Source: Hill, 1989.

Figure 37. Hill's model for the theory and practice of sustainable development.

TABLE 6. ELEMENTS OF HILL'S SUSTAINABLE DEVELOPMENT MODEL.

1. Conservation/Development of Natural Capital:

- biodiversity; gene pool
- soil, air, and water quality
- environmental quality for all humans and all wildlife
- ecological processes, e.g. maintenance and repair, waste recycling

2. Conservation/Development of Cultural Capital - Psycho-social Development and Evolution:

- satisfaction of basic needs vs. manipulated wants
- optimal physical and mental health
- empowerment, awareness, lovingness, zest
- spontaneity, flexibility, creativity
- knowledge, skills, wisdom
- equity, peace, justice, openness, accessibility, honesty
- spiritual development, self-actualization, fulfillment, meaning

3. Decision-making:

- Levels: individual, family, group, organization, political, species
- Basic Cycle: integration (action), balance (goal), feedback (monitoring), prediction - planning - policy
- Characteristics: long time frame (future generations), planetary space frame but self-reliance, transdisciplinary, universal responsibility, commitment, participatory, public trust, early indicators, formal and informal economics

4. Behaviour Leading to Sustainable Development:

- benign, rational, responsible, just, humane, sustainable,
- resource-efficient with emphasis on renewable, solar, recycling
- problem prevention through lifestyle and ecosystem redesign and management
- implementation through appropriate mix of support, reward and penalty
- emphasis on appropriate technologies

Source: Hill, 1989.

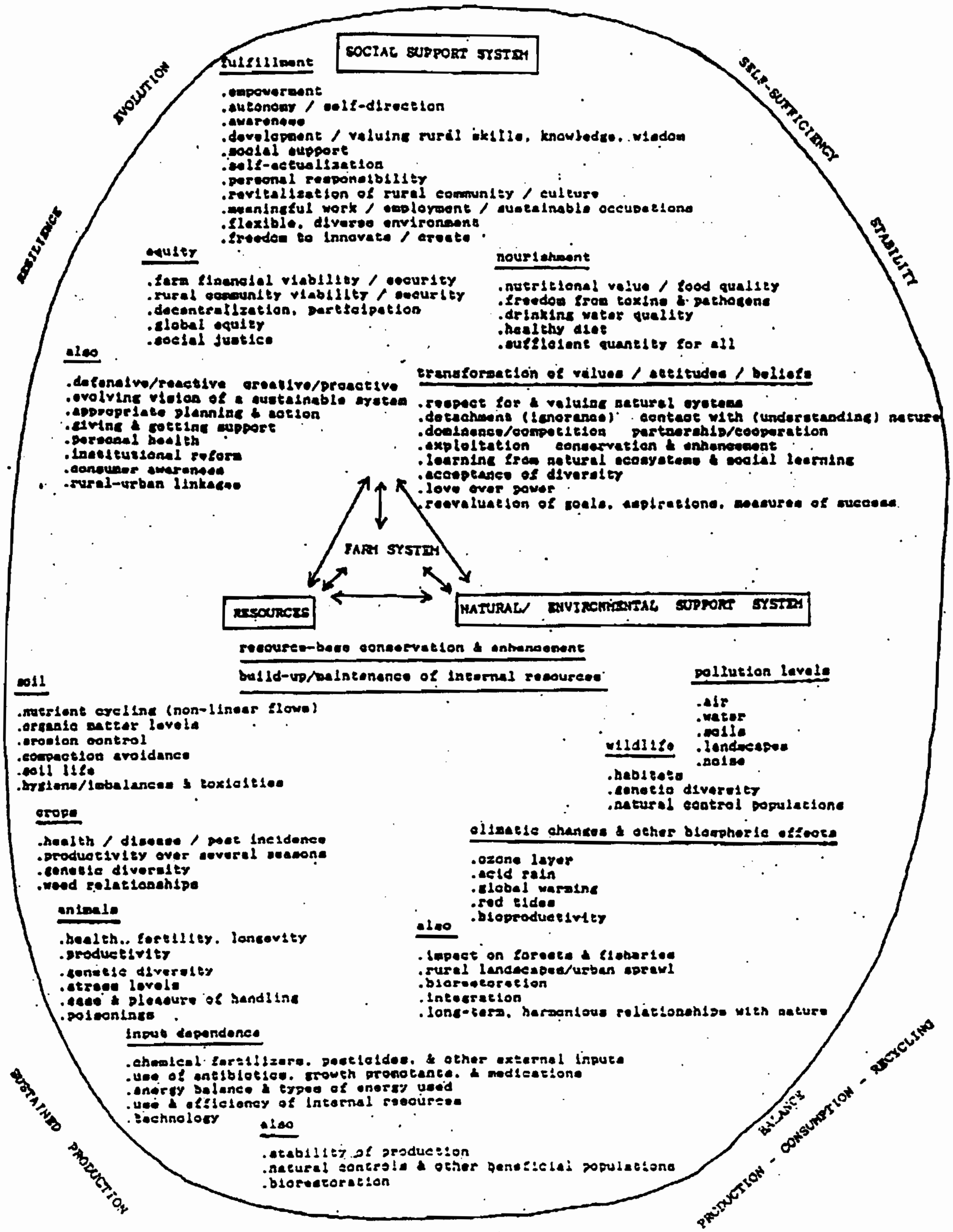
Hill's model provides a useful synthesis of issues related to sustainability. In particular, his recognition of the central role of human activities and behaviour is a critical insight. However the model is not a systematic treatment of the human-ecosystem relationship but rather a model of factors affecting and affected by human activities.

8.4 Nault's Analysis of Farm System Health

Nault (1991) examines the requirements for development of sustainable farm systems and proposes a composite model of possible criteria and indicators of farm system health. He sees the farm system dependent on:

1. the social support system (assessed in terms of fulfillment, equity, nourishment, and transformation of values/attitudes/beliefs);
2. the natural/environmental support system (assessed in terms of pollution levels, wildlife characteristics, climatic change and other biospheric effects); and
3. resources (assessed in terms of characteristics of soil, crops, animals and input dependency).

His composite model is shown below as Figure 38. Nault's differentiation of "resources" and the "natural — environmental support system" provides a useful perspective but like Hill's work, the elements are not systematically organized and appear as a haphazard listing of important contributing factors.



Source: Nault 1991, 47.

Figure 38. Nault's composite model of possible criteria and indicators of farm system health.

8.5 Discussion

Each of the four contributions presented in this section offer important insights. Robinson's work on indicators and reporting (the Sustainable Society Project) is noteworthy for at least four reasons: (1) its explicit recognition of values as an influence on socio-political and environmental/ecological design criteria; (2) its systematic approach; (3) its use of a well-founded conceptual framework (a variation of the stress-response approach; and (4) its use of a more complete description of the human-ecosystem interface than is offered by the old depletion/pollution model. Their hierarchy of indicator categories, measures, and specific indicators (see Figure 36a) is particularly useful.

The IUCN led work on World Conservation Strategies is helpful in its recognition of the need to monitor and assess both human conditions (they suggest assessment of quality of life) and ecosystem conditions (they emphasize maintenance of life-support systems and biodiversity; sustainable renewable resource use and minimum depletion of nonrenewable; and ecosystem carrying capacity limitations).

Hill's focus on human activities as the key to the analysis of sustainability is a critical insight. His realization that there are both natural and cultural aspects of what he calls "capital" is important. Unfortunately, the elements under each of the four categories include a haphazard mix of characteristics, system elements, and value statements. Because neither the model nor its components are systematically organized and presented, application as an organizing framework for a system of reporting is impeded.

Nault's farm system analysis is influenced by Hill's work and lacks a systematic approach. However, his recognition that farm system health is dependent on (1) a social support system; (2) a natural/environmental support system; and (3) resources provides a useful perspective and one that will be seen to be consistent with the framework proposed in this dissertation.

9. AGENDA 21 MACROSTRUCTURE

The United Nations Conference on Environment and Development (Earth Summit) was held in Rio de Janeiro, Brazil, 8-14 June, 1992. The concept of sustainable development, championed in the report of the World Commission on Environment and Development five years earlier (WCED, 1987), was identified as the driving theme. Five documents resulted:

- AGENDA 21, an overall framework for follow-up action from the conference;
- The Rio Declaration on Environment and Development;
- A Framework Convention on Climate Change;
- A Convention on Biological Diversity
- A non-legally binding statement of principles on the management, conservation, and sustainable development of forests.

Of these documents, it is AGENDA 21 that provides an overview of the conference outcome. Macelli points out the inevitable link between the conceptual approach taken in any project and the format of the final report (1977, 1). Using this insight (as was done in the review of state-of-environment reports presented in APPENDIX V) it is possible to review the content and organization of AGENDA 21 to obtain insights into the conceptual approach to sustainable development taken by the authors of AGENDA 21 and the participants of the Earth Summit. Table 7 thus lists the overall structure and content of AGENDA 21.

TABLE 7. THE STRUCTURE AND CONTENT OF AGENDA 21 (CHAPTER REFERENCES IN BRACKETS)

I. SOCIAL AND ECONOMIC DIMENSIONS

- accelerating sustainable development (2)
- poverty (3)
- consumption patterns (4)
- population growth (5)
- human health (6)
- human settlements (7)
- integrating environmental costs into decision making (8)

II. RESOURCE MANAGEMENT

- atmospheric protection (9)
- land-use (10)
- deforestation (11)
- desertification (12)
- mountain development (13)
- agriculture and rural development (14)
- biodiversity (15)
- biotechnology (16)
- ocean protection (17)
- fresh water protection and management (18)
- toxic chemicals (19)
- hazardous waste (20)
- solid waste, sewage (21)
- radioactive waste (22)

III. STRENGTHENING MAJOR GROUPS

- participation (23)
- women (24)
- children and youth (25)
- indigenous people (26)
- non-governmental organizations (27)
- local authorities (28)
- workers, unions (29)
- business, industry (30)
- science, technology (31)
- farmers (32)

IV. IMPLEMENTATION

- financial resources and mechanisms (33)
- technology transfer (34)
- science for sustainable development (35)
- education and public awareness (36)
- capacity building (37)
- international institutions (38)
- legal institutions and mechanisms (39)
- bridging the data gap (40)

Source: UNCED, 1992.

Six observations emerge from a review of AGENDA 21. First, the four-part structure of AGENDA 21 reflects a primary concern with human conditions and a secondary concern for resource management, part of which includes protecting the environment as a source of resources for human needs and wants. Thus, the conceptual framework that emerges for sustainable development from this document could be described as a two-part model dealing with (1) people and (2) natural resource management. Such a framework is not rooted in the value set underlying this dissertation: care and respect for people and the ecosystem of which we are a part.

Second, while AGENDA 21's explicit recognition of the human dimension of sustainable development is important, its focus on resource management reflects the pollution/depletion model at best and in many ways its organization and content reflect ideas that were prevalent in the 1970s and before.

Third, AGENDA 21 does not recognize the face that while human society does indeed manage the use of "resources" that are within the operating human system (e.g., copper ingots, bags of sugar, tins of fish), human society does not manage or make decisions directly controlling the environment. Rather, human society manages and makes decisions about human activities which in tern have an influence (along with other known and unknown factors) on the ecosystem. By recognizing this fact, AGENDA 21 would have emphasized the responsibility that individuals and society have for their actions. It would also have introduced an appropriate sense of humility. Without these insights, the strength of AGENDA 21 is lessened.

Fourth, AGENDA 21 does not assume an approach to human activities that attempts to balance the value of these activities with the stress they impose upon the ecosystem. There is discussion of integrating environmental and economic accounting (Chapter 8) and adding natural resource satellite accounts to national accounts (Chapter 40), but the implicit value set underlying the System of National Accounts is not recognized. Because it does not facilitate consideration of human activities that balances their contribution to human well-being with the stress imposed on the ecosystem (and/or their restorative contribution), an educational opportunity is missed.

Fifth, while there is discussion about broadening participation in decision-making and various sub-populations are identified and discussed, there is no recognition of either the different groups of decision-makers within any society or of the differences between various societies.

Lastly, AGENDA 21 does not provide an overall sense of the system that would facilitate anticipation of weak-links or even system-breakdown. Rather, individual chapters lie as a check-list of current concerns.

Given the above observations, AGENDA 21 does not provide an adequate framework for a reporting system for assessing progress toward sustainability. It does provide an important check list of current issues that must be dealt with by the needed reporting system.

Table 8 below groups the same elements according to the proposed conceptual framework. A number of gaps become evident: (1) not all ecosystems are addressed; (2) not all human activities are addressed; (3) the range of physical, chemical, and biological stress imposed by human activities is not considered; (4) the potential for human activities to restore ecosystem functions is not recognized; (5) an overall perspective on human well-being is not provided but rather a listing of special interests appears; and (6) a synthesis that would provide a sense of the overall system and relevant actions to be taken with this in mind is lacking completely.

TABLE 8. ELEMENTS OF AGENDA 21 GROUPED BY THE PROPOSED FRAMEWORK (CHAPTER REFERENCES IN BRACKETS)

I. ECOSYSTEMS

- air and climate (9)
- forest ecosystems (11)
- dry-land ecosystems (12)
- mountain ecosystems (13)
- cultivated ecosystems (14)
- freshwater ecosystems (18)
- coastal, island, and marine ecosystems (17)
- biological diversity (15)
- data, information, and analysis (40)

II. INTERACTION

- trade (2)
- poverty (3)
- consumption (4)
- settlements (7)
- other activities contributing to
  atmospheric conditions (energy production and use, transportation, industrial development, agriculture and land use)(9)
- deforestation (11)
- desertification (12)
- agriculture (14)
- biotechnology (16)
- fishing, shipping, tourism (17)
- other activities contributing to freshwater conditions (18)
- hazardous waste generation, storage, and management (20)
- solid waste generation, storage, and management (21);
- radioactive waste generation, storage, and management (22)
- data, information, and analysis (40)

III. PEOPLE

- trade and cooperation (2)
- poverty (3)
- consumption (4)
- demographic dynamics (5)
- human health (6)
- settlements (7)
- women (24)
- youth (25)
- indigenous people (26)
- non-governmental organizations (27)
- local authorities (28)
- workers and trade unions (29)
- business and industry (30)
- scientific and technological community (31)
- farmers (32)
- technology transfer (34)
- financial resources and mechanisms (33)
- science (35)
- education and public awareness (36)
- capacity building (37)
- institution building (38)
- legal instruments and mechanisms (39)
- data, information, and analysis (40)

IV. SYNTHESIS

- integrated policy-making for sustainable development (8)
- integrated land-resource management (10)
- data, information, and analysis (40)

Source: Hodge 1993, Appendix V.

The above critique is not intended to imply that a document like AGENDA 21 should deal comprehensively with everything. Rather, a limited set of actions are appropriate to identify. However, such focussing should be undertaken within the context of the whole system. In future, actions that are not undertaken may be just as important to know about and understand as actions that are undertaken. And in any case, the rationale for choosing one set of actions as opposed to another is critical to document if learning is to be maximized. It is the conceptual framework that provides the context for systematically choosing priority actions and rationalizing such decisions.

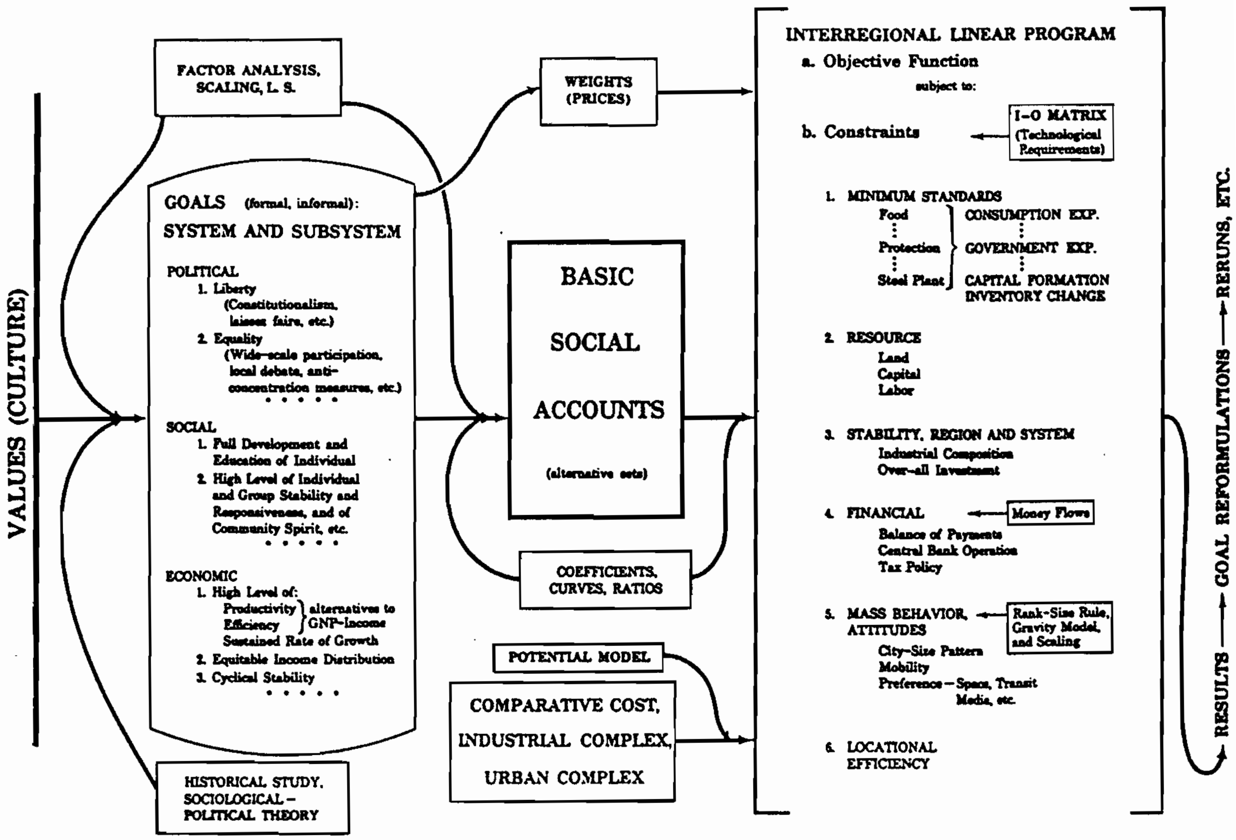
10. MISCELLANEOUS CONTRIBUTIONS

10.1 Isard's Approach to Regional Analysis

Walter Isard, a professor at the Massachusetts Institute ofTechnology, pioneered many of the pragmatic and operational techniques for undertaking regional analysis. Thirty years ago, Izard presented five alternative "channels" for synthesizing regional planning analysis (1960, Chapter 12).

The first three depend on optimizing regional systems using a variety of tools including interregional flow analysis, industrial location analysis, interregional and regional input-output techniques, industrial complex analysis, interregional linear programming, and gravity, potential, and spatial interaction models.

The fourth is a conceptual approach driven by culturally-based values that lead to definition of goals (political, social, and economic) which in turn govern design of "social accounts". He points out that at the time of writing, 1960, the process by which the social system established goals was not well understood. As a result he identifies a need for greatly improved sociological, psychological, and anthropological theory and methods. In addition, he suggests that significant advances in political theory and administrative analysis are require before the value-based approach can be effectively applied. Isard's value-based conceptual approach to regional planning is shown schematically in Figure 39.



Source: Isard 1960, 684. Copyright (C) 1960 by The M.I.T. Press. Reprinted with permission of the publisher.

Figure 39. Isard's values-social goals framework for regional analysis.

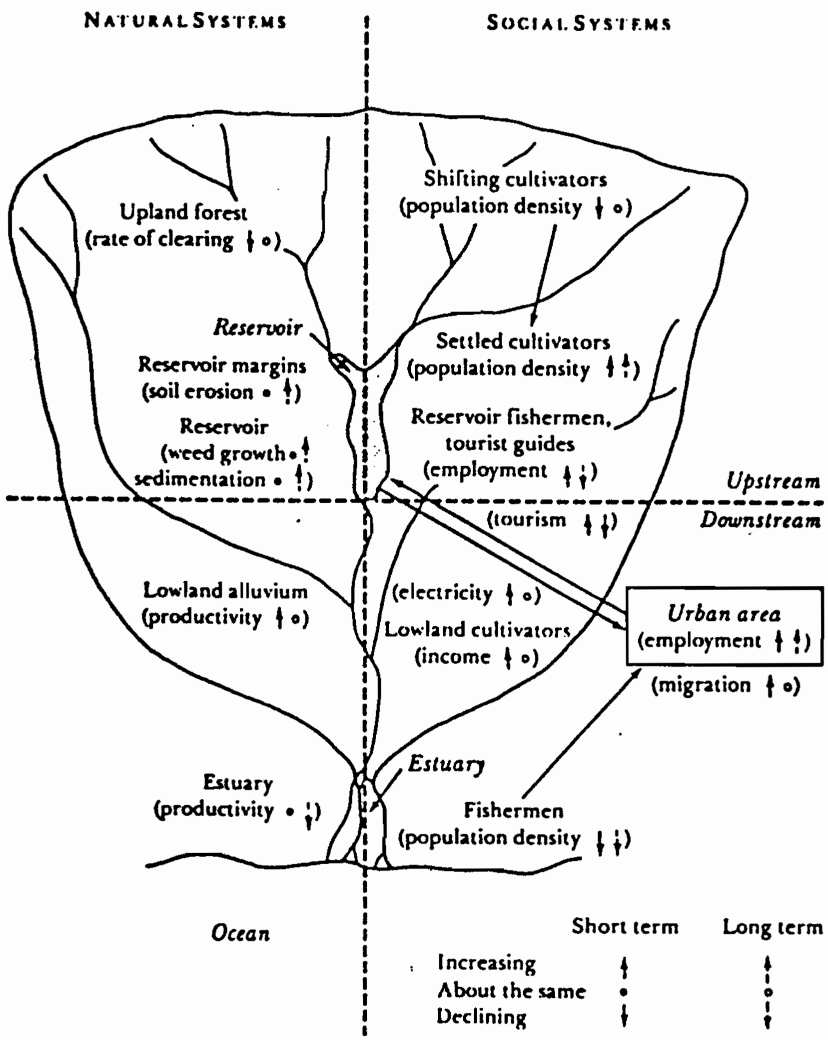
In his fifth "channel" he reverts to an optimization approach while attempting to factor in at least the values and goals that are subject to approximate quantitative representation.

Isard's work pre-dates the rise in environmental concern that occurred in the late 1960s. Thus, it is not surprising that ecosystem conditions don't figure in his work until much later. However, this early attempt to systematically factor values and goals into a formal and sophisticated systems approach to regional analysis is noteworthy.

10.2 Easter et al.'s Watershed Analysis

Easter et al. undertake an assessment of watershed resource management drawing on a variety of case studies throughout Asia and the Pacific (1986). Their analytic framework recognizes interacting "natural" and "social" systems and is shown in Figure 40.

Like so many of the models in this review, in practical application and applying systems ideas, Easter et al. found it useful to work with an ecosystem dimension (the "natural system") and a human subsystem within (the "social system").

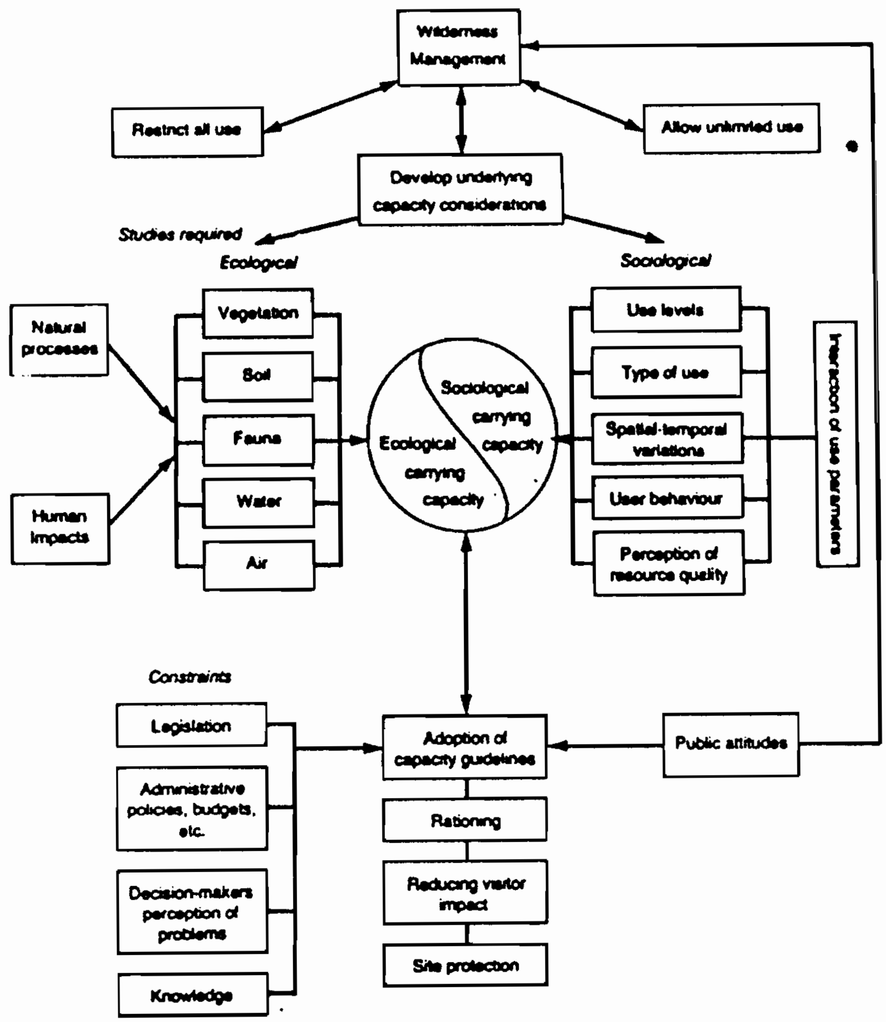


Source: Easter et al. 1986, 8. Reprinted with permission of the author.

Figure 40. Easter et al.'s analytic framework for watershed resource management.

10.3 Stankey's Carrying Capacity Model

In 1972, Stankey proposed an analytic framework for guiding wilderness management based on the concepts of ecological and sociological carrying capacity. His framework is shown in Figure 41.



Source: Stankey, 1972. Copyright (C) 1972 by The John Hopkins University Press. Reprinted with permission of the publisher.

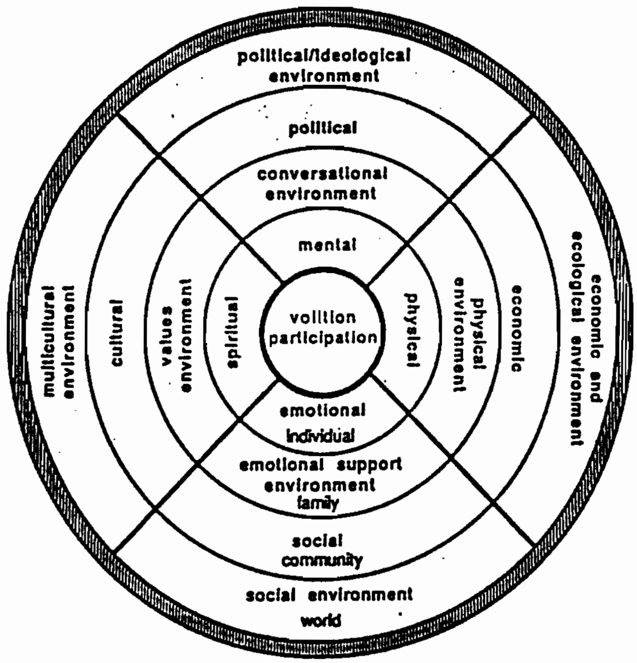
Figure 41. Stankey's analytic framework for wilderness management based on ecological and sociological carrying capacity.

Stankey's model is noteworthy in its identification of a human or sociological dimension and an ecological dimension. His human dimension deals systematically with use activities and his ecological dimension deals systematically with ecosystem components. This core conceptual model is appropriately nested within a

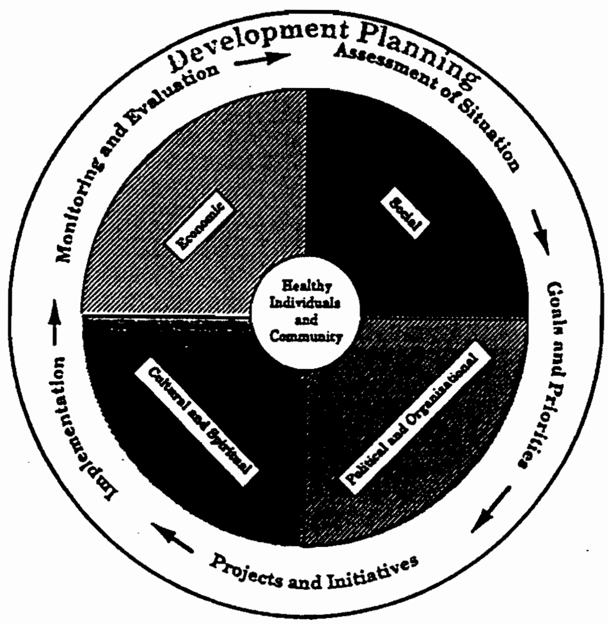
10.4 Application of the Medicine Wheel as a Conceptual Guide for Aboriginal Development

In February, 1990, a meeting of personnel from the Economic Development Staff Program of Indian and Northern Affairs Canada and representatives of several First Nations led to the creation of a Development Indicator Project Steering Committee. In turn, the Steering Committee developed a Guide Book, "Using Development Indicators for Aboriginal Development" (DIPSC, 1991). An important element of their work is the integration of the North American Indian ***medicine wheel*** with planning concepts. The result is a framework for guiding aboriginal community development.

The medicine wheel identifies four elements of personal and community life: mental/political, emotional/social, cultural/spiritual, and physical/economic. From these elements is drawn a ***development wheel*** which is enveloped within a five stage development planning process. The medicine wheel and development wheel are shown in Figure 42.



a. Medicine Wheel



b. Development Wheel

Source: DIPSC 1991, 21 and 23.

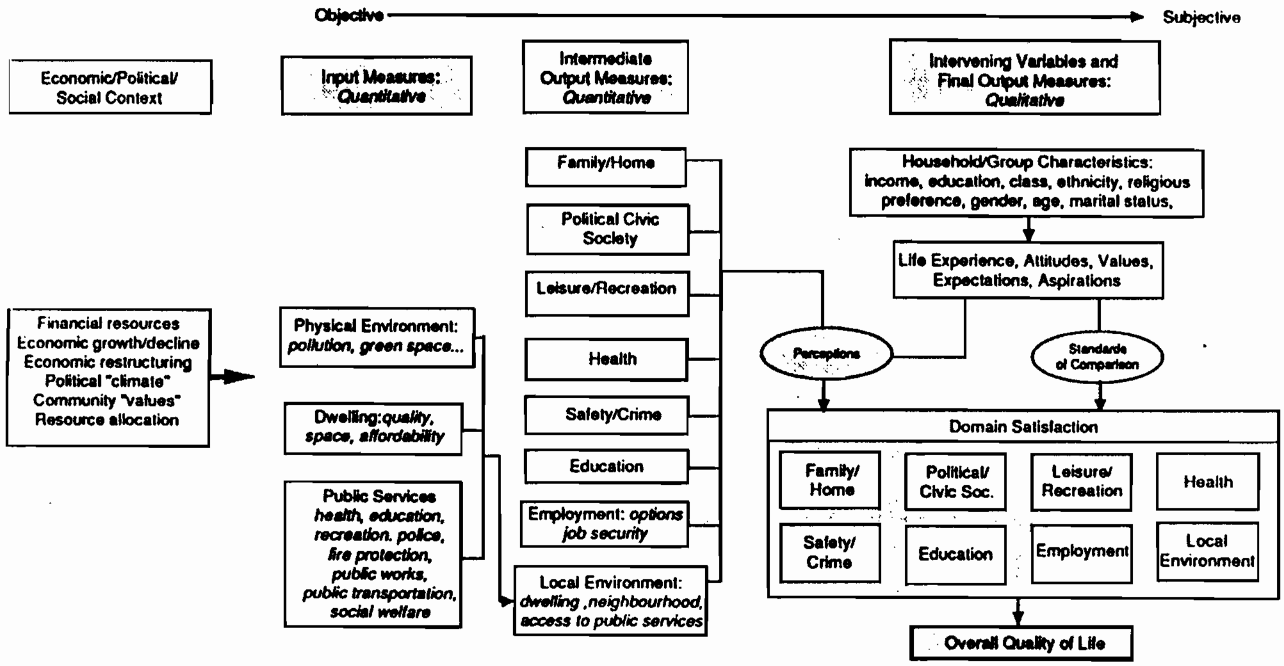
Figure 42. The North American Indian *medicine wheel* with its counterpart Aboriginal *development wheel*.

For assessing progress, indicators are then listed in terms of the following categories: (1) economic development; (2) social development; (3) cultural - spiritual development; and (4) political - organizational development. While the "ecological" environment is identified as important in the ***medicine wheel*** the development wheel focuses on human development and no mention is made of ecosystem conditions. In its current form, the development wheel is not an appropriate template for reporting on sustainability.

10.5 CMHC's Conceptual Framework of Quality of Life

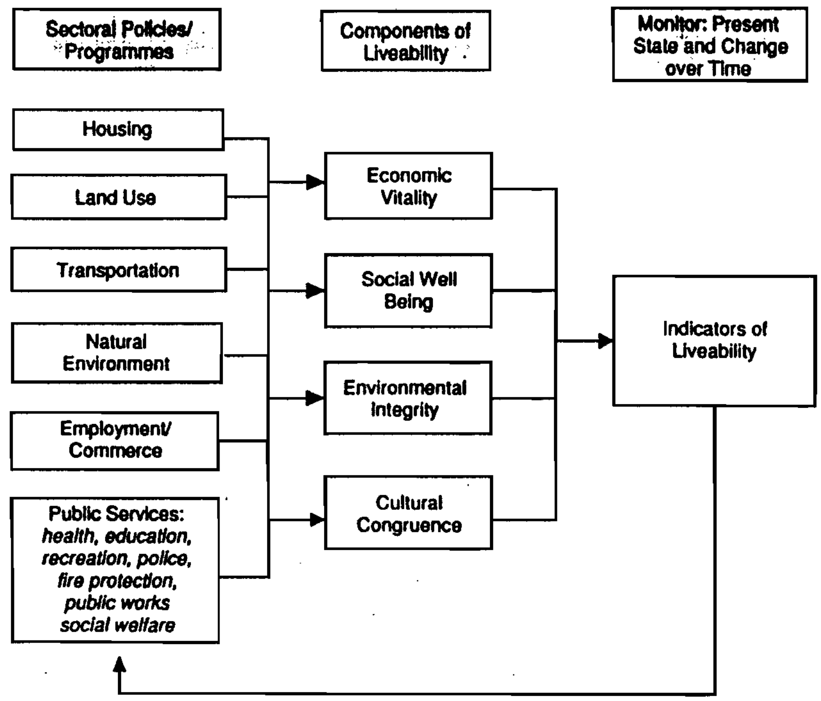
Signalling a return to interest in quality of life that was so dominant in the 1960s and 1970s, the Canada Mortgage and Housing Corporation commissioned a study of quality of life indicators (Murdie et al., 1992). The conceptual framework that they developed for their work is shown in Figure 43 and their community oriented model of the lived environment is presented in Figure 44. The second model leads to "indicators of liveability" that draw on economic, social, environmental, and cultural components.

In both Figures 43 and 44, ecosystem characteristics are recognized as key contributors to the quality of life. However the explicit focus is on human quality of life and not on the broader concept of sustainability.



Source: Murdie et al. 1992, 24

Figure 43. CMHC's conceptual framework of quality of life.



Source: Murdie et al. 1992, 28

Figure 44. A community oriented model of the lived environment.

11. SUMMARY AND CONCLUSIONS

This review has set out to identify insights and common elements or characteristics from thirty different models that in some way deal with the human-ecosystem interface. The intent is to use these ingredients to help build a conceptual "roadmap" to serve as a framework for reporting on sustainability.

The following conclusions emerged.

1. **ALMOST ALL OF THE MODELS REVIEWED OFFER USEFUL INSIGHTS FOR THE NEEDED CONCEPTUAL FRAMEWORK AND REPORTING SYSTEM.** They represent a rich source of ideas spanning a broad range of perspectives.

2. **NO EXISTING MODEL THAT COULD SERVE AS A FRAMEWORK FOR REPORTING ON SUSTAINABILITY HAS EMERGED.** No one of these models rigorously and systematically describes the ecosystem and its relationship to the human sub-system in a way that lends itself to broad application in support of improved decision-making. It is apparent that any discipline- specific model is unlikely to provide the needed framework. For example, economics-derived models have evolved from a conventional circular model through a material-energy balance model to the now dominant depletion/pollution model. While the latter model is encouraging consideration of some important environment-economy relationships, it is inadequate for dealing with the broad range of physical, chemical, and biological stresses imposed by human activity on the ecosystem. Its portrayal of the nature and role of the ecosystem itself is also incomplete.

3. **MANY FACTORS THAT MUST BE TREATED SYSTEMATICALLY IF CONFUSION IS TO BE AVOIDED ARE AT PLAY.** Definitional clarity regarding system components, relationships between components, and processes at play within or influencing the system is critical.

4. **THE ECOSYSTEM, THE HUMAN SUBSYSTEM, AND THE INTERACTION BETWEEN THE TWO, ARE THE PRINCIPAL SYSTEM COMPONENTS THAT ARE COMMON TO THE MODELS REVIEWED.** These elements represent the common ground of all of these models and offer the possibility of finding an area of "overlapping consensus" upon which to build a bridging conceptual framework.

5. ONLY A FEW OF THESE MODELS ARE ORIENTED TOWARDS BALANCING CONCERN FOR BOTH PEOPLE AND THE ECOSYSTEM. Some of the models emphasize human well-being, while others focus on the health or integrity of the ecosystem. Only the work of Easter et al. (1986) aimed at watershed resource management and Stankey's (1972) framework for wilderness management based on ecological and sociological carrying capacity seem to strike this balance. At a project level, recognition in the early 1980s of the need for both environmental impact assessment and social impact assessment within an "ecological framework" is a significant precursor to such a model (Beanlands and Duinker 1983).

6. SURPRISINGLY LITTLE EFFORT HAS BEEN DIRECTED AT SYSTEMATICALLY EXAMINING THE BROAD RANGE AND IMPLICATIONS OF HUMAN ACTIVITIES. Human activities — how they are valued, how they draw from the ecosystem and how they in turn impose stress — are the primary areas that can be managed and controlled by human decision-making. A systematic treatment of human activities is therefore critical to reporting on sustainability. Hill's (1989) model of the Theory and Practice of Sustainable Development rightly centres on human activities and Isard's work on regional analysis also deals systematically with human activities. Rapport and Friend's (1979) systematic description of both human activities and human imposed stress on the ecosystem is also a major contribution.

7. ASSESSING PROGRESS TOWARDS SUSTAINABILITY MUST INVOLVE BOTH QUANTITATIVE AND QUALITATIVE MEASURES. JUDGEMENT WILL BE REQUIRED TO BALANCE COMPETING AND SOMETIMES CONTRADICTORY FACTORS. This review of models and the related discussion served to demonstrate the potential complexity of the related data and information. Inevitably the resulting indicators (at whatever level of aggregation) will never all trend in the same direction. In practice, contradictory evidence will require assessment. This implies a judgement process that will require balancing competing and sometimes contradictory factors.

8. VALUES PLAY A CRITICAL ROLE AND EVERY ATTEMPT SHOULD BE MADE TO TREAT VALUES EXPLICITLY. Explicit expression of values is a difficult task: many, perhaps most people have never attempted to identify their operating value set let alone express it. Furthermore, values shift as new insights are gained. Isard's early work on regional analysis (1960) and Robinson's work on the Sustainable Society Project (1989, 1991) demonstrate the importance of doing so. The overall topic emerges as an important focus of needed research.

END NOTES

1. I am indebted to Paul Omundi, Ph.D. Candidate, Department of Geography, McGill University, for drawing this work to my attention.

2. Robert and Associates, Ottawa.

APPENDIX VII

QUANTITATIVE AND QUALITATIVE MEASURES

CONTENTS

TABLE

FIGURE

APPENDIX VII.

QUANTITATIVE AND QUALITATIVE MEASURES

1. INTRODUCTION

The conclusion is drawn in Chapter Eight that there is need for both quantitative "objective" measures as well as data and information derived from qualitative assessment. In Appendix IV, "subjective" and "objective" are defined in terms of different modes of assessment. An objective mode of assessment draws on external evidence that is independent of the observer. In contrast, subjective indicators are judgmental, often in mode and concept, and reflect perceptions or opinions (Horn 1993, 8). These definitions beg the question of actual measurement.

The issue of measurement is complex and well beyond the scope of this dissertation. A recent review that deals with many of the key issues is provided by Horn (1993). However, in the course of this project, work by Gerald Hodge from the early 1960s was reviewed that dealt specifically with the issue of quantitative and qualitative measures. His work on this issue is summarized below.

2. QUANTITATIVE AND QUALITATIVE MEASURES

Hodge defines measurement as "the assignment of numbers to objects according to rules" (G. Hodge 1963, 114 - 115). He points out that:

> When we select the relevant aspects of our observations, we perform a level of measurement. It is a low level, of course, in a hierarchy of logical concepts proceeding from classification, to ordering, to various quantitative ones.
>
> (1963, 113)

Hodge's analysis provides the foundation for the two-part taxonomy of measures listed in Table 1 and illustrated in Figure 1. This taxonomy is taken from a discussion of measures of effectiveness.

Techniques that have been used with varying degrees of success for gathering qualitative measures include questionnaires, interviews, and interactive video. The related methodological questions are complex and not addressed further in this dissertation.

TABLE 1. A TWO-PART TAXONOMY OF MEASURES.

1. **QUANTITATIVE MEASURE** - numerical measure on any of the following scales:

   a. **Ordinal (or ranking) scale.** Reflects only which of two levels of effectiveness is better, without indicating by how much. For example, assigning the values 1st, 2nd, and 3rd to the best, second best and third best. These numbers reproduce only the quality of order, it is not valid to perform any arithmetic operation on them.

   b. **Cardinal (or interval) scale.** Differences between measures can be compared, but the values of the measures are not absolute indicators. For example,Fahrenheit and Centigrade temperatures and calendartime are on Cardinal scales. Interval scale values can be multiplied or divided by a constant and thedifferences between scale values van be addedor subtracted.

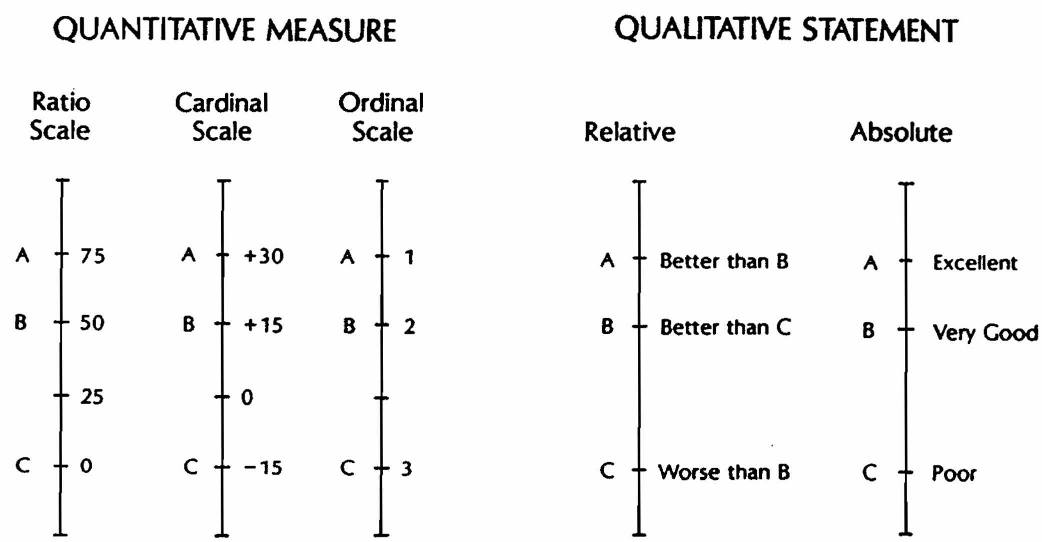
   c. **Ratio scale.** Indicates the absolute level ofeffectiveness. A well-defined zero value is required. Cost, length, and weight are on ratioscales. These numbers can be subjected to arithmetic.

2. QUALITATIVE MEASURE - verbal statement of either arelative or absolute measure:

   a. **Relative statement.** Indicates the degree of effectiveness relative to other programs, for example "better than;"

   b. **Absolute statement.** Indicates the degree of effectiveness against an absolute level of effectiveness, for example "very good" or "twice as good as."

Sources: Byers et al. 1979, 19 - 20, Hodge, G. 1963, 114 - 115.



Sources: Byers et al. 1979, 19; Hodge, G. 1963, 114 - 115.

Figure 1. A taxonomy of quantitative and qualitative measures.

APPENDIX VIII

REPORTING ON SUSTAINABILITY: INDICATOR FAMILIES AND INDICATORS BY DECISION-MAKING GROUP

CONTENTS

APPENDIX VIII

REPORTING ON SUSTAINABILITY INDICATOR FAMILIES AND INDICATORS BY DECISION-MAKING GROUP

1. INTRODUCTION

This Appendix provides lists of example indicator topics and indicators organized on the basis of the conceptual framework developed in this dissertation. It is offered as a starting point for development of specific reporting applications. Detailed assessment of many of the individual topics with experts in the field will inevitably lead to modification and refinement for any specific application.

The focus of this Appendix is on four groups of decision-makers: (1) individuals and families; (2) corporations; (3) communities; and (4) regional, provincial, and federal governments. Thus, the following four sets of indicators are listed:

1. Indicators of sustainability for individual, family, or household decision-making;
2. Indicators of sustainability for corporate decision-making:
    - individual corporations
    - corporate groupings
3. Indicators of sustainability for community, town, or city decision-making; and
4. Indicators of sustainability for regional, provincial (or state), and national decision-making.

Each set is organized on the basis of the four key domains or areas of diagnosis of data and information that emerged from the conceptual framework introduced in Chapter Five.

DOMAIN I - ECOSYSTEM

A. **Ecosystem health and integrity:** data and information facilitating an assessment of the well-being of the ecosystem.

DOMAIN II - INTERACTION

Data and information facilitating an assessment ofthe interaction between people and the ecosystem:

A. **Activity profile:** contribution to provision of basic needs and the quality of life (the "value" of activities);

B. **Stress assessment:** assessment of environmental stress and opportunities for stress reduction; efficiency of resource use and opportunities for improved efficiencies;

C. **Restoration:** identification of actions taken to restore ecosystem integrity;

D. **Success and compliance:** assessment of the degreee of success achieved at meeting the goals and objectives of policies, regulations and legislation, record of compliance.

DOMAIN III - PEOPLE

A. **Human Well-being:** data and information facilitating an assessment of the well-being of people (individuals, communities, corporations, regions, provinces (states), territories, nation) including the range of physical, social, cultural and economic attributes.

DOMAIN IV - SYNTHESIS:

A. **Synthesis:** data and information facilitating the recognition of emergent system properties and providing an integrated perspective for decision-making and anticipatory analysis that spans Domains I, II, and III.

Each of the above four areas of diagnosis contain an array of data and information that falls into a hierarchical form in any assessment process. The assessment hierarchies for each domain are found in Chapter 9.

The above structure is intended to facilitate an assessment of progress towards sustainability that is motivated by the goals for achieving progress toward sustainability shown below.

GOALS FOR ACHIEVING PROGRESS TOWARD SUSTAINABILITY

I. Ecosystem

1. To maintain or improve ecosystem health and integrity;

II. Interaction

2. To increase the ability of human activities to provide support for human well-being;

3. To reduce the physical, chemical, and biological stress imposed on the ecosystem by human activities;

4. To increase the extent to which human activities restore ecosystem health and integrity;

III. People

5. To maintain or improve human well-being.

IV. Overall Synthesis

6. To maintain or improve human and ecosystem well-being.

Any reporting system itself is a subset of the decision-making system. Thus, the overarching goal of reporting on sustainability is to improve the way we make decisions — to support informed and responsible decision-making and decision-making processes in achieving progress toward sustainability. Five specific objectives for the reporting system follow:

REPORTING SYSTEM OBJECTIVES

1. to communicate key signals to targeted decision-makers, in particular to give early-warning signals for required policy and/ or institutional and behavioural change;

2. to ensure accountability;

3. to encourage initiative by giving credit where credit is due;

4. to identify knowledge gaps and provide rationales for giving priority to filling these gaps; and

5. to provide a systematic framework for
   a. organizing investigation and choosing researchers;
   b. identifying required research tasks; and
   c. determining the format of the final report.

The preceding goals and objectives provide an framework for assessing progress. The indicator families and indicators (or appropriate modifications) that are listed below should be assessed individually and collectively with reference to this framework.

2. EXAMPLE INDICATORS OF SUSTAINABILITY FOR THE INDIVIDUAL, FAMILY, AND HOUSEHOLD DECISION-MAKERS

2.1 DOMAIN I - ECOSYSTEM

2.1.1 Subjective assessment of the quality, integrity and/or health of the ecosystem with which the individual, family, or household has direct interaction (natural, modified, cultivated, built)

- air (indoor and outdoor) and climate
- drinking water
- inland surface water (lakes and rivers)
- groundwater (underground water)
- marine waters
- land, soils
- biota (plants, birds, fish, animals, insects, etc.)
- hazards; extreme natural events

2.2 DOMAIN II - INTERACTION

2.2.1 Personal activity profile, contribution to the community, opportunities for stress reduction and ecosystem restoration: hours; proportion of actual and desired time spent on; assessment of opportunities for environmental stress reduction in each case on a scale of 1-10:

- sleep
- personal maintenance (hygiene, clothing, etc.)
- eating
- commuting (all activities)
- paid work
- unpaid work - household:
    - personal finance and administration (paying bills, banking, completing tax returns, insurance, licence applications etc.)
    - childcare and rearing
    - daily, weekly, seasonal, and annual - household - maintenance (regular cleaning, laundry, non-food shopping, repair)

- improvements (additions, retrofitting, upgrading)
- food:
- producing (growing and raising)
- transformation and processing
- shopping
- preparing and cooking

- unpaid work - contribution to community well-being: annual hours contributed for:
  - overcoming inequities in the community (working with disadvantaged groups or individuals)
  - advocacy, education, research and decision- making
  - culture and the arts
  - sports and recreation
  - religious institutions
  - other

2.2.2 Personal Assessment of Environmental Stress, Efficiency of Resource Use, and Opportunities for Stress Reduction, Efficiency Improvements, and Ecosystem Restoration

- food
  - source: portion with plant and animal origin
  - portion consumed that is organically raised
  - life cycle energy input per calorie of food consumed:
  - in growing/rearing
  - in initial processing (to retail level)
  - in packaging
  - in transportation
  - in final preparation
  - in final return to the soil through composting

- consumer purchases:
  - total annual consumer purchases (dollars) and portion with origin in local community, Ontario, Canada, and foreign
  - assessment on scale of 1-10 in terms of ability to:
  - reduce use of either the product or the resources the product draws on
  - reduce packaging
  - reuse
  - recycle

- annual resource use:
  - energy by end use and form[1]
  - volume of water by end use
  - hazardous chemicals by volume/weight and type

- annual waste generation by volume/weight and type
- annual recycling by volume/weight and type
- annual composting by volume/weight and type

2.3 DOMAIN III - PEOPLE: PERSONAL, FAMILY, OR HOUSEHOLD WELL-BEING

2.3.1 Food - Nutrition - Health - Survival

Preventative - Anticipatory

- food/nutrition:
  - caloric intake relative to body weight and activity level requirements
  - nutrient intake relative to age and life phase requirements
  - portion consumed in raw vs. refined state
- sleep
  - average hours of sleep obtained relative to personal needs
- physical fitness (appropriate units):
  - cardiovascular
  - body fat
  - strength and endurance
  - reaction time

Reactive

- occurrence of sickness and disease:
  - annual occurrence of sickness by type, degree, and duration
  - substance and alcohol abuse
- access to health care: facilities, personnel, program delivery

2.3.2 Knowledge, Literacy, and Education

- knowledge and literacy levels
- schooling (formal and informal)
- degree of skill development; access to services to upgrade skills

2.3.3 Material Wealth, Poverty, Unpaid Work, and Employment

- financial security
    - difference between income and expenses
    - annual and cumulative savings
    - indebtedness
    - projected retirement income (pension and savings) adjusted for inflation
- unpaid work: types, participation rates,satisfaction
- employment status and satisfaction

2.3.4 Leisure

- activity options and participation rates
- support organizations
- government/private support

2.3.5 Overall perception of well-being, scale of 1-10:

- degree of worry
- sense of freedom
- fear of or confidence in the future
- degree of self-reliance
- strength of personal support network (family, friends)
- degree of input into decisions affecting one's life
- degree of comfort, either alone or with another person in silence, when all outside stimuli have been eliminated (i.e. sound)
- quiet voice within: can you hear it? can you listen to it? do you follow its advice?
- degree of satisfaction with one's physical fitness
- degree of satisfaction (what one has compared to what one feels the need for) with one's level of:
    - general knowledge
    - general life skills
    - literacy
    - education

- adequacy of personal financial security
- degree of satisfaction with quality of housing
- degree of satisfaction with quality of food consumed
- degree of satisfaction with leisure opportunities
- degree of satisfaction with available health care
- degree of satisfaction with the state of built infrastructure, support systems, and other services in the surrounding community
- degree of satisfaction with community, provincial, national, and international decision-making
- strength of link to history, culture, and heritage
- overall sense of community social fabric and well- being

2.4 DOMAIN IV - SYNTHESIS

2.4.1 Assessment of the whole; key linkages across the above three domains of data and information.

3. EXAMPLE INDICATORS OF SUSTAINABILITY FOR CORPORATE DECISION-MAKING

3A. INDIVIDUAL CORPORATIONS
(PRIVATE COMPANIES, CROWN CORPORATIONS,
PUBLIC AGENCIES AND DEPARTMENTS,
NON-GOVERNMENT ORGANIZATIONS)

3A.1 DOMAIN I - ECOSYSTEM

3A.1.1 Subjective assessment of the quality, integrity and/or health of the ecosystem with which the establishment has direct interaction (natural, modified, cultivated, built)

- air (indoor and outdoor) and climate
- inland surface water (lakes and rivers)
- groundwater
- marine waters
- land
- biota (plants, animals, birds, insects, fish, etc.)
- hazards, extreme natural events

3A.2 DOMAIN II - INTERACTION

3A.2.1 Corporate profile and benefits contributed:

- direct and indirect employment
- annual value added contributed to the local, regional, and national economies
- ratio of jobs and income to output/productivity
- status of ownership and control
- portion of materials or parts purchased in the local community

3A.2.2 Key Expenditures and Subsidies: annual expenditures made (fixed and variable) and subsidies received (direct and indirect, e.g. waived taxes, free use of municipal land, reduced costs of services etc.) for:

- operation and maintenance
- new development:
  - plant
  - product
- environmental protection/stress reduction:
  - operation and maintenance
  - new development:
  - plant
  - product
  - clean up of accidents and spills
  - restoration and/or abandonment
- employee retraining and relocation

3A.2.3 Corporate Assessment of Environmental Stress, Efficiency of Resource Use, and Opportunities for Stress Reduction, Efficiency Improvements, and ecosystem restoration

- procurement:
  - portion of total materials/parts purchased (dollars) with origin in local community, province, nation, and foreign
  - assessment (scale of 1-10) - ability to:
  - reduce use of either the product or the resources the product draws on
  - reduce packaging
  - reuse
  - recycle
- product stewardship:
  - portion of product life cycle (legislated and voluntary) for which company is taking full responsibility

- resource use per unit of time and/or unit of output or productivity (to allow assessment of efficiency and opportunities for substitution):
  - value added per unit of resources used
  - energy by end use and form[1]
  - water volume by end use (including withdrawals, diversions, consumption)
  - hazardous/harmful chemicals by volume and type
  - other feed stocks
  - labour

- harvesting and extraction:
  - annual harvest of renewable resources, physical units/dollars
  - annual extraction of minerals and building materials, physical units and dollar value
  - comparison with total (confirmed) stock available

- physical restructuring and landuse change (appropriate units):
  - damming, dyking, dredging, induced erosion and sedimentation, filling or other modifications of waterways and lakes;
  - shoreline protection (groins, seawalls etc.) and modification such as harbour construction;
  - forest and bushland clearance for agriculture, industry, transportation corridor or settlement development;
  - wetland drainage, excavation, and development;
  - excavation, filling, clearing, or otherwise altering land areas.

- loading of substances, heat, radionuclides, etc. per unit of time and per unit of output/productivity:
  - common and toxic contaminant releases to air, surface water, groundwater, land, and shipmentfrom establishment facilities
  - discharge of phosphorous, nitrogen, and other nutrients

- generation of solid and hazardous waste by volume/weight and type; total and per unit of output/productivity

- frequency and nature of accidents and spills

- imposed biological stresses (appropriate units):
  - changes to wildlife habitat
  - introduction of non-native species (by accident or design)
  - biotechnological applications

- recovery, reuse, and recycling of feedstocks by volume/weight and type

3A.2.4 Success at meeting goals and objectives of policies, regulations and legislation, record of compliance

- record of compliance with environmental and other regulations

3A.3 DOMAIN III
PEOPLE: CORPORATE WELL-BEING

3A.3.1 Financial strength:

- trends in earnings (total and per share)
- shareholder return on investment
- trends in output/productivity
- degree of indebtedness
- credit ratings,

3A.3.2 Research and development:

- priority given
- level and quality of human and other resources allocated

3A.3.3 Employee satisfaction:

- turnover rate
- degree of participation in decision-making

3A.3.4 Operating environment:

- degree the public considers the corporation in a positive light;
- effectiveness of the total regulatory regime;
- effectiveness of the direct and indirect competitive positioning
- management focus - degreee of reactive verses anticipatory planning and implementation
- stakeholder participation in corporate activities and decision-making

3A.3.5 Subjective assessment of operating environment on a scale of 1-10:

- degree to which the public perceives the entity in a positive light
- effectiveness of the total regulatory regime
- degree of positive spin-offs of technological change for the entity
- effectiveness of the direct and indirect competitive positioning of the entity
- management focus of reactive vs. anticipatory planning and implementation
- stakeholder participation

3A.4 DOMAIN IV - SYNTHESIS

3A.4.1 Assessment of the whole; key linkages across the above three domains of data and information

3B. CORPORATE GROUPINGS

3B.1 DOMAIN I - ECOSYSTEM

3B.1.1 Assessment of the integrity and health of the ecosystem with which the sector has direct interaction (natural, modified, cultivated, built)

- air (indoor and outdoor) and climate
    - ambient concentrations of common and toxic contaminants
    - mbient levels of radioactivity
    - emperature
- airborne contaminant deposition to land and water
- inland surface water
    - quality:
    - ambient concentrations of common and toxic contaminants
    - temperature
    - quantity: available supply
- groundwater
    - quality:
        - ambient concentrations of common and toxic contaminants
        - temperature
    - quantity:
        - available supply
        - water levels where applicable
- discharge of groundwater borne contaminants to surface and marine water
- marine waters
    - quality:
        - ambient concentrations of common and toxic contaminants
        - temperature
    - quantity: water levels where applicable
- land
    - rates of soil erosion
    - soil fertility

- biota[2]
    - indicators of species health:
        - population levels and trends
        - birth and survival rates
        - rates of deformities
        - leaf/needle loss
        - increase in the rate of disease prevalence
        - numbers and degree of threatened species
        - concentrations of contaminants in tissue (flora, fauna, humans); enhanced circulation of contaminants and toxic substances and their bioaccumulation in the food web
    - biological diversity:
        - genetic (diversity within a species; composition, structure, function)
        - species (diversity in the number of species; diversity in the size spectrum of biota; composition, structure, function))
        - ecosystemic (diversity in the number of distinct systems; composition, structure, function)
    - changes in mineral macro-nutrient stocks
    - robust food chain supporting the desired biota
    - trends in primary productivity (or yield) in terrestrial systems (reductions signal overstress)
    - adequacy of habitat for desired diversity and reproduction of organisms
    - adequacy nutrient pool for desired organisms
    - adequacy of nutrient cycling to perpetuate the ecosystem
    - adequacy of energy flux for maintaining the trophic structure

- hazards, extreme natural events

3B.2 DOMAIN II - INTERACTION

3B.2.1 Sector profile and benefits contributed:

- direct and indirest employment

- annual value added contributed to the community, provincial, and national economy (dollar and other currencies of measure such as time consumed and land used)

- ratio of jobs and income to output/productivity

- status of ownership and control

3B.2.2 Key expenditures and subsidies: annual expenditures made (fixed and variable) and subsidies received (direct and indirect) by the corporate grouping or sector

- operation and maintenance
- new development:
    - plant
    - product
- environmental protection/stress reduction:
    - operation and maintenance
    - new development:
    - plant
    - product
    - clean up of accidents and spills
    - restoration and/or abandonment
- employee retraining and relocation

3B.2.3 Sectorial assessment of environmental stress, efficiency of resource use,and opportunities for stress reduction/efficiency improvements

- procurement:
    - portion of total materials/parts purchased (dollars) with origin in local community, province, Canada, and foreign
    - assessment on scale of 1-10 of ability of the sector to:
        - reduce use of either the product or the resources the product draws on
        - reduce packaging
        - reuse
        - recycle
- resource use per unit of time and/or unit of output or productivity (to allow assessment of efficiency and opportunities for substitution):
    - value added per unit of resources used
    - energy by end use and form[1]
    - water by volume and end use (including withdrawals, diversions, consumption)
    - hazardous/harmful chemicals by volume and type
    - other feed stocks
    - labour

- harvesting and extraction:
  - annual harvest of renewable resources, physical units and dollar value
  - annual extraction of minerals and building materials, physical units and dollar value
  - comparison with total (confirmed) stock available

- physical restructuring and landuse change (appropriate units):
  - damming, dyking, dredging, induced erosion and sedimentation, filling or other modifications of waterways and lakes;
  - shoreline protection (groins, seawalls etc.) and modification such as harbour construction;
  - forest and bushland clearance for agriculture, industry, transportation corridor or settlement development;
  - wetland drainage, excavation, and development;
  - excavation, filling, clearing, or otherwise altering land areas.

- loading of substances, heat, radionuclides, etc. per unit of time and per unit of output/productivity:
  - common and toxic contaminant releases to air, surface water, groundwater, land, and shipment from establishment facilities
  - discharge of phosphorous, nitrogen, and other nutrients

- generation of solid and hazardous waste by volume/weight and type; total and per unit of output/productivity

- frequency and nature of accidents and spills

- imposed biological stresses (appropriate units):
  - changes to wildlife habitat
  - introduction of non-native species (by accident or design)
  - biotechnological applications

- recovery, reuse, and recycling of feedstocks by volume/weight and type

3B.2.4 Success at meeting the goals and objectives of policies, regulations and legislation; record of compliance

- record of compliance with environmental and other regulations

3B.3 DOMAIN III - PEOPLE: WELL-BEING OF THE CORPORATE GROUPING OR SECTOR

3B.3.1 Financial strength:

- trends in earnings (total and per share)
- shareholder return on investment
- trends in output/productivity
- degree of indebtedness
- credit ratings,

3B.3.2 Research and development:

- priority given
- level and quality of human and other resources allocated

3B.3.3 Employee satisfaction:

- turnover rate
- degree of participation in decision-making

3B.3.4 Operating environment:

- degree the public considers the corporate grouping or sector in a positive light;
- effectiveness of the total regulatory regime;
- effectiveness of the direct and indirect competitive positioning;
- degree of positive spin-offs of technological change for the corporate grouping or sector;
- management focus - reactive verses anticipatory planning and implementation
- stakeholder participation in the activities and decision-making of the sector or corporate grouping

3B.3.5 Subjective assessment of operating environment on a scale of 1-10:

- degree to which the public perceives the corporate grouping or sector in a positive light
- effectiveness of the total regulatory regime
- degree of positive spin-offs of technological change for the entity
- effectiveness of the direct and indirect competitive positioning of the entity
- management focus of reactive vs. anticipatory planning and implementation
- stakeholder participation

3B.4 DOMAIN IV - SYNTHESIS

3B.4.1 Assessment of the whole, key linkages across the above three domains of data and information

4. EXAMPLE INDICATORS OF SUSTAINABILITY FOR COMMUNITY, TOWN, AND CITY DECISION-MAKING

4.1 DOMAIN I - ECOSYSTEM

4.1.1 Assessment of the integrity and health of the ecosystem with which the community has direct interaction (natural, modified, cultivated, built)

- air (indoor and outdoor) and climate
  - ambient concentrations of common and toxic contaminants
  - ambient levels of radioactivity
  - temperature
- airborne contaminant deposition to land and water
- inland surface water
  - quality:
  - ambient concentrations of common and toxic contaminants
  - temperature
  - quantity: available supply
- groundwater
  - quality:
  - ambient concentrations of common and toxic contaminants
  - temperature
  - quantity:
  - available supply
  - water levels where applicable
- discharge of groundwater borne contaminants to surface and marine water
- marine waters
  - quality:
  - ambient concentrations of common and toxic contaminants
  - temperature
  - quantity: water levels where applicable
- land
  - rates of soil erosion
  - soil fertility
- biota[2]

- indicators of species health:
- population levels and trends
- birth and survival rates
- rates of deformities
- leaf/needle loss
- increase in the rate of disease prevalence
- numbers and degree of threatened species
- concentrations of contaminants in tissue (flora, fauna, humans); enhanced circulation of contaminants and toxic substances and their bioaccumulation in the food web
- biological diversity:
- genetic (diversity within a species; composition, structure, function)
- species (diversity in the number of species; diversity in the size spectrum of biota; composition, structure, function))
- ecosystemic (diversity in the number of distinct systems; composition, structure, function)
- changes in mineral macro-nutrient stocks
- robust food chain supporting the desired biota
- trends in primary productivity (or yield) in terrestrial systems (reductions signal overstress)
- adequacy of habitat for desired diversity and reproduction of organisms
- adequacy nutrient pool for desired organisms
- adequacy of nutrient cycling to perpetuate the ecosystem
- adequacy of energy flux for maintaining the trophic structure

- hazards, extreme natural events

4.2 DOMAIN II - INTERACTION

4.2.1 Community profile and benefits contributed

- demographic profile
- activity profile: SIC-related activities, non-market activities, bridging activities:
- articipation rates (unpaid work, leisure contributions), employment (paid work)
- value added by dollar and time currencies
- ratio of jobs and income to output/productivity

4.2.2 Key expenditures and subsidies: annual expenditures made (fixed and variable) and subsidies received (direct and indirect) in the community

- operation and maintenance
- new development:
    - plant
    - product
- environmental protection/stress reduction:
    - operation and maintenance
    - new development:
    - plant
    - product
    - clean up of accidents and spills
    - restoration and/or abandonment
- employee retraining and relocation
- clean-up of accidents and spills

4.2.3 Community assessment of environmental stress, efficiency of resource use, and opportunities for stress reduction, efficiency improvements, and ecosystem restoration

- community procurement:
    - portion of total materials, parts, or consumer products purchased (dollars) by citizens, companies, and government in the community with origin in the community, Ontario, Canada, and foreign
    - assessment on scale of 1-10 of ability of the community to:
    - reduce use of either the product or the resources the product draws on
    - reduce packaging
    - reuse
    - recycle
- overall community resource use per unit of time and/or unit of output/ productivity (to allow assessment of efficiency and opportunities for substitutions):
    - value added per unit of resources used
    - energy by end use and form[3]
    - volume of water by end use (including withdrawals, diversions, consumption)
    - hazardous/harmful chemicals by volume and type
    - other feed stocks
    - labour

* overall community annual harvesting and extraction of renewable and non-renewable resources

- physical restructuring and landuse change (appropriate units):
    - damming, dyking, dredging, induced erosion and sedimentation, filling or other modifications of waterways and lakes;
    - shoreline protection (groins, seawalls etc.) and modification such as harbour construction;
    - forest and bushland clearance for agriculture, industry, transportation corridor or settlement development;
    - wetland drainage, excavation, and development;
    - excavation, filling, clearing, or otherwise altering land areas.

- overall community loading of substances, heat, radionuclides, etc. per unit of time and per unit of output/productivity:
    - common and toxic contaminant releases to air, surface water, groundwater, land, and shipment from the community by residential, transportation, commercial, industrial, and energy producing activities
    - discharge of phosphorous, nitrogen, and other nutrients

- generation of solid and hazardous waste by volume/weight and type; total and per unit of output/productivity

- frequency and nature of accidents and spills

- imposed biological stresses (appropriate units):
    - changes to wildlife habitat
    - introduction of non-native species (by accident or design)
    - biotechnological applications

- recovery, reuse, and recycling of feedstocks by volume/weight and type

4.2.4 Success and meeting the goals and objectives of policies, regulations and legislation, record of compliance.

- compliance with environmental and other regulations

4.3 DOMAIN III
PEOPLE: COMMUNITY WELL-BEING

4.3.1 Characteristics of citizens (see SECTION 2):

- food, nutrition, health, and survival:
  - food and nutrition
  - sleep
  - physical fitness
  - sickness and disease
  - life expectancy
  - mortality: under 5 years old; maternal; untimely deaths
  - characteristics of the health care system: facilities, personnel, program delivery, access
- knowledge, literacy, and education
  - knowledge and literacy levels
  - schooling (formal and informal): types; opportunities; participation rates; government and private support
  - skill development: types; opportunities; participation rates;
  - government and private support
- leisure and recreation:
  - options;
  - participation rates;
  - support organizations;
  - levels of support from public and private sources

4.3.2 Social fabric, cultural attributes and community well-being

- political participation: amount of community participation and control in decision-making
- volunteerism: participation rates in elements of the "civil society" (self-defined non-government organizations)
- degree of poverty:
  - population below the poverty line; numbers of homeless;
  - level and types of social assistance required
- equity: access to services, distribution of income and costs born by citizens
- community: sense of satisfaction and spirit
- dependency: collective self-reliance; economic vitality (employment, income, wealth)

- cultural characteristics/diversity
- cultural interrelationships
- esence of special community features and cultural events leading to community identity and pride
- existence or loss of freedom and openness
- family structure; family break-up
- safety and crime
- social security expenditures

4.3.3 Economic vitality

* levels of business start-ups and bankruptcies
* material wealth, unpaid work, and employment
    - material wealth: annual income; difference between income and expenditures; savings rate
    - unpaid work: types, participation rates, satisfaction
    - employment: types, rates, labour organizations, satisfaction (financial and otherwise)
* construction activity: new, retrofits
* public aid and debt

4.3.4 State of built infrastructure and support systems

* housing (ownership, physical characteristics, surroundings, overcrowding, length of residence, satisfaction, likes and dislikes)
* commercial facilities
* water and sewage
* energy supply
* transportation
* recreation facilities
* overall infrastructure quality: cleanliness; degree of maintenance; life remaining; cost implications short and long term
* public services and programs (health, education, recreation, crime and safety, social welfare)

4.3.5 Overall perception of community well-being, scale of 1-10:

- overall perception of individual well-being
- overall range and quality of available housing
- overall range and quality of available leisure-time activities
- overall quality and availability of health and social services
- overall quality and availability of required built infrastructure, support systems, and other services in the community
- citizen participation in community activities
- degree of satisfaction with community decision-making
- strength of community link to history, culture, and heritage
- overall sense of equity in the community
- overall sense of community social fabric and well- being
- degree of substance and alcohol abuse

4.4 DOMAIN IV - SYNTHESIS

4.4.1 Assessment of the whole, key linkages across the above three domains of data and information

5. EXAMPLE INDICATORS OF SUSTAINABILITY FOR REGIONAL, PROVINCIAL (STATE), TERRITORIAL AND NATIONAL DECISION-MAKERS

5.1 DOMAIN I - ECOSYSTEM

5.1.1 Assessment of ecosystem health and integrity;transboundary implications

- air (indoor and outdoor) and climate
  - ambient concentrations of common and toxic contaminants
  - ambient levels of radioactivity
  - temperature
- airborne contaminant deposition to land and water
- inland surface water
  - quality:
    - ambient concentrations of common and toxiccontaminants
    - temperature
  - quantity: available supply
- groundwater
  - quality:
    - ambient concentrations of common and toxic contaminants
    - temperature
  - quantity:
    - available supply
    - water levels where applicable
- discharge of groundwater borne contaminants to surface and marine water
- marine waters
  - quality:
    - ambient concentrations of common and toxic contaminants
    - temperature
  - quantity: water levels where applicable
- land
  - rates of soil erosion
  - soil fertility

- biota[2]
    - indicators of species health:
        - population levels and trends
        - birth and survival rates
        - rates of deformities
        - leaf/needle loss
        - increase in the rate of disease prevalence
        - numbers and degree of threatened species
        - concentrations of contaminants in tissue (flora, fauna, humans); enhanced circulation of contaminants and toxic substances and their bioaccumulation in the food web
    - biological diversity:
        - genetic (diversity within a species; composition, structure, function)
        - species (diversity in the number of species; diversity in the size spectrum of biota; composition, structure, function))
        - ecosystemic (diversity in the number of distinct systems; composition, structure, function)
    - changes in mineral macro-nutrient stocks
    - robust food chain supporting the desired biota
    - trends in primary productivity (or yield) in terrestrial systems (reductions signal overstress)
    - adequacy of habitat for desired diversity and reproduction of organisms
    - adequacy nutrient pool for desired organisms
    - adequacy of nutrient cycling to perpetuate the ecosystem
    - adequacy of energy flux for maintaining the trophic structure

- hazards, extreme natural events

5.2 DOMAIN II - INTERACTION

5.2.1 Activity profile and benefits contributed

- demographic profile
- activity profile: SIC-related activities, non-market activities, bridging activities:
- participation rates (unpaid work, leisure contributions), employment (paid work)
- value added by dollar and time currencies
- ratio of jobs and income to output/productivity

5.2.2 Key expenditures and subsidies: annual expenditures made (fixed and variable) and subsidies received (direct and indirect)

- operation and maintenance
- new development:
    - plant
    - product
- environmental protection/stress reduction:
    - operation and maintenance
    - new development:
    - plant
    - product
    - clean up of accidents and spills
    - restoration and/or abandonment
- employee retraining and relocation
- clean-up of accidents and spills

5.2.3 Assessment of environmental stress, efficiency of resource use, and opportunities for stress reduction, efficiency improvements, and ecosystem restoration

- procurement:
    - portion of total materials, parts, or consumer products purchased (dollars) by citizens, companies, and government in the region, province (state), territory, or nation with local and foreign origin
    - assessment on scale of 1-10 of ability to:
    - reduce use of either the product or the resources the product draws on
    - reduce packaging
    - reuse
    - recycle
- overall resource use per unit of time and/or unit of output/productivity (to allow assessment of efficiency and opportunities for substitutions):
    - value added per unit of resources used
    - energy by end use and form[3]
    - volume of water by end use (including withdrawals, diversions, consumption)
    - hazardous/harmful chemicals by volume and type
    - other feed stocks
    - labour

- overall annual harvesting and extraction of renewable and non-renewable resources
- physical restructuring and landuse change (appropriate units):
  - damming, dyking, dredging, induced erosion and sedimentation, filling or other modifications of waterways and lakes;
  - shoreline protection (groins, seawalls etc.) and modification such as harbour construction;
  - forest and bushland clearance for agriculture, industry, transportation corridor or settlement development;
  - wetland drainage, excavation, and development;
  - excavation, filling, clearing, or otherwise altering land areas.
- overall loading of substances, heat, radionuclides, etc. per unit of time and per unit of output/productivity:
  - common and toxic contaminant releases to air, surface water, groundwater, land, and shipment from the community by residential, transportation, commercial, industrial, and energy producing activities
  - discharge of phosphorous, nitrogen, and other nutrients
- generation of solid and hazardous waste by volume/weight and type; total and per unit of output/productivity
- frequency and nature of accidents and spills
- imposed biological stresses (appropriate units):
  - changes to wildlife habitat
  - introduction of non-native species (by accident or design)
  - biotechnological applications
- recovery, reuse, and recycling of feedstocks by volume/weight and type

5.2.4 Success at meeting goals and objectives of policies, regulation and legislation, record of compliance.

- compliance with environmental and other regulations

5.3 DOMAIN III - PEOPLE

5.3.1 Human well-being (synthesized from the three previous domains)

* individuals, families, households
* corporations
* communities, towns, cities
* regions, territories, provinces (states)
* nation

5.4 DOMAIN IV - SYNTHESIS

5.4.1 Assessment of the whole, key linkages across the above three domains of data and information

6. SOURCES

Compiled on the basis of literature addressing:

- state-of-environment reporting (see Appendix V) and assessment of ecosystem integrity (for example, Costanza et al. 1992; Herricks and Schaffer 1987);
- environmental statistics (Rapport and Friend 1979; Friend and Rapport 1979; Friend 1991; CES 1993);
- modelling of human - ecosystem interactions (see Appendix VI);
- the determinants of human health (Evans and Stoddart 1990; Hertzman 1990);
- quality of life (Dann 1984; Murdie et al. 1992);
- state of human development (UNDP 1991, 1992, 1993; UNICEF 1993);
- healthy cities (WHO 1987, YUCHS 1990, Hancock 1990a and b, Jacksonville 1992, Sustainable Seattle 1992, and 1993, City of Toronto 1993) and
- corporate reporting (BM 1993, IISD 1992, CICA 1992, Nitken and Powell 1993, I. Taggart 1994, personal communication).

An earlier version of this Appendix is found in Hodge and Taggart 1992.

END NOTES

1. Four energy end use categories are useful to delineate: warmth or"comfort"- mainly low-temperature heating and cooling of air and domestic hot water; process heat - mainly high - temperature heat used in industrial processes; liquid fuels - land, sea, and air transport, as well as other jobs requiring portable energy; and electricity specific - lighting, communications, stationary motors, and other jobs requiring clean, high quality, highly controllable energy. Delineation of these categories allows assessment of whether or not a particular end use is being supplied by the most appropriate form of energy (e.g. electricity, diesel fuel, wood, etc.). See Bott et al. 1983, Chapters 5 and 6, for a good discussion.

2. See Herricks and Schaeffer 1987; Colborn et al. 1990, and Torrie Smith Associates and The Institute for Research on Environment and Economy 1993 amongst many others.

3. See footnote 1. Analysis is required for the following energy sectors: residential, transportation, commercial, industrial, and energy producing activities

APPENDIX IX

1990 ACTIVITY INDICATORS
THE EIGHT GREAT LAKES STATES
AND ONTARIO

CONTENTS

TABLE 1. MINNESOTA ACTIVITY INDICATORS FOR 1990: CONTRIBUTION TO VALUE ADDED AND EMPLOYMENT BY INDUSTRY.

industry	*value added (million $US 1987)*		*employment (thousands)*
GOODS PRODUCING			
farms	3,075		
agriculture services, forestry and fisheries	357		
mining	630		8.21
construction	3,699		79.25
manufacturing	19,633		398.32
	27,394	sub-total	485.78
DYNAMIC AND TRADITIONAL SERVICES			
transportation and public utilities	7,680		108.71
wholesale trade	6,670		125.74
retail trade	8,509		390.94
finance, insurance,and real estate	14,857		124.37
services	14,447		552.49
	52,163	sub-total	1302.25
NONMARKET SERVICES			
federal civilian government	1,728		35.20
federal military	230		
state and local government	7,262		303.17
	9,220	sub-total	338.37
GROSS STATE PRODUCT	**88,777**	**TOTAL**	**2126.40**
HOUSEHOLD CONTRIBUTION TO VALUE ADDED (NOT IN GDP)[1]			
$US millions, 1987	31,516		
CONTRIBUTION TO VALUE ADDED FROM VOLUNTEER ACTIVITIES (NOT IN GDP)[2]			
$US million, 1987	1,980		

Sources: Value Added: Regional Economic Analysis Division, Bureau of Economic Analysis, Washington; Employment: Federal Reserve Bank of Chicago

TABLE 2. WISCONSIN ACTIVITY INDICATORS FOR 1990: CONTRIBUTION TO VALUE ADDED AND EMPLOYMENT BY INDUSTRY.

industry	*value added (million $US 1987)*		*employment (thousands)*
GOODS PRODUCING			
farms	2,696		
agriculture services, forestry and fisheries	423		
mining	139		2.26
construction	3,419		81.01
manufacturing	25,960		559.66
	32,637	sub-total	642.93
DYNAMIC AND TRADITIONAL SERVICES			
transportation and public utilities	7,162		106.31
wholesale trade	5,377		117.78
retail trade	8,200		420.36
finance, insurance,and real estate	14,373		119.86
services	12,974		531.18
	48,086	sub-total	1295.49
NONMARKET SERVICES			
federal civilian government	1,332		30.21
federal military	226		
state and local government	7,173		311.66
	8,731	sub-total	341.86
GROSS STATE PRODUCT	**89,454**	**TOTAL**	**2280.30**

HOUSEHOLD CONTRIBUTION TO VALUE ADDED (NOT IN GDP)[1]	
$US millions, 1987	31,756
CONTRIBUTION TO VALUE ADDED FROM VOLUNTEER ACTIVITIES (NOT IN GDP)[2]	
$US million, 1987	2,084

Sources: Value Added: Regional Economic Analysis Division, Bureau of Economic Analysis, Washington; Employment: Federal Reserve Bank of Chicago

TABLE 3. INDIANA ACTIVITY INDICATORS FOR 1990: CONTRIBUTION TO VALUE ADDED AND EMPLOYMENT BY INDUSTRY.

industry	*value added (million $US 1987)*		*employment (thousands)*
GOODS PRODUCING			
farms	1,762		
agriculture services, forestry and fisheries	345		
mining	830		8.07
construction	4,142		119.32
manufacturing	30,432		634.98
	37,511	sub-total	762.37
DYNAMIC AND TRADITIONAL SERVICES			
transportation and public utilities	9,797		132.03
wholesale trade	5,643		126.53
retail trade	10,326		473.46
finance, insurance, and real estate	13,924		122.79
services	13,390		530.25
	53,080	sub-total	1385.06
NONMARKET SERVICES			
federal civilian government	1,802		46.28
federal military	385		
state and local government	7,143		329.81
	9,330	sub-total	376.06
GROSS STATE PRODUCT	**99,921**	**TOTAL**	**2523.47**

HOUSEHOLD CONTRIBUTION TO VALUE ADDED (NOT IN GDP)[1]
$US millions, 1987 35,472

CONTRIBUTION TO VALUE ADDED FROM VOLUNTEER ACTIVITIES (NOT IN GDP)[2]
$US million, 1987 2,228

Sources: Value Added: Regional Economic Analysis Division, Bureau of Economic Analysis, Washington; Employment: Federal Reserve Bank of Chicago

TABLE 4. MICHIGAN ACTIVITY INDICATORS FOR 1990: CONTRIBUTION TO VALUE ADDED AND EMPLOYMENT BY INDUSTRY.

industry	*value added (million $US 1987)*		*employment (thousands)*
GOODS PRODUCING			
farms	1,582		
agriculture services, forestry and fisheries	547		
mining	1,020		9.26
construction	6,228		139.98
manufacturing	48,244		940.23
	57,621	sub-total	1089.47
DYNAMIC AND TRADITIONAL SERVICES			
transportation and public utilities	13,087		157.10
wholesale trade	10,795		199.33
retail trade	16,257		745.12
finance, insurance, and real estate	26,179		191.12
services	27,555		938.52
	93,873	sub-total	2231.19
NONMARKET SERVICES			
federal civilian government	2,003		61.36
federal military	510		
state and local government	14,839		567.23
	17,352	sub-total	628.57
TOTAL GROSS STATE PRODUCT	168,847	TOTAL	3949.23

HOUSEHOLD CONTRIBUTION TO VALUE ADDED (NOT IN GDP)[1]
$US millions, 1987 59,940

CONTRIBUTION TO VALUE ADDED FROM VOLUNTEER ACTIVITIES (NOT IN GDP)[2]
$US million, 1987 3,765

Sources: Value Added: Regional Economic Analysis Division, Bureau of Economic Analysis, Washington; Employment: Federal Reserve Bank of Chicago

TABLE 5. OHIO ACTIVITY INDICATORS FOR 1990: CONTRIBUTION TO VALUE ADDED AND EMPLOYMENT BY INDUSTRY.

industry	*value added (million $US 1987)*		*employment (thousands)*
GOODS PRODUCING			
farms	1,761		
agriculture services, forestry and fisheries	626		
mining	1,386		17.57
construction	7,681		198.45
manufacturing	55,462		1111.74
	66,916	sub-total	1327.76
DYNAMIC AND TRADITIONAL SERVICES			
transportation and public utilities	17,577		219.69
wholesale trade	12,761		262.83
retail trade	19,593		910.75
finance, insurance,and real estate	30,172		254.87
services	31,790		1195.63
	111,893		sub-total
2843.77			
NONMARKET SERVICES			
federal civilian government	3,476		98.03
federal military	748		
state and local government	14,760		626.19
	18,984	sub-total	724.22
TOTAL GROSS STATE PRODUCT	197,792	TOTAL	4,895.78

HOUSEHOLD CONTRIBUTION TO VALUE ADDED (NOT IN GDP)1

$US millions, 1987	70,217

CONTRIBUTION TO VALUE ADDED FROM VOLUNTEER ACTIVITIES (NOT IN GDP)2

$US million, 1987	4,410

Sources: Value Added: Regional Economic Analysis Division, Bureau of Economic Analysis, Washington; Employment: Federal Reserve Bank of Chicago

TABLE 6. ONTARIO ECONOMIC INDICATORS FOR 1990: CONTRIBUTION TO VALUE ADDED AND EMPLOYMENT BY INDUSTRY[3]

industry	*value added*[4] *(million $1986)*		*employment (thousands)*
Goods Producing			
manufacturing	47,814		966
construction	12,019		324
utilities	5,325		60
agriculture	2,572		138
mining	2,320		35
forestry	537		17
fishing, hunting, trapping	49		3
	70,636	sub-total	1,543
Dynamic and Traditional Services[5]			
finance, insurance,and real estate	34,081		302
commercial, business, and personal services	30,763		727
wholesale and retail trade	22,717		744
transportation , communication and storage	14,240		255
	101,801	sub-total	2,028
Nonmarket Services[6]			
education services	9,438		287
health and social services	7,413		378
federal administration and defense	6,859		158
local administration	2,935		84
provincial administration	2,568		66
	29,213	sub-total	973
GDP AT FACTOR COST	**201,650**	**TOTAL**	**4,544**
GDP AT MARKET PRICES[7]	**228,900**		
HOUSEHOLD CONTRIBUTION TO VALUE ADDED (NOT IN GDP)[8]			
$ millions, 1986	81,300		
CONTRIBUTION TO VALUE ADDED FROM VOLUNTEER ACTIVITIES (NOT IN GDP)[9]			
$ million, 1986	4,500		211

TABLE 7. PENNSYLVANIA ACTIVITY INDICATORS FOR 1990: CONTRIBUTION TO VALUE ADDED AND EMPLOYMENT BY INDUSTRY.

industry	*value added (million $US 1987)*		*employment (thousands)*
GOODS PRODUCING			
farms	1,722		
agriculture services, forestry and fisheries	807		
mining	1,972		27.51
construction	9,779		228.70
manufacturing	44,868		1014.92
	59,148	sub-total	1271.13
DYNAMIC AND TRADITIONAL SERVICES			
transportation and public utilities	21,668		266.37
wholesale trade	13,535		277.37
retail trade	20,708		904.36
finance, insurance, and real estate	38,823		300.23
services	41,941		1450.41
	136,675	sub-total	3198.74
NONMARKET SERVICES			
federal civilian government	5,308		142.62
federal military	882		
state and local government	14,830		564.91
	21,020	sub-total	707.52
TOTAL GROSS STATE PRODUCT	**216,842**	**TOTAL**	**5177.40**

HOUSEHOLD CONTRIBUTION TO VALUE ADDED (NOT IN GDP)[1]

$US millions, 1987 76,972

CONTRIBUTION TO VALUE ADDED FROM VOLUNTEER ACTIVITIES (NOT IN GDP)[2]

$US million, 1987 4,835

Sources: Value Added: Regional Economic Analysis Division, Bureau of Economic Analysis, Washington; Employment: Federal Reserve Bank of Chicago

TABLE 8. ILLINOIS ACTIVITY INDICATORS FOR 1990: CONTRIBUTION TO VALUE ADDED AND EMPLOYMENT BY INDUSTRY.

industry	*value added (million $US 1987)*		*employment (thousands)*
GOODS PRODUCING			
farms	2,771		
agriculture services, forestry and fisheries	875		
mining	1,746		19.78
construction	10,589		218.15
manufacturing	47,793		983.73
	63,774	sub-total	1221.66
DYNAMIC AND TRADITIONAL SERVICES			
transportation and public utilities	24,060		307.70
wholesale trade	19,964		357.74
retail trade	22,246		900.34
finance, insurance, and real estate	45,200		375.46
services	44,750		1340.04
	156,220	sub-total	3281.28
NONMARKET SERVICES			
federal civilian government	4,404		113.57
federal military	1,413		
state and local government	16,363		648.80
	22,180	sub-total	762.38
TOTAL GROSS STATE PRODUCT	242,174	TOTAL	5265.32

HOUSEHOLD CONTRIBUTION TO VALUE ADDED (NOT IN GDP)[1]

$US millions, 1987 — 85,972

CONTRIBUTION TO VALUE ADDED FROM VOLUNTEER ACTIVITIES (NOT IN GDP)[2]

$US million, 1987 — 5,400

Sources: Value Added: Regional Economic Analysis Division, Bureau of Economic Analysis, Washington; Employment: Federal Reserve Bank of Chicago

TABLE 9. NEW YORK ACTIVITY INDICATORS FOR 1990: CONTRIBUTION TO VALUE ADDED AND EMPLOYMENT BY INDUSTRY.

industry	*value added (million $US 1987)*		*employment (thousands)*
GOODS PRODUCING			
farms	1,417		
agriculture services, forestry and fisheries	925		
mining	457		5.39
construction	15,850		314.28
manufacturing	60,963		1131.17
	79,612	sub-total	1450.84
DYNAMIC AND TRADITIONAL SERVICES			
transportation and public utilities	37,906		428.29
wholesale trade	29,311		465.95
retail trade	33,687		1218.85
finance, insurance, and real estate	101,855		777.01
services	87,951		2395.85
	290,710	sub-total	5285.95
NONMARKET SERVICES			
federal civilian government	5,862		168.68
federal military	1,249		
state and local government	38,494		1303.21
	45,605	sub-total	1471.88
TOTAL GROSS STATE PRODUCT	**415,927**	**TOTAL**	**8208.65**

HOUSEHOLD CONTRIBUTION TO VALUE ADDED (NOT IN GDP)[1]	
$US millions, 1987	147,654
CONTRIBUTION TO VALUE ADDED FROM VOLUNTEER ACTIVITIES (NOT IN GDP)[2]	
$US million, 1987	9,275

Sources: Value Added: Regional Economic Analysis Division, Bureau of Economic Analysis, Washington; Employment: Federal Reserve Bank of Chicago

END NOTES

1. This estimate of the value added of household work in the eight Great Lakes states is based on the work undertaken by Statistics Canada for the ten provinces of Canada. It is calculated using a figure of 35.5 percent of gross state product. See end note 8.

2. This estimate of the value added of volunteer activities is based on figures for Ontario developed byStatistics Canada. It is calculated using a figure of 2.23 percent of gross state product. See end note 9.

3. Because of the variety of data sources, figures must be considered rough estimates. However, they are useful for indicating relative contributions.

4. Conference Board (1991) estimates unless otherwise noted.

5. The service sector structure is from Betcherman et al. 1991.

6. Value added figures for nonmarket services are estimated from both Conference Board 1991 and Statistics Canada 1990b.

7. Ontario Office of Economic Policy 1992.The difference between this figure and the total of contributions to value-added by the various components above is accounted for by the addition of indirect taxes minus subsidies.

8. The most recent estimates of the value of household work (VHW) in Canada are given by Jackson 1992. Using both opportunity cost and replacement cost valuation methods, he estimates that the VHW in Canada ranges from 32 % to 39 % of GDP. The figure in Table 8 is simply the average of these percentages applied against the 1990 GDP figure. VHW is not included in calculation of GDP.

9. D. P. Ross 1990. Economic Dimensions of Volunteer Work in Canada. Ross estimates the economic value of volunteer activities in 1986/1986. The figure for value added used in these tables has been modified upward slightly to approximate 1990 conditions. For example, figures for Ontario were adjusted from $4.2 to $4.5 billion. This later represents 2.23 percent of gross provincial product. This proportion was used to generate the figures for the eight Great Lakes states.

   The figure in the employment column (Ontario only) is Ross's estimate of volunteer hours as full-time equivalent positions. For Ontario, this represents 5.3 % of all full time employees.