SUSTAINING ENGINEERING: RATIONALE AND DIRECTIONS FOR PREPARING ENGINEERS FOR SUSTAINABLE DEVELOPMENT

by

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ABSTRACT

This thesis offers a rationale and directions for preparing engineers to meet the challenges of sustainable development. More specifically, this study (a) examines various interpretations of sustainable development and articulates a defensible interpretation of its meaning and requirements; (b) investigates the current status of the engineering profession as it pertains to sustainable development; (c) identifies gaps in engineers' knowledge, skills and practices which have implications for engineers' role and effectiveness in sustainable development; and (d) proposes and justifies directions for change in the practice and education of engineers in Canada.

The study proceeds by reviewing the literature of sustainable development, describing the landscape of sustainable development and different perspectives arising out of the tensions between the economy and the environment. This review yields a reasonable and comprehensive interpretation of sustainable development including its goals and basic principles. Subsequently, the study examines the alignment between ideals of sustainable development and engineering.

Next this investigation examines B.C. engineers' current understandings of sustainable development by focussing on engineers' perceptions of (a) the meaning of sustainable development, (b) their roles and responsibilities for sustainable development, (c) knowledge and skill requirements for sustainable development, and (d) adequacy of current knowledge, skills and practices. Other studies of engineers, bearing on the requirements of sustainable development, are drawn upon to enrich understanding of current knowledge, skills and practices.

When compared with the ideals, the findings reveal that engineers' knowledge, skills and/or practices for sustainable development are deficient in a number of areas. Deficiencies include knowledge of contexts, environmental sciences, social sciences; interpersonal, communication and group process skills; education and training. Recommendations for overcoming these deficiencies and better preparing engineers for sustainable development focus on a) increasing engineers' awareness and understanding of sustainable development; b) improving knowledge and skills; and c) improving or developing organizational and educational support.

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TABLE OF CONTENTS

List of Tables

List of Exhibits

List of Figures

List of Abbreviations

APEGBC	Association of Professional Engineers and Geoscientists of B.C.
ASCE	American Society of Civil Engineers
BCRTEE	British Columbia Round Table on Environment and Economy
BCTFEE	British Columbia Task Force on Environment and Economy
CCPE	Canadian Council of Professional Engineers
CEAB	Canadian Engineering Accreditation Board
CEI	Consulting Engineering Industry (referring to HRDC study)
CEQB	Canadian Engineering Qualifications Board
Co-op	Cooperative Education
CORE	Commission on Resources and Environment
CPA	Center for Policy Alternatives
DSP	Dominant Social Paradigm
EIT	Engineer in Training
EPC	Engineering, Procurement and Construction
EPTA	Expanded Programme of Technical Assistance
FAO	Food and Agriculture Organization of the United Nations
HRDC	Human Resource Development Canada
IEEP	International Environmental Education Programme
IKS	Interdisciplinary knowledge and skills
IUCN	International Union for Conservation of Nature and Natural Resources
MSWG	Multi-Stakeholder Working Group on Pulp Mill Regulation in B.C.
NABC	North American Bioregional Congress
NCDEAS	National Committee of Deans of Engineering and Applied Sciences
NEP	New Environmental Paradigm
NGO	Non-governmental Organization
NRTEE	National Round Table on the Environment and Economy
NTFEE	National Task Force on Environment and Economy
SFU	Simon Fraser University
TQM	Total Quality Management
UBC	University of British Columbia
UNCED	United Nations Conference on Environment and Development
UNESCO	United Nations Education, Scientific and Cultural Organization
UNEP	United Nations Environmental Program
VPR	Vancouver Parks and Recreation
WCED	World Commission of Environment and Development
WCS	World Conservation Strategy
WEPSD	World Engineering Partnership for Sustainable Development

CHAPTER 1

BACKGROUND AND STATEMENT OF THE PROBLEM

> Moscow, December 1986. A group of people gather around a hotel conference table to consider the nearly final draft of a report on environment and development they have worked on for three years. A discussion of the first chapter opens, someone suggests adding a question mark to the working title of 'A Threatened Future'. The debate on that idea does not last long. All assembled agree, with good cause, that our future is undeniably threatened. (Starke, 1990, p. 1)

The report Starke refers to was published five months later as Our Common Future (World Commission on Environment and Development [WCED hereafter], 1987). Although the ideas of 'sustainable development' and 'sustainability' predates it, this report in particular popularized the idea as the needed response to threats to our future. The WCED defines sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987, p. 43). Although the WCED report focusses particularly on the environmental, economic and social problems and their interconnectedness, it is clear that the concept of sustainable development embraces technical, organizational, political and cultural problems as well.

The premise of both the WCED report and this study is that a good quality of life on earth in the future depends on humans making changes in their relationships with each other and with the biosphere upon which they depend. Since popularized by the WCED, 'sustainable development' has become the subject of much discussion and debate largely because it requires fundamental changes in the mediation between humans and between humans and Earth at multiple levels: ideological, attitudinal, behavioral; individual, professional, organizational; local, national, global. In essence, 'sustainable development' invokes a paradigmatic contest between the "dominant social paradigm" and a "new environmental paradigm" (Dunlap & Van Liere, 1984; Kuhn & Jackson, 1989; Milbrath, 1981).

The "dominant social paradigm" (DSP) or "human exceptionalism paradigm" (Catton & Dunlap, 1978) is anthropocentric, expansionist, technocratic and mechanistic; it includes, for example, the assumption that humans have dominion over nature, belief in limitless economic and technological growth, faith that market systems and technology can ensure stability and equilibrium. The "new environmental paradigm" (NEP), fueled by recent additions to knowledge and events that contradict ideas of the DSP, is biocentric and holistic. The NEP incorporates such ideas as that interdependency exists among species (where humans are but one species) and the natural environment, there are physical and biological limits to economic growth, existing economic systems are problematic, and human activities must change to achieve balance. Tensions between the DSP and NEP thus stem from different ideas about growth, technology, quality of life, relations between humans and the environment, and limits to the biosphere. Although these tensions have simmered for many years, sustainable development brings them to the forefront.

The context and contests of sustainable development have elicited various technological and other product and process 'solutions.' Since technology is popularly considered the primary domain of engineers, and since engineering involves both mediation between humans and Earth and mediation between humans as with, for example, transportation and communication, it is reasonable to expect engineers to contribute to the conceptualization and operationalization of sustainable development. As of 1990, however, the voice of professional engineers was largely absent from discussions about sustainable development. Ideally, engineers' contributions to sustainable development will arise out of (a) an awareness and understanding of the meaning and requirements of sustainable development; (b) well-developed technical skills and non-technical skills such as communication, collaboration and facilitation) skills; and (c) commitment to action. The effectiveness of engineers' contributions, may, however, be restricted by weaknesses in particular knowledge, skills and practices, hence raising questions about the ways engineers' education and work experiences/practices prepare them to address sustainable development.

Both the influence of technology and breakdowns in life support systems are increasing; although not always the case, technology can influence the health of life support systems. Given engineers' specialized technical knowledge and expertise, and given that many issues incorporated by the call for sustainable development involve engineers (e.g., waste management, energy efficiency, pollution prevention, human health, urban and rural planning, forestry, agriculture, impact assessment), engineers are in a unique position to act effectively in determining the nature and degree of application of technologies consistent with the aims of sustainable development. This dissertation provides a rationale and directions for preparing engineers for sustainable development by investigating the idea of sustainability/sustainable development and the status of the engineering profession regarding sustainable development.

Statement of the Problem

Technological solutions are increasingly sought for many of the problems to be addressed by sustainable development. Since virtually all applications of technology are formulated, developed, controlled, supervised or monitored by professional engineers, engineers need to fully understand, and actively participate in achieving, sustainable development to ensure that engineering solutions are consistent with its aims. It is not clear, however, that engineers are prepared -- aware, able and willing -- to respond to the call for sustainable development. Further, it is not clear how engineers' understanding, support and acquisition of competencies for sustainable development are or can be facilitated. Ensuring engineers are prepared to address sustainable development requires attention to the following kinds of problems: there is uncertainty about the meaning and means of sustainable development; engineers' responsibilities and knowledge and skills needs for sustainable development are not well articulated; and there is a lack of support and/or direction for responding to changing needs.

1. There is uncertainty about the meaning and means of sustainable development. 'Sustainable development' is a complex idea intended to address a number of problems and difficult issues (e.g., economic, political, environmental, social, cultural). Although the WCED's definition may seem clear (at least as a broad goal), the definition has come under attack from various quarters, the concept itself is inadequately articulated and variously interpreted, and the means for achieving sustainability are poorly understood. The role of technology has received explicit as well as implicit attention: both hopes (technology will help solve problems) and fears (technology caused many problems) often focus on technology. The different viewpoints such hopes and fears represent, as well as the different viewpoints of economists, political scientists, environmentalists, sociologists and others who study our technological society

(viewpoints reflected in meanings attributed to sustainable development), point to the difficulty in framing any coherent objectives or plans of action.

2. Engineers' responsibilities and knowledge and skill needs for sustainable development are not well articulated. Engineering policies and/or codes of ethics and engineering practice that reflect concerns for sustainable development have been or are being developed;[1] strategies for meeting new obligations and responsibilities, and mechanisms to respond to failure, however, are less well developed if they exist at all. Further, my initial findings[2] suggest that practising engineers lack specific kinds of knowledge and skills required to effectively contribute to sustainable development -- for instance, knowledge/skills related to communication (writing, speaking, listening), collaboration (interpersonal and facilitation skills), conflict resolution (mediation and public relations).

3. Lack of support and/or direction for responding to changing needs. The change in engineers' obligations and responsibilities -- along with reports by practising engineers and people who work with them -- challenge engineering educators to incorporate complex and diverse areas of expanding knowledge and skills sets into engineering programs. Both the Canadian Engineering Accreditation Board (CEAB hereafter) and the Canadian Engineering Qualifications Board (CEQB hereafter) provide definitions and requirements to clarify the knowledge and skill areas engineering programs must include. Nonetheless, requirements are often vague calls for "awareness" and "understanding", some studies indicate that such mandated requirements to date have received only limited support,[3] and practising engineers' reports indicate that, while an understanding of sustainable development is necessary, it is insufficient to assist engineers to contribute more significantly to the discussion and resolution of sustainable development issues. Further, some engineering faculty members are indifferent to or unconvinced of the need to change programs substantively; others, along with many students, are overwhelmed by the idea of adding more to an already burgeoning curriculum. Overall, it is not yet clear how engineering education programs may better prepare students and practitioners to fulfil professional obligations and responsibilities inclusive of sustainable development.

Intentions of the Study

The primary intention of this study is to provide a rationale and directions for preparing professional engineers for sustainable development. More specifically, the purposes of this study are:

1. To examine various interpretations of sustainable development and to more adequately articulate a defensible interpretation of the meaning and requirements of sustainable development;

2. To investigate the current status of the engineering profession as it pertains to sustainable development (responsibilities, understanding, skills, practices);

3. Based on 1 and 2, to identify gaps or weaknesses in engineers' knowledge, skills and/or practices that have implications for engineers' role and effectiveness in implementing sustainable development; and

4. To propose and justify directions for change in professional engineers' education and practice.

Assumptions

The valuing of life and a desire for a good quality of life are preconditions to accepting the idea of sustainable development and, therefore, both the value and the desire are assumptions implicit in this study. Additional assumptions include:

1. Sustainable development is a reasonable strategic response to threats to our future; further, it is a growing concern that warrants the attention given to it in this study;

2. Engineers are well-placed to address and take leadership regarding issues inherent to sustainable development and they are, and will increasingly be, obligated to do so;

3. Engineers are more than technical job-holders; their designation as professionals obligates them (among other things) to provide quality service and to take responsibility for their actions[4];

4. Engineering codes of ethics and codes of engineering practise are intended to define and describe the obligations and responsibilities of professional engineers and guide professional engineering practice; and

Approach and Methods

The overarching approach used in this study follows from Dearden's (1975) criteria for identifying and justifying needs and interventions. He states:

> ... first, that there should be some kind of norm, for example a standard of living, the 'proper functioning' of a thing, an explicit rule or a notion of what it is to do something properly or efficiently. Secondly, there is the matter of fact that this norm has not been achieved, or could well fail to be maintained . . . If we wish to go beyond saying that someone is 'in need' to saying what exactly it is that is needed, in order to measure up to the norm or standard implied, then a third criterion must be satisfied, namely that what is said to be needed really must be the relevant condition for achieving what the norm prescribes. (p. 51)

Building on Dearden's logical points, a three-step model is here used to apply the concept of need. Rephrased, step one is to define some acceptable standard or norm; step two is to identify deficits in the current state; and step three is to define actions that target deficits and bring conditions more in line with the norm.

Based on Dearden's examples of a "norm," I take it that goals, ideals or requirements, that is, notions of what is to do something properly, can constitute a "norm" or "standard." In this study, step one is represented by (a) the ultimate goal of sustainable development, its requisite conditions (economic, environmental and social health), and the processes required to achieve sustainable development,[5] and (b) the goals, obligations and ideals of the engineering profession. Together, the goals and ideals of sustainable development and professional engineers represent the "standard" by which engineers' current status with respect to sustainable development is assessed. Step two consists of an investigation of the current status of engineering as it pertains to sustainable development, and the identification of current deficits or weaknesses in, for example, responsibilities, knowledge, skills, and practices. The third step is to propose and justify a number of recommendations intended to facilitate achievement of the ideal states defined in step one. The methods used in this study are summarized below and described in more detail in the following chapters.

Step 1: Articulating "Standards"

To begin, I undertook a conceptual study of the idea of sustainable development. This study includes an investigation into the origin and history of the terms "sustainability" and "sustainable development." By way of library subject and title word searches, the idea of sustainable development is traced over time and actor networks (e.g., those involved in agriculture, international development, energy production, environmental issues, economics). Materials turned up by these searches, especially various commission and task force reports, policy documents, and focussed discussion papers on sustainable development, are the primary sources of information about (a) the goals of sustainable development, (b) the essential issues that need to be considered, and (c) the main values and beliefs embedded in various interpretations of sustainable development.

Concern was not that the list of sources be exhaustive; rather, the key was to turn up enough redundancy to indicate that the list of issues was relatively complete and that there was some degree of agreement about beliefs and values. Authors often differ in the ways they conceptualize, weight or cluster values in terms of sustainable development and, therefore, in the actions they propose; in some cases, the differences lead to seemingly conflicting interpretations of sustainable development. To determine a reasonable interpretation of sustainable development, consequences of certain interpretations are highlighted and set against the goals of sustainable development to assess interpretations' relative strengths and weaknesses. The core defining elements (substantive principles) of sustainable development are described along with supportive elements (process principles) without which sustainable development would be difficult if not impossible to achieve. Together with the ultimate goal of sustainable development, the two sets of principles represent the goals, ideals and basic requirements of sustainable development and constitute a "standard."

Policy documents of the Canadian Council of Professional Engineers[6] (CCPE hereafter) are intended to define and guide the practice of professional engineering in Canada. They describe the goals and requirements of professional engineering practice and the obligations of professional engineers; in sum, they provide a picture of the ideal to which professional engineers are to aspire. The contents of these documents (e.g., definition of professional engineering, codes of engineering ethics and practice, qualification requirements) provide the primary resource for defining the "standards" for professional engineers.[7] Further support for the standards is drawn from recent documents providing guidelines for engineers and sustainable development. (Findings of the study of B.C. engineers' perceptions of their roles in and responsibilities for sustainable development (highlighted below and described more fully in Chapter 3) lend support to the standards obtained from policy documents.) The alignment between sustainable development's and professional engineers' standards forms a new "standard" by which the current status of the engineering profession, as it pertains to sustainable development, is assessed.

Step 2: Determining the Current Status of the Canadian Engineering Profession

The investigation of the current status of the engineering profession is confined to those areas of responsibility, knowledge, skills, and practices which pertain to the goals and ideals of sustainable development. A study of the members of the Association of Professional Engineers and Geoscientists of B.C. (APEGBC hereafter) was undertaken to provide an indication of the current status of professional engineers with respect to sustainable development (the study is described in detail in Chapter 3). Central to this investigation were questions about the meaning engineers attribute to sustainable development, how they define their roles and responsibilities regarding sustainable development, and the degree to which they feel able to contribute to discussion and resolution of sustainability issues they identify as key. Survey questionnaires, interviews and focus groups were used to obtain information; survey results, audiotape transcriptions and summaries of focus groups and interviews constitute the study's primary 'data.' Information collected was categorized by topic area such as, for example, meaning or responsibilities, coded by issue and/or theme, and assessed for frequency of occurrence and degree of agreement among participants. Information from the study leads to tentative conclusions about engineers' current awareness and understanding of sustainable development, their willingness to respond to sustainable development, and their ability to do so.

Aside from the investigation described here, only one other study (Vanderburg, 1991, 1992) was found to have directly investigated engineers' preparedness to address sustainable development; that study focussed on the contents of the undergraduate engineering curriculum. As a result, I draw on commentaries and studies that involve engineers and have bearing on particular requirements of sustainable development to enrich our understanding of the current knowledge, skills and practices, and to lend credence to the findings of the APEGBC study. Collectively, information from the APEGBC study and from commentaries and studies in the literature, when compared to ideal standards, provide the basis for conclusions about the current status of engineers regarding sustainable development.

Step 3: Recommending Changes

Following from deficiencies the study reveals, I offer a number of recommendations for change. The recommendations are not intended to exhaust all possible change or improvement initiatives; in fact, in some cases, further research is required to determine what kinds of specific approaches are most effective in what kinds of contexts. Recommendations offered include both general and specific suggestions for moving current conditions toward the ideal; some directions for further research are also suggested. Theoretical and practical (where available) justifications for the recommendations are provided.

Limitations

This study is limited to the broad ideals and requirements captured in the discussion of sustainable development; it does not attend to narrower ideals such as the ability to use growth and decay models for analyzing ecosystems, expertise in total cost accounting or other specialized forms of scientific/technical knowledge.

The standards of the engineering profession are determined primarily from CCPE policy documents. Although, where relevant and appropriate, some evidence supporting this study is drawn from sources outside Canada, the study is limited to the Canadian context.

Practicing engineers' self-perceptions of their preparedness to address sustainable development (in terms of responsibilities for and understanding of sustainable development, available knowledge/skills, and current practices) was obtained through the voluntary participation of 600 of the 14000 members of the APEGBC. Although some of the evidence provided by this study is substantiated by other studies, the APEGBC study is limited by the voluntary nature of this study and the fact that the B.C. context may be quite different from other Canadian contexts.[8] Most particularly, the meaning participants attribute to sustainable development should not be generalized to the general population of engineers in Canada.

Definition of Terms

Cooperative education (Co-op). This refers to programs in which students are placed with employers for varying periods of practical experience.

Cooperative learning. This refers to an active learning pedagogy which encourages student participation through student-student interactions and small group interactions (Bellamy, 1994).

Engineer. In this paper, all references to "engineer" refer to professional engineers (see *Professional Engineer).*

Equity. As in the WCED (1987) report, the term "equity" here has its common meaning of fairness or justice. The term does, however, have specific legal and economic meanings. For example, Daft (1991) defines equity as "A situation that exists when the ratio of one person's outcomes to inputs equals that of another's" (p. 410).

Principles. This paper contains discussion of general "principles" of sustainable development and professional engineering. In the sustainable development literature, similar ideals and requirements for sustainability/sustainable development are variously referred to as "principles," "themes," "pre-requisites," "requirements", and "priorities." Most of the primary policy documents referred to, however, use the term "principles" (e.g., APEGBC Task Force, 1992; BCRTEE, 1990, 1992; Environment Canada, 1990b; WCED, 1987). Concerning engineering, the CCPE outlines a series of "guiding principles" which "form the basis and framework" for responsible professional engineering practice. In sum, the term "principles" is commonly used to discuss ideals and requirements of sustainable development and engineering. In this paper, therefore, "principles" refer to basic tenets intended to define and guide right action; they are used to represent goals, ideals and requirements of sustainable development and engineering.

Professional engineer. A professional engineer is one who engages in activity that "requires the application of engineering principles and that concerns the safeguarding of life, health, property, economic interests, the public welfare or the environment" (CCPE-CEQB, 1992, p. 16). Professional engineers are distinguished from others involved in engineering by the fact that they are members of profession which, "like all professions, are "founded upon four cornerstones: service, a body of knowledge, a standard of conduct, and the authority to regulate those who would practice" (Britton & Laliberte, 1987, p. 20). Professional engineers are responsible for the consequences of their actions. In Canada they are registered with and licensed by a provincial or territorial association of professional engineers responsible for the regulation of engineers practicing within their jurisdictions. Professional engineers in Canada are expected to have met the qualification requirements set out by the licensing body in accordance with guidelines established by the Canadian Council of Professional Engineers.

Sustainability/Sustainable Development. The terms "sustainability" and "sustainable development" are both used in the literature; sometimes they are used interchangeably. In the sense that both terms (as used in the literature) emphasize human dependence on the environment and incorporate the goal of achieving balance between human activity and Earth's capacity to renew itself, it is reasonable to use the terms interchangeably. There are, however, debates about what the terms mean and which terms most adequately represent both the goals and concerns to be addressed in achieving the goals. Some extended discussion of the terms is therefore warranted.

Some people prefer to use the term "sustainability" on the grounds that it provides a "clearer message" (BCRTEE, 1992, p. 11) evolving out of the idea of sustainable development (BCRTEE, 1993a); others criticize continued reference to sustainability on the grounds that it is vague (ability to sustain what?), obscures the contradictions development implies for the environment, or that it focusses too strongly on environmental issues to the exclusion of economic and social factors (Redclift, 1992). Some people choose to focus more specifically on the term "sustainable development" in recognition that "development is needed – development that has been examined so that its effects are recognized, development that is sustainable or is the best compromise towards sustainability" (APEGBC, 1992, p. 5). The term has been criticized, however, for "being open to a wide range of interpretations, many of which are contradictory" (BCRTEE, 1992, p. 11); merely putting a new guise on the traditional economic development paradigm by tying it to the environment; and continuing to obscure structural and cultural limitations to the idea of sustainability (Redclift, 1992; Sachs in Durbin & Nieto, 1993; Shiva, 1989).

Although I empathize with those who prefer "sustainability," I believe it is useful to distinguish the two terms; in fact, distinctions are already revealed by the debates about terminology (e.g., "development . . . *towards* sustainability"). In this paper, therefore, both terms incorporate the idea of achieving conditions whereby resource consumption and waste production do not exceed nature's productive and absorptive rates (Wackernagel, 1993) but sustainability will refer to and directly represent the goal, and sustainable development will refer to the means for achieving the goal.

> ***Sustainability***: Sustainability is the achievement of sustainable conditions, that is, conditions where resource consumption and waste production do not exceed nature's productive and absorptive rates. It represents a vision for the relationship between humans and the environment.
>
> ***Sustainable development***: This term was popularized and defined by the WCED as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987, p. 43); it is the proposed means by which sustainability can be achieved and in that sense is a pre-condition for both sustainability and future human health and well-being.

Sustainable development is an agenda focussed on resolving environmental, economic and social issues involved in achieving sustainability. Further, by focussing on *sustainable* development, it is intended to restore both complexity and balance to discussions of development.

Overview of Chapters

This chapter has introduced the problem to which the study responds, defined the study's intentions, underlying assumptions, terms and limitations, and briefly described the research approaches. The chapters which follow deal directly and more fully with these aspects.

The primary purpose of Chapter 2 is to establish the goals, ideals and requirements, that is, the "standards," of sustainable development and the engineering profession. The first part of Chapter 2 focusses on sustainable development by reviewing the evolution and use of the term, describing the ultimate goal, examining various interpretations of sustainable development, and articulating a number of sustainable development principles. Together with the overarching goal, the principles represent the "standards" for sustainable development. The second part of Chapter 2 describes how the engineering profession's standards are aligned with those of sustainable development.

Chapter 3 turns to the current status of professional engineers regarding sustainable development. The chapter describes the conduct and findings of the APEGBC study, and discusses other studies and commentaries. Together, these provide evidence of current conditions of the engineering profession as it pertains to sustainable development.

In Chapter 4, conclusions are drawn from evidence provided in Chapter 3. Implications these conclusions have for the profession and sustainable development are discussed.

Chapter 5 includes recommendations for overcoming current deficits in engineers' ability to respond effectively to concerns of sustainable development. Suggestions are made for future research and the dissertation is summarized.

Endnotes

1. These efforts are continuing and, in fact, the study has facilitated and contributed to the changes. For example, one outcome of the study was the formulation, by the Association of Professional Engineers and Geoscientists of B.C., of Sustainable Development Guidelines for Engineers and Geoscientists to which the investigator also directly contributed.

2. Initial findings are based on literature reviews, comments of employers of engineering personnel, researcher observations, and engineers' self-reports.

3. For example, based on a detailed study of undergraduate engineering curriculum at the University of Toronto and on comparisons with curricula at other Canadian engineering faculties, Vanderburg (1992) claims that "students learn very little about how to use knowledge of the way technology affects human life, society and nature to adjust engineering methods and approaches to ensure the greatest possible compatibility between technology and its context" (p. 822). Further, he suggests that "the next generation of engineers is not in a good position to make a significant contribution to the development of a more sustainable way of life" (p. 825).

4. That service is an essential element of a profession is reflected in numerous writings. For example, Britton and Laliberte (1987) state that "various authors have argued, and we agree, that all professions are founded upon four cornerstones: service, a body of knowledge, a standard of conduct, and the authority to regulate those who practice. If these four conditions exist, a profession exists. If but one is missing, [it is] ... not a profession ... Professionalism demands responsibility" (p. 20).

5. Dearden (1975) describes a number of conditions under which needs become defined. For example: (a) where "a state of affairs conceived of is absent... and this absence *ought not* to exist"; (b) "where an explicit rule creates a need"; (c) where needs arise out of "norms of *proper functioning*"; and (d) where "something is needed, not in order to attain a social standard, properly fulfill a function or satisfy a rule, but in order to achieve a particular purpose" (pp. 50-51; italics in original).

6. The CCPE is "the federation of Provincial and Territorial associations of Professional Engineers which license engineers and regulate the practice of engineering across Canada" (CCPE-CEQB, 1994, p. 2). Documents generated by two of CCPE's primary boards, the Canadian Engineering Qualifications Board (CEQB) and the Canadian Engineering Accreditation Board (CEAB) are those used in this study. Both boards consist of professional engineers drawn from the private, public and academic sectors. Regional representation and representation from a wide range of engineering disciplines is provided for. The CCPE-CEQB documents are consensus documents resulting from several iterations of discussion papers developed and reviewed by the CEQB, its sub-committees and task forces, provincial and territorial associations, and the CCPE Executive Committee. The CCPE-CEQB provides national guidance to the constituent associations on matters relating to professional

qualifications. It acts in concert with the CEAB which is responsible for the accreditation of engineering educational programs in Canada and for other educational issues.

7. In establishing the "standards" of professional engineers, no distinction is made between CCPE and its constituent associations. Legislative and disciplinary authority for administering standards resides with provincial and territorial associations; "standards" may vary across these associations.

8. For instance, the B.C. economy is resource-based and largely dependent on forestry and mining. Further, environmental issues and regulations have generated a great deal of conflict and, as a result, have commanded a lot of media attention. In addition, among the Round Tables established in Canada to investigate and foster sustainable development, the B.C. Round Table on Environment and Economy (BCRTEE) has been identified as one of the most active and productive Round Tables in Canada. The activities of the BCRTEE included, for example, extensive consultation with various stakeholders and experts; research on environmental and economic conditions and strategies; investigation of alternative approaches to conflict resolution; and preparation of background papers on such things as decision processes and analytical methods for land allocation, air quality issues, waste management issues, resource accounting, and energy development processes. Given the BCRTEE's extensive work, the large numbers of people involved, and the fact that reports were widely distributed (in draft or completed form) to various stakeholders and experts, and the central importance of resources in B.C., people in B.C. may be more aware of and sensitive to sustainability issues than people in other regions.

CHAPTER 2

SUSTAINABLE DEVELOPMENT AND PROFESSIONAL ENGINEERS: GOALS, IDEALS AND REQUIREMENTS

> My thesis . . . is that our culture is undergoing, and is in need of, a major paradigm shift . . . We need unifying insights capable of enabling us better to understand human and ecosystem processes. (Drengson, 1980, p. 225)

> We must find a better way of harmonizing economic development with the environment, and yet still build a better society for ourselves and for those who come after us. (BCRTEE, 1990, p. 5)

We are witnessing multiple crises arising out of human-human and human-non-human relations. Morgan (1989) highlights a number of trends related to such inter-related crises as, for example, the crisis in environmental systems (e.g., environmental degradation, depletion of resources, increasing risk of major environmental disaster), in social systems (e.g., high unemployment and drop-out rates, changing social values, worldviews, role of marginalized groups), in eco-political systems (e.g., multi-nationals as political forces, global debt, trade relations) and in traditional sectors of industry and agriculture (e.g., labor costs, economic recession, work force competence, low capacity for organizational change). Awareness of the complex and interrelated environmental, economic and social problems in our world is increasing; the debate no longer focusses on whether changes are necessary but about what kind of changes are needed and how they can be carried out. The ideas of 'sustainable development' or 'sustainability' have been claimed as guides for action.

The meaning and goals of sustainable development, however, are not always clear. Meanings reflecting different emphases (e.g., environmental, social or economic) have led to confusion and debate about the focus of sustainability. Goals often seem to be in conflict (e.g., environmental and economic). Further, suggested approaches for sustainable development often reflect narrow-interests or are so context-bound that they only add to the confusion. This chapter investigates the landscape of sustainable development by (a) tracing the development of the concept from the seed of the idea through to current use, (b) more clearly defining the goals, (c) examining alternate interpretations of sustainable development, and (d) identifying a number of primary principles that help to define and guide efforts toward sustainability.

Sustainable development will serve as an effective guide for action only if there is a a better understanding of the goals of sustainable development and the kinds of activities which contribute or interfere with achievement of these goals. Detailed knowledge of the impacts of activities will be crucial to decision-makers at all levels and most particularly to those most actively engaged in reshaping our world through the technological products and processes they design. In the final part of this chapter, the ways sustainable development goals and ideals align with the goals and ideals of professional engineers are discussed. Based on the alignments, it is suggested that the goals and ideals of sustainable development and those of the engineering profession are consentient, and that professional engineers are professionally obligated to contribute to sustainable development.

Sustainable Development: A Historical Review

> The world's growing population, now more than two thousand million, must draw all their sustenance . . . out of the fertility of the land . . . Nothing more deeply concerns the well-being of men and nations. (Food & Agriculture Organization of the United Nations [FAO hereafter], 1992, p. 13, quoting from the first FAO Conference in 1945)

> Broadly speaking, the problems are much the same as they were in earlier years, but with a world population tending towards 6000 million by the end of this century, the issues have drastically changed in magnitude, urgency & complexity . . . more [than] technical and economic problems . . . today it also encompasses social and political dimensions of international importance. (FAO, 1992, p. 15)

To place the ideas of "sustainability" or "sustainable development" in historical context, a literature review was undertaken to trace the roots of both the idea and the terms. The difficulty of this undertaking stems from the fact that much of the concept and elements of sustainable development that have begun to be made explicit in recent years – particularly since the development of the World Conservation Strategy in 1980 and the report of the World Commission on Environment and Development (WCED) in 1987 – are implicit in activities, organizations and writings of earlier times. For example, recovered mythologies, folk tales, guides for living,[1] and past and current practices of indigenous cultures, reflect many of the principles we now take as central to sustainability. Consequently, suggestions rather than definitive answers regarding the origin and growth of the ideas underlying sustainability/sustainable development are offered.

The seed of the idea of sustainability appears to be located around food concerns and most particularly around insufficient or poor quality food and/or around crises of food production; that is, hunger appears to provide the first tie to issues of sustainability. For those in abundant environments where food is easily accessible or easily produced, the question of sustainability rarely arises. When the question does arise, it is a consequence of natural disasters such as drought or floods, or when it becomes clear that current practices are degrading the environment upon which people depend. The "dust bowl" of the 1930s is one example of how a combination of climate conditions and unsustainable grazing practices enlightened people to the need to address the question of sustainability and reexamine practices.[2] For people living in harsh environments where soil quality is poor and water and other resources are limited, questions of how they are to sustain themselves rest much closer to the surface. Historically (and logically) sustainable development is tied – first and foremost – to natural resources and the environment.

International Attention

The transfer of sustainability issues to the global arena and the specification of requirements for achieving sustainability can be traced to the almost simultaneous founding in 1945 of the Food and Agriculture Organization (FAO hereafter, October 16) and the United Nations (October 24). It was through the founding of these organizations that, for the first time, nations of the world joined together to address the problems of malnutrition, food production and distribution. Cooperation, attention to human needs, equity, conservation of natural resources, improved methods of production – requirements incorporated in current discussions of sustainable development – were made explicit at this time. Sensitivity to culture was also highlighted in these early years. In 1949, the fifth session of the FAO Conference specified that the approach to projects of the Expanded Programme of Technical Assistance (EPTA) "should be through the culture of the local people and in accordance with their accustomed ways and institutions" (FAO, 1992, p. 15). Projects initiated by the FAO and the United Nations during the 1950s (e.g., providing technical assistance, establishing training centers, conducting soil surveys, assessing water and forest resources, resource development and management activities) can be seen to represent initial efforts towards achieving sustainability; efforts of this kind continue to be called for today. It should also be noted that the use of pesticides, developed as outgrowths of chemical engineering efforts during World War II, increased during the 1950s. Although pesticides were useful for increasing harvest, questions would later be raised about the kinds and degree of pesticide applications and about their dominance over "accustomed ways" (e.g., companion planting).

In 1960, the world population reached three billion, an increase of more than one billion people in a mere forty years (United Nations, 1969, p. 67).[3] This 'population explosion' not only raised questions of the earth's carrying capacity but resulted in a shift of focus from distribution of industrialized countries' accumulated surpluses, to intensification of, and establishment of funding for, country-based development projects to raise agricultural productivity where it was most needed. 'Development' and 'productivity' became catch words of increasing currency during this time. Public awareness of world food problems was raised through such activities as the Freedom-from-Hunger Campaign and the efforts of various government and non-governmental organizations (NGOs hereafter), private organizations and religious groups. For those residing in North America at this time, many will remember the frequent television coverage of starving children and the living conditions of less advantaged people in the world.

Several other events through the 1960s and 1970s also shaped current understandings of sustainable development. The green revolution began in the early 1960s with more applications appearing in the 1970s with the introduction of new engineered seed varieties (particularly of rice and wheat), and promotion of irrigation technology and use of fertilizers and pesticides.[4] Increasing concern about applications of newer agricultural technologies (particularly chemical engineering), preservation of genetic resources, and a re-evaluation of interactions between humans and other life systems might well be marked by the publication of Rachel Carson's book The Silent Spring (1962). Prior to this, there was very little awareness of the chemical poisoning of North America (Berry, 1988). The rising visibility of environmental degradation triggered an increase in public concern and environmental groups began to emerge. The subsequent energy crisis in the United States in the 1970s, and publications such as The Limits to Growth (a report of the 1968 meeting of the Club of Rome, Meadows et al, 1972), Toward a Steady State Economy (Daly, 1973), Small is beautiful (Schumacher, 1975), Ecoscience: Population, Resources, Environment (Ehrlich, 1977) which spoke of the Earth as a complex of life systems, The Unsettling of America: Culture and Agriculture (Berry, 1977), Gaia: A New Look at Life on Earth (Lovelock, 1979), and Soft-energy Paths (Lovins, 1979), did much to add to the realization that conservation and productivity would not alone address food problems or the host of new issues (e.g., land, air and water pollution, degradation of resources through erosion, deforestation, desertification, overexploitation of fisheries) which were crowding in as threats to human health and well-being.

The above issues were central to the United Nations Conference on the Human Environment held in Stockholm in 1972; it was here that the concept of sustainable development was born out of an attempt to address both developed nations' concern about environmental consequences of increased global development and developing nations' needs for continued economic development. During this period of increasing awareness and concern it became clear that conservation and productivity could not adequately address issues without improvement in social justice (in the United States, issues of social justice were additionally fueled by the Civil Rights Movement). In 1979, the World Conference on Agrarian Reform and Rural Development adopted the Peasants' Charter which "recognizes that growth is necessary but not sufficient; it must be buttressed by equity and, above all, by *people's participation* in designing, implementing and evaluating rural development programmes and policies" (FAO, 1992, p. 64, emphasis mine). In this statement the earlier concern for equity is again expressed and, by including peoples affected by decisions in planning and decision-making, the beginning of a movement away from "expert"-only approaches. The combination of population growth, technological developments, recognition of pressures and negative impacts on the environment, and increasing disparity between developed and developing nations, facilitated an awareness of the interdependence of environmental, economic and social systems, the three core systems with which sustainable development, as it is now understood, is concerned.

With growing awareness of an impending (if not already present) global crisis threatening human life and life support systems, it is not surprising that efforts to understand and find solutions to the difficult and complex problems would escalate. The 1972 Stockholm conference heightened awareness of the global nature of environmental problems, particularly as related to industrial expansion. Out of this conference the United Nations Environment Programme (UNEP) was formed to promote the idea of environmentally-sound development; this program eventually led to the International Environmental Education Programme (IEEP) in 1975, the World Conservation Strategy (WCS) in 1980, and the WCED in 1983. The World Conservation Strategy (IUCN et al, 1980) was a program developed by over seven hundred scientists from more than one hundred countries with a special concern for the developing world. The report of the WCED, Our Common Future (WCED, 1987) was some three years in the making and involved thousands of people from all over the world. It was this report that popularized the term and the idea of "sustainable development" as a means for meeting the needs of all people – now and in the future – and ensuring Earth's capacity to sustain life. Such international events as Globe '90, Globe '92, and the United Nations Conference on Environment and Development (UNCED hereafter) in Rio in 1992 were intended to further work in developing strategies and reaching agreements regarding the complex issues involved in achieving sustainable development.

The Canadian Response

Canada has been involved in debates about sustainable development from the outset; in fact, Canada is seen as "a world leader in the effort to examine the issues of sustainability and its implications for its citizens" (BCRTEE, 1993, p. 23). Canadian Maurice Strong acted as Secretary-General for the 1972 Stockholm Conference, represented Canada on the WCED, and was Secretary-General for the UNCED in Rio, Brazil in 1992. Canada adopted the 1980 World Conservation Strategy and was the first developed nation to sign or commit to sign some of the documents arising out of UNCED. In 1986, responding to the challenge of the WCED, the Canadian Council of Resource and Environment Ministers created a National Task Force on Environment and Economy (NTFEE hereafter) "which confirmed that economic developers and environmental protectors could not continue to operate in isolation from each other in Canada" (National Round Table on the Environment and Economy, 1992, p. 2).

Recommendations of the NTFEE led to the establishment of the National Round Table on Environment and Economy (NRTEE hereafter) in 1989 and to the eventual establishment of Round Tables in each province. Each Round Table is an independent forum composed of individuals drawn from government, the corporate sector, academic and research institutes, the scientific community and various public interest and professional groups. The Round Tables represent a new approach to consultation and consensus building by bringing together people with different backgrounds (values and experiences), perspectives, and traditionally competing interests, to address common imperatives. Their purpose is:

> to act as catalysts to forge new strategic partnerships, to stimulate the search for viable solutions, and to build a broad consensus on what must change, who should bear the costs, and how and when those costs should be borne. (NRTEE, 1992, p. 2)

Increasing Currency of the Idea

As an indicator of the increasing currency of the terms of sustainability, several title and subject word searches were conducted at the University of British Columbia (UBC hereafter) libraries. The searches were conducted electronically through the UBC library database and included books, papers, and conference proceedings. Subject and title word searches included, for example, "sustainable," "sustainability," and "sustainable development" (see Appendix A for further information on searches). Citations within each results list were examined for duplication and then profiled by topic area and year of publication to get an indication of the topics being explored and the extent of publications over time. Topic areas were determined by both citation title and subject words listed for each citation; since many of the citations pertained to more than one topic area, citations were listed for each topic area to which they pertain. Although additional searches could be done to investigate the currency of the idea and terms of sustainability (e.g., by searching the various related subject headings provided within citations), those that have been done are sufficiently revealing for current purposes.

The most striking observation made from the profiles is that the terms "sustainable," "sustainability," and "sustainable development" are in greater use; this may also suggest that the idea of sustainability is receiving greater attention and interest. After 1987 (when the WCED report was published) many more publications appear that use this language and the volume of publications is increasing rapidly. For example, between February and December 1993, citations resulting from title word "sustainable" increased by 162 to a total of 589, an increase of almost 30%; for subject word "sustainable", they increased by 81 to a total of 175, an increase of 46%. (A profile of the results for title word "sustainable" is presented in Appendix A, Table A-2). Also notable is the fact that the subject word searches rarely included citations prior to 1987. For example, only two of the 93 citations for subject word "sustainable" were dated prior to 1987; both of these were published in 1986 as a result of conferences concerned with sustainable agriculture. Further investigation revealed that the Library of Congress did not issue such subject words as "sustainable development" and "sustainable forestry" until after 1987.[5] The fact that the Library of Congress has recently issued these subject terms provides additional evidence of the increasing currency of both the terms and the ideas they represent.

The Ultimate Goal

> Everyone has the right to a standard of living adequate for [their] health and well-being. (United Nations Declaration of Human Rights)

At the base of discussions of sustainability is concern for human health and well-being. The concern is expressed through such things as concerns about the availability of food, water and shelter, contaminated air, water and soil threatening human health and survival, and the means by which people can obtain livelihoods to support themselves and their communities. In fact, concern about health is made explicit in much of the writing on sustainable development through references to human health, economic health, healthy society, social wellbeing, and environmental or ecological health (e.g., B.C. Ministry of Education, 1990; BCRTEE, 1990, 1992, 1993a, 1993b; B.C. Task Force on the Environment and Economy [BCTFEE hereafter], 1989; WCED, 1987). Whether implicitly or explicitly, sustainable development is ultimately concerned with assuring human health and well-being. Before proceeding further with discussion of sustainable development, therefore, we need an approximate definition of "health."

Although we all know what it feels like to be healthy, it is difficult to give a precise definition. While we may say that health is a state of well-being that arises out of certain functioning of an organism, how we describe that organism and its interactions with its environment will lead to different definitions of health. For example, we might say a person is healthy if the results of various blood and urine tests, and examinations of eye, ear, throat, heart rate, blood pressure, and so on, resulted in "a clean bill of health." This information would not, however, assure us of the mental health of the individual. And even if we are assured that the individual is 'healthy,' it does not follow that a collection of such individuals would constitute a healthy society.

> The concept of health . . . and the related concepts of illness, disease, and pathology, do not refer to well-defined entities but are integral parts of limited and approximate models that mirror a web of relationships among multiple aspects of the complex and fluid phenomenon of life. (Capra, 1988, p. 321)

How we communicate our health problems, what we conceive them to be, what is healthy or sick, normal or abnormal – that is, the very experience and conception of health – varies across time and among cultures as do responses to states of ill health. In shamanistic traditions, for example, human beings are considered integral parts of an ordered system; illness is intimately linked with the patient's social, cultural and spiritual environment and seen as the consequence of some disharmony with the cosmic order. Classical Chinese medicine (having roots in shamanistic traditions) incorporates similar ideas about health and illness: "the healthy individual and the healthy society are integral parts of a great patterned order, and illness is disharmony at the individual or social level" (Capra, 1988, p. 313). Where the shaman's principal treatment is concerned with the sociocultural context in which the illness occurs (including attention to spirits which are believed to actively intervene in human affairs and with less importance placed on the individual per se), the Chinese practitioner focusses on manipulating processes inside the body and communal practices (e.g., meditation, chanting) which are intended to bring the individual and the society into greater harmony.

In western medicine, the prevailing view has been one of the human being as a machine to be analyzed in terms of its parts. Disease is seen as the breakdown or misfunctioning of biological structures, and health is commonly defined as the absence of disease or symptoms of illness (Russell, 1983). Prevailing treatments have tended to focus on the human body's biological mechanisms and physiological processes that produce evidence of ill-health. This view is being slowly altered by a more holistic and ecological view that emphasizes interrelatedness and interdependence not only between internal biological and physiological structures and functions, but also between mind and body, the individual and society, society and the natural environment.[6] Health practitioners operating within this expanded view go beyond physical examinations to explore stress factors, emotional states, home and working conditions, and so on. This view is not inconsistent with traditions underlying western medicine, that is, with Hippocratic themes of health as a state of balance, the importance of environmental influences and the interdependence of mind and body (Dubos, 1979). "Treatments" are now more focussed on prevention through the promotion of healthy living habits and an emphasis on personal responsibility for health by adopting necessary changes and participating in the healing process (Knowles, 1977).

The expanded view of health is based on a non-mechanistic systems view of life. Living organisms and systems display a high degree of stability. This stability is not the result of static equilibrium; rather, it is characterized by continual, multiple and interdependent fluctuations (Berry, 1988; Bohm, 1987; Swimme, 1984). The health of a system is dependent on the degree to which a number of its variables are fluctuating within their various tolerance limits. The idea of tolerance limits (be they in an individual, or in a social or ecological system) supports the view that health is not an absolute, static state; instead, health is a condition that exists within a particular tolerance range which itself may fluctuate. Take, for example, the parameters of health we might use to define infant, adolescent and octogenarian health.

Health is really a "multidimensional phenomenon involving interdependent physical, psychological and social aspects" (Capra, 1988, p. 322) and, increasingly, a recognition of the involvement of ecological aspects as well.[7] This conception of health suggests that the healthy individual and the healthy society are integral parts of a functional system which includes health at three interdependent levels: that of the individual, the societal group and the environment. Presumably then, health is the experience of well-being resulting from the dynamic balance of physical and psychological aspects of the individual in interaction with the natural and social world.

In the context of societal health, it is assumed that we have a special concern that this well-being is shared by all. Looking to the current conditions of our society, we see many indications of increased crime, drug use and dependence, poverty, unemployment, inequity, pollution, resource depletion, and so on. To what degree are these manifestations congruent with the goal of achieving economic, social and environmental well-being and dynamic balance?

Poverty and extreme unemployment are not conditions normally attributed to a healthy society and both these conditions are often related to poor personal health and increased crime. It is unlikely that we would consider a society healthy if crime, especially violent crime, were so prevalent that people lived in fear for their lives. In fact, increased instances of crime and drug use are seen as indications that a society is in trouble. We consider societies to be sick when the inequities are so extreme that some people are deprived of food, housing or medicine while other people live in relative luxury; when access to education is limited to only a few; when civil rights are routinely violated. Likely we would also claim that a society is in trouble if individuals transgress and lower the carrying capacity of the environment upon which they depend. Here we see how individual actions or conditions reflect on our assessment of the societal condition. On the other hand, societies are considered comparably healthy if they have policies to ensure equal educational and employment opportunity and continued availability of essential resources, and if there are structures which ensure civil rights. These policies and structures benefit both the individual and society at large.

The environment's impact on our health probably needs very little discussion. Doctors send allergy patients to the desert to remove them from the pollen-generating plant life that causes their distress.[8] Health practitioners are aware that clean, relatively germ-free environments are essential to prevent infection. Individuals increase their chances of good health by either avoiding or protecting themselves against harmful environmental conditions such as radiation, air pollution or water contamination. Air and water pollution are examples of how environmental health impacts on the health of individuals and also how the actions of individuals and societies impact on environmental health. Individuals who pollute the environment or societies that do not have policies and structures to prevent such pollution put themselves at risk. In the end, in extreme cases, environmental degradation may fracture the society itself. This is particularly evident in societies that are directly dependent on the environment for their well-being. Agriculture-based, fisheries-based, or forestry-based communities, for example, find all manner of their social structures crumbling when either the soil or water has been contaminated or depleted and can no longer support the very industries upon which the communities were based. The survival of these communities depends on accommodating changes within the limits of tolerance.

The preceding discussion suggests that any definition of a healthy society must include consideration of (a) the individuals within that society, (b) the conditions of systems which exist within society (e.g., local economic and cultural systems) and (c) the larger systems in which the society is embedded (e.g., global economic systems; eco-system). Since the goal of sustainable development is to achieve economic, ecological and social health or 'wellness,' a comprehensive definition of sustainable development must incorporate broad notions of health and wellness. If sustainable development is to be the means by which 'good health' (in the broader sense) is achieved, it will require finding ways to integrate, and achieve dynamic balance within and between, individual, societal and ecological systems and thereby (at minimum) ensure that fluctuations do not exceed limits of tolerance. In effect, the goal is to create 'synergy' (Russell, 1983), that is, a harmonious working together of these systems, in order to ensure the health of each system and to improve the functioning of their collective whole.

Assuring human health and well-being is clearly the primary focus of sustainable development; it is also clear that to assure good health a balance must be achieved between multiple complex systems. The sustainability literature, in fact the very coining of the term "sustainable development," results from the recognition that various systems are connected and that there is a need to achieve balance among these systems; further, the literature also recognizes that sustainability, like health, is not a static condition. These ideas are well reflected in the following statement by the BCTFEE:

> Today it is widely accepted that long term economic and social health are closely tied to ecological health, abundance, and diversity, as well as to economic activity. Therefore, sustainability must depend upon a partnership and balance between economics, the environment, and social values and benefits. Sustainable development is not static; it is the process of maintaining a fluctuating and difficult balance as these values and their

interdependent circumstances change. (BCTFEE, 1989, p. 16)

This statement is both commentary on and extension of the WCED definition of sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987, p. 43). While the WCED definition is embraced as a broad goal, it is becoming clear that creating the "partnership and balance" upon which sustainable development depends is fraught with difficulty. Just as "health" has meant different things, the environment means different things to those who use it, and economic interests and social values vary across people, regions, and time. As Redclift (1992) notes, "One person's world of resource depletion is another person's world of resource abundance" (p. 202). In spite of agreement about broad goals of sustainable development and acceptance of the need to balance economic, environment and social values and benefits, therefore, divergent views and interests have led to different interpretations of what sustainable development means and how it is to be achieved. To better understand sustainable development and to improve decision-making, it is important to recognize and understand the ways in which sustainable development is variously interpreted.

Different Perspectives

> Understanding is living in a house where every room has a point of view.
> (benShea, 1989, p. 99)

The findings of the BCTFEE illustrate the diversity of interpretations of sustainable development. In 1989, the BCTFEE attempted to define sustainable development based on discussions, consultations with leading experts in the field, and written submissions from more than 200 associations, organizations, businesses and individuals in British Columbia. They discovered that while "virtually all submissions state that sustainable development is an important ideal or objective for society . . . the concept means very different things to different people" (BCTFEE, 1989, p. 15).[9] Beliefs reflected in submissions received by the BCTFEE range from a conviction that growth and development activities can (and should) continue (and, implicitly, a belief that environmental concerns are either inconsequential or temporary), to the conclusion that continued growth and development will so damage the environment that all life will end. Between these two extreme views are those who believe that a balance can be struck, that is, that development can continue while environmental integrity is maintained.

These three views also dominate submissions received by the BCTFEE regarding a conservation strategy (BCTFEE, 1989, pp. 26-28), parallel Jessen's (1981) descriptions of three forms of modern ideologies, and are reflected in the writings of those who discuss different worldviews and perspectives related to sustainable development (e.g., Bateson, 1988; Berry, 1988; Capra, 1988; Henderson, 1978, 1988; Plant & Plant, 1990). Summary profiles of the three views are presented in Table 2-1. The categorizations and views in the table are drawn explicitly from the findings of the BCTFEE; value preferences, assumptions and some information on beliefs and approaches is drawn from the work of Jessen and others as noted above.

The table reveals a spectrum of interpretations and 'ideologies' bounded at one end by a view focussed on development needs; in this view the primary concern is for ensuring continued development activities, that is, to sustain production, employment and industrial growth. At the other end, environmental protection and preservation is the primary concern. Other writers have similarly polarized such views variously described as expansionist versus ecological (Taylor, 1991), technocentric versus ecocentric (Kuhn & Jackson, 1989), anthropocentric versus biocentric (Devall & Sessions, 1985; Dryzek & Lester, 1989), disembodied versus embodied (Devall & Sessions, 1985), human exceptionalism paradigm or dominant social paradigm versus new environmental paradigm (Catton & Dunlap, 1978; Milbrath, 1981, 1989), technocratic or mechanistic versus person-planetary or organic (Drengson, 1980), atomistic versus holistic (Oelhaf, 1979), and runaway growth versus dynamic steady-state (Laszlo, 1973). Polarizing the views in this way makes transparent the basis of conflict: "what we have is . . . the clash of *plural rationalities* each using impeccable logic to derive different conclusions (solution definitions) from different premises (problem definitions)" (Thompson in Redclift, 1992, p. 202; italics in the original). In essence, the meanings given to sustainable development reflect beliefs about the way the world/society is and/or ought to be; they indicate the various, often competing, beliefs or "rationalities" that must be traversed in order to come to some kind of agreement about the meaning, intent and preferred actions for achieving sustainable development.

Table 2-1
The Meaning of Sustainable Development:
Differences in Interpretations

	PREOCCUPATION: ECONOMIC/ DEVELOPMENT	A MIDDLE WAY	PREOCCUPATION: ENVIRONMENT
DEFINITION	* sustain production and employment levels	* protect the environment while permitting economic development	* limit impact of development on the environment in the short and long term
PROBLEM	* Assure continued supply from nature	* protecting the environment AND continuing economic development of natural resources	* Environmental crisis
STRATEGY	* balance present consumption rates and future options for use	* Balance environment with economic interests	* rectify balance between development and preservation; the preservation of the natural environment should take top priority
VALUE PREFERENCE	** unlimited growth	** assimilated growth	** no growth
ASSUMPTIONS	** earth to be tamed; unlimited resources; temporary scarcity	** the two poles can be moderated	** too much pollution & depletion of resources; too many people and demands
BELIEFS	* It is possible to integrate and share resources	* economic health is needed to support environmental quality; environmental health assures a sustainable supply of resources for a vibrant economy	* economic growth & population growth and even maintenance of the status quo in developed nations is unsustainable
	* access to as much of land base as possible is required to sustain production and employment levels	* it is possible to protect the environment while permitting economic development	* if development is tightly controlled and limited, environmental impact can be kept in check
	** growth is good and causes only incidental damage to the environment and damage is easily remedied	** an appropriate rate of growth is fine, appropriate being defined as the rate that balances the well-being and survival of people and the environment	** further development will bring the Apocalypse
			* environment and economic demands on a collision course
APPROACHES	* ensuring policies support economic development projects to sustain certain land uses	* safeguards and controls	* tightly control and limit development
	* proper resource management		* radical changes to priorities and decision-making structures
	* development of comprehensive cost-benefit analyses and measurable indicators	* slow - especially developed nations' - per capita consumption of resources; greater levels of conservation and sharing of resources	
	** more technology and innovation combined with both managerial and political leadership	** install assimilation as guiding principle for achieving balance; moderation in all things (Aristotle's 'golden mean')	** zero population growth; zero economic growth
Jessen's 'IDEOLOGIES' **	(Cowboy Economics/pro-modernism)	(Assimilative/post-modernism)	(Neo-Malthusian/anti-modernism)

Sources: * BCTFEE, 1989; **Jessen 1981

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The extreme views, and the more moderate views that may exist between them, are largely promoted by well-meaning people often armed with the same 'data.' Although misunderstanding or misinformation may contribute to the differences, the different views appear to arise primarily out of differences in interests, values, culture, traditions, knowledge and experiences which together contribute to the formation and maintenance of belief systems and ideologies which subsequently influence the views that are held.[10] It is important to recognize the power beliefs and ideologies have to influence the ways information is gathered and interpreted and how problems and solutions are defined. Consider the following: In recent years, Earth's resource deficits and functioning have been documented in a long series of specialized studies and general evaluations of increasing volume. Empirical data is mounting to support the contention that current rates of consumption and waste production occurring on the planet (in industrialized nations in particular), if unchecked, will lead to the end of life. There are those, however, who believe such 'evidence' merely constitutes over-inflated claims of special interest groups; there are others who do not believe such a disaster could occur; there are those who believe that technology (by finding or developing alternatives) will avert the disaster; and others who believe that such signs of stress as species extinction or habitat destruction merely reflects Earth's natural cycles. Regardless of what may be true or real, it is clear that such beliefs have consequences in terms of how sustainable development is defined, what does or does not receive primary attention, and how sustainable development will be pursued. It should be fairly obvious that people who hold beliefs such as those above are unlikely to experience much urgency to change current behavior or practices; they may in fact undermine or actively oppose change initiatives.

When there are extreme differences in the ways problems or solutions are conceived, conflict is inevitable. Examining the interpretations of sustainable development, the most obvious ground for conflict is between those with a primary focus on development (as traditionally conceived) and those with a primary focus on protection and preservation of the environment. What has come to be known as the "battle for the trees"[11] in Clayoquot Sound, B.C. is a case in point. On one side are loggers, timber owners and others who argue that removing land from their operating territory threatens their livelihood and the strength of the B.C. economy itself. On the other side are environmentalists, First Nations peoples and others who are opposed to current logging practices (rates and methods of extraction); they variously argue that continued logging in the area will destroy watersheds, wildlife habitats and our ancient natural heritage, endanger or bring certain species to extinction, damage streams, reduce the viability of such potential industries as fisheries or tourism, and ultimately destroy the forestry industry itself. The conflict between the two sides has manifested in public protests, logging road blockades, violence, legal action, anger and distrust within communities, and even estrangement among family members. Polarizing the issues as development (or economy) versus environment reveals the problem of competing demands and values inherent in achieving sustainability but exaggerates the differences and seems to do more to generate rather than resolve conflict.

The divergent views are not necessarily correct or false; rather, they are views that emphasize either the environmental or socio-economic aspects of sustainable development. Ddifferences in emphasis are at the heart of debates about the meaning and enactment of sustainable development. Unfortunately, since each of the divergent views may incorporate one or more concerns of sustainable development (even though one concern may receive more attention than others), many people assume that their interpretation of sustainable development is singularly correct. For example, in the various discussions, workshops, interviews and focus groups I have conducted over the past few years to investigate the meaning of sustainable development, it has not been uncommon to hear individuals claim that those who hold a view of sustainable development different than their own just "aren't sufficiently informed" or "don't know what they're talking about" or "just have it wrong." In fact, individuals often discount alternate views with little (if any) examination of the biases or assumptions inherent in their own or in others' definitions or choices for action. A disturbing, similar observation is reported by the BCTFEE:

> Most submissions do not recognize the possibility that their particular definition of sustainable development may not be universally held. Instead, the common perception is that people with other opinions simply do not believe in sustainable development. (BCTFEE, 1989, p. 16)

The lack of recognition or investigation of alternative perspectives narrows the range of possible options we consider for sustainable development. In addition, a lack of consideration of other ways of viewing the idea of sustainable development may confine our interpretations and even our goals to those which either are only appropriate to a local context or only serve certain interests to the exclusion of others. In the end, our efforts may work at cross-purposes to the broader goals sustainable development is intended to achieve. Policies and practices conceived in isolation (e.g., self-contained within an interpretive emphasis, ideology, interest area or special context) are often fragmented and unrelated to one another (being conceived by different self-contained units). As a consequence, impacts of these policies and practices on areas of concern to those who hold different points of view may be ignored or denied. Unless we identify and openly discuss our own and others' biases and assumptions, it is unlikely that common ground can be identified, that the strengths and weaknesses of various interpretations will be made clear, that our understanding of sustainable development will be complete, or that policies and practices more consistent with our goals will be developed and used.

The meaning and means of sustainable development will continue to be mediated through and molded by competing ideologies and definitions of reality (influenced by contextual presuppositions), the clash of group interests, changing patterns of social relationships, and through evolving knowledge and experience. Problems are likely to occur if conflicts cannot be resolved and if differences lead to emphases which minimize or exclude important concerns of sustainable development. To facilitate sustainable development, therefore, it is important to recognize that people have different interests, contexts, and sources of knowledge which influence their views of and responses to sustainable development. Further, it is important to identify the ways views or actions are myopic and/or may undermine or work at cross purposes to the aims of sustainable development.

> We need an essentially new way of thinking if mankind [sic] is to survive.
> (Einstein, 1946, quoted in Barnaby, 1988, p. 164)

The broad goal of health and well-being, and the recognition that a dynamic balance or synergy among environmental, social and economic systems is needed to achieve that goal, can guide our choices for future action. An emphasis on "no growth," for example, may deny the needs of peoples in many developing nations who require rapid (but controlled) growth and development simply to meet essential needs for health (e.g., food, shelter, jobs, any hope of betterment) and to reach levels of potential sustainability (Knelman, 1978, p. 49; WCED, 1987, p. 32). On the other hand, a primary focus on continued growth may ignore local or global carrying capacities and obscure the inadequacies, or make less important the negative impacts, of certain initiatives or practices (Redclift, 1992).

A reasonable interpretation of sustainable development cannot, therefore, be confined to either an anti- or pro- growth and development perspective – there will be occasions when restrictions will be necessary and occasions when development will be urgently needed. This points to the need for openness to both options and for contextual sensitivity in choice of direction. Ecological, social and economic approaches must be defined with respect to their implications for any given context, that is, in terms of what is to be sustained, for whom, by what means, for how long and with what kinds of consequences. Since the idea of sustainable development can be seen to have arisen because of the inadequacies and negative effects of past choices and related choice mechanisms, our current and future choices (e.g., of products, processes, institutional structures and values to be emphasized) require critical examination. Most particularly, as many have suggested (e.g., Leiss, 1978; Meadows et al, 1972; Perelman, 1976; Simonis, 1990; Wachtel, 1989; WCED 1987), both the means and goals of 'growth' and 'development' will need to be re-examined.[12]

Durbin and Nieto (1993) note that development "has been studied primarily in the guise of economic growth without qualification" (p. 1); the assumption is that if there is more growth and development (i.e., more production), more people will be able to consume and more needs will be met. However, estimates suggest that per capita resource consumption and waste production in developed nations far exceeds that in developing nations (Barnaby, 1988; WCED, 1987). The net effect of this disparity has been to decrease the ability of people in developing nations to meet their own needs; "to support growth in the economically developed countries based as it is on the consumption of the global store of resources, is to deny the equitable distribution of these to the future world" (Knelman, 1978, p. 32). Further, even within developed nations it is becoming clear that, despite increases in development, apparent increases in GNP, and continued economic growth, the conventional approach to growth and development has not resulted in a similar net increase or improvement in personal, social or environmental well-being (Leiss, 1978; Mishan, 1977; Wachtel, 1989;

Wackernagel & Rees, 1993). As the BCRTEE (1990) states:

> The combined effect of development decisions, intended to contribute toward a better world, has in many cases damaged the environment that sustains it . . . Humanity's present relationship with the environment is clearly unsustainable. (p. 5)

As a result of such observations, questions are being raised about traditional economic conceptions of growth and development, and ways are being sought to transform practices and moderate problems associated with the process of economic growth. The sustainability literature is replete with calls "to put consumption in its proper place among the many sources of personal fulfillment" (Durning, 1991, p. 166) and to redirect attention towards 'qualitative' rather than 'quantitative' growth. The critical issues incorporated by the qualitative growth idea are probably best summarized in three main points that arise out of discussions.

1. Distinctions should be made between 'growth' and 'development.' For example, Manning (1990) states:

> Development must be interpreted differently from growth. While growth in production or in the level of activity of one or more sectors may be components of an overall development strategy, development transcends narrow (particularly sectoral) measures of quantitative improvements . . . Development needs to be interpreted as improvement, not growth, and certainly not growth as defined through narrow economic indicators. (p. 5)

This is not to suggest that growth be abandoned; quantitative increases in output and consumption may be required in certain areas in order to meet essential needs for health and to reach levels of potential sustainability. However,

2. The content of growth and development needs to be redefined. The challenge is to "change the content of growth" (WCED, 1987, p. 52) by redefining the forms, structures and uses of growth in order to minimize detrimental social and environmental effects; what counts is the quality of services rendered (Brown et al, 1992). This means that GNP becomes obsolete as a measure of growth or progress (Henderson, 1978, 1988; Mishan, 1977). For example, bicycles, mass transit systems, water-efficient appliances, and irrigation systems are less resource intensive and harmful

to the environment than automobiles, large dams and canals, yet the latter lead to much greater increases in GNP than the former. When environmental damage occurs (e.g., oil spills, soil contamination) one would expect these to be negatively reflected in a measure concerned with meeting peoples' needs and ensuring the health of the environment; however, rather than "subtraction from GNP of some estimate of the damage sustained by the proliferation of adverse spillovers" (Mishan, 1977, p. 33), the costs of clean up or repair are *added* to the GNP![13]

While it is true that practices premised on traditional ideologies of growth and progress have realised improvements in the standard of living for at least some people, and that material consumption has been at the base of this improvement, it is also clear that growth and development that occurs, as it often has, at the expense of others (e.g., through inequity, dependency or environmental degradation), "should not be referred to as 'development' but as 'exploitation'" (Simonis, 1990, p. 10).[14] The notion of qualitative growth and of appropriate/responsible development incorporate social, environmental and inter-generational equity issues as well as local contextual factors in considerations of growth and development. The intention is to reframe and thereby initiate a transition from the narrower, conventional notions of economic growth and development.

3. Distinctions need to be made between "standard of living" and "quality of life." The first is concerned with quantitative measures of economic growth in terms of production and consumption and is seen to be an inadequate measure of social welfare. Although "in affluent nations the quality of life becomes confused with the ever-expanding consumption of goods and services" (Brown, 1981, p. 350), 'quality of life' is an idea that represents a reorientation away from energy- and material-intensive consumerism to a focus on fulfillment in other than material terms (Leiss, 1978; Redclift, 1992; Wachtel, 1989; WCED, 1987). Quoting Gardner & Roseland (1989a):

> The measure of wealth would reside not in the growth of the GNP, but in the sense of personal belonging and usefulness that can be found in sharing and community; in the sense of empowerment and the opportunity for creativity that comes with self-determination; in the sense of connectedness to our natural environment associated with increased access to and understanding of healthy ecosystems; in the sense of well-being that comes from plenty of good food, clean air and clean water, and in the assurance that we will not lose these essentials through poverty. (p. 31)

In sum, qualitative growth represents a shift in emphasis from quantitative (consumptive) economic growth as the paramount development objective to an increased emphasis on "a myriad of ideas which give meaning to our lives: self-preservation, peace, democracy, right, good, and beauty, among others" (Starr, 1977, p. 93). The goal is "to put consumption in its proper place . . . and to find ways of living within the means of Earth" (Durning, 1991, p. 166). As such, it will require a re-examination of values, priorities, habitual responses (e.g., in consumption and production), and lifestyles, as well as the encouragement of attitudes and public policies which have "a more knowing and affirmative relation to the good life" (Borgmann, 1984, p. 226). The shift in focus will not be easy; what can be hoped for is that people will find that working to foster a more just and sustainable world will provide them with a purpose larger than fulfillment of narrow self-interests and desires and that there will be "a gradual weakening of the consumerist ethos of affluent societies" (Durning, 1991, p. 167).

Although the idea of qualitative growth is not yet fully formed, distinctions that are suggested may be helpful in clarifying purposes of sustainable development and reorienting practices. Further, by pointing to weaknesses in certain economic assumptions and measures, it calls for a broader perspective inclusive of social and environmental concerns. In effect, discussions of qualitative growth help to increase our understanding of what needs to be incorporated within and addressed by sustainable development. Given different needs, contexts, norms and decision-making criteria that exist in the world, cooperation, collaboration and wide-ranging participation will be required to achieve collective understanding and appropriate responses to various challenges of sustainable development. Different perspectives and experiences have the potential to expand our perceptions and broaden the ways we think about problems and alternatives. There will be times when differences generate conflict; difference will need to be bridged in order to find common ground and facilitate actions congruent with the goals of sustainable development.

What is needed, therefore, are some base principles which, together with the ground provided by broad and inclusive goals of good health, would constitute a reasonable framework for the concept of sustainable development. While specific tools and substantive issues may vary from one context to another, the critical point is that principles underlying actions should be compatible with requirements for sustainability. The following section focusses on six principles which provide the basis of sustainable development and can guide the design and choice of a full range of human activities consistent with sustainable development.

Principles of Sustainable Development

> The elements of a program to promote sustainable development support each other and are attractive both environmentally and economically (Repetto in Gardner, 1989, pp. 344-345)

Variously referred to as "principles" (e.g., BCRTEE, 1990, 1992; Environment Canada, 1990b; Gardner 1989; Miller, 1990; WCED, 1987), "themes" (e.g., Keating, 1989), "pre-requisites" (e.g., Faby, 1984), "requirements" and "priorities" (e.g., Jacobs, Gardner & Munro, 1987), a number of commissions and authors have articulated ideas they believe are fundamental to sustainable development. As noted in Chapter 1, the term "principles" is here used to refer to these ideas. Three general observations help to frame later, more detailed discussions of specific principles. First, while some discussions vary by context (e.g., global or local; disciplinary area) or emphasis (e.g., ecological, economic, social) there is considerable agreement among documents regarding what defines and should guide efforts toward sustainability. Second, in spite of differences in emphasis, almost all authors express the view that the principles of sustainable development are "profoundly interdependent and . . . cannot be ordered by priority or selected among" (Gardner, 1989, p. 344). The relatedness and interdependence is made clear when one recognizes the overlap that exists among principles. Consider, for example, three principles that are common to all current and comprehensive discussions[15] of sustainable development: meeting human needs, maintaining ecological integrity, and assuring equity/social justice. Meeting human needs is dependent on the health of the ecosystem and, as previously noted, the health of the ecosystem is dependent (in part) on addressing such needs-related issues as poverty, equity and social justice. It is apparent, therefore, that isolating one principle from another or placing greater priority on one than another, is likely to seriously compromise both our understanding and our ability to achieve sustainability. Finally, as this example also begins to illustrate, a goal represented by one principle becomes a requisite means for another;[16] in this way, the principles are consistent with the idea of sustainable development as both goal and means.

As noted above, discussions of principles vary by their focus on global or local contexts, disciplinary interests, and/or their emphasis on ecological, economic or social issues. Lists of principles that have been generated may include from four to sixty or more principles which either represent or could be grouped into clusters of related principles. In a search for some general set of principles, I have attempted to synthesize the literature and then distill from it the principles that dominate and are held in common (more or less).[17] I have drawn upon sources that specifically refer to sustainability or sustainable development (and use this language) and related material arising out of discussions of environmental ethics, eco-philosophy, technology, society, citizenship, democracy, global systems, systems modelling, impact assessment, and organizational change. Almost all sources used refer to sustainability and/or sustainable development explicitly. Other sources represent discussions which (a) have contributed to the evolution of the idea of sustainable development and are often referenced in more recent writings; (b) are identified in current literature as earlier forms of the idea of sustainable development; or (c) expand on the ideas represented by principles identified in the literature. Appendix B provides a sample of sources by principle.

The distillation of the literature reveals a mix of essentially two kinds of principles. First there are principles which give primary attention to environmental, economic and social issues and systems involved in achieving sustainability. Regardless where emphasis is placed, the concept of sustainable development is not complete without recognition of these three interacting systems; all comprehensive definitions of sustainable development identify its environmental, economic and social aspects. Consistent with the literature, the three aspects are here translated into three core, substantive principles of sustainable development: meeting human needs (economic aspect), maintaining ecological integrity (environmental aspect) and achieving equity and social justice (social aspect). These core principles represent the primary objectives underlying the goal of health and well-being.

Second, there are principles which are supportive of the core principles but are more strategic or means-focussed. Some of these principles are very specific -- for instance, full cost accounting, matching energy quality to energy tasks, affordable recycling. Others pertain to broader requirements considered fundamental to achieving the primary objectives of sustainable development. The broader requirements (at least) are such that, if one accepts sustainable development, one implicitly accepts certain strategies as well. The literature reflects general agreement about some of these broad requirements and, therefore, three "process-oriented" principles -- the use of appropriate technology; ensuring cooperation/participation; effective organizational structures -- are included in the discussion here. The six principles are described in more detail in the following sections. Although each principle warrants consideration and discussion that extends beyond what can be included here, for the purposes of this paper, discussion will be limited to the key ideas and issues contained within each principle.

Human Needs

> Sustainability requires views of human needs and well-being that incorporate such non-economic variables as education and health enjoyed for their own sake, clean air and water, and the protection of natural beauty (WCED, 1987, p. 53)

Meeting basic human needs is a key requirement of sustainable development. In fact, the issue of meeting human needs can be considered *foundational* to the concept since it was concerns about starvation, poverty and the risks to human health and survival presented by environmental contamination and degradation, that gave rise to the concept. Further, the subsequent recognition of the weakness of the 'trickle-down' hypothesis[18] and the inadequacy of traditional growth-oriented economic policies/strategies for satisfying human needs, has led to increased attention being given to the idea of 'basic needs' (Simonis, 1990). When not explicit, meeting human needs is implicit in virtually all discussions of sustainable development.

But what are the 'basic needs'? Are we to focus only on material needs or non-material needs as well? Are we to define needs in terms of minimum requirements for survival or in the broader terms of health and well-being? Accepting that health/well-being (in the broad and inclusive sense articulated earlier) is the ultimate goal of sustainable development, it is assumed that needs are to be defined in terms consistent with this goal and will, therefore, include both material and non-material needs at the levels of the individual, group and society as a whole. When viewed collectively, the needs identified by various authors concerned with achieving sustainability support the idea that 'basic needs' are inclusive of material and non-material needs. For example, Wackernagel and Rees (1993), state that "basic human needs are not only physical in nature . . . but also psychological, such as dignity and self-esteem, love and social connectedness, self-realization and control over one's life" (p. 12). Further, as will be made more clear through discussion of principles, even meeting requirements for mere survival may today require attention to more than meeting individual material needs. In this paper, therefore, basic human needs will include material and non-material needs that must be met in order to obtain the goal of human health and well-being.

Material needs, most of which draw on the products of photosynthesis, include such individual physical-survival necessities as air, water and food. In most environments some form of shelter (clothing or structure for protection from the elements) is required, and, in extremely cold environments, heating fuel may also be a survival need. Although not explicit in any of the literature reviewed, I suggest that some form of tool is also a survival necessity in most if not all environments. As individuals gather together and form communities and societies, the conditions for obtaining these necessities may begin to change, and other kinds of 'needs' may arise. For example, obtaining physical necessities in a North American urban setting requires that one successfully operate in accordance with the explicit and implicit rules of order governing the acquisition of these necessities. Dominant among these rules are those concerned with property rights and legitimate employment; employment incorporates such preconditions as being appropriately clothed and having certain pre-requisite education and/or training. An individual choosing or forced by circumstance to transgress rules (e.g., by finding shelter in a park or parking garage; by taking or using something without 'permission'), must become adept at avoiding incarceration or worse; for society, there is the need to respond to such behavior in some way that protects both the individual and the community.

Other kinds of needs arise merely out of the fact that more people have gathered together in one place. Among these needs are those which might be termed "materials-related needs" since they are resource or materials dependent and often overlap with what might otherwise be considered 'non-material' needs. For example, in order for groups or communities to sustain themselves, people need to communicate and cooperate with each other; in simpler times these needs could be considered "non-material needs" since they could be met with few if any material resources. Today, in a world of rapid change in information and activities, staying informed, not to mention communicating and cooperating, may be dependent on access to the sophisticated technology of telecommunications, computers, and other electronic networking systems. As another example, in order to protect and better use resources available and to stretch them further, and to develop a more conscious response to the generation and treatment of wastes, there is a need for "improvements in education, health and nutrition" (WCED, 1987, p. 96; note that the need for food has been elevated to the need for nutrition).

Along with material needs (especially for food, clean water, energy), materials-related and non-material needs are increasingly being incorporated into the list of human needs to be met by sustainable development. For example, the National Task Force on Environment and Economy in Canada suggests that meeting human needs is dependent on meeting "the fundamental needs of present and future generations . . . including food, shelter, ***employment***, clothing, ***community stability, human dignity, equity and justice***" (NTFEE in BCTFEE 1989, p. 10; italics mine). Expressed needs for community stability, dignity, equity, justice, good health, and education, often materials-related, are among needs comprising broader 'quality of life' requirements and are now considered key factors in achieving sustainability.

> A state that shortchanges its people in the field of physical health, a state which is indifferent to emotional needs . . . a state that restricts the free exchange of ideas and discourages thinking, a state that puts little emphasis upon the clarifying of values, a state that is forgetful of the need we all have to feel some sense of power, is indeed dwarfing us all, and under those circumstances we cannot look forward to the accomplishment of great things. (Raths, 1972, p. 7)

Achieving sustainable development will require the accomplishment of "great things." In some sense, meeting Maslow's[19] "higher-order" needs for understanding ("knowledge of relationships, systems and processes . . . the integration of knowledge") and knowledge ("having access to information") has become essential for ensuring health and well-being. Among other 'non-material' needs identified in the literature are the need for: leisure ("protection against intensity and duration of work that are harmful to health"; Simonis, 1990, p. 85); meaningful work; satisfactory relations with others;

spiritual and political freedom; psychological-emotional well-being; security (physical, social and economic); personal development and self-fulfillment through expression of one's potential (see, for example, Barnaby, 1988; Gardner & Roseland, 1989b; Jacobs et al, 1987; Simonis, 1990; WCED, 1987). In sum, one of sustainable development's principal objectives is to ensure that the material and non-material requirements for human health and well-being are fulfilled.

Ecological Integrity

> We are returning to our native place after a long absence, meeting once again with our kin in the Earth community. For too long we have been away somewhere, entranced with our industrial world. (Berry, 1988, p. 1)

> A thing is right when it tends to preserve the integrity, stability and beauty of the biotic community. It is wrong when it tends otherwise. (Leopold quoted in Heinegg, 1979, p. 326)

Environmental concerns often have dominance, even primacy, in discussion of sustainable development.[20] Despite our faith in the ability of the biosphere to continue unfailingly to provide us with resources and recover from our abuses, and our faith in human ingenuity to find technological solutions to problems, it is clear that we cannot consider ourselves separate from or better "than nature which, in addition to synthesizing compounds too numerous to mention, synthesized [us] as well" (de Ropp quoted in Plotkin, 1993, p. 14). Humans are a part of nature[21] and our behaviour in treating the rest of the natural world as if it were an infinite pool of resources and an infinite sink for wastes is threatening the primary biospheric processes and support systems upon which all life depends. It is not surprising, therefore, that maintaining ecological integrity, that is, ensuring wholeness and soundness of ecological systems, is fundamental to sustainable development.

Human existence depends on our ability to draw sustenance from natural resources in ways which do not destroy the natural systems which regenerate this world; assuring ecological integrity essentially means ensuring the health of ecological processes and life support systems. Maintaining ecological integrity encompasses such constituent ideas[22] as:

(a) staying within limits of carrying capacity;
(b) preservation/conservation of biological diversity; and
(c) sustainable utilization of species and ecosystems.

Carrying capacity generally refers to the capacity of an area to sustain a population of a species without reducing its capacity to support the same species in the future. Carrying capacity is concerned with rates of resource consumption and waste discharges and is therefore dependent upon both the productive and the absorptive capacity of the area. When humans are the species of focus, the 'area' requiring attention is the whole ecosphere. The whole ecosphere requires attention because humans are increasingly consuming resources and discharging wastes in ways which effect the whole world. Although carrying capacities are often defined in terms of *maximum* population levels, it is suggested here that the focus be on *optimal* levels for the following reasons: (1) operating at the limits/edges of tolerance which maximums suggest carries with it the risk of vulnerability to small changes in conditions; (2) a focus on maximizing certain populations may bias approaches in favor of one or another species; and (3) seeking optimal levels, especially when including diversity as a requirement, is more likely to encourage a focus on options and possibilities rather than on stretching or reaching limits.

Biological diversity encompasses genetic diversity (diversity within a single species), species diversity (diversity across species) and, by implication, ecosystem diversity (since, particularly at the global level, species diversity is dependent on ecosystem diversity, i.e., variety of different kinds of ecosystems). Biological diversity is necessary to ensure resilience and adaptability to change. For example, breeding a species for particular genetic characteristics seen to be 'preferred' increases our dependence on a narrower genetic base and can make us particularly vulnerable to disease or pests which may eliminate this base entirely. In monocultured tree farms, for example, a disease or pest that favors the single species can destroy the entire crop and with it, other species that may have resided within the farm. Diverse forest ecosystems are not so vulnerable to species-specific pests or diseases and, in fact, often contain chemicals or other defenses which limit the spread of pests or disease. Species diversity is also often essential to the very existence of other species. The underground network of fine filaments of the mychorrhizal mushroom, for example, help feed the forest. As one specific case, Douglas fir, the most valuable timber tree in the Northwest, just would not grow without its mycorrhizal fungi;[23] scientists estimate that Douglas fir "may form mutually useful associations with as many as 2000 kinds of mycorrhizal fungi" (Lipske, 1994, p. 45). Removal of species, therefore, can have profound economic as well as ecological impacts. This point is further emphasized by botanists, ethnobotanists, and others (e.g., IUCN, 1980; Plotkin, 1993; Redclift, 1992) who argue that extinction of species removes from the resource pool resources which are vital not only for ecological health, but for potential agricultural, medical and biotechnical development as well.

Sustainable utilization of species and ecosystems speaks directly to human behavior and activities which draw on species and ecosystems as resources whether for economic gain, the satisfaction of basic human needs, or for leisure. Sustainable utilization requires that humans use resources in a way that does not interfere with sustainability. The current overuse of resources compromises their future productivity and use and is therefore unsustainable. Simply put, sustainable utilization requires the preservation of nature's productivity.

In sum, one of the core principles of sustainable development is to maintain ecological integrity and assure the health of the primary biospheric processes and support systems upon which all life depends. It is imperative, therefore, that we stay within limits of carrying capacity; preserve/conserve biological diversity; and ensure that human utilization of species and ecosystems does not interfere with achieving sustainability.

Equity and Social Justice

> As a system approaches ecological limits, inequalities sharpen . . . [O]ur inability to promote the common interest in sustainable development is often a product of the relative neglect of economic and social justice within and amongst nations (WCED, 1987, p. 49)

The third core principle of sustainable development is concerned with equity, that is, with issues of fairness and justice in terms of access to, and distribution of resources and decision-making power (authority and control). It includes both ***inter-generational*** equity (equity between generations) and ***intra-generational*** equity (equity for individuals and societies existing today). This principle is justified not only on moral or ethical grounds, but, as has already been noted and as historical patterns[24] clearly reveal, on empirical and practical grounds as well (e.g., Barnaby, 1988; FAO, 1992; Gardner & Roseland, 1989a; Khosla, 1987; WCED, 1987). Intergenerational equity depends largely on maintaining ecological integrity. As previously illustrated, assuring ecological integrity requires that attention be given to current inequities (such as poverty and the extreme differences in resource access and consumption) which negatively impact the ecosystem. Intergenerational equity, with its primary focus on assuring ecological integrity, is therefore dependent on intragenerational equity as well.

> Why can't you hear? Why can't you see? You kill yourselves if you kill me.
> (song lyrics, Armstrong in Pike & Selby, 1989, p. 264)

It is with the principle of ecological integrity in mind that a number of people -- deep ecologists, bioregionalists, ecofeminists and animal rights activists among them -- make the more contentious claim that the principle of equity should be extended to non-human life.[25] With recognition of the reality of life and death and 'predator-prey' relationships as caveat, these people have the view "that all things in the biosphere have an equal right to live and blossom and to reach their own individual forms of unfolding and self-realization within the larger Self-realization" (Devall & Sessions, 1985, p. 67). Arguments forwarded for extending rights to non-human life are not altogether dissimilar from past arguments for extending rights to African-Americans, Asians, and women; they ultimately rest on the idea that we are all part of the same kin-dom. Following from this notion, the Third North American Bioregional Congress (NABC hereafter), designated humans as representatives of non-human species -- winged beings, swimming beings, four-legged beings (and "crawling cousins") and plant beings -- in order "to represent the interests and perspective of our non-human cousins" (NABC, 1989, p. 39). This act clearly represents the idea that, in addition to various voices of humans (e.g., women, rural people, indigenous peoples) that need to be heard when considering equity of access to resources, there are non-human 'voices' that also need to be acknowledged. These non-human 'voices' are seen, heard or felt by us in such forms as dead fish floating on the water, dying forests, soil erosion and depletion, and even in our own longing for clean, wild spaces. The voices remind us that when we act, we must act not only on behalf of our own (human) selves, but on behalf of a larger self, our "ecological self" (Naess, 1988); we need "to hear within ourselves the sound of the earth crying" (Seed, 1988).

In terms of fairness and justice in decision-making, it is not likely that many would suggest such power can be forwarded to non-human beings. However, we could conceive of science and technology as the vehicles by which we can better 'hear' the non-human voices and which, through the greater understanding they provide, awaken us to other 'perspectives' which then help to define parameters for the decisions that we humans make. The discussion within this and the previous paragraph may not resonate with many members of a wide audience. It is suggested, however, that the ideas presented here (a) represent a substantial number of people (particularly indigenous peoples) whose perspectives cannot be discounted, and (b) are compatible with the need for a more equitable and less growth-oriented form of development that "aims to promote harmony among human beings and between humanity and nature" (WCED, 1987, p. 65). Even if one accepted that only human interests were important, then to act in the human interest requires full consideration of costs and benefits regarding that interest. Destruction of species is typically not in the long-term human interest; the interests of human beings cannot, ultimately, be divorced from other species since "natural species [are] located in food chains and these food chains [serve] the interests of human populations" (Redclift, 1992, p. 21).

Focussing on the more familiar idea of equity among humans (within and between societies), the call for equity is based on awareness of the increasing disparities between rich and poor; between the few who consume the most and the many who are unable to adequately meet even their most basic physical needs; between those with high degrees of influence and power and those with little or no power of influence (e.g., between dominant and minority cultures; between men and women). That grave disparities threaten sustainable development should by now be quite obvious. First, if many people are unable to meet even their most basic physical needs, and/or if they are unable to exercise some degree of control over their situation, then the goals of sustainable development are not obtained; even those focussed on traditional ideas of growth and development are finding that attention to these concerns are essential for their own economic viability. Second, those who are struggling to survive often heighten problems. For example, in their search for food and fuel, people living in poverty and in environments with limited resources may "transgress the [environment's] carrying capacity more and transgression results in lowering the carrying capacity in the future" (Hardin quoted in Commoner, 1990, p. 145). When previously rural peoples seek shelter in cities (as in Pakistan and Thailand for example), they heighten problems of explosive urban growth -- crowding, pollution, and the breakdown of public services (Barnaby, 1988). Third, and perhaps most importantly, such disparities, even environmental damage itself, cause conflict. The previous Clayoquot Sound example illustrates how conflicts can generate hostile adversarial relationships; in the extreme, conflict may escalate into war. As Barnaby (1988) reports:

> In key areas of superpower tension -- Central America, the Horn of Africa, Iran and Afghanistan -- political instability can be indirectly linked with soil erosion and reduced crop yields. A report on the state of the environment in El Salvador, prepared by USAID in 1982, declared that the "fundamental causes of the present conflict are as much environmental as political, stemming from problems of resource distribution in an overcrowded land." Inequitable land distribution, and loss of livelihood through erosion and deforestation, create ideal breeding grounds for conflict and strife. (p. 102)

In sum, disparities cause tension; when tension escalates into conflict, the environment is often put under even greater pressure. This leads to more conflict, even to war; war brings devastation to infrastructure and the natural environment, generates refugees who in their struggle to survive put pressure on ecosystems and on urban facilities, and so the circle continues. Clearly, if sustainable development is to be achieved, grave and debilitating disparities will have to be reduced if not eliminated. Achieving equity between and within generations is a fundamental facet of sustainable development; sustainable development cannot be accomplished unless there is greater equity in access to resources and decision-making power, and in the distribution of costs and benefits.

Although "goods and services provided by industry, and . . . a continuing flow of wealth from industry" (WCED, 1987, p. 16) may be needed to address certain global equity concerns, they are neither sufficient nor without negative effects. As many discussions of sustainability point out, we cannot avoid the fact that substantial reduction in the consumption of resources and the production of wastes by the affluent may be required -- the pie is not getting any bigger. To better address disparities, a number of ideas closely linked to the principle of equity have been suggested. They include, for example: self determination (Gardner, 1989; Gardner & Roseland, 1989b; Heinegg, 1979; Jacobs et al, 1987; WCED, 1987); greater citizen involvement in decision-making (BCTFEE, 1989; Environment Canada, 1990b; FAO, 1992; Sadler & Hull, 1990; WCED, 1987); decentralization (Boulding, 1988; Devall & Sessions, 1985; Garbarino, 1988; Gardner, 1989; Heinegg, 1979; Jacobs et al, 1987;); and 'democracy' (Devall & Sessions, 1985; Jacobs et al, 1987; Milbrath, 1989; Pasmore, 1986). These ideas are seen as critical to achieving equitable distribution of resources and power; so critical, in fact, that they are often identified as distinct and key principles of sustainable development (e.g., in BCRTEE, 1992; Environment Canada, 1990b; Jacobs & Munro, 1987; NTFEE, 1987; WCED, 1987). The ideas give rise to two process-oriented principles discussed in the following sections under the headings "participation and cooperation" and "organizational structures and systems."

Participation and Cooperation

> Historical patterns of resource use repeatedly demonstrate the importance of commonality of interest and egalitarianism. (Jacobs, Gardner & Munro, 1987, p. 21)
>
> An engaged citizenry must become involved with the choice, governance and even the design of technological artifacts and processes. (Sclove, 1991, p. 240)

The solution to metaproblems that sustainable development is intended to address (e.g., reversing land degradation while maintaining economies; increasing self-determination and self-reliance without distorting the system to favor the rich) go beyond any single individual, discipline or organization. As a result, one of the process-oriented principles of sustainable development is to facilitate and promote wide-ranging participation and cooperation in discussion, decision-making, planning and implementation of solutions for resolving the numerous and complex problems associated with achieving sustainability.[26] The need for participation and cooperation is explicit in the literature through calls for increased cooperation among disciplines, among government, NGOs, industry and the public, and among nation states. The principle is also embedded in broader discussions of democracy (especially participative versus representative) and self-determination (including such issues as localized decision-making, self-reliance and self-governance). What is central to the principle of participation and cooperation is the idea that decisions should be made by those who will be affected by them.

While decision-making structures and systems will be discussed further in the following section, it is appropriate to begin discussion here. First, the tendency to compartmentalize disciplines and function areas (e.g., management, finance, marketing, operations, research) has led to incomplete understandings and to decisions and practices which are fragmented and often work at cross purposes. Second, in traditional systems of decision-making (including expert and market systems) power and control is located in the hands of the few who, by acting on the basis of limited or narrow conceptions of common- or self-interest, have contributed to environmental crises and to a widening of disparities between the haves and the have-nots. The principle of participation/cooperation is intended to counteract such negative outcomes and to initiate a transformation of the decision-making process. More "enlightened" managers and decision-makers recognize the failings of traditional systems and are increasingly incorporating the principle of participation/cooperation in their approaches (e.g., quality circles, team-management, public consultation, consensus decision-making, involvement of local people in international projects, formation of alliances across disciplines, interest groups and industry sectors). Recently proposed legislation in B.C., for example, is intended to "define the governmental and public responsibilities required to ensure cooperation and efficiency in the achievement of economic, environmental and social sustainability" (Commission on Resources and Environment [CORE hereafter], 1994, p. 39); the Sustainability Act proposed "would provide a legal framework to ensure coordination of government initiatives, meaningful public participation in decision-making, an effective dispute resolution system, and independent oversight" (CORE News Release, November 24, 1994).

The principle of participation and cooperation is seen as a means by which the productive potential of a diversity of human resources can be tapped (Pasmore, 1986). More specifically, it is the means for (a) melding different kinds of objectives (e.g., environmental, economic, sociocultural) in ways that serve an expanded notion of 'common interest'; (b) dealing constructively with diverse interest groups; (c) determining strategies most appropriate and acceptable to both local and global contexts; (d) helping citizens learn to better perceive, anticipate and act on problems inherent in achieving sustainability; and (e) reducing the need for (and costs of) governmental intervention. Further, increasing levels of participation fits with the higher education levels of many citizens and with citizens' desire, and even demand, for greater involvement in decision-making.[27] Participation and cooperation will necessarily require, and success will be dependent on strong communication, interpersonal and group process skills, and the kinds of approaches used. Participation and cooperation, however, does not imply that group processes replace individual leadership or initiative. In fact, it is expected that through greater cooperation and participation in decision-making, individuals will feel more empowered, leadership will be distributed more widely, and individuals will make greater commitments to actively resolving problems.[28]

In sum, participation and cooperation among a diversity of stakeholders in problem-solving, decision-making and implementation of strategies is necessary to address the cross-sectoral, cross-boundary and cross-disciplinary issues involved in achieving sustainable development. The call for increased participation and cooperation challenges all nations to play a role "in changing trends, and in righting an international economic system that increases rather than decreases inequality, that increases rather than decreases numbers of poor and hungry" (WCED, 1987, p. 22). Unfortunately, increased participation/cooperation requires a reorientation that is often "simply beyond the reach of present decision-making structures and institutional arrangements" (WCED, 1987, p. 23).

<u>Organizational/Relational Structures and Systems</u>

> [O]rganizations [need to develop] "contextual competencies" that focus on bridge building between different sectors of society, reframing shared problems to create new solutions, blending the ability to act locally and nationally, and developing a new sense of social responsibility. (Morgan, 1989, p. xiv)

Overall, the current state of the world and the call for sustainability is causing us to develop "new big pictures out of . . . value systems and world views that are unfamiliar, themselves evolving, and in many cases completely untried" (Vaill, 1989, p. 111). These "new pictures" have several organizational implications. For example, organizations will need to find ways to do more with less (especially if they are resource-intensive); management and planning will need to shift attention from top-down or expert approaches to approaches that are more interactive and collaborative and include individuals and/or groups not traditionally involved in decision-making;[29] and education and training will be required to ensure that necessary understandings (e.g., of issues, processes, leadership, group effectiveness) and skills (e.g., technical, participative, leadership) are acquired. To accomplish this "we all need continuous help from each other. Interdependence is the greatest challenge" (Lewin quoted in Weisbord, 1987, p. 104).

Responses to these needs can be found in the burgeoning of grassroots organizations, in the establishment of additional mechanisms for decision-making in government, in the organizational restructuring of corporations and even in the establishment of legislation requiring public consultation and/or participation in major development project review processes. All of these demonstrate that meaningful participation and positive, pro-active action is largely dependent on redistribution and decentralization of power. Grassroots organizations,[30] for example, have been very influential in increasing awareness, understanding and attention to issues, in providing skills,[31] and in providing the means through which concerned citizens can have a voice and potential influence in decision-making that was previously beyond their spheres of influence; in many ways, grassroots organizations and coalitions have provided the support systems to nurture leadership and innovation.

Often in response to such grassroots and other non-governmental organizations, governments are challenged to find ways to be more collaborative in their decision-making processes. Many levels of government (national, provincial, regional and municipal) in Canada are currently exploring the possibilities of "roundtables" consisting of member representatives of diverse interest groups. Most roundtables act as consultative or advisory bodies and a few, generally at the more local levels, have been empowered to implement action. Governmental roundtables have been useful in soliciting input from citizens and various interest or stakeholder groups and have done much to increase awareness of issues; however, the long term benefits of roundtables in terms of action-implementation remains to be seen. Governments have also initiated legislation requiring that proponents of large projects (e.g., mining, dam-building) and certain sector-based corporations (e.g., private forestry companies) provide more broadly-based justification (e.g., social or environmental impact assessments) for their intended activities and involve citizens in the planning and implementation of such activities. Unfortunately, public 'involvement' tends to take the form of consultation often with questionable results.[32]

Some governmental organizations, recognizing that consultation is insufficient, are exploring and experimenting with ways to more adequately involve the public in problem-identification, problem-solving, and decision-making. The City of North Vancouver's Department of Engineering and Operations, for example, has established a committee – which includes members of the public -- to develop a process of joint-planning and decision-making between members of the public and the department of engineering and operations;[33] a process which empowers citizens as well as individuals within the engineering department. Transportation, waste management, funding, land use planning and development, housing, resource consumption and supply of services (e.g., energy, water) are among the issues targeted in the joint-planning process.[34] The engineering department recognizes, however, that concerns "will arise involving some, if not all, City departments" (from submission to Mayor and Council) and that internal organizational changes will likely be required. The forms these changes may take are still to be seen but the engineering department is at least clear that participation and agreement will be required from most, if not all, City departments in order to develop innovative responses to the challenges.

Corporations like 3M, IBM, Digital, and others have recognized the benefits of redistributing and decentralizing decision making within their organizations and have concluded that 'small is beautiful' (Morgan, 1989; Peters & Waterman, 1982). These high-performing companies have developed systems to empower and support smaller working groups and to encourage innovation. Vancouver Parks and Recreation (VPR) provides another example of "buying-in" to the small-is-beautiful idea as a way of transforming the organization. In response to employee feedback regarding desires for increased involvement in decision-making, VPR sponsored a workshop in team-building for the whole organization (Crofton & Dickinson, 1994) and initiated a "Self-Managed Teams Pilot Project" whereby discretionary control and accountability regarding operations, budget and staffing is decentralized to a "self-managed team."

It is clear that some significant organizational changes are occurring at various levels of human organization. In some sense, the process of change initiated by the call for sustainable development – and particularly the call for increased cooperation and meaningful participation – has become "autocatalytic" (Lynch & Kordis, 1990, p. 243);

it is, in effect, reproducing itself. For example, as the engineering department becomes involved in joint-planning with the public, old decision-making structures will necessarily be transformed or give way; in the likely event that the VPR extends the pilot project to other of its centers, organizational structures and systems will again change.[35] Since current thinking is going towards decentralization and "loosely coupled systems" (Weick, 1976), there will be a need for linkages and ways to liason between or otherwise hold together the various 'units,' groups and systems, not in some tightly controlled hierarchical way, but "as some kind of community of vision and feeling" (Vaill, 1989, p. 70) that facilitates commitment and progress toward sustainability. New technologies may provide one means for connecting decentralized groups by creating possibilities for new styles of organization to emerge. In spite of what appears to be a tendency for increased commitment to decentralization, however, we should be sure that such a commitment does not prevent us from asking which functions are best done by decentralized groups and which by centralized organizations and systems. Neither centralization nor decentralization are moral absolutes; treating them as such will inhibit the design of a system that best incorporates them both.

Sustainable development has other kinds of organizational implications as well. As the WCED (1987) notes:

> The integrated and interdependent nature of new challenges and issues contrasts sharply with the nature of institutions that exist today. These institutions tend to be independent, fragmented, and working to relatively narrow mandates with closed decision processes. Those responsible for managing natural resources and protecting the environment are institutionally separated from those responsible for managing the economy. The real world of interlocked economic and ecological systems will not change; the policies and institutions must. (p. 310)

Organizations without mandates to concern themselves with sustaining resources upon which they depend will need to develop them; where mandates exist but are grouped in separate agencies, departments or work units, organizations will need to focus on ways to increase linkages, liasons and cooperation between various (often non-traditional) individuals and groups. For example, organizations will have to develop new capacities for performing group liason and group process design and facilitation functions. These capacities will be in terms of material resources (e.g., information systems technologies), physical facilities (e.g., to accommodate working groups and meetings), and human resources (e.g., facilitators, group process designers, different kinds of 'managers'[36]) pertaining to groups both internal and external to the organization. It will also mean organizations will need find ways to involve individual citizens or group representatives who, due to financial or time constraints, are restricted from participation.

In order to 'ride the waves of change' (Lynch & Kordis, 1990; Morgan, 1989), managers and administrators will need to anticipate change, test and retest plans, and become more comfortable and skilled in the "science of muddling through" (Lindblom, 1959). Organizations will need to be adaptable to diverse settings as well as diverse planning or problem situations (including unexpected changes and unintended consequences). Adaptive mechanisms such as monitoring and feedback systems, experimentation, and learning will need to be part of organizational systems (Gardner, 1989; Jacobs et al, 1987; Khosla, 1987; Laszlo, 1973). When uncertainty is high and rapid and multiple changes are occurring or called for, "only raw creation of wholly different ways of running businesses and organizations will suffice" (Lynch & Kordis, 1990, p. 251). It is not entirely clear what new organizational approaches will develop but it *is* clear that situations are being shaped by multiple stakeholders with multiple understandings, expectations and demands. Institutions will need to incorporate sustainable development into their policies and practices, exhibit greater flexibility and openness to increasing demands for involvement in the decision-making process, and be willing to change in the course of the learning process.

In sum, organizational structures and systems which are consistent with and supportive of sustainable development are required. In particular they must be designed to (a) account for and facilitate linkages and connections among people and organizational systems; (b) account for the temporal and spatial contexts of decision-making; (c) facilitate the convergence of individual and societal interests; and (d) promote and support increased self-determination and self-reliance at the local community level.

Appropriate Technology

> Design should follow, not oppose, the laws of nature. (Todd & Todd, 1990, p. 61)

A third process-oriented principle of sustainable development requires that technology chosen or developed is appropriate to its application context and consistent with the sustainable development goals. The principle of appropriate technology arises from the recognition of the power technology (tools, practices, systems) has in transforming the environment and relationships between people, and between people and the environment.[37] Although technology has had many positive impacts (e.g., financial gains from new innovations; computer/information systems which permit us to not only do old things better but to do new things in new ways), the call for *appropriate* technology is most often focussed on the negative impacts and general failings of technology. Negative impacts include damage to the environment through extensive resource consumption, waste generation and pollution, and the impacts of robotics and automation on employment and in making human minds and hands redundant rather than productive (Schumacher, 1973). The general failings for which technology has been criticized include its primary focus on narrow utility or efficiency of production or profit in the short term (Devall & Sessions, 1985), efficiency-induced increases in resource consumption (Wackernagel & Rees, 1993), inadequate focus on norms and values or justice and equity issues, and the relegation of decisions to 'experts.'[38]

The principle of *appropriate technology* represents a shift in focus from 'gadgetry', narrow utility and efficiency and an almost exclusive concern with expanding economic output, to "self-help, or democratic or peoples' technologies" (Schumacher, 1973, p. 143). That is, to technologies which are "compatible with the growth of autonomous, self-determining individuals"[39] (Devall & Sessions, 1985, p. 35), which serve vital needs and are not ecological destructive. Technological appropriateness "include[s] its relation to social appropriateness or equity" (Gunnerson, 1988, p. 299). Embedded in the principle of appropriate technology is the recognition that technology and society are interacting systems and "there can be no technology isolated from society or society isolated from technology" (Layton, 1991, p. 73); we design and change technologies and these technologies, in turn, 'design' and change us and our relations with the world. The principle of appropriate technology calls us to recognize and establish some self-limiting principles for technology.[40]

The key idea behind the principle of appropriate technology is one of 'fit' (Devall & Sessions, 1985; Khosla, 1987; Vaill, 1989). Considerations include, for example, fit with known biological laws; fit with psychological impact on human beings who will operate the technology and be affected by its outputs; fit between the intended output and the needs these outputs are to meet; fit with the norms and taboos of the culture in which the technology will exist;[41] and, of course, fit with the principles of sustainable development. Obviously, the success of a technology will depend on critical assumptions made around questions of fit; more importantly, success will depend on the degree to which the chosen technology has synthesized and reinforced individual and societal interests. Success will rely heavily on (a) knowledge of the physical, economic, cultural, social and political contexts that need to be considered (and creative use of that knowledge); (b) awareness of various alternative technologies including the more traditional or 'primitive' technologies that have been utilized effectively in the past; and (c) participation by diverse stakeholders who can provide feedback on assumptions, design choices, and implementation of technologies.

The latter point reinforces the importance of the principle of participation and cooperation discussed previously. Effective dialogues -- what Morgan (1989) calls "learning-oriented conversations" -- which maximize user involvement in development and selection of technologies and which enable and strengthen user capabilities and understanding of technologies, will be essential. At this time, most urgently needed technologies are those which are benign, restorative, and predictive (e.g., monitoring and assessment technologies). We should not, however, expect that a technology proved effective in one setting or context will automatically be transferrable to another: technologies cannot be limited to one prescription; a diverse array of technologies appropriate to a particular set of needs and contexts must be considered. Further, we have learned that as some problems are solved, new problems may appear; there will always be a need to return to and re-evaluate goals and objectives as we develop "a relative value system of the basic parameters in our objective of an improved quality of life" (Starr, 1972, p. 215). Technology has become part of the fabric of human activity; technologies which are appropriate to particular needs and contexts and congruent with the aim to achieve sustainability, are essential in the movement towards sustainable development. As a result, existing technologies must be re-examined, inappropriate applications must be altered or eliminated, older technologies may need to be re-established, and new technologies must be developed in order to achieve sustainability.

Summary

The preceding principles, together with the ultimate goal of health and well-being, represent key requirements for sustainable development. Although other principles or sub-principles could be included in this list, the principles discussed here are sufficient to provide a basic framework for sustainable development. Three of the principles direct attention to the core, substantive concerns of sustainable development. In essence, they pertain to relationships, conditions and exchanges: between humans and the environment (economic aspect), within and among ecosystems (environmental aspect), and among humans (social aspect). Briefly, sustainable development requires that (a) humans' basic needs for survival and psychological well-being be met; (b) ecological integrity is maintained; and (c) equity and social justice is assured. A further three process-oriented principles were also discussed. These principles focus on support mechanisms without which it would be difficult if not impossible to achieve sustainable development. Thus, sustainable development also requires (d) participation and cooperation among diverse stakeholder groups; (e) development of appropriate organizational structures/systems; and (f) use of appropriate technology. Collectively the principles should form the basis and framework to which the design, organization and choice of projects, products, settlements, industry, social institutions, and socio-political-economic systems should adhere. (Sustainable development goals and requirements are represented simply in Exhibit 2-1.

Exhibit 2-1:
A Simple Representation of Sustainable Development Goals and Requirements

Achieving the primary goal of sustainable development		Human Health and Well-being	
requires health and balance of various systems	Economic Systems	Environmental Systems	Social Systems
and, therefore, attention to conditions and exchanges within those systems.	Human-Environment Relationships	Relations within & across Ecosystems	Human-Human Relationships
Sustainable development incorporates three primary, foundational principles	Meet human needs (material & non-material)	Maintain ecological integrity	Ensure equity & social justice
and three supportive, process-oriented principles	Facilitate Participation & Cooperation	Use Appropriate Technology	Develop Appropriate Organizational Structures
intended to facilitate the meeting of sustainable development's goals.			

Alignment with Goals and Requirements of Professional Engineers

Sustainable development's ideals and requirements are closely aligned with those of the Canadian engineering profession. The alignment can be demonstrated by comparing sustainable development's goals and requirements with those of the engineering profession. Policy documents of the Canadian Council of Professional Engineers (CCPE) provide guidelines to the various provincial and territorial associations of professional engineers responsible for the regulation of engineering practice in Canada. The guidelines "are an expression of general guiding principles which have a broad basis of consensus" (CCPE-CEQB, 1994, p. 8) and "form the basis and framework for responsible professional practice . . . [Practicing professionals are to] interpret the essence of the underlying principles within their daily decision-making situations in a dynamic manner, responsive to the needs of the situation" (CCPE-CEQB, 1992, p. 21). Since a consensus on norms already exists[42] and is expressed within CCPE policy documents, CCPE guidelines will be used to reveal the ways engineers' ideals and requirements are aligned with those of sustainable development.

Human health and well-being, and the constituent economic, environmental and social concerns, are clearly evident throughout the policy documents. For example, the qualification criteria outline the academic, language, and experience requirements for becoming a professional engineer. It is expected that candidates have knowledge and experience in, for example, analysis (including "safety and environmental issues, technology assessment, economic assessment, etc."); design and synthesis (including "integration of components and sub-systems into larger systems . . . human and environmental aspects and the societal implications of the product or process"); implementation methods (including "cost/benefit analysis, safety and environmental issues"); the management of engineering (including, e.g., planning "through to social ramifications of project implementation" and "risk assessments related to . . . social and environmental impacts") (CCPE-CEQB, 1994, pp. 10-11). Other expectations related to health, environmental, economic and social concerns are contained in detailed discussion of the Code of Ethics under such headings as "Protection of the Public and the Environment," "Fairness and Integrity in the Workplace," and "Professional Accountability and Leadership."[43] In fact, the core concerns of sustainable development are part of what defines the practice of engineering:

> The "practice of professional engineering" means any act of planning, designing, composing, evaluating, advising, reporting, directing or supervising, or managing any of the foregoing, that requires the application of engineering principles, and that concerns the *safeguarding of life, health, property, economic interests, the public welfare or the environment.* (CCPE-CEQB, 1994, p. 8; italics mine)

Health is explicitly stated in the definition of engineering. Further, given the inclusion of environment, economic interests and public welfare in the definition and elsewhere in the guidelines for professional engineering practise, it appears that engineers are expected to take the broad view also required for health and sustainable development. Further assurance that a broad and wholistic view is a professional ideal is provided by other statements. For example, a requirement of the management of engineering is "project control, which requires understanding the elements of a greater whole"; even scheduling is to go "beyond to broader aspects such as interactions with other projects and the market place" (CCPE-CEQB, 1994, p. 11). In a later section interpreting the definition of engineering, it is emphasized that "protecting the public interests and the question of whether the public is a risk must be considered in the broadest terms. . . . the outcome of the engineering undertaking must be viewed from its broader societal perspective" (CCPE-CEQB, 1994, p. 19).

It is clear that sustainable development's goals and ideals (core concerns) are part of what defines engineering; it is also clear that engineers are expected to be qualified to attend to these concerns in the context of their engineering work. Further, engineers "have an *obligation* to be mindful of the effect that their decisions will have on the environment and the well-being of society" (CCPE-CEQB, 1994, p. 24; italics mine). In fact, the engineers' Code of Ethics makes it very clear that health and well-being have primacy in engineering work:

> Professional engineers shall hold paramount the safety, health and welfare of the public and the protection of the environment . . . The meaning of "paramount" in this basic tenet is that all other requirements of the Code are subordinate if protection of public safety, the environment or other substantive public interests are involved. (CCPE-CEQB, 1994, p. 21)

Although economic concerns are not explicitly stated in this basic tenet, it would be reasonable to expect that concern for public welfare and/or "other substantive public interests" is inclusive of economic concerns. The language of protection and safety found throughout the CCPE-CEQB document (e.g., "protect the public" (pp. 12 & 18); "protecting public interests" (p. 19); "safeguard the public" (p. 24)) reiterates the concern for health and well-being. It should be noted, however, that engineering work is not limited to minimizing risk and protecting from harm; engineering is also intended to improve conditions. For example, "dedication to generally enhancing the quality of life" is considered one of the "cornerstones of professional responsibility" (CCPE-CEQB, 1994, p. 23), and engineers are to be aware of their role and responsibilities regarding "the environmental, economic, social and cultural *aspirations* of society" (CCPE-CEAB, 1994, p. 13; italics mine).

It is true that, although the core concerns and goals of sustainable development are incorporated, even emphasized, in engineers' policy documents, the term "sustainable development" is not generally used. Given that the term has only recently been used to represent the inter-related ideals of health (environmental, economic, social), this should not be surprising. In fact, prior to 1991, the only professional engineering association found to have developed a policy specific to sustainable development was the Institute of Engineers Australia (Jenkins & Codner, 1990). By 1990, however, sustainable development was clearly placed on the agenda for consideration by B.C. professional engineers; by 1992, the APEGBC had stated a series of objectives for engineers and sustainable development and thereby made sustainable development an explicit part of the B.C. engineers' agenda. As of 1994, the concept of sustainable development is itself associated with expectations of professional engineers in Canada:

> The engineering profession expects of its members . . . an understanding of the effect of engineering on society. Thus, . . . they must also develop communication skills and an understanding of the environmental, cultural, economic and social impacts of engineering on society and the concept of sustainable development. (CCPE-CEAB, 1994, p. 13)

Since the publication of the CEAB document, a companion document to the CCPE Guidelines for professional engineering practice, <u>CCPE Guidelines for the Environmental Practice of Professional Engineering</u>, was approved by Council (November 1994). This document describes "four basic tenets which are key to the environmental role and responsibility of the professional engineer" (CCPE Task Force, 1994b, p. 2): (a) education, awareness and competence; (b) integration of environment into all engineering work; (c) cooperation and compliance; and (d) leadership and responsibility. The document is also explicit about engineers' role and responsibilities in sustainable development. For example, "principles" to guide the integration of environmental concerns into all engineering decisions include: "Engineers must strive to develop solutions to engineering problems compatible with the environment within technical, social and economic constraints; appropriate management of resources, in adherence to the principles of sustainable development, must be practiced at all times" (CCPE Task Force, 1994b, p. 3). Further, the fourth tenet, concerned with Leadership and Responsibility, states that:

> Technical responsibilities extend to maintaining the viability of natural systems which may be impacted by engineering works including prevention . . . improvement of existing systems . . . and mitigation of past damages. . . . Engineers must recognize the key role of engineering in sustainable development. (CCPE Task Force, 1994b, p. 4)

There can be no question that sustainable development goals and ideals are embedded in the goals and ideals of engineering practice. Although the "principles of sustainable development" are not directly specified in any of the CCPE documents, it is evident that the core defining principles of sustainable development (i.e., those concerned with environmental, social, economic issues) are essential components of all engineering work. Further, there are indications that sustainable development's supportive, process-oriented principles defined earlier are also represented among the engineers' ideals. The idea of appropriate technology, for example, appears to be implicit in engineering work. Engineers are required to engage in technology assessment (CCPE-CEQB, 1994, p. 10), assure quality, use optimization techniques, understand the greater whole, and "take appropriate action" (CCPE-CEQB, 1994, p. 11).

Sustainable development's process principles concerned with participation/cooperation and organizational structures are evident in recent studies of engineers (e.g., Crofton, 1991e; Dickinson & Crofton, 1994) but are less clearly evident in engineers' policy documents. Nonetheless, policy documents do provide indications that these process principles are also part of engineering ideals and requirements. For example: The CCPE Task Force recommends that engineers contribute to public policy decisions and participate in environmental groups; further, the Task Force underlines "the need for CCPE to have a strategy to address the environment, *supported by effective organization and communications*" (CCPE Task Force, 1994a, p. 4; italics mine). Communication skills are also targeted by CCPE qualification requirements: Communication skills are to be applied "to all areas of the work environment including communication with superiors, co-workers, government regulators, clients, and the general public" (CCPE-CEQB, 1994, p. 11). Further, the Code requires that engineers "ensure that clients and employers are made aware of societal and environmental consequences of actions or projects and endeavour to interpret engineering issues to the public" (CCPE-CEQB, 1994, p. 15). The new CCPE companion guidelines require that engineers "follow a consultative and interdisciplinary path in evaluating risks and benefits" (CCPE Task Force, 1994b, p. 2), that they cooperate fully with regulating authorities, work on multidisciplinary teams and seek public input where appropriate (CCPE Task Force, 1994b). Two of the APEGBC sustainable development objectives are perhaps even more explicit: "To ensure that decision-making is comprehensive and multi-disciplinary"; "To contribute to public discussion and to seek information from, and opinions of, the public" (APEGBC Task Force, 1992, pp. 12-13). The CCPE also states that "the outcome of an engineering undertaking must be viewed from its broader societal perspective - the judgement of the engineer's employer or client, or the engineer, are not necessarily adequate" (CCPE-CEQB, 1994, p. 19). This implies that people other than those immediately involved with the undertaking must be involved in decision-making.

The preceding illustrative policy statements resonate with sustainable development requirements for participation/cooperation among diverse stakeholders and enlarged participation in decision-making; multidisciplinary teams, effective organization, and "team-building" (one of the requirements for the management of engineering, CCPE-CEQB, 1994, p. 11), also resonate with organization structure requirements of sustainable development. Further, since communication is an essential requirement for success of participative/cooperative activities and organizational change efforts, the CCPE requirements clearly support sustainable development's process requirements. Given that sustainable development ideals and requirements (health and well-being and its core and process-oriented principles) are incorporated within and are part of what constitute the ideals and requirements of the Canadian engineering profession, it is reasonable to conclude that engineers are already obligated to concern themselves and take actions consistent with achieving sustainability.[44]

Summary

> The earth will continue on some level no matter what humans do. But if we continue our . . . assault on the planet, all future possibilities will be severely limited. To expect Rembrandt to create a new painting is fine, but if you first remove an eye and large portions of his brain, you will have to accept what he is able to give you out of his diminished capacity. (Swimme, 1984, p. 74)

Sustainable development, to ensure decent human life, challenges humans to design their productive and consumptive systems in ways which minimally impact the environment. In effect, it calls the human community to find "its particular place within the living and dying that marks the interdependence of life in an integrated ecosystem" (Plant, 1990, p. ix). This chapter has reviewed the history of the idea of sustainable development and the challenges it presents. It is clear that the environmental, social, and economic ills of the world are inter-related and that to achieve sustainability all need to be addressed. Fortunately, although interpretations and directions may vary by particular emphasis, there is considerable agreement about what should define and guide efforts toward sustainable development. The ideals of sustainable development were articulated by way of three core substantive and three supportive process-oriented principles. A comparison of these ideals with those of engineers revealed that sustainable development's primary concerns (core substantive principles) are part of what defines engineering and are what engineers are to hold paramount in their work. It was also shown that sustainable development's process-oriented principles are explicit or implicit requirements for engineering work.

Following from Dearden's (1975) model for identifying and justifying needs and interventions (as discussed in Chapter 1), the parallel ideals and requirements of sustainable development and engineering are intended to fulfill Dearden's first criteria "that there should be some kind of norm, for example a standard of living, the 'proper functioning' of a thing, an explicit rule or a notion of what it is to do something properly or efficiently" (p. 51). Briefly the ideals and requirements, that is the "standards," are as follows:

1. Meet present human needs "without compromising the ability of future generations to meet their own needs" (WCED, 1987, p. 8);

2. Maintain ecological integrity by staying within the limits of carrying capacity; preserving/conserving biological diversity; and ensuring that human utilization of species and ecosystems does not interfere with ecological sustainability;

3. Ensure equity, between and within generations, in access to resources and decision-making power and in the distribution of costs and benefits;

4. Address cross-sectoral, cross-boundary and cross-disciplinary issues by participating and cooperating with a diversity of stakeholders in problem-solving, decision-making and implementation of strategies;

5. Ensure that organizational structures and systems facilitate linkages and connections among people and organizational systems; account for the temporal and spatial contexts of decision-making; facilitate the convergence of individual and societal interests; and promote and support increased self-determination and self-reliance at the local community level;

6. Use technologies which are appropriate to the context of their application and consistent with the ideals and requirements of sustainable development.

The ability to meet these ideals and requirements depends on such things as an understanding of the systemic nature of the world, the interconnectedness of human and non-human systems and of local and regional issues; understanding of different perspectives and values that may not be universally shared; skills for constructive participation; and preparedness to take responsibility to contribute to sustainable development (BCRTEE, 1993a). Dearden (1975) suggests that a "need" exists when a 'norm' "has not been achieved or could well fail to be maintained" (p. 51). To determine what "needs" may exist within the engineering professions, the next chapter investigates the current state of engineers' knowledge, skills, practices and responsibilities regarding sustainable development.

<u>Endnotes</u>

1. 'Ecological integrity,' the idea of ensuring the health of environment, is one principle that is central to sustainable development and it is an idea incorporated by a number of religions and cultures. For example, the Australian Aborigines' "Songlines" or "Way of the Law" connect humans to each other and to the earth: "To wound the earth, is to wound yourself, and if others wound the earth, they are wounding you" (Chatwin, 1988, p. 11); the Christian Bible states, "Hurt not the earth, neither the sea, nor the trees" (Revelations 7:3).

2. The "dust bowl" example was provided by Dr. Michael Pitt of UBC Agricultural Sciences in a personal communication.

3. It should be noted that population statistics provided are population *estimates*. In making my statement of population increases I referred to estimates for 1920 (1.860 billion), 1940 (2.295 billion) and 1960 (2.991 billion) provided by the United Nations (1969). The 1960 population figure of 3 billion is also reported by the WCED (1987, p. 100) and the FAO (1992, p. 15); the FAO (1992) further states that population increased by one billion between 1930 and 1960.

4. General support for suggested timing and intensification of fertilizer and pesticide use was received from soil fertility specialist Dr. Art Bomke, UBC Soil Sciences Department. Dr. Bomke notes, however, that the timing of increased "add-chemical" approaches varies from location to location. For example, taking nitrogen use as an indicator of increased use of fertilizers, a sharp rise in nitrogen consumption was reflected in the United States in the late 1950s; a similarly sharp rise was reflected in Canada about ten years later. Dr. Bomke also believed it was reasonable to locate the rise in environmental concerns (e.g., pesticide use, levels of nitrates in rivers and lakes) in the 1960s and 1970s. In support of this perception, he recalls that the beginning of his doctoral work in 1968 "almost exactly coincided with the first environmental crisis"; he describes this as a time when a whole range of real and perceived problems regarding agricultural problems were raised (particularly as a result of Rachel Carson's work) and when campus activity (e.g., teach-ins, debates) were focussed on environmental concerns. The energy crisis of the 1970s and subsequent efforts in energy accounting were also offered as examples of increased environmental awareness during this time.

5. The Library of Congress established *Sustainable agriculture* as a subject heading in 1987 and *Sustainable forestry* in 1989. The Library of Congress had been assigning the slightly broader heading *Economic development-Environmental aspects* to materials on the topic of sustainable development for several years until *Sustainable development* was established as a topic in its own right in 1992 (personal correspondence, December 23, 1993).

6. The contents of "Health and Healing" sections in bookstores attest to the variation in conceptions of health and health care. The increasing diversity of health-care options (e.g., polarity therapy, massage, chiropractics, naturopathy, homeopathy, acupuncture, herbology) as alternatives to or extensions of the standard western medical model also demonstrates this expanded view of health.

7. For further discussion of the effect of society and culture on health and conceptions of health see Capra (1988), Dubos (1979) and Russell (1983). Various books on sustainability and development (e.g., Our Common Future, WCED, 1987; The Gaia Peace Atlas, Barnaby, 1988) and on pollution, also point to the interrelationship between individual health and larger political, economic and environmental issues. The recent requirement for Bulgarian school children to wear masks to guard against air pollution is an example of how integrated these issues are.

8. Ironically these same patients in their desire for familiar environments have transformed desert areas into small oases with many of the same trees and shrubs that produce the pollen from which they were to escape.

9. The BCTFEE categorized the range of responses into four basic groups representing differing beliefs and approaches, with some submissions reflecting more than one of these categories. The categories are not strictly discrete. One category, for example, "reflects a global consciousness regarding consumption of resources" (BCTFEE, 1989, p. 16) where greater conservation and sharing of resources is seen to be needed. Beliefs of many of those falling into two of the other categories also reflect concern about resource consumption, and individuals in all three of the other categories endorse, to some degree, the idea of conservation. The difficulty in forming discrete categories and the fact that some submissions reflect more than one of the categories demonstrates the connectedness of various interpretations.

10. Many writers have explored various systems of influence; further, they have critiqued these systems in terms of the influence they have or have had on our ways of seeing and acting. Among others, these explorations and criticisms have focussed on (a) Judeo-Christian ideology (Berry, 1988; Chicago, 1979; French, 1985; Walker, 1988); (b) the influence of Cartesian-Newtonian conceptions in science (and subsequent theories of relativity and quantum mechanics) (Bateson, 1988; Bohm, 1987; Capra, 1988; Sahtouris, 1989); (c) the development of the market economy along with the impact of the rise of capitalism and industrialism (Dale, 1982; Eisler, 1988; Henderson, 1978, 1988; Russell, 1983); and (d) the influence of societies based on male-dominated hierarchies (Berry, 1988; Diamond & Ornstein, 1990; Eisler, 1988; Plant, 1989; Walker, 1988).

11. "Battle for the Trees" is also the title of a film (National Film Board, 1993) documenting the conflict.

12. For example, if we define global goals of growth and development in terms of current lifestyles of Canadians, sustainability will not be possible. Based on 1991 Canadian consumption statistics and 1992 global population statistics, Wackernagel and his associates conservatively estimate that, for everyone on Earth to live like today's Canadians, an additional two Earths would be required to provide all the resources (Wackernagel, 1993; Wackernagel et al, 1993).

13. Redclift (1992) details a number of limitations of GNP as a measure of development including: (a) "GNP measures 'productive' activity in a very narrow way." It is a measure confined to 'formal sector' activity (e.g., agriculture, manufacturing); it excludes the " 'informal sector' in which markets exist but are not fully reported statistically, and where people produce for their own consumption" (e.g., collecting firewood, cooking food). (b) GNP "is a blunt instrument for economic

development without considerable attention being given to demographic profiles. Per capita figures . . . disguise the number of dependents within families, the number of single parents and elderly people without dependants. . . . per capita figures tell us very little about the relationship between income, wealth and patterns of income distribution." (c) GNP is an inadequate measure of how production is deployed. "All measureable production activity is considered the same, whether it is channelled towards arms expenditure or the maintenance of a primary health-care system. This makes it impossible to distinguish between countries." (d) GNP figures also fail to distinguish between groups of people within a country. Some countries share their wealth much more equally than others with similar GNP standing. (e) "GNP statistics record the productive utilization of resources, whether or not these resources are renewable. . . . GNP is a particularly inadequate guide to development since it treats sustainable and unsustainable production alike and compounds the error by including the costs of unsustainable economic activity on the credit side" (pp. 15-17).

14. Exploitation has two kinds of meanings: one having to do with use and one having to do with benefitting at the expense or to the disadvantage of others (Crofton, 1991b). In case there is any confusion, Simonis is here using the term exploitation in the latter sense.

15. Not all discussions are comprehensive. For example, some early discussions about achieving sustainability were less attendant to issues of equity and social justice; some current discussions of sustainable development, especially if they are more narrowly focussed on particulars such as resource management, are less explicit (or may even ignore) issues of equity and social justice. As illustrated in the discussion of different perspectives, some discussions obscure or ignore either economic or environmental concerns.

16. In discussions of principles, it becomes evident that some principles are focussed on goals, others focus on the means for achieving these goals, and some (either explicitly or implicitly) attend to both goals and means. Gardner (1989) highlights this feature of principles by categorizing the principles in her list as "substantive principles" (values related principles describing the ends of decision-making) or "process-oriented principles" (describing the means of decision-making). Nonetheless, "means" are incorporated within her discussions of substantive principles and goals are implied within her process-oriented principles. Given that sustainable development incorporates both goals (e.g., achieving sustainability) and means, it is not surprising that goals and means are not easily separated. Further, separating means and ends can result in a fragmentation of approaches which often work at cross purposes and generate unintended outcomes. Our approaches must always be tied to and consistent with our goals.

17. The Brundtland Report (WCED, 1987) and the World Conservation Strategy (IUCN, 1980) have probably been the most widely disseminated and discussed reports related to sustainable development; locally, the reports of the BCRTEE have been central to discussions. These reports propose a number of principles believed necessary for establishing conditions for sustaining human and non-human life. The majority of other discussions of sustainable development draw in some manner on one or more of these reports.

18. The 'trickle-down' hypothesis represents a belief that maximization of GNP would "set in motion a chain of structural changes which, in turn, would ensure that the 'fruits of growth' were passed on to the mass of the population . . . [I]n its simplified form, [it] is based on the assumption that growth depends upon the accumulation of capital" (Simonis, 1990, pp. 78-79). However, as many authors and studies have revealed (e.g., Barnaby, 1988; Leiss, 1978; McHale & McHale, 1979; Mishan, 1977; Wachtel, 1989) the 'fruits of growth' have not reached the mass of the population. On the contrary, the gap between the 'haves' and the 'have nots' has widened.

19. Information and quotations regarding Maslow's hierarchy of needs is based on a formulation of Maslow (1954) as modified by Root (1970) found and discussed in Gage & Berliner (1979, pp. 378-379).

20. The idea of the primacy of the natural resources/environment is reflected in statements about the need for balance and in discussions about principles of sustainable development. For example, statements about balance include concerns about balance of human and natural systems (Gardner, 1989); society and nature (Watts et al, 1981) of environmental requirements, limited availability of resources, and need for increased agricultural production (FAO, 1992); of types of land uses (Nelson, 1991a); and "among population, resources, environment and development" (Jacobs, Gardner & Munro, 1987, p. 20). The dominance of the environment in various discussions can be illustrated as follows: 18/22 of Manning's (1990) building blocks for sustainable development specifically refer to the environment/ecological base; 8/12 of principles included in an Environment Canada report (1990) on implementing sustainable development directly refer to environmental concerns; 5/7 of the BCRTEE's (1992) principles of sustainability are focussed on the environment; the WCED's (1987) proposed legal principles focus on environmental protection and sustainable development: 19/22 of the principles specifically address the environment (21/22 if two that are focussed on transboundary issues are included).

21. It should be noted that the idea of humans as part of -- rather than separate from or superior to -- nature is not a new idea; it has appeared, and in many cases continues to exist, in cultural traditions across time and place (e.g., Canadian First Nations, American Indian, indigenous tribes of the Amazon rainforest, the Penan of Borneo, Australian aborigines). However, it is not an idea that has as yet truly been integrated into modern cultures which are dominant today. There are several reasons for this. First, sustainable development is an idea created by humans and therefore essentially anthropocentric in nature; it represents a human perspective and any recognizable voice is a human voice. Further, since much of our communication requires distinctions be made, we talk as if humans and the natural environment are separate. Second, our activities in the areas of stewardship, conservation, protection, recovery and rehabilitation of the natural world, can even suggest that humans are 'superior' to (i.e., have power over and are in control of) the rest of nature. Third, there are, in fact, important differences between humans and the rest of the natural world. For example, while consumption by other species is largely confined to their food, the bulk of human consumption consists of such things as energy and forestry products (Wackernagel, 1993). Further, human-made goods require natural resources while the reverse is not true. The point in raising the idea of humans as part of the natural world is only to emphasize (a) our belongingness to and with the natural environment and (b) our need to broaden our perception to include more than our less self-conscious and/or conventional perceptions provide. At base, it means that

both non-human and human needs are among the needs that must be met to achieve sustainability.

22. Miller's (1990) "Principles for Understanding and Sustaining the Earth" as briefly stated on the inside front cover, include attention to the environment, economics, politics, worldview and ethics. Principles concerned with the environment include the ideas incorporated in this paper as well as other related ideas. He includes, for example, the principle of limits, principle of moderation, principle of sustainable yield, principle of global commons, principle of resource diversity, principle of energy use and flow, principle of interrelatedness, principle of complexity.

23. Tree growers learned the importance of mycorrhizal fungi the hard way when the practice of fumigating soil to kill root diseases became common in nurseries.

24. Feminist and ecofeminist theories contribute to the literature on historical patterns regarding use of and access to resources and power. Briefly, in *feminist* critiques of human relationships, patriarchy and andropocentricity are seen to be at the base of systems of dominant and exploitive relations (i.e., inequities). *Ecofeminists* examine and critique human and non-human relationships; when set beside the feminist critique, they conclude that both women and Earth have been the objects of self-interested patriarchs. Ecofeminists argue that "shedding the privileges of patriarchy [does] more than create equal rights for all; . . . [the] effort may actually save the earth and the life it supports" (Plant, 1989, p. 2). Some good sources for further information on the ecofeminist perspective include: Caldecott & Leland (1983), Diamond & Orenstein (1990), Plant (1989), and Starhawk (1990).

25. For detailed discussions and arguments in support of this view see, for example: Berry (1988), Starhawk (1990), Swimme (1984). Good sources of collected works (including the writings of Bookchin, Griffin, D'Souza, Macy, Merchant, Naess, Plant, Seed, and others who have established themselves in environmental and/or sustainable development discourse) can be found in Andruss et al (1990), Diamond and Orenstein (1990), Plant (1989), Plant and Plant (1990), and Seed et al (1988).

26. Participation from and cooperation among, for example, government, NGOs, industry and the public; various disciplinary areas (e.g., environmental science, engineering, sociology, political science); people from different function areas (business development, marketing, finance, research, administration), and nation states is required. For example: one country's commitment to reducing carbon emissions will have little effect if their neighbors do nothing.

27. This 'involvement' is not simply limited to giving input; people need to work on important tasks. Greater involvement means moving from tokenism (informing, consulting the public) to increasing degrees of citizen power through partnerships (shared decision-making), delegated power, and in some cases, citizen control of decisions (see Arnstein's ladder of citizen participation in Parenteau, 1988, p. 23).

28. For example, delegating power to citizens usually involves the formation of task forces, planning teams or advisory groups. These kinds of groups provide opportunities for joint studies (diagnosis) of problems and allow people to bypass formal structures while they consider changes in policies, procedures and systems. As many of Weisbord's (1987) case studies indicate, a great deal of learning occurs

during these group activities and people being to absorb the general principles for using task forces on their own. Drawing on the original work of Kurt Lewin and Margaret Mead in reducing civilian consumption of rationed foods during World War II, Weisbord refers to another sub-principle of participation that is crucial to the changes being called for by sustainable development: "we are likely to modify our own behavior when we participate in problem analysis and solution and likely to carry out decisions we have helped to make" (1987, p. 89).

29. This will present a particular challenge to organizations or groups that are highly bounded as a result of specialization (e.g., function or discipline 'experts') or perceived need for secrecy (e.g., industries wanting to protect process/product innovations); in some cases it may require some relaxing of laws governing military and trade secrecy, or a corresponding strengthening of the laws governing freedom of information and expression.

30. Examples of grassroots organizations that can be considered effective include: Greenpeace (formed as a small group in Vancouver, B.C. and now a large international organization and network); Western Canada Wilderness Committee; B.C. Environmental Network (a network of several environmental groups); Friends of Clayoquot Sound (which gave birth to other organizations like Friends of Friends of Clayoquot Sound, Vancouver Temperate Rainforest Action Coalition); and the Multi-stakeholder Working Group (MSWG) on Pulp Mill Regulation in B.C. (For further information on the MSWG, see Crofton, 1992b.)

31. For example, the Peace Camp that was set up as part of the protest against logging in Clayoquot Sound, ran training sessions each evening to help participants understand and acquire the skills and techniques of cooperation, consensus decision-making and non-violent protest.

32. Consultation processes usually involve providing participants with information and seeking comment or input in return. As a decision-making tool it can be useful if concerns expressed are indeed addressed in decisions which result. However, as a public *involvement* tool, consultative practices are often used to defuse criticism or to give the appearance of participation in decision-making while 'business-as-usual' continues. Such mis-use of consultation or other participatory mechanism breeds suspicion and resistance and undermines cooperative and participatory processes. Consider, for example, statements made by members of two different public 'involvement' processes. (1) Statements made by members of the Tofino Sustainable Development Committee established by the B.C. Government: "We ended up in this planning process that was supposed to treat Clayoquot Sound differently. . . . It's shown us how really we've been manipulated, we've been lied to, we've been handled, shafted." "When . . . you feel that you can bring your point to the table but it's not going to be dealt with because they can just keep going on with things regardless of what you're saying or feel needs to be addressed, then I think we should get the hell out." (2). Statements made by members of the Kyuquot people on Macmillan Bloedel's "involvement" process regarding logging in the Kyuquot people's territory: "You've been hearing ever since the beginning that we don't want this logged. Ever since the original committee was set up . . . you just ignored the whole community . . . So now this committee comes here . . . and you want us to comment on a plan when you know the answer is 'no' to the whole thing!" "This is just a big show. . . . they come up here and ask what the people think and then they go home and forget about it" (National Film Board, 1993).

33. The process by which the proposal was initiated and approved illustrates a number of factors upon which organizational change is dependent. Factors include *visionary leadership* (both the idea to involve the public in a joint-planning process and to establish a joint-planning committee to design the process came from Chief Engineer Chuck Gale); *education, and empowerment of others* (Gale created, and encouraged staff to take advantage of, related educational and leadership opportunities; a number of briefing papers on public involvement were prepared and distributed to the Mayor, City Council, and other City departments); *building alliances* (Gale and engineering staff members introduced the ideas to members of City Council and to key personnel in other departments over a period of time); and *appreciative executive action* (in spite of the centrality of Gale's role, Gale attributes the success of the proposal to the efforts of his staff; staff members report that Gale "is the best boss" they've ever worked with).

34. For further information regarding the issues and strategies that Municipal engineers are considering see Crofton et al (1992), Crofton (1994), and APEGBC Municipal Engineers Division (1993).

35. This process of 'autocatalytic' change is dependent on ongoing participation and cooperation among a diversity of individuals. For example: As decentralized units of organizations develop their own rules and processes for functioning, and as they become more high-performing, it is not unlikely that they will become more closed to (even resentful of) interventions or restrictions coming from 'outside,' and less able to see themselves in the broader organizational context. Ongoing cooperation and participation across groups will be necessary to ensure organizations continue to be aware of and responsive to the broader organizational context. In some cases this will mean than new groups or 'organizational units' will form. For example, when Greenpeace was transformed from a small grassroots environmental group into a larger international organization, some members split off and formed other organizations; organization and groups will be challenged to reshape themselves in order to avoid becoming bureaucratically ineffective and/or suffer from the same kinds of exclusive and synoptic behaviors that their initial coalitions were formed to combat.

36. The organizational changes will require the development of different kinds of managerial competencies. Morgan's (1989) book, Riding the Waves of Change: Developing Managerial Competencies for a Turbulent World, is a good source for information about some "emerging managerial competencies." He includes, for example: "developing contextual competencies" (e.g., building alliances, reframing problems, social responsibility); "reading the environment" (e.g., scanning, forecasting); "proactive management"; "leadership and vision"; "human resource management" (e.g., managing in an environment of equals, blending specialist and generalist qualities); "promoting creativity, learning and innovation" (e.g., developing an appropriate corporate culture); "skills of remote management" (e.g., promoting self-organization, managing ambiguity); "managing complexity" (e.g., multiple stakeholders, transitions); and "using information technology as a transformative force" (e.g., new network concepts of organizations).

37. As one example of the transformational power of technology, Pacey (1983) examines how the snowmobile has altered the environment, the organization of work, and even the cultural integrity of a community of Lapps, Eskimos and Dene people (see especially pp. 1-4; 143-145). Other examples of technologies that have

altered the environment and relations between humans include automotive, energy and irrigation technologies.

38. The technology literature is extensive and, while interesting and relevant, there is no need to trace the details of various discussions, controversies and debates here. See, for example, discussions of technology as a decision-dominated (versus technical-knowledge dominated) social process or kind of social practice (e.g., Bunge, 1984; Goldman, 1990; Ropohl, 1991); cultural, moral and political assumptions and aspects of technology – including examination of the idea of technology as 'value neutral' (e.g., Bunge, 1984; Goldman, 1991; Milbrath, 1989; Pacey, 1983; Whelchel, 1986); values dimensions (e.g., Barbour, 1980; Drengson, 1980; Ellul, 1981; Franklin, 1990; Herrmann, 1978; Lenk, 1984, 1991); deficiencies in epistemologies of technical knowledge (e.g., Broome, 1991; Goldman, 1984, 1990, 1991; Kay, 1989; Vaughn Koen, 1991); impacts of technology (e.g., Broome, 1991; Kay, 1989; Herrmann, 1978; Rogers, 1983); technology control (e.g., Apple, 1982; Frost and Egri, 1989; Goldman, 1984, 1991; Milbrath, 1989); democracy (e.g., Borgmann, 1984; Franklin, 1990; Sclove, 1991); information systems and organizational change (Morgan, 1989; Vaill, 1989); technology education (e.g., Holstein and McGrath, 1960; Jester, 1989; Meisen, 1989; Ropohl, 1991; Vanderburg, 1992).

39. Water pumps in Bangladesh provide a case illustration of how technology can either contribute to hierarchical application of power or place power and control more firmly in the hands of users. Initial efforts to bring water to parched winter lands in Bangladesh focussed on installing mechanized water pumps ("shallow tube wells"). These efforts (usually the result of World Bank and U.S. Aid projects) required large investments of capital since mechanized water pumps are relatively expensive, require fuel, and some special tools (even a screw-driver is a "special" tool in some regions) and expertise for their maintenance. The pumps had "15-60 acre command areas," that is, they were designed to provide water to large parcels of land. Most land holdings, however, are less than 1 acre; in fact, land holdings in Bangladesh are usually expressed in "decimals" (e.g., 30 "decimals" equals .30 of an acre). The effective use of the pumps depended, therefore, on the cooperation of large numbers of land owners/operators. The expertise and economic status of land holders varied widely; it was not long before the wealthy gained control of the pumps, began to charge their less well-off neighbors for water and otherwise controlled access. In some cases, land holders were told what day and time they could have water; the day and time bore little relationship to crop needs for water. While diesel and electric pumps of this kind did help to bring water to otherwise desert-like lands during the winter (water is not a problem during the rainy summer season), it was clear there were significant problems with this technology. The solution to the various problems came by way of a Mennonite Central Committee (MCC) project which initiated the exploration of hand pumps. As a direct result of that project, 40,000 hand pumps were installed in Bangladesh; today over 400,000 hand pumps are in the fields. The hand pumps provided all the water needs of a single family (in some cases even up to 12 families), and overcame expense, distribution, control, fuel and maintenance problems that plague mechanized pumps. On cash crops alone, an owner could recover total costs (materials and installation) in a single season; literally hundreds of thousands of land owners became healthier, more autonomous, self-determining individuals no longer so dependent on those with greater wealth and power. (The preceding information was obtained from George Klassen, an agricultural engineer who worked on the MCC project, was given the task of exploring the hand pump option, and who eventually designed and tested

the hand pump that was so instrumental in bringing water and control to so many land holders. Additional information is available through the Mennonite Economic Development Association in Manitoba [MEDA] and from the Canadian International Development Agency.)

40. In 1980 the National Science Foundation in the United States defined 'appropriate technologies' as "those which possess many of the following qualities: they are decentralized, require low capital investment, are amenable to management by their users, result in solutions that conserve natural resources, and are in harmony with the environment; they are small or intermediate in scale [and] take into account site-available natural and human resources" (quoted in Richter, 1982, p. 52). This definition is useful, however, as pointed out in the previous discussion of organizational systems, decentralization or small scale operations may not always be the most appropriate; we must be careful that technology selection is not limited by definitions or requirements that may be inconsistent with particular situations or contexts.

41. For discussion of the relationship between technology and culture see, for example, Bernard and Pelto (1972), DeGregori (1985), McWhinney and Batista (1987), Pacey (1983), Rybczynski (1983).

42. Recall that the purpose of this chapter is to establish desirable standards that can be used to determine needs. As Dearden notes: "norms . . . have to be thrashed out by argument and debate. Where, however, there already exists a consensus on norms, either as a shared assumption or as a formal declaration of some sort, then specialist researches, resting on a background of common agreement, may well settle questions of need, since in those cases it is only at an empirical level . . . that the question is an open one." (Dearden, 1975, p. 53).

43. Further, in November 1994, fourteen of fifteen recommendations put forward by the CCPE Task Force on the Engineer's Role in Environmental issues were approved by the CCPE Board of Directors. The accepted recommendations included a change in accreditation criteria regarding subjects to be included in programs such that environmental studies now <u>must</u> be included (previously environmental studies were optional). Other recommendations include one emphasizing sustainable development and ensuring it is given weight during the accreditation process, and another focussed on making environmental awareness more explicit in National Guidelines on Continuing Competence (CCPE Task Force, 1994).

44. It should be noted that the standards and obligations discussed here, based as they are on contents of CCPE documents, are not legally binding or enforceable unless incorporated with provincial or territorial legislation. Professional engineers are bound by the provisions of a legal Act, such as the *Engineers and Geoscientists Act* in B.C., governing the region in which they are licensed to practice. Each Act includes legally binding provisions such as Association bylaws and codes of ethics. Specific details of the provisions may vary across provinces and territories. In B.C., for example, such things as the ensuring safety, health and welfare of the public, guarding against threats to the environment and extending public knowledge, are part of the code of ethics contained within the Act. Disciplinary action can occur if, after an inquiry, the discipline committee determines "that the member or licensee . . . has contravened this Act or the bylaws or the code of ethics of the association or has demonstrated incompetence, negligence or unprofessional conduct" (APEGBC,

1991, p. D8). Disciplinary actions may include reprimand, imposition of conditions on membership or license, suspension or loss of membership or license of the member or licensee.

CHAPTER 3
CURRENT STATUS OF THE ENGINEERING PROFESSION

> Today it is increasingly evident that all disciplines, all sectors and all areas are inter-related. A riverside industrial plant may create industrial jobs, displace agricultural workers, pollute and harm a fishery, generate acid rain in another country. Engineers and geoscientists can no longer isolate their activities to local single discipline technical issues. (APEGBC Task Force, 1992, p. 23)

In Chapter 1 it was suggested that, (a) since engineers are involved in both mediation between humans and between humans and Earth, it is reasonable to expect that engineers will contribute to sustainable development; and (b) by their specific involvement in sustainability issues (pollution control, waste management, energy efficiency, etc.), engineers are well-placed to further the aims of sustainable development. The discussion in Chapter 2 revealed that engineers are in fact obligated by the goals and standards (ideals and requirements) of their profession to be pro-active in efforts towards the achievement of sustainable development. This chapter turns attention to the profession's current status regarding the parallel standards of sustainable development and engineering.

Achieving the parallel standards of sustainable development and professional engineering presupposes a number of underlying requirements.[1] First, an understanding of the meaning, issues and goals of sustainable development is required. This includes (a) understanding the systemic nature of the world, interconnected environmental, economic and social concerns, and knowledge of the various environmental, economic and social systems; (b) recognition that many events and activities have effects across time and space (e.g., air pollution) and that "the character and well-being of person and planet are inescapably locked together" (Pike & Selby, 1989, p. 34); (c) understanding the global nature of the world and how local and regional issues are part of the whole; (d) understanding that a variety of perspectives exist and reflect values and beliefs that may not be universally shared; and, to ensure that appropriate technology is used, (e) knowing about the nature and impacts of technology. Second, to ensure effective participation and cooperation in discussion, debate, negotiation, and decision-making regarding sustainable development, appropriate communication and group process skills are required. Third, organizational supports (e.g., economic systems, education, democratic structures which facilitate participation in decision-making) need to be in place to facilitate movement toward sustainability. Finally, the will to achieve the goals of sustainable development is required and those involved in furthering the aims of sustainable development must be adequately prepared (through their knowledge and skills) and able (through effective participation and authority) to take responsibility for contributions made.

This chapter explores the status of the engineering profession regarding these requirements. Questions central to the exploration include (a) How do engineers define sustainable development? What issues and concerns do they believe are incorporated by sustainable development? (b) What knowledge and skills do engineers believe they have/need to respond to sustainable development? (c) What kinds of organizational supports exist for engineers? (d) What kinds of responsibilities do engineers assume for sustainable development and how able are they to act on these responsibilities? Only one study, a study of the perceptions of professional engineers in B.C. (Crofton, 1991), is known to have directly investigated engineers' responses to some of these questions. In answering the questions, therefore, the B.C. study will receive particular attention. Since a detailed account of the conduct of the study has not been reported elsewhere, the chapter includes a description of the background to the study, data collection and analysis procedures. Findings of the B.C. study and those of two other Canadian studies (one on curriculum and one on consulting engineers) are the primary sources of information used to address the questions above. Some information is gleaned from other Canadian studies and corroborating evidence is provided by non-Canadian sources.

The APEGBC Study

The Association of Professional Engineers and Geoscientists of B.C. (APEGBC), like other provincial professional engineering associations in Canada, is an essentially self-regulating body which establishes and administers standards of admission, discipline of members, and enforcement of the provisions which require Association membership for licence to practise engineering. As of 1991, there were approximately 14000 members in the APEGBC. In the Fall of 1990, the APEGBC received a request from the BCRTEE to provide input into the Round Table's preparation of a proposed sustainable development strategy for B.C. The APEGBC Council considered the request and forwarded a motion to the October 1990 APEGBC Annual General Meeting. The motion was passed and directed Council to respond to the BCRTEE call and to "invite comments and suggestions from the membership and form a Task Force to prepare a Brief" (Affleck, 1990, p. 2). In November 1990, the Council struck a Task Force on Sustainable Development with former APEGBC President Peter Jones as Chairman; the Task Force was to receive comments from members and to prepare a brief for discussion at the 1991 annual general meeting and subsequent submission to the BCRTEE.[2] In March 1991, based on discussions with Peter Jones and Task Force members, and due to the fact that the open call[3] for response from the membership resulted in negligible returns (five were received), a research proposal[4] was submitted to the Task Force to assist them in addressing four needs that seemed central to fulfilling their mandate:

1. Need to determine degree of membership awareness and understanding of sustainable development;
2. Need to define what is to be included in a definition of sustainable development;
3. Need to define and/or stipulate responsibilities of engineers around issues of sustainable development;
4. Need to develop engineering guidelines for promoting sustainable development.

The investigation, including instrument development and piloting, data collection, data analysis and report writing, occurred between March and August 1991. The first phase, begun in March 1991, involved the development of a survey questionnaire (Crofton, 1991c) which was subsequently distributed to members in June 1991. The second phase, begun in June 1991, included developing discussion schedules, conducting and summarizing information from interviews and focus groups, and beginning analysis of first questionnaire returns. Data analysis/synthesis and report writing occurred in late July and August 1991. Final reports were published in the October and November 1991 issues of The B.C. Professional Engineer (Crofton, 1991d, 1991e).

Data Collection and Analysis

Questionnaires, interviews, and focus groups were used to obtain information about APEGBC members' perceptions of sustainable development; more specifically, information obtained was used to answer the following key questions:[5]

1. How do APEGBC members define sustainable development?
2. How do members perceive their role and responsibility regarding sustainable development?
3. What is the degree of members' awareness and understanding of sustainable development?
4. Are members prepared (aware, able, willing) to address issues of sustainable development?

All participants in the study were members of the APEGBC who had volunteered to complete questionnaires and/or participate in interviews and focus groups. A total of 600 of the 13765 APEGBC members participated. Engineers in the civil, mechanical and electrical disciplines are dominant in the member population and were also dominant among study participants. Most participants were male and graduated between 1950 and 1990. (For a detailed description of member population and study participants see Appendix C.)

Questionnaires. Questionnaires were used to provide the Task Force with an initial indicator of members' awareness, understanding and beliefs about sustainable development and about the degree to which they felt obligated, as professional engineers, to accept responsibilities for fostering sustainable development. Due to space restrictions (1 page maximum), background information was limited to "fill-in-the-box" and "fill-in-the-blank" questions; the content of the questionnaire was limited to Likert-type items requiring response on a 7-point scale. (See Appendix D for copy of questionnaire). In developing the questionnaire, focus groups were used to begin to explore issues and to formulate items for inclusion in the questionnaire; checklists for questionnaire preparation were used as a guide in the selection and construction of items.[6] Questionnaire responses provided initial information regarding members' preparedness to address sustainable development. Table 3-1 shows the relationship between Questionnaire items and Key Research Questions.

Table 3-1
Relationship between Research Questions and Questionnaire Items

1. Definitions (perceptions)	Items 2-6
2. Responsibilities	Items 7a-g, 8, 9, 12
3. Awareness & Understanding	Items 1, 10
4. Preparation (ability)	Item 11

Questionnaire items 1-6 (familiarity, definitions and strategies) and item 10 (boundaries) were included in the questionnaire to acquire some initial information about engineers' awareness and understanding of sustainable development. Since the Brundtland report is recognized as the document which popularized the term and which is also the most widely distributed document, it was used as an indicator of members' awareness and possible knowledge. Item 1 asked whether members' were familiar with the Brundtland Report. Items 2-4 were intended to reflect three different orientations in defining sustainable development and asked respondents to indicate the degree to which they agreed with each statement; an additional item (Item 5) forced them to choose among the three as the one most representative of their own beliefs. Item 6 asked respondents to choose between three strategies for addressing sustainable development. While no certainty existed, each strategy was believed to be associated with a particular definition-perspective on sustainable development. That is, resource management was a strategy associated with a definition of sustainable development centered on economic growth and development (definition in Item 2); development of controls and safeguards was associated with a definition focussed on environmental protection (definition in Item 3); altering expectations and behaviors was associated with recognizing limits (definition in Item 4). The statements of, and linkages between, definitions and strategy orientations were drawn from a report by the B.C. Task Force on Environment and Economy, Sustaining the Living Land (BCTFEE, 1989, pp. 15-16). The definitional and strategy orientations provided in the BCTFEE report were based on more than 200 submissions received by the Task Force from academic/educational institutions and associations, business and industry, citizen associations, environmental institutions and associations, and the general public. Since sustainable development incorporates transboundary issues, Item 10 (pertaining to boundaries) was formulated as an additional awareness/understanding indicator.

It was assumed that what engineers include among their professional responsibilities and/or obligations is likely to influence the kinds of activities they engage or are willing to engage. Based on accounts of what sustainable development includes and involves, it was further assumed that those who are more likely to include sustainable development among their responsibilities are those whose responsibilities include:

1. attention to economic, environmental and social concerns;
2. participation in professional development opportunities which relate to or assist in resolving sustainable development issues;
3. involvement with the public (especially around issues related to sustainable development);
4. participation in formulating codes, legislation and policy.

Questionnaire Items 7a-g were developed to provide initial indicators of the degree to which members define their professional responsibilities as inclusive of these elements. Since sustainable development points to the number and diversity of stakeholders impacted by various decisions and practices, Item 8 was included to determine the degree to which engineers may include a responsibility to consider effects of their work beyond the immediate user/client. Further to these primary items, Item 9 asked participants to indicate the degree to which establishing guidelines should be the responsibility of the Association. As an indicator of commitment, participants were also asked whether they would be willing to pay higher annual Association fees to support sustainable development efforts (Item 12). Finally, Item 11 was intended to provide an indication of the degree to which members felt able to address environmental, economic, social and technical concerns of sustainable development based on (a) their formal education and (b) their practical experience.

Although time and resource constraints prohibited extensive piloting, questionnaire drafts were "hot-house" piloted three times with changes made after each pilot other than the last. (Hot-house pilots are small pilots which also ask respondents to comment on the form and content of the questionnaire; 10-15 people – including engineers and researchers with special knowledge of questionnaire design – participated in each of the hot-house pilots.) The questionnaire was published in the June 1991 issue of the Association journal and additionally distributed in branch mailings; members were asked to forward the completed questionnaire by mail or fax to the APEGBC office. Given resource constraints of the study, the questionnaire provided the greatest opportunity for participation; it also provided the possibility of obtaining a representative sample of member views. Five hundred and thirteen valid questionnaires were returned; the sample approximated the member population in terms of distribution across gender (96% male in sample and population), year of graduation (87% of sample and population graduated after 1951) and dominant discipline areas (70% of the sample and 65% of the population from civil, mechanical and electrical disciplines). Details are provided in Appendix C. Statistical analyses of the data included frequency distributions, cross-tabs (Chi-square), correlations (Pearson), and ANOVA.

Interviews and Focus Groups. Both interview and focus group sessions explored four topic areas:

1. the meaning of sustainable development;
2. essential issues in sustainable development;
3. knowledge, skills and training requirements; and
4. draft sustainable development objectives and guidelines.

Due to time and resource constraints, all participants (with the exception of participants of a Kelowna, B.C. focus group) were drawn from the B.C. lower mainland area. Participants for both interviews and focus groups were obtained by a number of means. First, an initial call for participation was published in the June, 1991 issue of the B.C. Professional Engineer (sent to all APEGBC members) and distributed in May/June branch mailings;[7] one interviewee was obtained as a result. Second, senior executives of engineering firms listed in the yellow pages were contacted by phone and/or fax and asked to invite their engineers to participate. Third, Task Force members and engineers responding to the invitation to participate were asked to suggest other individuals who might be willing to participate; slightly more than half of the participants were obtained by this networking. Finally, in order to ensure participation by women and to obtain a sufficient number of women for participation in one of the focus groups (see discussion below), the Chair of the APEGBC Women Engineers Group was contacted for a list of potential participants. No attempt was made to ensure that the distribution of participants across gender, degree year and discipline area reflected the general membership although attention was given to ensuring that members from the dominant discipline areas were represented.

It should be noted that several interview and focus group participants declared they had little or no awareness of "sustainable development" prior to their being contacted to participate in interviews or focus groups; almost none of the participants had given much or any thought to sustainable development (especially in terms of engineers' role) prior to being contacted or seeing the questionnaire in the journal. Some participants requested a definition of sustainable development and a few focus group participants asked for guidance in finding reading material in order to prepare for the focus group discussion. These participants were informed that part of the study centered on exploring possible meanings and definitions of sustainable development and that to provide one prior to an interview/focus group would distort the findings. Those requesting sources of information were directed to APEGBC journal issues where background to the establishment of the Task Force and its role was provided, and where initial commentary appeared. Since the Brundtland Report was considered a foundational document, this was cited as a possible source; participants were also informed that the BCRTEE had published a number of reports they might find useful.

Discussion during interviews and focus groups included attention to the content of the questionnaire, and more open-ended topical discussion of questions central to the study. A discussion guide was prepared to provide basic direction of the inquiry while allowing individual perspectives and experiences to emerge. (See Appendix E for discussion guide.)

Interviews. Since the questionnaire technique could only capture a limited amount of information, interviews were chosen in order to (a) obtain more detailed information about the professional and educational background of participants which would provide some context for their responses; (b) clarify responses to the questionnaire (all interviewees completed the questionnaire); (c) pursue new leads generated by discussion; and (d) obtain more detailed information regarding participant understanding and conception of sustainable development.

Thirty approximately one-and-a-half hour long interviews were conducted. Each interview was audio-tape recorded and extensive notes were taken during the interview. At the end of each interview, the researcher summarized the main points made in each of the topic areas and asked the interviewee to assess whether the summary captured the key points of the discussion and whether they had anything else to add. Subsequent to each interview, summary notes were prepared from notes taken during the interview and from the audio-tape recordings; these form the basis of interview findings. Summary notes were coded according to issues and themes arising out of discussion of the four topic areas that were the focus of the discussion; the coded notes were then examined for recurring elements and themes within each topic area.

Focus Groups. The focus group technique was chosen for several reasons. First, focus groups were used in the preliminary stages of instrument development to explore possible topics and questions for inclusion in the questionnaire and the discussion guide. Second, since time and resource constraints prohibited the extensive use of the one-to-one interview technique, focus groups provided the possibility of obtaining large amounts of similar as well as different information in less time and with less expense.[8] Third, focus groups involve participant-participant interaction.[9] Interaction often leads to spontaneous participant responses and insights and allows the researcher to observe a concentrated set of interactions on a topic and to hear how participants respond to each other throughout the discussions (e.g., nature of topic vocabulary, challenges and responses to challenges). Collectively, these interactions provide more information about the content and frequency of perspectives and a broader base for determining and understanding specific attitudes and opinions. Finally, by virtue of its participant-participant interaction element, the focus group technique provided opportunities for participants to discuss different viewpoints, find common meanings and reach agreement on various issues;[10] points of agreement and disagreement could be used to provide additional information regarding member views of sustainable development. In this study, focus groups had an additional, less explicit benefit: they provided an opportunity for members to meet with other engineers, to share ideas, and to experience a collective process for reaching agreement around certain aspects of sustainable development.

Participants agreed to participate in one of six focus group sessions to explore and discuss their ideas with others in the profession and to have their discussions audiotape recorded. A total of 57 individuals participated in focus group sessions; each focus group was approximately four hours long. The participants included individuals who received their degrees between 1948 and 1990. Since almost half (46%) received degrees between 1961-1970 and one quarter received degrees after 1981, there was some assurance that a range of practical experience would be reflected among participants and that any changes in engineering (e.g., methods, curriculum, disciplines) might also be captured. Discipline areas represented included bioresource, chemical, civil, electrical, forestry, geological, geophysical, industrial, mechanical, metallurgy, mining and structural engineering.

Six focus groups were held in July and August 1991 to explore the meanings that Association members attribute to sustainable development, the issues they believe are important, how they perceive their roles, and the skills, knowledge and training they believe are needed. Five focus groups were held in Vancouver, B.C.; one was held in Kelowna, B.C. Due to interest in and concern about the role of women in engineering, one focus group was held for women only. The rationale for making one group exclusive to women was based on findings from various studies (e.g., Frieze & Ramsey, 1976; Hall & Sandler, 1982; Ruble & Higgins, 1976) which suggest that women may be less assertive and tend to speak less in mixed-gender groups. Further, women engineers, many of them young and fairly inexperienced, are less likely to challenge the culture, language and habits of the profession to which they have been newly admitted particularly when in the company of older and more experienced male engineers (Crofton, 1992c; Franklin, 1985). Given the fact that "women's voices are not yet sufficiently prominent in the intellectual analysis of the phenomenon of technology per se" (Franklin, 1985, p. 2) and that women may define problems and contexts differently from men (Gilligan, 1982), it was considered important to ensure women had adequate opportunity to be heard.[11] With the exception of one focus group (geoscientists), no attempt was made to group participants by discipline area. Geoscientists were targeted as participants for one focus group for two reasons. First, with their involvement in mining operations, geoscientists were seen to be among those members who operate within a highly-regulated (especially environmentally-regulated), resource-based industry and might, therefore, have different perceptions than members operating in other areas. Second, since geoscientists only recently joined the Association (effective January 1991),[12] their views were not likely to be well-reflected in Association norms and policies to date and the Task Force wanted to ensure that their views were captured. (See Appendix F for profile of participants by group.)

In general, focus groups were conducted in the following way. An overview of the study and the purpose of the focus group was provided and participants were then asked to introduce themselves. Self-introductions complete, participants engaged in a facilitated discussion of the meaning of sustainable development and identification and discussion of examples of what is or is not sustainable. Participants were then directed to form two sub-groups to explore issues of sustainable development. Each participant was asked to generate a list of issues s/he believed to be essential areas of concern; each sub-group was asked to reach a consensus on the issues, attempt to prioritize them, and to identify factors limiting or promoting sustainability. Lists of issues generated by each sub-group were posted on flipcharts and were discussed in large group. A similar approach was used in addressing general and engineering-specific knowledge, skill and training requirements for addressing issues identified. The final task of focus group participants was to review and provide feedback on the Task Force's initial draft of sustainable development guidelines for engineers. Since receiving feedback on these guidelines was not a primary goal of the focus group, very little time was allocated to this task; in some cases, participants merely received the document and agreed to forward feedback at a later date.

Summary reports were prepared for each focus group session. Information used in preparing these reports included (a) lists generated by subgroups; (b) notes taken by the researcher during the focus group; and (c) subsequent notes made from audio-tapes. This information was then coded and examined for recurring themes using the same approach as was used in examining information obtained from interviewees. Each participant received a copy of the summary report for the focus group in which they participated; attached to the report was a request for participant review and comment regarding the accuracy and comprehensiveness of the summary; 40 of the 57 participants commented on the summaries and agreed that they were accurate and comprehensive reflections of the session they attended.[13] Findings of focus groups are based on the summary reports, coded summary notes of each focus group session, and the elements and themes found to be dominant across focus groups.

Findings of the Study: General Comments

Findings of the APEGBC study as they pertain to the questions central to this chapter are provided in the following sections. Some general comments, however, are appropriate here. First, with the exception of Questionnaire item 6, there were no statistically significant demographic differences (gender, age, year of graduation, number of people supervised) in responses to the questionnaire. For questionnaire item 6, age was a factor in strategy preference. (Questionnaire Item 6 is discussed more fully in the following section). Second, information obtained from interviews and focus groups suggest that questionnaire responses reflect the ideas respondents intended to communicate. (For example, participants said things like "that's why I strongly agree with item X" or "that's why I was tentative about item Y.") Third, participants who worked in the natural resource sector directly (e.g., forestry, water management), were involved in projects that were highly environmentally regulated and "watch-dogged" by the public, or had extensive international experience in resource-related projects, appeared to have more indepth understanding of sustainable development requirements than those who had not had these kinds of experiences. Finally, focus group participants reported that they found the discussions useful and most participants were eager for additional opportunities to meet to pursue and extend discussion. More specific findings from the APEGBC study are included in the discussions that follow.

The Meaning and Issues of Sustainable Development: Awareness and Perceptions

Questionnaires. The data provided by the questionnaire indicates that most respondents (64.3%) are relatively unfamiliar with the Brundtland Report. Nonetheless, most of the respondents (73.3%) did not believe that sustainable development could be achieved in B.C. without considering events outside B.C. (Item 10). Further, responses to Items 2-4 indicate that respondents tend to more strongly endorse interpretations which incorporate environmental concerns and the idea of limits than they endorse an interpretation narrowly focussed on economics. Such broader and more inclusive interpretations are consistent with the Brundtland Report and other similar reports. As

Table 3-2
Questionnaire Data: Means and Percentage Responses

Q	Description	Mean	S.D.	Miss'g	% 1-3[a]	% 4[b]	% 5-7[c]
Awareness/understanding							
1	Familiarity with reports	5.214	1.873	26	22.8	12.9	64.3
10	Considering events beyond B.C.	5.339	1.879	29	20.0	6.6	73.3
Perceptions of the meaning of sustainable development							
2	support economic growth and development	5.168	1.946	14	22.8	8.6	68.5
3	envtal protection & econ development	2.417	1.562	12	79.4	8.8	11.8
4	recognize limits; do more with less	2.584	1.731	11	75.5	8.8	15.8
5	(See below)						
6	(See below)						
Responsibility							
7a	formulate guidelines	2.519	1.565	29	77.5	11.6	11.0
7b	support economic development	3.669	1.740	27	46.9	23.5	29.6
7c	account for environmental effects	1.729	1.221	26	94.0	1.6	4.3
7d	account for social effects	2.581	1.589	26	76.0	12.1	11.9
7e	formulate societal policy	2.172	1.496	26	82.5	8.0	9.4
7f	increase public awareness	2.238	1.351	25	83.0	10.7	6.3
7g	professional development	2.443	1.349	25	81.6	11.5	7.0
8	beyond immediate users	2.165	1.481	21	86.2	4.9	8.9
9	Association guidelines	2.763	1.688	23	70.2	15.5	14.3
12	pay higher fees	3.565	1.974	49	54.7	16.8	28.4

Education/Experience						
11a1 environment: education	4.149	1.903	291	41.0	15.8	43.2
11a2 environment: experience	2.968	1.411	261	70.2	16.3	13.5
11b1 economic: education	4.013	1.759	288	40.0	22.2	37.8
11b2 economic: experience	3.147	1.469	268	64.9	22.0	13.1
11c1 social: education	4.878	1.683	291	22.1	18.9	59.0
11c2 social: experience	3.404	1.448	263	55.6	23.2	21.2
11d1 technical: education	2.850	1.572	279	76.1	8.5	15.4
11d2 technical: experience	2.648	1.369	269	79.5	11.5	10.1

5 *Definition Preference: (Forced Choice; 13 missing cases)*

Q2: support economic growth & development	7.4%
Q3: envtal protection & econ development	46.6%
Q4: recognizing limits	46.0%

6 *Strategy Focus: (Forced Choice; 7 missing cases)*

S1: resource management	28.5%
S2: controls	14.6%
S3: alter expectations	56.9%

[a] Percentage of responses indicating agreement with or support of item (Points 1-3 on scale)
[b] Percentage of neutral responses (Point 4 on scale)
[c] Percentage of responses indicating disagreement with or lack of support for item (Points 5-7 on scale)

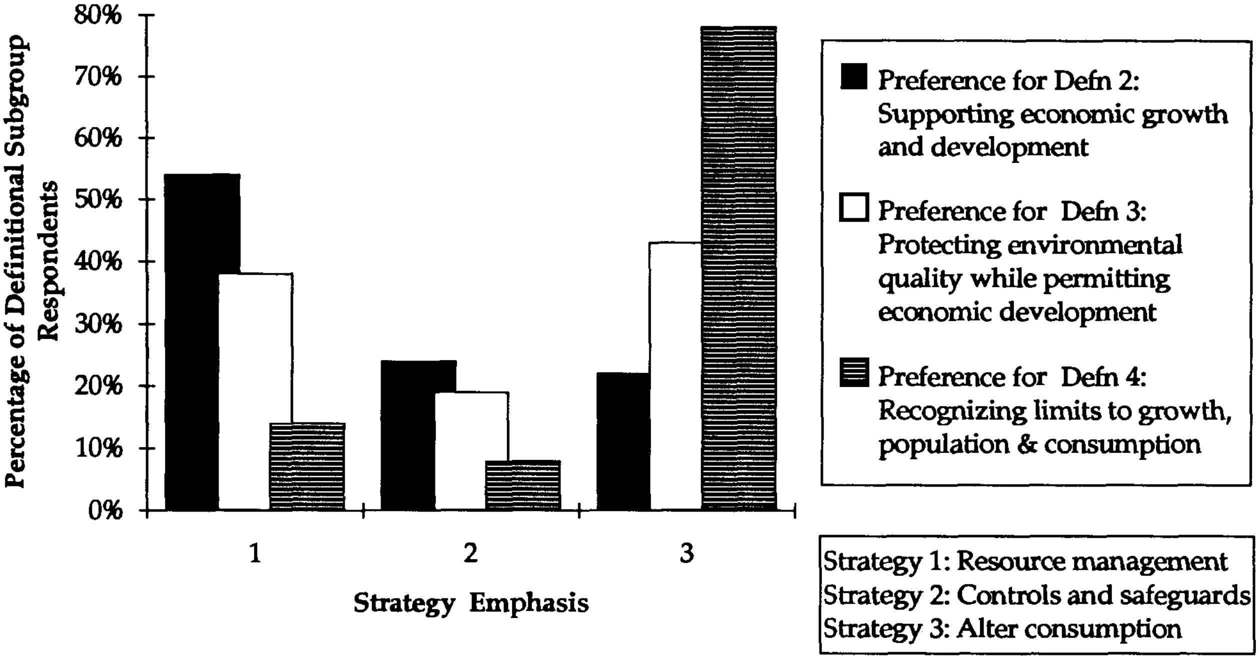
can be seen in Table 3-2, the preference for such interpretations was made even more clear in Item 5 where respondents were forced to choose one of the three interpretations of sustainable development: 46.6% of respondents tended to believe sustainable development was about simultaneously ensuring economic development and environmental quality (Item 3), and 46.0% believed sustainable development was about recognizing limits and learning to do with less (Item 4); only 7.4% favored the narrow, economic interpretation of sustainable development (Item 2). In terms of which of three strategies needed most attention (Item 6), over half of the respondents (56.9%) chose "altering consumption expectations and behaviors" over resource management (28.5%) or development of controls and safeguards (14.6%); this concern about consumption, especially in developed nations, is also prominent in the Brundtland Report and other similar reports. It is interesting to note, however, that the Chi Square test revealed that age was a factor in choice of strategy (.05 level of significance). Specifically, although over half of the people over 65 preferred altering consumption (strategy 3), as a group they chose controls and safeguards (strategy 2) more often than people in the other age categories chose this strategy.

The Chi Square test also revealed that a strong relationship exists (at .0000 level of significance) between interpretation of sustainable development (Item 5) and choice of strategy (Item 6). When forced to choose one interpretation over others, those who chose supporting economic growth and development (Item 2), favored resource management over the other two strategies. Those favoring "protecting environmental quality while permitting economic development" (Item 3), preferred either strategy 1 (resource management) or strategy 3 (altering consumption) over controls and safeguards. Finally, those choosing Item 4 (recognizing limits and doing with less) as most representative of their beliefs, strongly favored altering consumption expectations and behaviors (strategy 3) over other strategies. Percentage details are provided in Table 3-3; a visual representation of the findings is provided in Exhibit 3-1.

Table 3-3:
Definitional Preferences and Choice of Strategy

Subgroup:	Strategy 1 Resource Management	Strategy 2 Controls	Strategy 3 Alter consumption
1. Preference for Definition 2: Supporting economic growth and development.	54%	24%	22%
2. Preference for Definition 3: Protecting environmental quality while permitting economic development.	38%	19%	43%
3. Preference for Definition 4: Recognizing limits to growth, population and consumption.	14%	8%	78%

Exhibit 3-1
Comparison of Strategy Choices by Definitional Preference



Some respondents included notes and additional comments with their questionnaires. Most of these notes are not of particular interest here. For example: some of the notes were not directly related to the questionnaire (e.g., comments about articles written in the journal or responses to an inquiry about whether the journal should be printed on recyclable paper); some notes provided more detailed information about the respondent's background; and some participants expressed interest in having closer contact with the Task Force and volunteered their help. Other notes, however, are worth reporting since they are directly concerned with issues of sustainable development. Most particularly, a number of people stated it was important to pay attention to the issue of population growth; two people wondered why this issue was not incorporated in the questionnaire:

> . . . do not lose sight of the underlying problem. As long as populations increase, there will be a need of enough development to sustain consumption demands (Respondent 0022)
>
> The major problem of today is over-population (Respondent 0084)
>
> Sustainable development should also address the problem of burgeoning world population levels (Respondent 0085)
>
> I would like to emphasize the importance of stopping, in no uncertain terms, population growth (Respondent 0239)
>
> Where is zero population growth? (Respondent 0260)
>
> One must start with population control and the questionnaire doesn't directly query this fact. Why not? (Respondent 9030)
>
> Most important - limiting population growth (Respondent 9189)
>
> Any species that gets too numerous will eventually deplete its resources and poison its environment. It is the growth syndrome we need to get rid of (Respondent 9134)

On sustainable development in general:

> I would like to support the statement of Maurice Strong: "Do not fall into the trap of using . . . the language of sustainable development to provide a fig leaf for the status quo. What we need is fundamental change. Sustainability requires a restructuring of national and international economic life, an integration of the concept into every level of human activity" (Respondent 0239)
>
> I believe #3 [environment & economics] is the definition by the Brundtland report, however, #4 [recognizing limits; doing better with less] more closely represents the real "facts of life." I stand to be corrected? (Respondent 9040)

Interviews. Virtually all interviewees considered sustainable development to be concerned with balancing environmental, economic and social concerns across geographic and time boundaries in order to achieve and maintain an improved global quality of life. Collectively, interviewees gave primary attention to the use and allocation of resources. Environmental considerations (e.g., damage, degradation, waste, protection issues) and economic considerations (e.g., livelihood, marketplace issues) were the most frequent elements cited in this regard; social issues (standards of living: food, housing, health, education), while often directly or indirectly implied, were not as frequently specifically raised. The ideas of balance and a global frame of reference were considered central to sustainable development. Other ideas included those concerning consumerism, biodiversity, cultural sensitivity, and long time horizons.

Change was a recurring theme in discussion of the meaning of sustainable development. Interview participants believed that sustainable development called for modification and/or transformation of current attitudes and practises. For example, most believed sustainable development meant changing attitudes toward consumption: "We have to do with less." Some believed that, as measured by North American standards, the change would translate into reduced standards of living in developed countries; others felt that the quality of life would remain relatively unchanged or perhaps even improve.[14] Participants also focussed on change in practices and suggested establishing or improving resource policies and decision-making guides, expanding risk assessment to include sustainability issues when planning, and developing more "environmentally-friendly" products and practices.

Several issues were identified as related to sustainable development and in need of attention. Some participants framed the issues as problems (e.g., overconsumption of resources) while others talked about strategy needs (e.g., reduce resource consumption). Issues focussed on attitudes, lack of awareness, consumerism, environmental degradation, inadequate legislation, politics, government and leadership, quality of life issues, economic issues, the influence of "the West" on the developing countries, resources and waste, population control, education and research. Education rose to the top of almost everyone's list as both problem (insufficient or inadequate education) and as strategy (e.g., increasing awareness, changing attitudes, instilling particular kinds of values, distributing reliable, objective information). Participants talked both about education for engineers and for the public; several participants were concerned and frustrated by the general public's "technical illiteracy"[15] and almost all talked about the need for engineers to become better at communicating with the public (see Knowledge and Skills discussion following).

Environmental and economic concerns also dominated the list of problems; issues concerned with establishing equivalent regulatory and legislative systems across the globe, population growth, and consumerism followed close behind. Some interviewees noted that economic decisions were largely dependent on a client's budget and the economy in general. Part of an engineer's job is to recognize and work within these constraints; failure to do so would result in loss of work. In particular – assuming appropriate and accurate information is available -- accounting for and/or creating optimal designs in response to environmental, economic and social concerns represented by sustainable development would likely raise project costs and reduce their competitiveness in the marketplace: "the client will go to the guy down the street" who will do the job that is minimally required by rules of engineering, legislation and regulation. Most interviewees were also concerned about the lack or inadequacy of existing organizational structures in responding to the issues of sustainable development and about the kind and degree of responsibility engineers could or should be expected to assume (these concerns are discussed in detail in the sections on organizational supports and responsibilities).

Focus Groups. In general, focus group participants considered establishing the meaning of sustainable development to be a "subjective" (i.e., value-laden, relativistic) and complex exercise made more difficult since several participants felt that "sustainable development" was a "contradiction in terms";[16] at minimum, sustainable development was seen to embody a number of contradictions and potential conflicts. Nonetheless, all groups talked about environmental and economic issues, balance, having a long-term or "future" view, recognizing local and global contexts, and quality-of-life/standard–of-living concerns. Four of the groups also explicitly discussed consumerism, limits and constraints, resource and social issues, and future lifestyle directions. Groups 2, 3, 5 and 6 identified "quality of life" and/or "well-being" as central to, or the essential purpose of, sustainable development. The other two groups, both with civil engineers dominant in numbers, did not so clearly identify a central purpose. Group 1 believed "balance" was the critical issue but, in spite of exploration of possible meanings, issues, examples, and strategies, this group had more unresolved questions than answers. Group 4 also raised a number of questions which they could not definitively answer; they did decide that ceasing development was not an option and defined sustainable development as the achievement and "maintenance of a reasonable standard of living with minimum environmental damage."

Each group came to some agreement about the meaning of sustainable development in a broad and general sense, and ideas across groups were similar. In coming to this agreement, experiences were shared and participant knowledge expanded. Ideas that at first appeared to be in conflict (e.g., belief that people would have to do with less versus belief that people would not necessarily have to do with less and in some cases would need more), were clarified and contextualized, and, in broad terms, participants could reach agreement on the meaning of sustainable development. At the more detailed or specific level, however, participants were less able to reach agreement; the difficulties, not surprisingly, most often centered on issues and strategies of sustainable development. The difficulties involved both values-related and empirical questions. For example: What are we trying to sustain and for whom? For people? For animals? What is a reasonable "standard of living"? What priorities should we have and/or set? How accurate is the data we have about limits? What are the real limits? How effective are our measures? It was on these questions that either agreement was tentative or answers could not be found.

The issues explored in focus groups reflected the host of issues identified by interview participants. For example, all focus groups identified education (for engineers and the public), environment (including issues of pollution, planning, accounting, resource and land use), and population in their lists of issues. Government, politics, legislation and regulation were also dominant among issues identified. It is interesting to note that, although economic and funding concerns arose in general discussions and were perhaps implied by other issues identified, four of the groups did not explicitly include economics or funding in their final list of primary issues demanding attention. A diverse list of other issues explored by one or more groups included consumerism, appropriate technology, establishing measures, consideration of the "Third World" situation, military expenditures, public participation and reaching consensus. Participants became very engaged in the discussion of issues both within smaller groups and in the large group; they did not easily disengage the task and many expressed a desire to continue to explore issues. Though not well-captured by lists of issues prepared by groups, participants noted that context would be a factor in the more specific definition of issues and in the choice of strategies; nonetheless, groups felt that environmental, economic, and social issues would need to be addressed in every context.

Preparedness: Knowledge and Skills

Questionnaires. With the exception of a note attached to one of the questionnaires suggesting that "engineers should get some background in biology to fully understand what is happening to the human race" (Respondent 9134), questionnaires did not provide, or seek to provide, information specific to knowledge and skill requirements for sustainable development. Responses to Item 11 do, however, provide information about engineers' perceptions of how well their formal education and work experience has prepared them to address the environmental, economic, social and technical concerns of sustainable development. Responses to Item 11 required special handling due to the fact that almost half the participants used check marks instead of scale values in responding to this item. Those who responded to Item 11 with check marks were designated as Group A; those using scale values were designated as Group B. Check marks were assumed to be indications of agreement and were coded as '1'; blanks were coded as '0'. Scale-value responses on all items for both groups were recoded such that scale values of 1, 2, or 3 equalled 1, and all other scale values equalled '0'. Group A and B responses for all questions were then compared; no significant differences were found to exist between the two groups and the results of Group B (those who used scale values in responding to Item 11) were therefore taken to be indicative of the whole sample.

Based on Group B responses to Item 11, the data suggests that experience outweighs formal education as a contributor to engineers' preparedness to address sustainable development. In an attached note, one respondent stated, "I am NOT well prepared and can rely only on experience" (Respondent 9050). The difference in the degree to which experience outweighs education is not particularly great regarding technical concerns but becomes increasingly greater when considering economic, environmental and social concerns. Engineers appear to be most confident about their ability to address technical concerns and least confident about addressing social concerns. Given the way in which participants completed Item 11, detailed analyses were not warranted.[17] (See Table 3-2 for Item 11 detail.)

Interviews. Interviewees had several recommendations regarding the knowledge, skills and training that would be required to address sustainable development. The long list includes the following skills: teaching (how to effectively communicate information and increase awareness), communication, negotiation, mediation, conflict resolution, collaboration, team-building, defining and solving problems, leadership, public relations, and, particularly, "thinking skills." An understanding of different cultural values, global issues, the international context, was considered important; emphasis was given to having a "systems point of view." Participants supported exposure to and knowledge of such various discipline areas as economics, sociology, psychology, political science, philosophy, mathematics, biological and environmental sciences. Participants stated that their education included attention to mathematics (strong emphasis), economics and, in some cases philosophy by way of a course on ethics (those that had an ethics course said it focussed on engineers' code of ethics and legal issues). As one participant put it, "Few engineers can relate to what we're talking about" (Participant 2021).

The skills/knowledge most frequently called for were those pertaining to communication (writing, speaking, listening) and the ability to get people to work together collaboratively (including negotiation, mediation and conflict resolution skills). Almost without exception, interviewees said that engineers were particularly weak in these areas. For example, one participant claimed that engineers border on illiterate when it comes to writing; others talked about "backroom engineers" (i.e., those who prefer to work alone "number crunching" or working on exclusively technical problems) saying "you don't want to let them get near a client"; still others said that "engineers just aren't good communicators." Some interviewees suggested there should be courses to help engineers with communication and group process skills; others felt "You only learn by doing" and "from years of work experience." The few participants who reported taking a "communications" course said it was limited to technical writing and/or oral presentations.

Interviewees consistently reported that technical skills were important but not sufficient for addressing sustainable development (some believed that environmental problems were essentially technical problems). Those interviewed emphasized the importance of having a broad education (one they did not feel they obtained in their engineering training) and believed that, given the limited usefulness of many of the technical courses they received, the replacement of some technical course requirements with courses in the humanities or social sciences would be beneficial to engineers. Economics and courses in environmental science were cited as essential to ensure engineers are able to adequately address the issues of sustainable development. When asked how knowledge and skills they believe are required could be obtained outside of university, almost all claimed there were few opportunities and it was really up to the individual to seek them out.

Focus groups. All groups included "communication" in their lists of knowledge/skill requirements and almost all groups identified it as the most essential knowledge/skill area. "Communication" was an umbrella term encompassing interpersonal skills and the usual writing, speaking and listening skills; also included under the "umbrella" was the need for sharing of information and for knowledge/skills of teaching, facilitating, negotiating, lobbying, advocacy, and consensus-reaching. When asked why this communication knowledge/skill was important, participants talked about a number of things: the need to get clients and the public to understand technical issues; the fact that more and more of their engineering work was being conducted in teams; the need to be able to persuade others that certain designs or decision-solutions were preferable to others; the need to resolve conflicts that arise when diverse interests are involved; the need to understand a variety of perspectives and problem-solving approaches (even among engineering disciplines); the need to find ways to reach consensus on certain kinds of decisions. In general, focus group participants agreed that communication within teams of similar discipline engineers was good (though some suggested it could be improved); when teams included individuals outside of engineering, however, problems of language and differences in perspectives contributed to communication problems. In one group, participants stated that only a "rare few" engineers had the necessary skills to effectively work with the public, resolve conflicts, engage in consensus decision-making, or to persuade diverse audiences of the benefits of certain kinds of engineering solutions.

Technical knowledge/skills and analytic skills (including, e.g., problem-solving, evaluation/assessment, measurement) and knowledge from economics (including raising capital), social and environmental discipline areas were considered necessary. For engineers, however, "expert" knowledge should be confined to technical areas; others should be drawn upon for their economic, social and environmental expertise. Nonetheless, participants believed that engineers must have (a) general knowledge and understanding of these three knowledge areas as they apply to engineering and sustainable development, and (b) more "sophisticated" knowledge of areas that pertain to their specific activities and areas of practice (e.g., mechanical engineers working in forestry should have knowledge of forest ecosystems and soil sciences). Participants believed non-engineering expertise would be required to help identify, understand and respond to the host of issues that may need to be addressed when determining most appropriate engineering solutions; however, participants felt that "multi-disciplinary" knowledge and skills required in order to increase understanding across disciplines and activities was generally lacking among engineers.

Most participants felt that their own education and training had been narrowly focussed on the technical although younger participants felt this was changing. Almost all participants agreed that they did not use a lot of the technical training they received once they graduated (one even claimed he used less than 80%). Several participants stated that they used little from the mathematics courses they took; others said computer and other technology-specific training they had was either inappropriate (didn't match technology in the work place) or out of date. For these reasons, participants claimed that undergraduate programs could (and should) place more emphasis on knowledge and skills beyond the strictly technical. There was agreement that more preparation in the areas of management, politics, and other social sciences would be useful, especially if they were specific to the engineering context. Most participants wanted to see the study of environmental sciences included as a requirement for engineers; others suggested that environmental science was relevant to some engineering disciplines/activities and not to others (e.g., computer technology; electronics) and extensive study of environmental sciences should not, therefore, be required of all engineers.

Other sources. A number of other sources also provide information about engineers' knowledge and skills. For example, Human Resource Development Canada (HRDC hereafter) recently sponsored two studies that provide information about engineers' current knowledge and skills. One study focussed on the Canadian pulp and paper industry (Price Waterhouse, 1994). The study included document review and data base analysis, interviews and focus groups with some 300 industry members (industry association members, trainers and educators, students, technology experts, suppliers, labour representatives, workers, government representatives, and managers of pulp and paper operations), a two-round delphi analysis (33 people in round 1; 16 people in round 2), a mail survey (81/145 returned), and in-depth site visits to 15 pulp and paper operations across Canada. Declaring that a transformation from current hierarchical structures is necessary and will have significant impact on the skills engineers require, the report identifies communication skills, interpersonal skills, and skills for leading groups in problem solving as "skill deficiencies" among engineers. Further, the report identifies a focus on optimization rather than trouble shooting as an emerging trend and states that engineers require "broader involvement and understanding of the full socio-technical system . . . managers will need to have a better understanding of the impacts of technology and how it should be implemented" (Price Waterhouse, 1994, p. 95).

The second study focussed on the Canadian consulting engineering industry (Dickinson & Crofton, 1994; KPMG, 1994; Pacific Leadership et al, 1994). This study included document review and analysis, interviews (CEOs, human resource managers, and employers from 65 firms), focus groups (168 people in 21 focus groups involving employees and engineering educators and students), a two-round delphi analysis (92/161 participants in round 1; 86/118 participants in round 2), eight indepth case-studies, and two round tables (80 participants including employers, educators, and representatives from professional associations and government; the round tables also served as a vehicle for formulating an overall human resource strategy and action plans). Study participants were drawn from across Canada, from various industry sectors, and from organizations ranging from small firms employing less than 10 people to large international EPC (engineering procurement and construction) companies. The findings of this study resemble those of the prior study. Participants felt "that the type of leadership required, and the skills, knowledge and attitudes called for in the present and future business environment are fundamentally different from the past." (Dickinson & Crofton, 1994, p. 23). The ability to develop and communicate vision, listening skills, and open, consensus-based decision making styles, were identified as critical competencies. Study participants stated that engineering graduates and many practising engineers have "inadequate skills in communication, management and problem-solving [and] lack knowledge about business practices in general" (Dickinson & Crofton, 1994, p. 33). Communication needs highlighted included ability to write, make presentations, negotiate, get along with others on teams, conflict resolution and ability to reach compromise.

Vanderburg's (1992) study of undergraduate engineering curriculum in Canada also has bearing on the discussion of engineers' knowledge and skills. Vanderburg observed that "the unintended 'byproduct' of our modern way of life, namely a loss in the health and integrity of social and natural ecologies . . . are steadily moving up the agendas of the public, corporations and governments. These developments have had virtually no impact on engineering education, however" (p. 823). As a result, he decided to assess undergraduate engineering education in the light of two questions:

> 1. How much do we teach our students about the way technology interacts with human life, society and the natural ecology?
>
> 2. To what extent do we teach them to use this knowledge in a negative feedback mode to adjust engineering methods and approaches to achieve a greater compatibility with these contexts? (p. 823)

Vanderburg focussed on the formal curriculum in seeking answers to these questions. His examination included course outlines, textbooks, class handouts, supplementary reading, student lecture notes, projects, exercises, examinations, tutorials, laboratories, field trips and audiovisual materials used in the 1988-1989 academic year of the Faculty of Applied Science and Engineering of the University of Toronto; faculty research publications were an additional resource. Two scales (one for the technical core and one for the complementary studies portion of the program) were developed and tested to assess the afore-mentioned materials in terms of the degree to which context issues are included in materials/courses. Scale values of 0 (no reference made to context) to 4 (use of context information "to adjust engineering methods and approaches to ensure greater compatibility with human life, society, and the natural ecology") were assigned.[18]

Context issues included:

a. implications of technology for human life, society or nature;
b. ethical considerations and relationships to values;
c. non-technical aspects of engineering education and the professional paradigm;
d. implications of engineering theories and practices, including the consequences of quantification and mathematization, particularly of a qualitative socio-cultural human reality; and
e. implications of engineering decision-making, including implicit and explicit values, beliefs, assumptions and models which guide it. (p. 824)

Ninety-five percent of all courses offered and about 70% of all self-reported research publications were used in the analysis. Advanced doctoral students in Engineering, Sociology, Political Science and the Philosophy of Education, working under the direction of Dr. Vanderburg, did the scoring. The results of the study were compared with other Canadian engineering faculties by examining CEAB requirements and calendar course descriptions; the University of Toronto results were probably "slightly better than those that might have been obtained for other schools because the University of Toronto appears to be leading in introducing context issues into the curriculum" (p. 825).[19]

The average score for the technical core of the curriculum was 0.82; when technical electives are added, this reduces to 0.78. Factoring in the Complementary Studies component raises the score to 0.80. Given that (a) an understanding of contextual issues is essential to achieving sustainable development, and (b) engineers need to have contextual awareness and knowledge in order to design and develop appropriate engineering solutions,[20] this "report card" is cause for serious concern. Vanderburg states that "students learn very little about how to use knowledge of the way technology affects human life, society and nature to adjust engineering methods and approaches to ensure the greatest possibility of compatibility between technology and its contexts" (p. 822). The study suggests that "the next generation of engineers is not in a good position to make a significant contribution to the development of a more sustainable way of life" (p. 825).

Vanderburg's claim reflects concerns of APEGBC study participants and is supported by others. For example, as a result of an examination of the UBC engineering curriculum and current social and environmental contexts, Hyde (1992b) identifies four engineering education problems: "separation of engineering from social context; separation of engineering from environmental context; preference for technological challenge over human interaction; and overdependence on quantification" (p. 12). Hyde also claims that "current engineering curriculum is not compatible with sustainability" (p. 14). Initial results of a study investigating engineering faculty and student perceptions of the meaning of sustainable development, its importance to engineers, and the degree to which sustainable development principles are included in programs, appear to support claims that sustainability issues and principles are less than well represented in current undergraduate engineering education programs (Crofton, 1993[21]).

Given the similarities in the goals and requirements of engineering practice throughout North America, U.S. sources can also be drawn upon for corroboration of the Canadian findings. For example, Jester's address to the American Society of Civil Engineers (ASCE) Annual Convention incorporated elements important to achieving sustainable development and provided an assessment of the adequacy of current programs. He stated that engineers must "understand their world, the social fabric and their project from a total point of view . . . they must be able to read for concepts and applications as well as understand detail"; he concluded, however, that present courses "do not fit the bill" (Jester, 1989, pp. 359-360). The following discussions focus specifically on some of the problems identified in the United States; while they may not be identical to Canadian situations, they either corroborate or suggest reasons for Canadian findings.

Speaking directly to environmental concerns, Devon (1994), like Vanderburg, states that, despite the emergence of environmental concerns on the public, government and industry agendas, "this change is not reflected in engineering education" (p. 2828).[22] Hutzler and Baillod (1994) agree. They state that, although almost all universities include some general environmental science or ecology course (i.e., environmental knowledge is available to engineering students), "typically these are descriptive and qualitative in nature with little engineering content and are <u>not</u> adequate for problem solving" (p. 2689). Further, they see environmental engineering courses as "outgrowths of traditional engineering 'Water Supply and Pollution Control' courses . . . not well suited to providing the broad foundation in environmental engineering science needed by today's engineering students. . . . [F]uture practitioners need a more balanced curricular approach featuring the causes of environmental problems and the relevant engineering princples needed to solve them" (p. 2690). In partial support of their statements about the lack of environmental considerations in engineering education they refer to an article by a 1989 mechanical engineering graduate and statements in the 1993 U.S. Environmental Technology Act. The engineer states that the terms "environment" or "pollution" never appeared in homework problems or professors' lectures and that, upon entering the professional world, "I discovered that my ignorance of environmental engineering . . . has left a gaping hole in my education and in my engineering mindset." From the Technology Act, Hutzler and Baillod quote:

> The Congress finds the following: With the exception of environmental engineering curricula, environmental considerations are typically not integrated in the required design course work for the various engineering disciplines. (quoted by Hutzler & Baillod, 1994, p. 2690)

Such findings reflect statements made by APEGBC and CEI study participants and by Vanderburg.

Further, through comparison with humanities/social-science majors and business majors, Howard's (1986) studies of college experience and managerial performance also provide information about engineers' relative strengths and weaknesses. Howard's sample included two AT&T longitudinal samples of managers (422 managers who graduated in the 1950s and 344 managers who graduated in the 1970s) and samples of managers in 10 different organizations (386 middle-aged managers and 380 young managers). Assessments were based on questionnaires, personal interviews, extended essays, and a series of tests (e.g., cognitive, verbal and quantitative skills, personality and motivation inventories); the AT&T sample participants were also observed and rated on 26 managerial characteristics by assessors during a three-day assessment program. Howard's findings revealed that, in comparison with humanities/social-science majors and business majors, engineers rank lowest (along with, and sometimes lower than, mathematics and science majors) in creativity in problem-solving, social objectivity, personal impact, behavioral flexibility, and in leadership, interpersonal, oral communication and decision-making skills (greatest differences evidenced in decision-making skills). Such findings lend support to APEGBC participant claims that engineers need to develop communication, leadership and broader kinds of problem-solving skills.

Organizational Support

The APEGBC study did not directly investigate engineers' organizational structures and support systems. Participants' discussions, however, often included mention or assessment of supports (e.g., preparatory or continuing education) and organizational issues (e.g., resource allocation, reporting arrangements, authority structures). For example, as evidenced in the previous discussion of knowledge and skills, participants were somewhat critical of the content of their preparatory education. Along with other studies (as noted in the previous discussion) and commentators on engineering education (e.g., Johnston et al, 1988; O'Neal, 1990; Vanderburg, 1990a), participants were agreed that, although engineering education programs are efficient in providing students with technical and science knowledge and that they produce technically competent graduates, they seem to be less adequate in providing the means by which other kinds of knowledge and skills can be obtained. Further, when asked how they might obtain the broader knowledge and skills they believe are required, especially those related to communication, leadership and management, participants reported that few formal opportunities and little support exists. Participants pointed to lack of time and resources for further education and training and stated that the limited opportunities provided through employers tended to be informal (e.g., presentations by a technology supplier, discussions with colleagues or senior members of the company, conventions) and focussed on the technical aspects of work (e.g., new computer technology; new technical products/processes).

In their discussions of responsibilities (as detailed in the following section), participants emphasized that, in their experience, directives (e.g., concerning objectives, procedures, job instructions) tend to be received from "above" and that opportunities for upward communication are limited. APEGBC participants also reported that, given the nature of their roles on projects, they are often distant or excluded from decision-making that may have bearing on sustainable development concerns. Participants noted that, particularly when working on large projects, problems assigned to them were defined very narrowly and their participation and communication with others was generally limited to the more confined activities and members of a project team. Instead of interactive discussion and consultation, communication across work units tended to be limited to information distribution. Situations like these make it difficult to to both get and provide information that may influence engineers' decisions. The APEGBC Task Force (1992), referring to Association decision-making processes, provides a case illustration. Noting that Council "is required to consider many sustainability-related issues" (e.g., ethical, environmental, public-related), they also state that:

> Although all these issues are interrelated, they are studied by and prepared for Council by various standing or special committees. Committees have relatively narrow terms of reference and little contact with other committees. Decisions involving more than one committee often go up and down various organizational steps, from Council to standing commitee (and sometimes back several times). Sustainability issues cannot be compartmentalized and cannot be delayed if Council is to act effectively. (p. 11)

Participants expressed concern about the inadequacies of organizations to respond to sustainable development in more general ways as well. For example: Political systems were considered problematic since plans or projects were often forestalled with changes in political parties or leaders. Legal and regulatory systems were considered inadequate due to their focus on minimum versus optimum requirements; further, many were concerned that legal or regulatory systems had the potential to undermine the application of professional judgement. Market systems, bolstered by various subsidies, were seen to interfere with the establishment of a "level playing field." Large bureaucracies were seen to be too slow, "too staid" and too "status quo" to be responsive to needed changes.

The study of the Canadian consulting engineering industry (CEI hereafter) described previously reinforces perceptions of APEGBC study participants and provides more detailed information about organizational supports and structures that may influence the ways engineers can respond to sustainable development. First, concerning *undergraduate education*, all CEI study participants expressed the view that "soft" skills (e.g., communication, teamwork, management) are under-emphasized. Students reported that there are limited (if any) courses available that target the soft skill needs. Those that are available are often outside their departments, not specific or contextually relevant to engineering/technology, and difficult to access within the constraints and requirements of engineering programs. Students also report that success in engineering programs is "grade-driven" and that this grade-drive is a major factor in the selection of courses. Students do not believe that complementary studies courses are highly valued by engineering professors; students report (and faculty also recognize) that, given the demands of engineering programs, students will tend to choose complementary studies courses that are less demanding (i.e., not requiring a great deal of time or effort) and more likely to earn them a high grade.

Engineering educators reported that a number of schools are expanding the "complementary studies" components of their programs but admit that most courses continue to be either external to the engineering program or are only available to students within particular programs. In some cases, a course may be available to students throughout the engineering school but, because it is offered within a particular department (e.g., civil engineering), students from other discipline areas are unaware that the course could be included in their program or scheduling conflicts interfere with their access to the course. The evidence suggests that support for acquiring a broader range of knowledge/skill within existing programs is inadequate. Educators also suggest that the increase in computerized instruction and multiple choice exams, and the decrease in teacher-student dialogue exacerbates the situation. Further, some educators declared that the situation communicates a lack of valuing or importance of softer skills.

Most CEI study participants believed the technical background provided by universities is adequate (and essential) but complained about the lack of practical application components in university programs. Students complained about the lack of industry or practical experience among their professors; they also stated that, although some professors have experience, very little of the practical industry knowledge and experience is shared. In addition, students claimed professors lacked teaching expertise and that this made learning more difficult. All participants felt that cooperative education (co-op hereafter) and internship programs were extremely valuable in helping graduates gain experience and insight into engineering (employers preferred graduates with this kind of experience; at times students found future employment as a result of specific co-op experiences). Students noted, however, that it was difficult to get into co-op/internship programs for one or more reasons: programs were only offered within certain departments (if at all); few placement opportunities (industry not receptive); high competition for program entry; time tabling or course planning arrangements prohibited access or made access difficult.

Educators recognize the need for more practical application knowledge and experience (for students and instructors) and many are exploring various ways to meet the needs (e.g., co-op opportunities for instructors as well as students; extended work/research experience; special industry projects within courses). A number of university representatives emphasized, however, that university programs are not intended as job preparation programs except in the broader, education sense; a few expressed concern that co-op and other work practice programs "take away from academic learning time." Employers declared that the ideal graduate would have a combination of practical and theoretical knowledge and skills and suggested that students should take advantage of both university and technical school institutions. Unfortunately, although some "bridging" programs between universities and technical schools have been successfully negotiated, they are few in number and "territorial lines" between universities and technology institutes continue to exist. Further, even if students do take courses in technical schools, these courses are usually considered as "add ons" and rarely credited as part of their graduation requirements. In sum, CEI study participants felt that undergraduate engineering programs have few (if any) mechanisms and offer little support for obtaining broader and non-technical kinds of knowledge/skill. The situation also extends to the experience component of engineers' preparatory education and to the continuing education of engineers.

Engineer-in-training (EIT hereafter). By way of introduction, engineering experience "is a major component in the formation of an engineer in becoming acceptable for professional registration" (CCPE-CEQB, 1994, p. 10). The EIT program is a response to the fact that "it is obviously not possible to teach everything one needs to know to practise engineering . . . in a four-year university program" (APEGBC, 1993, p. 6). The experience requirement consists of a period of supervised engineering experience and serves as an internship for those who are academically qualified and may subsequently apply for professional registration. The CCPE-CEQB provides guidelines regarding what the engineering experience should include (e.g., application of theory, practical experience, management of engineering, opportunities to practice communication skills, involvement in activities which heighten awareness of social implications of engineering). The experience requirement "has as much significance for the individual sponsors of engineering applicants and the applicants' employers as for the applicants themselves" (CCPE-CEQB, 1994, p. 10).

Participants in the CEI study agreed that the consulting engineering context provides many opportunities to expand knowledge and skills and that these opportunities are different from those generally available outside of the consulting engineering context. Engineers working in consulting engineering report that their knowledge and skills are continually challenged and expanded by consulting engineering activities; in fact, success in consulting engineering is dependent on having a breadth of competencies. Consulting engineering firms, however, prefer to hire engineers with several years of experience and many prefer engineers with Masters degrees; that is, they prefer to hire people who already have particular attitudes and the broad range of competencies they require. Those consulting engineering firms hiring EITs tend to be limited to a few of the very large firms and even they hire only a few EITs. Many large firms have reduced the number or eliminated EITs from their hiring roster. The consulting engineering industry is also not very active in providing engineering students with work experience opportunities as part of co-op programs while they are still undergraduate students. In sum, although the consulting engineering context is seen to provide a preferred context for developing a broader range of knowledge and skill, access to the consulting engineering context is limited.

Most engineers and engineers-in-training reported that little support was provided to them in obtaining particular kinds of knowledge and skills (especially those related to communication and group process skills) to adequately function in the workplace. Most participants reported that supervisors provided little in the way of guidance (if they attended at all to developing the trainees' competencies) and often were themselves weak in certain areas to which the experience requirement was to attend; it was usually only through "trials by fire" that competencies could be developed. Participants also reported that during their EIT experiences they were often relegated to clerical/secretarial or exclusively technical support roles and had little opportunity to develop other competencies. This finding is also reflected in a smaller study of 22 women alumni of the UBC Faculty of Applied Sciences (Crofton, 1992c). A few participants, however, were more positive about their EIT or other early experiences. They reported that they were "taken under the wing" of a senior person in the firm and that this person became their mentor and guide. With the influence of their mentor, they were able to identify areas for development and, if only in some small measure, were able to participate in various activities that helped them gain new and broader knowledge and skills and further develop their technical competencies. Unfortunately, most participants did not report their EIT or other early professional experiences included the support of such a mentor.[23]

Overall, CEI study participants expressed the belief that the success of their early experiences, and the degree to which the experiences contributed to their acquiring broader knowledge and skills, was dependent on three factors: (a) the kind of job placement they obtained; (b) having some kind of mentor or guide; and (c) the kind of support and guidance that mentor provided. CEI study participant reports of the problems of obtaining good placements and the relative lack of support provided for developing an expanded set of knowledge and skills, give credence to APEGBC participants' claims regarding weaknesses in support systems for acquiring certain kinds of knowledge and skills believed to be important to sustainable development.

Continuing education. Many of the comments made about early professional or EIT experiences are reiterated about the state of continuing education. CEI study participants report that continuing education opportunities are limited and that most of those that do exist are focussed on the technical aspects of the work (e.g., new computer software/hardware, new products/processes). Some firms do support employees' further education and training through fee reimbursement for successful completion of programs. Unfortunately, due to economic conditions, fewer firms are able or willing to provide this support unless the program is directly linked to the work engaged by an individual and unless there is some assurance that the individual will remain with the firm for several years subsequent to completing a program. In many cases, opportunities to access and be reimbursed for courses or extended programs are limited to those individuals identified and selected by senior members in the firm.

More generally, whether or not firms provide or reimburse them for courses/programs, participants reported that, given the growth and rapid changes in technology, the time and effort required to stay abreast of innovations, and the demands of engineering work in general, if continuing education activities were engaged, they tended to focus on the technical aspects of their work. Further, they reported that courses and/or fuller programs that might provide them with particular kinds of non-technical knowledge/skills were (a) not easily accessible due to the length, timing, location or expense of the course/program, and/or (b) were not targeted or attentive to engineers' specific needs. The Price Waterhouse study, in its consideration of education and training practices, concluded that, although existing career paths provide early exposure to managing others, "engineers rarely have any opportunity to develop and practice the requisite interpersonal skills prior to assuming a supervisory position" (Price Waterhouse, 1994, p. 95). It appears that, despite widespread recognition of the need to develop new and different kinds of knowledge and skill, little support exists and little activity is occurring to address these needs.

Organizational norms and structures. New technologies, increased customer demand for both quality and increased involvement in projects, and changing employee values and expectations, are among the factors prompting change in ways of doing work and structuring organizations. "There is a growing understanding that past approaches are no longer sufficient" (Price Waterhouse, 1994, p. 62; see also Frost, Mitchell & Nord, 1989; Kanter, 1989; Morgan, 1989; Weisbord, 1987 & 1992). The CEI study discovered, however, that, "despite the emergence of looser, flatter organizations as the result of downsizing and rationalization, the traditional hierarchical model prevails" (Dickinson & Crofton, 1994, p. 20). The predominant features of consulting engineering firms include centralized, top-down decision-making, paternalistic policies and practices, the absence of long term strategic planning, and a dominance of operational and financial factors over human resource issues. (In the Price Waterhouse study interviewees "complained that most levels of management did a poor job of communicating with them and keeping them informed" (Price Waterhouse, 1994, p. 95).)

The goal of increased customer focus is widespread in the industry (as it is in other sectors), however, it translates into little more than increased attentiveness. Further, though a number of companies have initiated formal quality assurance or Total Quality Management (TQM) programs, initiatives are mostly intended to meet new market standards; only a small number of firms have also embraced the management and organizational philosophies inherent in these approaches. Employees are sceptical of change efforts; they report that while there may be more opportunities for teamwork and collaborative approaches, the hierarchy prevails. Some characterized attempts to increase attention to quality and customer concerns as "tokenism." There were several reports of economic considerations and pressure to produce taking precedence over developing the best solution for the client. (Participants acknowledged, however, that achieving a balanced position on these issues is an ongoing challenge.) The CEI study also revealed that, despite statements that leaders need broad knowledge and well-developed communication, management and problem-solving skills, "most managers are 'home grown' products, often promoted on the basis of technical competence, with little or no experience of other industries. . . . Few have received any formal training or education in management disciplines along the way" (Dickinson & Crofton, 1994, p. 23).

Responsibilities

The literature available about engineers' responsibilities most often attends to the kinds of responsibilities engineers *should* assume and why (e.g., Broome, 1987; Bugliarello, 1991; Cohen & Grace, 1994; Lenk, 1991; McFarland, 1986; Randolph, 1992). Philosophical, sociological, psychological and practical arguments are presented in defense of the responsibilities identified.[24] These writings provide support for the responsibilities identified by the CCPE but provide little information about the degree to which engineers are actually engaging these responsibilities. Information about engineers' perceptions of responsibilities and the ways they do or do not engage them will be limited to the findings of the APEGBC study as described below.

Questionnaires. The questionnaire data (refer to Table 3-2) indicates that respondents believe they have responsibilities in the areas of guidelines formulation (77.5%), accounting for the social effects of their work (76%), development of codes, legislation and policy (82.4%), increasing public awareness (82.8%), and professional development (81.4%). Almost all respondents (94%) indicated that accounting for environmental effects of their work was a member's professional responsibility. Respondents were less certain, however, about their responsibility to support economic development (46.9% agreed, 29.6% disagreed, and 23.5% gave neutral responses). Most respondents (86.2%) also believed they were required to consider effects beyond immediate users (Item 8) and that the Association should take responsibility for establishing a set of guidelines for sustainable development (Item 9; 70.2%). In terms of willingness to pay increased fees in support of sustainable development (Item 12), 54.7% of respondents indicated they were willing to pay increased fees; the mean (3.6), however, suggests that, collectively, willingness is rather tentative. The questionnaire did not ask participants to provide their views about how well they were engaging their responsibilities; in attached notes, however, two respondents expressed their views in this regard:

> The questionnaire is a good start but is "too little, too late" to use an old cliche . . . [O]ur association, so closely allied to commerce and industry has never opened its collective mouth to provide the kind of leadership that might be expected from trained, qualified "professionals." Professional as applied to our association is a mockery of the term. (Respondent 0066)

> Some engineers don't pay attention to the codes of ethics now; I don't know how you are going to enforce. (Respondent 0149)

Preferred interpretation (forced choice Item 5) was found to be a factor in responses to responsibility items. Using a one-way analysis of variance, difference at the .00 level of significance were found for all items except 7a (no difference) and 7f (.01 level of significance). Responses of those choosing the Item 2 interpretation narrowly focussed on economic development (Group 2 in the table) were significantly different from responses of those choosing the other two interpretations on items 7c, 7d, 7f, 7g and 8. Specifically, Compared with other respondents, respondents in Group 2 did not agree as strongly that they had responsibilities for accounting for the environmental effects (Item 7c) or social effects (Item 7d) of their work; increasing public awareness (Item 7f); participating in professional development (Item 7g); or considering effects beyond immediate users (Item 8). On Item 8, responses of those favoring the Item 3 interpretation concerned with ensuring environmental quality and economic development (Group 3 in the table), were also significantly different from those choosing the Item 4 interpretation oriented to recognizing limits (Group 4 in the table); respondents in Group 3 did not agree as strongly as respondents in Group 4 regarding responsibility to consider effects beyond immediate users. Respondents in Group 4 were also significantly different from the respondents in Groups 2 and 3 on items 7b, 7e, 9 and 12. On item 7b, responsibility to support and/or promote economic development, respondents in Group 4 tended to be more neutral than those in the other groups. Compared with other respondents, Group 4 respondents more strongly agreed that they had responsibility to participate in formulating codes, legislation and policy in society in general (Item 7e) and that the Association should take responsibility for establishing member guidelines for sustainable development (Item 9). Those in Group 4 were also

Table 3-4
Preferred Interpretation of Sustainable Development as a Factor in Responsibilities

Item#	Statement of Difference	Level of Significance	Group 2[a]	Group 3[b]	Group 4[c]
7b	Group 4 different from groups 2 & 3 re: economic responsibility	.0000			
	Mean		3.04	3.19	4.13
	95% Confidence Interval		2.52-3.55	3.00-3.39	3.91-4.35
7c	Group 2 different from groups 3 & 4 re: environmental responsibility	.0001			
	Mean		2.23	1.80	1.50
	95% Confidence Interval		1.83-2.62	1.64-1.95	1.39-1.62
7d	Group 2 different from groups 3 & 4 re: accounting for social effects	.0000			
	Mean		3.45	2.54	2.34
	95% Confidence Interval		2.96-3.95	2.36-2.72	2.16-2.53
7e	Group 4 different from groups 2 & 3 re: formulating codes, policy	.0003			
	Mean		2.94	2.45	2.12
	95% Confidence Interval		2.47-3.42	2.27-2.64	1.96-2.27
7f	Group 2 different from group 4 re: increasing public awareness	.0098			
	Mean		2.72	2.27	2.10
	95% Confidence Interval		2.25-3.18	2.11-2.44	1.95-2.25

7g	Group 2 different from groups 3 & 4 re: participating in professional development	.0001			
	Mean		3.08	2.49	2.23
	95% Confidence Interval		2.71-3.45	2.32-2.66	2.08-2.38
8	Group 2 different from groups 3 & 4; Group 3 different from group 4 re: effects beyond immediate users	.0000			
	Mean		3.15	2.27	1.83
	95% Confidence Interval		2.64-3.66	2.10-2.45	1.68-1.97
9	Groups 4 different from groups 2 & 3 re: Association role in guidelines	.0007			
	Mean		3.23	3.00	2.51
	95% Confidence Interval		2.78-3.68	2.79-3.21	2.32-2.71
12	Groups 4 different from groups 2 & 3 re: willingness to pay higher fees	.0000			
	Mean		4.38	3.89	3.07
	95% Confidence Interval		3.81-4.95	3.66-4.13	2.82-3.31

[a] Group 2 prefers Item 2: Sustainable development as supporting economic growth and development
[b] Group 3 prefers Item 3: Sustainable development as protecting environmental quality while permitting economic development
[c] Group 4 prefers Item 4: Sustainable development as recognizing limits

more willing to pay higher fees (Item 12) than those in the other groups.

Interviews and focus groups. Interview and focus group participants confirmed many of the questionnaire findings regarding areas of responsibilities. More importantly, and particularly in focus groups, additional information was gained about participants' perceptions of the nature of and constraints on their economic and social responsibilities. Supporting questionnaire findings, participants emphasized the importance of accounting for environmental effects (e.g., water, soil and air quality) and unanimously accepted this among their responsibilities. Participants also accepted their responsibility to consider effects beyond immediate users (though there was some concern about how far "beyond" such consideration may require); to contribute to the development of codes, legislation and policy; to increase public awareness; and to engage in professional development activities. Discussions of economic and social responsibilities were less straightforward. On the one hand, participants were agreed about certain kinds of economic responsibilities but uncertain about or resistant to accepting others (this may account for a more neutral mean rating of questionnaire responses regarding economic responsibility). On the other hand, while participants appeared to want to accept social responsibility (at least in principle), participants found it difficult to separate social effects from economic or environmental effects and expressed concern about what "accounting for social effects" might entail. Overall, participants' willingness to accept responsibility for the economic and social effects of their work or, more generally, for "safeguarding . . . life, health, property, economic interests, the public welfare or the environment" (CCPE-CEQB, 1992, p. 9), was dependent on what might be included in the accounting and how far such responsibility might extend.

Participants were prepared to accept responsibility for safeguarding economic interests in three ways: (a) by being attentive to client's cost concerns and budget constraints; (b) by providing appropriate processes/products that might be used in a client's development projects (e.g., by providing technology to increase effectiveness of resource extraction/processing); and (c) by marketing their products and services. Participants agreed that *promoting* economic interests (e.g., promoting development projects or a client's particular economic interests) should *not* be among their professional responsibilities. Between these two certainties there was a range of possible responsibilities; there was less agreement about how many of these responsibilities an engineer should be required to accept. Some participants felt that engineers should be involved in decisions around *choice* of development projects; others felt this was outside engineers' domain of responsibility. Some felt it was their responsibility to speak out against certain projects or practices (especially if, for budget reasons, the project/practice may have negative environmental and/or social consequences); others felt this was both impractical and outside their realm of responsibility. Several participants were concerned that speaking out against projects or practices may result in loss of jobs and/or clients. There was also the suggestion that speaking out may cause them to violate certain tenets of the code of ethics and result in professional censure.

In terms of social effects, a few interviewees suggested that consideration of social issues was outside the domain of engineering; these people were more inclined than other interviewees to disagree with questionnaire item 7d (social effects). They believed that decisions governing social issues, as well as certain environmental and economic decisions, were not "engineering decisions" and that responsibility for such decisions does and should rest with managers, clients and politicians. They felt that an engineer's responsibility was "to do a thing right" not to make decisions about "the right thing to do." Interviewees holding this view believed they had responsibilities to contribute to the decision-making process as citizens, and to make personal decisions around these issues, but that their roles as engineers and as citizens were separate.

The idea that social issues were outside the domain of engineering, was not raised by focus group participants; although they recognized that others were active in making decisions regarding social concerns, they did not exclude social issues from engineers' domain of responsibility. Further, focus group participants did not make distinctions between "doing the thing right" and "doing the right thing." Focus group participants did express concern, however, about how far engineers' range and breadth of responsibilities might be extended. For example, suppose that, as the result of some engineering work, large numbers of people might become unemployed or displaced from their lands. Does safeguarding public welfare or accounting for social effects mean engineers become "accountable" for this effect in the same way that they might be "accountable" for negative environmental impacts of their work? Would there be legal implications? Would they be obligated to provide compensation? Or is "accounting" for social effects confined to reporting the possible social consequences of their work? Is this reasonable? How far might such accounting responsibility extend? Would they, for example, be expected to "account" for potential social effects of electronic communication?

Regardless of participants' positions on the responsibilities that a professional engineer might be expected to assume, there was agreement about a number of constraints on their ability to assume responsibility in the most desirable ways. First, and most generally, for both practical and professional reasons, engineers need to be concerned with profit and attentive to budgetary constraints; in fact, if they were not, they would quickly find themselves out of work. Unfortunately, participants also stated that cost concerns often become the overriding driver of engineering design and related activities; as a result, the tendency is to meet minimum requirements rather than create potentially more expensive optimum designs/solutions. Second, projects with which engineers are involved are generally determined by people other than themselves. These others (e.g., clients, shareholders, government) make decisions about what is in the "economic interest." Further, as engineers, they are not usually the ones making capital investments. Third, especially in large projects, engineers are either not involved, or have limited opportunities to participate in decision-making. For that reason, they are limited in their ability to suggest alternative approaches or additional design components which, though potentially more costly, might reduce potential negative effects on the environment or the public. Further, engineers often do not have much input into job specifications or definitions of "problem space."[25] Fourth, participants reported that it is often the case that a client is not sufficiently well-informed about the kinds of actual or potential issues or problems that need to be addressed. In some cases, due to inadequate or insufficient data for example, engineers' own knowledge of issues or problems may be limited. As a result, the needs and parameters of a client's request(s) may not be adequately defined, and it may be difficult to argue for more expansive and/or costly engineering solutions. Participants also report that clients are often less interested in optimal solutions than they are in "just getting the job done." Finally, in the absence of supportive regulations/legislation, participants felt they "don't have a leg to stand on." They expressed the belief that, although the Code of Ethics could be used to govern engineers' behavior, disciplinary action is rarely taken. Further, the Code has no "teeth" in terms of regulating clients' behavior. Participants also raised concern that speaking out against certain kinds of activities may result in loss of jobs or clients. There was also the suggestion that speaking out may cause them to violate certain tenets of the code and result in professional censure.

Constraints such as these led some participants to conclude that the economic responsibilities they currently accepted were sufficient and that little more economic or social responsibility could reasonably be expected. Other participants, however, felt their activities should be expanded to include acceptance of a broader range of responsibility. Pointing to the negative consequences of less than optimal designs -- whether due to budget constraints, lack of legal requirements, inadequate problem definitions, or client's lack of information or interest -- these participants suggested engineers need to be more involved, insistent and proactive regarding the kinds of activities engaged or solutions offered in their engineering work. Recognizing that changes of this kind might be slow or meet with resistance, there was general agreement that the profession must assume responsibility for substantial efforts to educate members and increase their awareness of issues.[26]

For several participants, the emphasis on economic concerns over other concerns inhibited their ability to "do the thing right" and they found themselves in conflict about their work. These participants wanted more regulations and legislation in order to justify designs more attentive to environmental and social concerns. They argued that, with such regulations in place, debates with clients on design issues would be reduced as would be the risk of losing clients to "the guy down the street." Some structural engineers, pointing to the various building codes and regulations that govern their work and that they assume as part of their general practice, suggested codes specific to environmental and social concerns should be more fully developed. With the exception of one focus group (discussed further below), interview and focus group participants were generally agreed that, although it was unlikely that environmental or social regulations could take the form of building codes, more specific regulations and harder-hitting legislation would help them defend more optimum designs and support movement in direction of sustainable development.

When such regulation might directly govern engineering practice, however, the issue was rather more contentious. It was during the discussion of sustainable development guidelines (prepared by the APEGBC Task Force and pertaining specifically to engineers) that this became particularly clear. In general, although most participants were supportive of the Association's efforts to formulate guidelines, some participants felt that, if change was to occur, guidelines needed to be regulatory with significant consequences for failure to comply. At the other extreme were those who believed that guidelines, except as explanatory notes, were unnecessary since the Code of Ethics and various existing regulations already covered issues of concern. Those adopting a more middle-of-the-road approach felt that guidelines as general directions, were necessary but, given the diversity of contexts and areas of engineering practise, believed caution was warranted in attempting to make guidelines regulatory. Among both interview and focus group participants, a few expressed concern that guidelines, whether as general directions or as regulations, may interfere with or undermine the appropriate application of professional judgement.[27] Participants in one focus group (Group 3) were particularly vocal in this regard.

Focus Group 3, whose members were all involved in mining, was not supportive of the Association efforts to formulate guidelines. Although they did not express their views during the focus group session (time being too short to include discussion),[28] participants later indicated they were strongly opposed to the Association's guidelines for sustainable development. They felt that the mining industry was already over-burdened by regulation and feared that additional regulations would mark the end of the mining industry in B.C. In addition to writing protest letters to the Association's journal editor, members of this focus group submitted a formal request to the APEGBC president that the guidelines be withdrawn. (This request for withdrawal came in spite of the fact that the guidelines, as a draft document for discussion, were not established in any form that would require withdrawal.) Two people from the Task Force on Sustainable Development, including the Task Force Chair and the mining engineer, met with a small group of people from the focus group session. Based on information provided by the Task Force Chair, it appears there was general approval of "an integrated planning process for future generations that considers economic, social and environmental issues" (from letter of one of the meeting participants) and that some of the guidelines were "okay." There was a belief, however, that guidelines, as a code of practice, would be "dangerous." Mining representatives felt that proposed guidelines impose a further level of bureaucracy and that they could be used to discredit professional reports or even support court actions against their authors. Mining engineers and geoscientists also felt that some of the requirements would be "economic folly" during early exploration since "less than one in over 5000 prospects becomes a mineable deposit." Given that the mining industry is already heavily regulated, requiring approval at every stage of mine exploration and development, the primary concern of this group appeared to be that guidelines would add to the approval processes and further restrict their work activities.

Overall, leaving the mining group aside, participants felt that there was a need for clarification about the specific kinds of responsibilities engineers might be expected to accept with respect to sustainable development. Even so, they also felt that engineers should be more accountable and more proactive in fulfilling their various responsibilities and that mechanisms should be developed in support of their actions. Most particularly, participants believed that engineers should take responsibility for becoming more involved in discussions and activities regarding sustainable development and for bringing sustainability concerns to all their engineering work.

Summary

This chapter has drawn upon a number of studies to provide information about the status of engineers regarding the underlying and parallel requirements of sustainable development and engineering. The evidence suggests that most B.C. engineers define sustainable development in ways which incorporate environmental, economic, and social concerns and recognize the interdependency of systems; they also identify tensions arising out of different interests or perspectives on questions of sustainable development. Studies which provide information about engineers' knowledge and skills suggest there is reason to be confident about engineers' technical knowledge and skills; there is significant doubt, however, that technical knowledge/skill is sufficient for addressing sustainable development. Evidence suggests that engineers' technical knowledge/skills are not well-integrated with other kinds of knowledge/skills that have bearing on sustainable development. Further, reports suggest that such other knowledge/skills (especially environmental science, communication and group process knowledge/skills) are generally lacking among engineers. It also appears that opportunities and supports for developing an expanded set of knowledge/skills for sustainable development either do not exist or are extremely limited.

The lack of some kinds of knowledge/skills, the nature and organization of engineering work, and the absence of regulations/legislation which support more optimal design solutions, are among the constraints APEGBC study participants identify as interfering with their ability to effectively assume professional responsibilities related to sustainable development. Nevertheless, evidence suggests that most B.C. engineers are strongly committed to taking responsibility for accounting for the environmental effects of their work; they are also (though somewhat tentatively), willing to assume some kinds of economic and social responsibilities.

The findings of this chapter have implications for engineers' role and effectiveness in responding to sustainable development. In the following chapter the findings are used to draw conclusions about strengths and gaps or deficiencies in engineers' knowledge, skills and or practices. Further, implications the conclusions have for the engineering profession are discussed.

Endnotes

1. The underlying requirements can be drawn directly from the parallel goals and standards of sustainable development and professional engineers. Those reported here are also supported and explicit in discussions of the goals of sustainability education (BCRTEE, 1993, p. 15) and the aims of global education (Pike & Selby, 1989, pp. 34-35).

2. The Task Force included the Chair and four Association member volunteers. These members included two women (one involved in coastal and ocean sciences engineering and the other working as an environmental projects engineer) and two men (one a mining engineer and the other a civil engineer). Their initial efforts focussed on developing engineering guidelines for sustainable development; their attempts to formulate such guidelines led them to recognize the complexity of the concept of sustainable development, the trade-off conflicts inherent in attempts to deal with value-laden issues, and the difficulty of formulating guidelines for engineers working in diverse contexts. When I first met with the Task Force, members expressed frustration and the feeling that they were lost and floundering.

3. As a first attempt to receive comments from the membership, a general, open call for response was published in the December 1990 issue of APEGBC journal (APEGBC, 1990).

4. The research proposal, the design plan, alternative options and budget projections were discussed in detail with the Task Force. The Task Force approved the proposal in principle and it was then more formally presented to the Executive Council for approval and funding. Since the research proposal included a two phase

plan which would overlap fiscal years, the Council approved the proposal in two stages: beginning work for Phase I (which had already begun) was approved in April 1991; approval for the balance of the proposal was obtained in June 1991.

5. The Task Force also wanted to explore questions regarding sustainable development guidelines for engineers: Should guidelines exist? If so, who should be responsible for their formulation and what should be included? How reasonable are the draft guidelines prepared by the Task Force? To the degree that answers to these questions provide information about members' awareness and understanding of sustainable development and/or perceptions of their roles/responsibilities, discussion will be included here; in general, however, feedback received on Task Force's draft guidelines is not particularly relevant to the discussion here and is not, therefore, included.

6. Examples of the contents of the checklists can be found in Thurstone and Chave (1964, pp. 22,57) and in Munck and Crofton (1992).

7. No information was available regarding the numbers of members contacted through branch mailings; the APEGBC estimated that approximately 6000 members would have received branch mailings at this time.

8. Focus groups could not, however, be used as a substitute for interviews. First, focus groups require a larger time commitment from individual participants than interviews and would therefore exclude potential study participants. Second, interviews provide the opportunity to obtain detailed information from individual participants while this level of detail is usually lost in focus groups.

9. While some focus groups are highly researcher-controlled and structured, others are less structured and greater control is placed in the hands of participants; this study used the latter format (short of a self-managed group).

10. Focus groups also provide for the possibility of reaching consensus on higher order values (Majchrzak, 1984, p. 44). Since finding "common ground" and reaching agreement about complex issues are believed to be central to the success of sustainable development, this feature of focus groups is seen to be conceptually aligned with certain notions of sustainable development.

11. It should be noted, however, that when women were contacted, a couple of women were resistant or objected to the idea of a "women only" group and felt that it further alienated them from their peers; these women chose to participate in a mixed group.

12. Geoscientists were "grandfathered" into the Association for two years beginning January 1991; after 1992, formal requirements and qualifications had to be met for entry into the APEGBC.

13. Some additional comments were received regarding guidelines (one group, the mining group, submitted a formal request for withdrawal of the guidelines) and these were forwarded to the Task Force.

14. One participant was adamant that the idea of living with less was "ridiculous" and believed very strongly that in order for sustainable development to occur, more resource use, more growth, more population and more development would be required.

15. This frustration was evident in my work with the Multi-Stakeholder Working Group (MSWG) on pulp mill regulation in B.C. (Crofton, 1992b). The MSWG was "formed to further the knowledge and understanding of all aspects of pulp mill discharges in B.C. including the environmental, social, cultural and economic impacts" (MSWG mission statement, 1991). The group included representatives from environmental groups, federal and provincial governments, Native peoples, pulp and paper industry, shellfish associations, technology suppliers and consulting engineers, and unions. Over several months, a number of information sessions were held to present various stakeholder views; following this, representatives met together to identify key issues, develop recommendations, and reach consensus on those that would be put forward. During the early stages of the process, engineers were often frustrated by what they perceived to be non-engineers' lack of attention to and understanding of central technical issues. Non-engineers, for their part, were often not attentive to engineers' presentation and/or discounted engineers' "data" as being unimportant or irrelevant to the values and concerns central to the non-engineer participants. (Additional note: During the interactive phase, these barriers were overcome and consensus was reached on a series of recommendations; engineers and non-engineers alike expressed surprise and satisfaction with the common ground that was established.)

16. The idea of sustainable development as a "contradiction in terms" stemmed from beliefs that sustainability was about protecting and conserving resources while development was about using resources. Further discussion revealed that participants were pointing to the tension between environmental and economic interests.

17. The problem of response style was not identified in the pilots. One additional problem also not identified in the pilots was indicated by the comments of one participant: he noted that he assumed "prepared" meant "able" rather than "willing." Although all interview and focus group participants stated that their responses to Item 11 were focussed on ability rather than willingness, given possible confusion in the meaning of "prepared" and the problem of participant responses (check marks versus scale value), interpretations of Item 11 data must be cautious. Information provided by interview and focus group was weighted more heavily than the questionnaire item regarding *ability* to address sustainable development.

18. Briefly, the full scoring system is as follows: 0=no reference to context issues; 1=minor reference to context issues but these are peripheral to the thrust of the paper/course; usually little more than outlining context; 2=some reference to context issues with some consequences for the thrust of the paper/course; 3=major reference to context issues with substantial consequences for the thrust of the paper/course; 4=substantial consideration of context plus evaluation of consequences in order to adjust/reassess methods/theories.

19. The Toronto study required considerable expenditure of human effort and public funds; comparisons with other universities did not involve similar extensive study and was, in fact, limited to calendar course descriptions and requirements. Vanderburg states, however, that "based on a comparison of curricula and extensive

discussions with other engineering faculties, it appears that similar studies of other engineering schools would likely yield comparable results, with lower scores for complementary studies" (Vanderburg, 1992, p. 825).

20. In a paper examining complementary studies with a global perspective (Vanderburg et al, 1990), the authors note that "graduates tend to move into supervisory and managerial positions where an understanding of the context of technology is decisive. . . . they will come into increased contact with nations and cultures very different from their own. In these different contexts the effects of a particular technology or engineering undertaking will not be the same as in their own society" (pp. 375-376). This contributes to the argument for increasing contextual knowledge and understanding among engineers. Elsewhere Vanderburg (1990a) makes a strong argument for a "context-sensitive mode of engineering practice" by emphasizing that "technology is largely driven and assessed by values such as efficiency, productivity and cost-effectiveness, and to a much lesser degree, by values measuring its compatibility with the human, societal and ecological contexts" (p. 692). In this same paper, Vanderburg states that "present engineering curriculum does not adequately prepare our students for the kind of practice that will undoubtedly be expected of them in the years to come" (p. 699).

21. This study is ongoing. Initial results stem from (a) an experimental course on qualitative methods and sustainable development conducted in the School of Engineering Sciences, Simon Fraser University; (b) surveys of students at SFU (36 returns) and the University of Waterloo (19 returns); and (c) surveys of engineering faculty members at University of Waterloo (28 returns).

22. Devon (1994) states that "since the global ecosystem has very definite limits and all technology is environmentally transformative, then all engineering, not just traditional environmental engineering, must be green engineering geared to sustainable technology." Describing various activities which "characterize our present behavior" (e.g., biodiversity loss, depleting resources to exhaustion, overwhelming sinks with pollutants), he states that "right at the heart of this unsustainable behavior is technology and the work of engineers" (p. 2828). Devon then suggests reasons for the "green void in engineering education" including, for example: (a) belief that if the environment was a problem it could be fixed with environmental engineering – which he believes is "too much characterized by end-of-pipe solutions" (p. 2829); (b) lack of faculty interest in modifying curriculum; (c) general process of externalizing the environment (e.g., to the political arena); (d) the "myth" that green engineering costs more; (e) the myth that performance will suffer; (f) lack of incentives to change. Devon provides evidence to refute the myths, describes the nature of "green engineering" and suggests ways to "green" engineering curriculum.

23. It should also be noted that, at least in B.C., no selection criteria are applied and no orientation or training programs are provided to prospective sponsors of EITs; discussions with the APEGBC, APENB, and the CCPE provide are no indications that the situation is different in other provinces. It is assumed that all professional engineers have the ability to adequately assume "[t]he responsibility of providing the proper environment, opportunity, range and progression of activities necessary to meet the experience criteria" (CCPE/CEQB, 1994, p. 10).

24. The literature also includes (a) suggestions about why engineers may not adequately assume certain kinds of responsibilities (e.g., Bella, 1987a; Carper, 1991; Cohen & Grace, 1994; McCuen, 1991; Nelson & Peterson, 1982a & 1982b; Vesilind, 1991b, 1993), and (b) proposals for increasing engineers' ability to more adequately engage a broad range of responsibilities (e.g., Carper, 1991; Frezzo, 1989; Herkert & Viscomi, 1991; Koehn, 1991). On the question of why engineers may not be assuming responsibilities, reasons offered include, for example: educational program weaknesses; overspecialization in technical areas with negative consequences in engineers' ethical understandings; inadequate decision-making structures; a tendency for engineers to deal "with the social issues of society as an illogical, untechnical activity not worthy of our time or technical skills" (Randolph, 1992, p. 12). Proposals are almost exclusively focussed on changing educational programs.

25. Engineers often talk about "problem space" or "drawing the problem space." Mulling and Atman (1994) describe "drawing the problem space" as part of problem definition which "is the stage where the goals and objectives of the problem are determined, assumptions are made and requirements and constraints are noted" (p. 221).

26. Some participants suggested that efforts should be slow and incremental; others cautioned against incrementalism and argued for simultaneous, multiple approaches to both education and to formulating more pro-active responses to the environmental, economic and social issues of sustainable development with which engineers are involved. One participant suggested that if engineers move incrementally, they may do little more than give false confidences and delay tragic results: ". . . like the frog who [sic] expires without noticing the small, incremental increases in temperature that caused its death."

27. The concerns about undermining or interference with professional judgement could in some ways be tied to either implementation concerns or to the specific content of the draft guidelines. Implementation concerns focussed on issues of enforcement (responsibility, authority, policing) and practicality (time, cost, appropriateness for small projects). Time and costs involved in implementation and monitoring were seen as potential distracters from general engineering work; there was particular concern about who would make decisions and who would be responsible for additional expenses that may be incurred in adhering to guidelines. Both interview and focus group participants also expressed concerns related to specific content of draft guidelines suggesting that they were either too vague or too specific; that there was a need for clearer definitions; and that professional competence was not recognized. As one participant put it, "You'd think we were in kindergarten and need to have our hands held."

28. Recall that sustainability guidelines were an add-on to the primary purpose of the focus group.

CHAPTER 4

CONCLUSIONS AND IMPLICATIONS

> As the complexity of social, technological, economic, and ecological systems has grown, there is undoubtedly an ever increasing demand for technological and organizational expertise. The result is a tremendously increased demand for generalists, for people with a broad view ("specialists of the general") toward interdisciplinary complexes, for a systemic approach equal to the complexity of the problems and the tasks we face. (Lenk, 1984, p. 35)

Sustainable development poses an array of problems that go far beyond what is generally found in the textbooks or experiences provided as part of engineers' formal training, yet engineers are increasingly looked to for solutions. Business wants a competitive edge both in design and cost solutions; consumers want more convenient, reliable, safe, affordable products; government and society at large want solutions to economic, social and environmental problems and assurance that technological solutions are developed with full understanding of the social, economic and environmental contexts and without negative impacts on these contexts. Tension and conflict exists between the interests and goals of these overlapping constituencies. The intense demands and expectations from business, consumers and government are increasingly focussed on the engineering profession. The demands require that engineers understand and effectively respond to sustainable development.

Drawing on the findings of studies reported in Chapter 3, this chapter provides conclusions about how well engineers are currently able to meet the ideals and requirements of sustainable development. The conclusions provide reasons to be both optimistic (about engineers' technical knowledge and their understanding of sustainable development) and concerned. The concerns arise out of a number of often interconnected weaknesses in engineers' knowledge, skills, practises, organizational arrangements, support mechanisms and policies. The consequences of these conclusions are discussed in terms of effects on engineers, recipients of engineering work and the profession as a whole. Avenues of approach for mitigating problems and specific recommendations are found in Chapter 5.

Conclusions

1. Most engineers are relatively unfamiliar with the term, and reports of, sustainable development

Several APEGBC interview and focus group participants stated they had heard the term "sustainable development" but did not know what it meant; some participants said they had not heard the term before. Questionnaire data indicates that a fairly large percentage of participants (64.3%) were relatively unfamiliar with the Brundtland Report; interview and focus group participants confirmed their lack of familiarity with this and other reports of sustainable development prior to the study. At the time the study was undertaken, however, sustainable development had received a great deal of attention through the media, the BCRTEE, and such international conferences as GLOBE 90;[1] the APEGBC also placed sustainable development on the agenda for professional engineers. It was rather surprising, therefore, that few engineers had undertaken to become more familiar with discussions of sustainable development.

2. Reflection and focussed discussion facilitates understanding of sustainable development

The APEGBC study did, however, provide a catalyst for engineers to learn more about sustainable development. Several interview and focus group participants reported that they sought out information about sustainable development in preparation for their sessions; some referred back to an article that appeared in the Association journal; others referred to the WCED report and/or to BCRTEE reports; at least one participant in each focus group came with the WCED report or information from BCRTEE reports. Interview and focus group participants reported that the opportunity to discuss sustainable development caused them to reflect upon the issues and consider their roles as engineers. The host of issues identified by interview and focus group participants captured those found in more comprehensive writings of sustainable development. This was particularly true in focus group sessions where issues lists covered a broader range of issues than usually provided by a single interviewee.

3. There is reason to be optimistic about engineers' understanding of the goals and requirements of sustainable development, and their willingness to contribute to achieving sustainable development

Overall, APEGBC study participants overwhelmingly rejected a definition of sustainable development narrowly focussed on economic growth and development (only 7% of questionnaire respondents chose such a definition; only one interviewee was narrowly focussed on development). Instead, questionnaire responses indicated respondents believe sustainable development involves balancing environmental and economic concerns and being attentive to limits. Interview and focus group participants considered sustainable development to encompass a diversity of issues and to require a focus on ways to balance environmental, economic and social concerns across geographic and time boundaries. Participants also tended to focus on health and well-being as the over-arching goal of sustainable development and identified knowledge and skill requirements consistent with those incorporated by principles of sustainable development. The APEGBC study also indicates that engineers are willing to accept some kinds of responsibilities regarding sustainable development.

Other events that have occurred since the APEGBC study give reason to be optimistic about engineers' current and future understanding of sustainable development, and reinforce the idea that engineers are willing to accept a role in achieving sustainable development. Here are several examples. Reports of the APEGBC study and subsequent workshops sponsored by the APEGBC Municipal Engineers Division, have generated discussion and contributed to engineers' awareness and understanding (Crofton, 1994; Crofton et al, 1992). The APEGBC formulated sustainable development guidelines for engineers (APEGBC Task Force, 1992) and the development of similar guidelines is being considered or initiated by several other provincial associations. In 1994 the CCPE approved guidelines which recognize the key role of engineering in sustainable development; an understanding of the concept of sustainable development was also added to their accreditation policies. Such policy initiatives have the potential to increase engineers' attention to sustainable development. The Manitoba Round Table on Environment and Economy Sustainable Development Coordination Unit, and individuals from the International Institute for Sustainable Development (IISD, Winnipeg) have initiated discussions and projects to focus engineers attention on sustainable development. The UNCED in 1992 was a catalyst for the formation of the World Engineering Partnership for Sustainable Development (WEPSD), a combined effort of the World Federation of Engineering Organizations, the International Federation of Independent Consulting Engineers, and the International Union of Technical Associations. At least one Canadian engineering education program (UBC Civil Engineering) has developed a course on sustainable development and has included it among the core requirements for graduation.

There are many other reasons to be optimistic about the likelihood that Canadian engineers will increasingly be exposed to the ideals and requirements of sustainable development and that their practices/solutions will be increasingly compatible with and supportive of sustainability goals. For example, since engineers typically perform work assigned to them by others, they are now often responding to environmental and social concerns expressed by industry, government and the public. Further, more Canadian engineering firms are looking to the international market for business opportunities (Dickinson & Crofton, 1994); many of the international market opportunities are resource-related and international funding agencies are increasingly requiring attention to environmental and social issues in project design and implementation. Other evidence provided by investigations, however, also suggests optimism should be restrained.

4. There is reason to question the degree to which engineers are able to <u>respond</u> to sustainable development; engineers' ability to translate their understanding of sustainable development into engineering practice may be impeded in a number of ways.

It must be understood that sustainable development has only recently emerged as the goal and means by which various threats to humankind might be addressed; as a substantive idea, its formal acknowledgement and inclusion by the engineering profession is even more recent. As such, engineers' specific roles and activities regarding sustainable development are only beginning to be formulated. Notwithstanding, the studies reported raise questions about engineers' effectiveness in responding to sustainable development. Questions hinge on six issues: (a) the ways in which problems or tasks are defined; (b) adequacy of knowledge/understandings; (c) adequacy of skills; (d) the nature of engineering practice; (e) the kinds of education and training opportunities available; and (f) the kinds of responsibilities engineers may be expected to assume.

a. Problem or task definitions may result in less than optimal solution responses

Logically it is reasonable to expect that problem or task specifications (e.g., concerns to be addressed, priorities, time and space parameters) will influence the focus of a solution or activity. The APEGBC study supports this expectation in two ways. First, analysis of questionnaire responses revealed a relationship between preferred interpretation of sustainable development (problem definition) and preferred strategy (solution response). Second, interview and focus group participants reported that the kinds of solutions they provide are directly related to the problem specifications received from clients or managers/supervisors. Participants reported that, due to the role of their firm or their own individual roles in a project, engineers often have limited (if any) opportunity or authority to influence how problems/tasks are defined. Participants also reported that economic profitability, market conditions, and competition tend to be overriding factors governing problem definitions and choice of solutions. Further, lack of knowledge (e.g., client knowledge, engineers' knowledge of application context and/or potential effects of their work) and the tendency to focus on minimal legal requirements also constrain problem definitions and engineers' ability to provide optimal solutions. A recent study by Mullins and Atman (1994)[2] lends support to the expectation that problem definition and solution are linked; they report that the problem frame impacts on the ways individuals attempt to solve the problems. In sum, the effectiveness and compatibility of engineers' solutions regarding sustainable development depends on how well sustainability concerns are incorporated in problem/task definitions; studies indicate that, at the moment, the concerns are not well incorporated in problems/task definitions.

b. The majority of engineers find their current knowledge limits potential effectiveness of their contributions to sustainable development

Today, new technology, coupled with economic, social and environmental concerns, requires different ways of looking at the work and development of engineers. Tasks are now more interdependent and engineers, in order to optimize their performance, need to better understand how their work affects the efforts and/or lives of the recipients of engineering work. Recipients of engineering work are likely to include other engineers, other professionals (e.g., architects, planners, soil scientists), and the general public. Given the increasing number and complexity of concerns that may need to be addressed and the changing contexts (and recipients) of engineering work, many participants found the process of acquiring and using broader understandings -- of concerns, context, the effects of engineering work – potentially overwhelming.

Although engineers' expressed confidence in their technical knowledge, they also believe that the viability of various techniques and methods and a lot of technical issues are still unknown. APEGBC interview and focus group participants raised concerns about the lack of information, "facts" and practical aspects of sustainable development. They expressed a need for better information about thresholds and limits (e.g., pollution, resource extraction, current inventories), and improved technical knowledge for quantifying and controlling economic, social, and environmental impacts. While calling for more quantitative information and tools, engineers also recognized that (a) different perspectives influence perceptions of thresholds and limits; (b) values preferences are difficult (if not impossible) to quantify; (c) measurements or empirical evidence is at times inadequate or impossible to obtain; and (d) mediating between technical and non-technical requirements requires more than technical expertise.

APEGBC study participants were unanimous in their belief that technical knowledge is not enough. First, technical problems may themselves also be social, political or international problems (noted also in Johnston et al, 1988) and second, not all problems with which engineers are currently involved are merely technical (Jester, 1989; Karbhari, 1989; Tadmor et al, 1987, and others have made similar observations). For these reasons they believe that their ability to effectively respond to sustainable development is dependent on having a broad, multidisciplinary base of knowledge. Without exception, participants called for more courses in social sciences and the humanities; "almost all studies . . . have stressed the need for a stronger background in humanities and social sciences so as to help the engineer better cope with changing social, economic and political conditions" (Karbhari, 1989, p. 243). Almost all participants called for more discussion of sustainable development and for the inclusion of environmental studies in engineering education. Participants believed that multidisciplinary knowledge would help them better understand social, political and environmental issues and the wholes of complex systems, and make sense of the parts and their relationship to each other. That is, they believe that sustainable development requires "systems thinking" and systems thinking requires both a "broad base of knowledge and an ability to integrate piece parts into a meaningful structure" (Lucky, 1990, p. 17). Vanderburg's words succinctly capture views expressed by participants in the APEGBC and CEI studies:

> The effective practice of modern engineering requires not only technical excellence but the ability to incorporate into all professional activities a growing range of . . . socio-technical factors. These factors reflect the way each technology is incorporated into, and depends on, a network of relationships that are part of the larger fabric of society . . . It is clear that as the focus is broadened the methods and values of the applied sciences must increasingly be complemented by those of the social sciences and humanities. (Vanderburg, 1990b, p. 705)

When questioned, participants did admit their own discussions reflected knowledge of areas they suggested were absent from and should be included in preparatory education. Nonetheless, they also believed that their knowledge was both incomplete and dependent on their awareness of "current events" and on particular work experiences. Regarding work experiences, participants reported that work on multidisciplinary teams, work in international settings, involvement in environmentally sensitive projects, and work requiring public consultation or resulting in negative public feedback, were particularly valuable in gaining understanding about sustainable development issues and concerns. (Focus group participants also believed that discussions of the kind engaged in the focus group were valuable and should be ongoing.)

Participants acknowledged that these kinds of experiences could be expected to increase and that work experience is a vehicle to gain knowledge and understandings absent from preparatory education. They emphasized, however, that appropriate experience opportunities are as yet few in number and should not in any case be expected to overcome poor education or training. Further, other factors may limit engineers' ability to gain adequate and appropriate information (e.g., about how the efforts/lives recipients of engineering work are affected and how to alter engineering approaches to increase compatibility between technology and its contexts) from work experiences. For example, some people (APEGBC study participants among them) suggest that engineers' emphasis on objectivity, quantification and practical issues and their desire to "take emotion out of the debate" (Participant 2012) may mean they ignore or discount certain kinds of information. As one interviewee put it, "engineers' narrow frames of reference inhibit their ability to function well in integrated decision-making processes" (Participant 2022). Engineers' communication and group process skills and the ways engineering work tends to be organized are also identified as factors which may undermine the potential of work experiences to provide engineers with broader knowledge and understanding.

c. Engineers' ability to communicate effectively with others is impaired

Studies indicate that engineering work increasingly (a) involves teams of professionals (not all of whom may be engineers); (b) requires user involvement in decision-making; and/or (c) requires consultation with the public. Good communication skills (writing, speaking, listening) and well-developed "people skills" (especially group process skills – negotiation, conflict resolution, collaboration, team-building, etc.) were identified as essential for engaging in this kind of work. APEGBC study participants identified these skills as critical for sustainable development and especially critical for engineers since (a) certain knowledge and understandings are not gained from preparatory education, (b) knowledge about economic, environmental and social impacts of human activities is evolving, (c) perspectives and values change and vary by context, and (d) cooperation is needed in defining problems and finding solutions for sustainable development. Communication and cooperation – across departments and function areas and with experts in various fields, clients, and recipients of engineering work -- is seen to be the means by which knowledge and understanding can be obtained in the absence of other, more traditional knowledge sources.

For engineers to provide adequate impact assessments and solutions, they need to obtain information about the context(s)[3] of the work application and how their work may be applied. Further, to ensure the information is appropriate and adequate, engineers are likely to require information about recipients' current and desired ways of living, and the impact the engineering work is expected to have on their lives. For recipients to provide this information, they need to have sufficient understanding of the possibilities and limitations of the engineering work. Studies indicate, however, that engineers' knowledge and skills in communication and group processes are weak and in need of improvement. Engineers are seen to be "poor people people, . . . convergent rather than divergent thinkers" (APEGBC Participant 2012), short-sighted, more concerned about paying clients than the public, and dismissive of socio-political issues on the grounds that they are "full of opinion and therefore not relevant" (Participant 2027). When speaking with others, "engineers go into technical explanations which go over the head of a layperson" (Participant 2025) and "as soon as discussion goes outside of the technical, engineers start fidgeting" (Participant 2027). These tendencies, along with reported communication skills weaknesses, knowledge limits, and absence from decision-making activities, suggest that engineers are impaired in their ability to both give and receive information that may be relevant to recipients of their work.

d. Hierarchical structures and behavior patterns are problematic

Engineers generally divide work into tightly defined jobs and narrowly organized work units; traditionally, little communication and virtually no joint consultation occurs across these defined jobs/work units. Whether or not a hierarchical structure prevails, the tendency for engineers to compartmentalize work, knowledge and skills into specialized units, can by itself be seen as an obstacle rather than as an aid. While it may facilitate communication within groups, communication between groups is likely to be inhibited (Stoner & Freeman, 1989). Further, specialization and tight boundaries may create barriers (and even resistance) to the development of new interdisciplinary knowledge, skills and attitudes; when communication across specialized units is limited or lacking, the problems of integration are compounded. The occurrence of work on multidisciplinary teams which include individuals without technical backgrounds is still rare and engineers tend to exclude non-engineers from their work activities. For example, the CCPE excludes non-engineers from participation on boards or accreditation teams as a matter of policy.

Whether internal or external to a job/work unit, engineers traditionally accept the basic separation between decision-making (including, at least to some degree, problem definition), problem-solving and other work activities (Price Waterhouse, 1994). These separations are often formalized in vertical (generally top-down) authority and management structures and channels of communication; they determine who will interact with whom. APEGBC participants emphasized that, in their experience, directives (e.g., concerning objectives, procedures, job instructions) are received from "above"; opportunities for upward communication are limited. As many studies (e.g., in group and organizational behavior, social psychology, applied psychology) have shown vertical approaches effect the content and accuracy of information exchange (e.g., information may be filtered, modified, distorted, misinterpreted, lost or halted), and rigorous top-down approaches inhibit free flow of information and idea exchange and can also cause subordinates to become passive and dependent as well as decrease their sense of responsibility and self-control (Holt, 1990; Daft & Fitzgerald, 1992; Stoner & Freeman, 1989).

e. Current education and training programs are inadequate for preparing engineers for sustainable development

The usual minimum requirements to qualify and receive designation as a professional engineer include successful completion of an accredited undergraduate engineering program, a subsequent period as an "engineer-in-training,"[4] and, finally, the successful completion of a professional practice examination.[5] Education is not expected to stop here however. For the professional engineer, "the career-long continuing competence . . . is mandated by codes of ethics" (CCPE-CEQB, 1992, p. 26) and "requires a personal commitment to ongoing professional development and continuing education" (CCPE-CEQB, 1992, p. 23). Studies indicate, however, that current education and training opportunities are not adequate to meet the knowledge and skill requirements of sustainable development. Although participants in various studies are reasonably confident about their technical competencies, they believe their education and training is insufficiently broad (especially in the areas of environmental science, social sciences and the humanities), lacks attention to communication and general people skills, and so focussed on the technical that their ability to apply broader knowledge and non-technical skills to engineering approaches and solutions is impaired.

Scientific and technical knowledge is expanding, adding ever more content to existing engineering disciplines and resulting in the creation of new and more specialized discipline areas; engineers are challenged to keep abreast of developments.

At the same time, concerns about the "environmental, cultural, economic and social impacts of engineering" (CCPE-CEAB, 1992, p. 11) are increasing as are expectations that engineers become more involved with the public (especially through legislative requirements for public consultation or involvement in decision-making). Although such concerns and expectations are resulting in greater stress being placed on the nontechnical aspects of engineering education and training,[6] it appears that pressures to stay abreast of technical developments continues to relegate these concerns and expectations to the background. Continuing education opportunities are either not available, not accessible, or not adequately attentive to engineers' needs. Educational institutions, corporations and professional associations have as yet done very little to ensure that engineers attain knowledge and skills to help them more effectively contribute to sustainable development. It seems that society is simultaneously generating problems that require interdisciplinary team efforts for their solutions and engineers who are less and less able to participate.

f. Conceptual vagueness and practical constraints interfere with engineers' ability to act on responsibilities related to sustainable development

Recall that ideals and requirements established by CCPE guidelines include responsibility to safeguard "life, health, property, economic interests, the public welfare or the environment" (CCPE-CEQB, 1994, p. 8) and to hold "paramount the safety, health and welfare of the public and the protection of the environment . . . or other substantive interests" (CCPE-CEQB, 1994, p. 21). Although APEGBC study participants are in almost unanimous agreement about responsibility regarding the environment (96% of questionnaire respondents agreed they needed to account for environmental effects of their work), they are less certain and in less agreement about what their economic and social responsibilities could or should entail. Further, whether concerning environmental, economic or social responsibilities, confusion and uncertainty arise out of questions about how far their responsibilities could or should extend across time, space and recipients (especially in terms of effects – intended, unintended and unknown); legal questions (e.g., liabilities; conflict in loyalties to public versus client); and questions about what constitutes adequate competence.

Regardless of how responsibilities are defined, participants report that their capacity to account for and/or influence decisions about environmental, economic and social effects is often limited in practice. Limitations include, for example, lack of involvement in decision-making, overriding emphasis on profit, lack of funds or other kinds of resources (e.g., access to experts), lack of regulations, and lack of adequate and reliable information about possible effects. Further, enforcement is problematic. First, there is a lack of specificity regarding broad requirements to safeguard health and to protect public welfare, the environment and "other substantive interests." Second, accountability mechanisms for requirements are limited (if they exist at all) and are usually more concerned with specific technical issues (e.g., will the bridge stay up) than broader issues that are part of sustainable development and may be implied by the requirements.

A third limitation, linked to the first two, is the perception that certain tenets of the Code (regarding, e.g., loyalty and confidentiality) come into conflict when undertaking their "paramount obligations." For example, engineers are to "act as faithful agents of their clients or employers, maintain confidentiality, and avoid conflicts of interest" (CCPE-CEQB, 1994, p. 21). At times however, a client's interests may be at odds with the expressed interests of the public. Since engineers' livelihoods are dependent on serving paying clients, engineers claim it is impractical to attend to broader interests in the absence of other kinds of financial compensation. Another tenet states that fairness and integrity in the workplace is about "more than not misrepresenting, it also implies disclosure of all relevant information and issues" (CCPE-CEQB, 1994, p. 23); this seems to contradict the confidentiality requirement of the previous tenet. For these reasons, study participants report confusion and uncertainty about how to proceed. Finally, both whistle-blowing and peer adjudication are considered problematic since (a) the prior problems exist, (b) questions of loyalty to the profession arise, and (c) professional reputations may be put at risk.

Consequences

If engineers are unfamiliar with reports of sustainable development, if little discussion about sustainable development is occurring among engineers, if engineers lack relevant knowledge or skills, and/or if engineers are unable to translate broad understandings of the issues and requirements of sustainable development into engineering practices and solutions -- and communicate the ways this could or has been done -- then a number of unsatisfactory consequences for both the engineering profession and society in general will be the likely result. The consequences include, for example: engineers may be misunderstood; they may be excluded from decision-making; the public will not have good knowledge to inform decisions about engineering solutions; assessments or solutions may be inadequate; engineers may lose credibility. The consequences, like the problems, are interconnected: like cascading dominoes, one consequence sets off one or more others or amplifies problems. The following discussion illustrates interconnections among problems and some possible consequences (see also Figure 4-1).

There is an implicit expectation that those who are to contribute to sustainable development are at least familiar with primary reports of sustainable development which detail issues, principles and strategies. If engineers lack familiarity with these reports, their credibility is likely to be undermined. The lack of report familiarity may not be critical; however, engineers' credibility is also undermined if, due to a lack of knowledge or inadequate interpersonal or other communication skills, they are unable to demonstrate understanding of the systems or concerns being discussed. In addition, if there is doubt about whose interests engineers are serving, distrust may further damage credibility. In turn, a significant loss of credibility may result in (a) a perception (perhaps even a downgrading) of engineers as mere technicians; (b) less recognition or value being placed on engineers' contributions; (c) the exclusion of engineers from participation in discussions or decision-making about sustainable development.

Some of these latter consequences may also result from engineers' apparent knowledge and/or skill weaknesses in the areas of communication, group process, and interpersonal relations. Further, if engineers' communication and people skills are weak, it is likely that (a) engineers will be ignored or misunderstood; (b) the public and other recipients of engineering work will have less than adequate understanding of the impacts of engineering work; and (c) engineers will be unable to take advantage of information and knowledge from various stakeholders (because engineers have not provided stakeholders with an engineering perspective or because engineers have not received information from stakeholders). As a result, engineers' assessments or solutions

Key to Figure 4-1

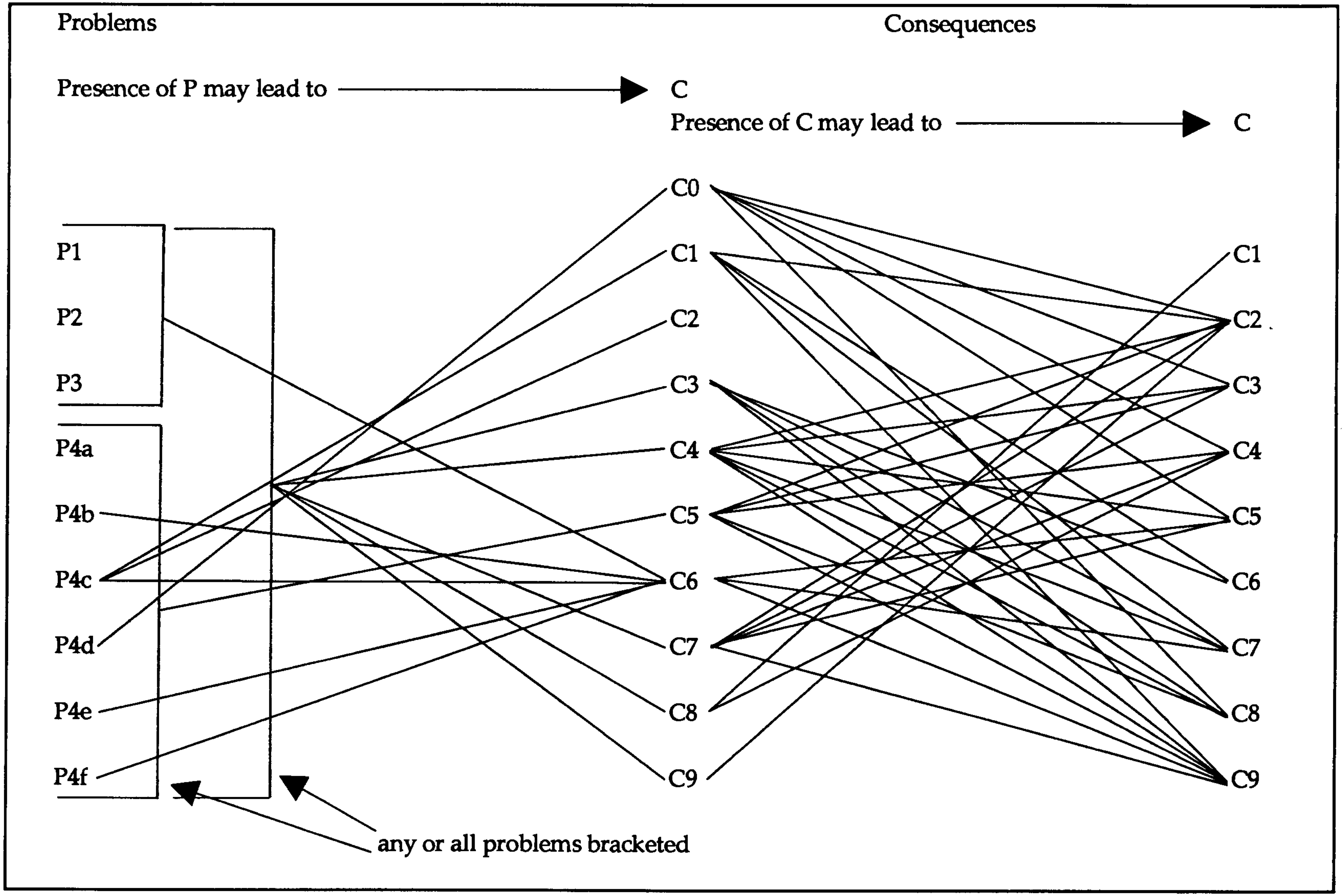
Problems

P1	Lack of familiarity with the term and reports of sustainable development
P2	Reflection and discussion is helpful (but relatively little occurring)
P3	Understanding of sustainable development & willingness to participate (but problems translating into practice)
P4a	Problem or task definitions may result in less than optimal solution responses
P4b	Current knowledge limits potential effectiveness
P4c	Ability to communicate is impaired
P4d	Organizational arrangements and structures are problematic
P4e	Current education and training is inadequate
P4f	Responsibilities unclear; practical problems of action

Possible Consequences

C0	Absent from decision-making
C1	Engineers misunderstood
C2	Public will not have good knowledge, understanding
C3	Inadequate assessments or solutions
C4	Unable to take advantage of knowledge and skills available
C5	Unable to participate
C6	Loss of credibility
C7	Excluded from decision-making
C8	Vulnerable to attacks regarding competence/ poor public image
C9	Downgraded to technician/technical functions only

Figure 4-1: Map of Some Interconnections between Problems and Consequences



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may be inadequate and engineers' once again risk loss of credibility and its attendant consequences. But the consequences of engineers' knowledge/skill weaknesses in these areas are not confined to engineers. If stakeholders (e.g., clients, government, the public) do not have adequate knowledge of engineers' actual or potential contributions (including at least some understanding of the technical aspects of engineering work), (a) stakeholders will be unable to take advantage of engineering knowledge/perspectives that may be important; (b) the effectiveness of stakeholders' contributions may be limited; and (c) their assessments or approaches may be deficient.

Engineers' focus on the technical and its values of efficiency, utility, productivity and cost-effectiveness (as a natural part of engineering work and emphasized in their education and training), and narrow specification of problems or tasks contribute to poor communication and misunderstanding. For example, technical complexity or size of many engineering projects, expanding scientific and technical knowledge (especially as concerns sustainable development), and rapid technological developments, require engineers to devote much of their time to maintaining technical competence, usually in a fairly narrow area. This necessary emphasis tends to relegate non-technical competencies to the background. Further, engineers report that their narrow specializations, narrow problem and task definitions, however necessary, interfere with their ability to access or utilize information required for a better understanding of and response to the whole problem or context to which their work is directed. In fact, engineers are often perceived by non-engineers (including employers), those focussed on other than technical values, and even by engineers themselves, to lack the broad understanding required to effectively address sustainable development.

Engineers also report that problems of acquiring or communicating a broader understanding are exacerbated by task and discipline compartmentalization, vertical organizational approaches, legal requirements, and policy. For example, the Code requires that engineers offer services or advise "only in areas of their competence by virtue of their training and experience" (CCPE-CEQB, 1994, p. 22). Since engineers' competence tends to be narrowly technical, engineers can become confined by their technical expertise and alienated from the broader group of recipients of engineering work (Franklin, 1985; Hyde, 1992a; Vesilind, 1993). In effect, since evidence suggests engineers do have understanding of a broad range of sustainable development issues and concerns, the technical emphasis and precision forms part of a barrier which hides engineers' broader understandings from others, and interferes with engineers' ability to access, contribute to, and/or act on broader understandings which ensure compatibility between technology and society.

Incorporating sustainable development's non-technical concerns into engineering practice is made further problematic by a lack of clarity about engineers' responsibilities and clients. Engineers admit they often push ahead with only a vague notion of how their service will influence or be used by those for whom the service is performed. Engineers are expressing uncertainty and conflict around defining who their 'clients' are and on whose behalf services are being rendered. Since the "essence of professionalism is the delivery of a service in response to a client need" (Schein, 1972, p. 21), it is critical to identify the client. When 'client' is limited to the immediate client, the standards and criteria are relatively clear: "Engineers shall act as faithful agents or trustees of their clients and employers with objectivity, fairness and justice to all parties." (CCPE-CEQB, 1992, p. 22). Recall, however, that the CCPE also states that "the highest obligation of a profession is to society which it serves" and that "this obligation rises above all others when there are conflicting responsibilities" (CCPE-CEQB, 1992, p. 18). This obligation, coupled with sustainable development's call for greater consideration of the ultimate client, makes engineers' 'clients' more than a little ambiguous.

If engineers are to "act as faithful agents" with "fairness and justice to all parties," the profession must define its role and responsibilities to the various clients; discriminate among client needs; resolve conflicts between clients; and reconcile or integrate the needs of the immediate client with those of other 'clients' or society as a whole. Failure to do so will likely have three consequences: (a) engineers will continue to be uncertain and in conflict about how standards and codes are to govern client relationships; (b) engineers will be more vulnerable to attacks and pressures from employers, clients, and the general public; and (c) engineers will be less effective in fulfilling their professional responsibilities.

In sum, the situation is as follows. Technical issues are the primary focus of engineering work, education and training. Engineers' professional obligations,[7] however, require attention to issues (e.g., environmental, social, economic) that are not entirely or strictly technical ones; their paramount obligation is to safeguard health, public welfare and the environment. Clearly, engineers are not expected to be medical, economic, social or environmental "experts"; nonetheless, they are expected to find ways to discharge their obligations. There are a number of ways that engineers can do this. For example, they discharge their obligations when they (a) "present clearly to employers and clients the possible consequences if engineering decisions or judgements are overruled or disregarded"; (b) "ensure that clients and employers are made aware of societal and environmental consequences of actions of projects" (CCPE-CEQB, 1994, p. 21); (c) "obtain the services of a specialist or expert if required or, if the knowledge is unknown, to proceed only with full disclosure of the experimental nature of the activity to all parties involved" (CCPE-CEQB, 1994, p. 22); and (d) "include all relevant and pertinent information in professional reports, statements and testimony" (CCPE-CEQB, 1994, p. 23).

It seems from this that engineers can discharge their obligations, without taking direct responsibility for the effects of their work, by shifting at least some responsibility onto others. But evidence suggests that the options (as above) are problematic and may not be sufficient to ensure health, public welfare and the environment are protected. First, parameters are unclear. For example, what kinds of consequences, for whom or what, and how large a range of possible impact is to be included for consideration? Second, knowledge about consequences, contexts, and even sources of appropriate expertise, may be inadequate. Further, engineers may be unaware, inattentive, or insensitive to issues for which they appear to be responsible, or to issues of concern to recipients of engineering work. Third, weaknesses in communication skills and the nature of work arrangements may mean that engineers are unable to (a) adequately communicate their understandings, or (b) receive relevant information from others. The situation is exacerbated if an engineer's audience is primarily focussed on non-technical concerns or lacks understanding of technical issues and constraints.

Summary

This chapter included a number of conclusions drawn from findings of studies reported in Chapter 3. The conclusions reveal a number of problems that need to be overcome if engineers are to more adequately meet the parallel ideals of engineering and sustainable development. Recall from Chapter 3 that achievement of the parallel ideals presupposes the existence of four underlying requirements. Briefly, these requirements include: (a) understanding of sustainable development; (b) effective participation and cooperation; (c) organizational supports; and (d) ability to take responsibility. The problems identified suggest a number of gaps in meeting these requirements. First, B.C. engineers do appear to have an understanding of the systemic nature of the world and the interconnectedness of environmental, economic and social concerns; they also recognize that many activities have effects across time and space, that global and local issues are interconnected, that values and beliefs are not always universally shared and that appropriate technology is needed. Nonetheless, engineers report gaps in their knowledge about environmental and social science; further, knowledge of application contexts, or the actual or potential impacts of engineering work is often less than adequate.

Second, according to APEGBC participants and findings of other studies, gaps between the real and the ideal are particularly evident in the area of participation and cooperation. Reports suggest that engineers' interpersonal, general communication and group process skills are weak. Further, and to the third point, work arrangements and organizational structures often interfere with engineers' ability to effectively participate in problem-solving and decision-making. For example, problem definitions are insufficiently attentive to sustainable development, engineers are often excluded from participation in various problem-solving and decision-making activities, and little communication or cooperation occurs across work teams. Organizational supports in the form of education and training are also insufficient to the task of preparing engineers to address the broader concerns of sustainable development. Finally, engineers ability to take responsibility is impeded by all of the above and by uncertainty about the nature and and degree of responsibility engineers should assume for their engineering work.

The problems identified are interconnected, each in some way contributing to another; together they interfere with engineers' ability to fulfill the ideals of engineering and sustainable development. The chapter described a number of possible consequences if the problems persist: engineers may be excluded from important problem-solving and decision-making activities; professional judgement may be undermined with the possible down-grading of engineers to technicians; the public will have less than adequate information to inform contributions to sustainable development; engineers assessments and solutions may be less than adequate. The following chapter suggests three general avenues of approach for dealing with the problems and offers specific recommendations in line with these general approaches.

Endnotes

1. GLOBE 90 was a conference held in Vancouver, B.C. in March 1990; over 3000 delegates from over 70 countries attended. GLOBE 90 focussed on "practical solutions and approaches to sustainable development, the business responsibilities and opportunities that flow from them, and the policies and institutions that are necessary to capitalize on these at both national and international levels" (Sadler & Hull, 1990, p. vi). GLOBE 90 also included a trade fair where the latest products, services and technologies available for the transition to sustainable development were presented.

2. Mullins and Atman's (1994) study involved sixteen engineering students. The students were asked to solve two different types of open-ended problems and to think aloud while they solved the problems. Verbal protocols were analyzed to identify the students' problem-solving strategies.

3. Contexts may include, for example, economic context, environmental context and social context. Questions to be answered include, for example: What are the economic constraints? How will these impact on design, choice of materials, etc.? What are the environmental constraints? Are materials available on site? How will the product/process impact on the environment? What are the social constraints? Are there qualified personnel available to operate/maintain/use the engineering work?

4. In B.C., the minimum required experience after receiving a bachelors degree is four years. This reflects a recent change (APEGBC, 1993) in requirements from the previous two year requirement. B.C. is the first engineering association in Canada to move from a two year to a four year requirement; however, this move to a four year EIT requirement has been endorsed by the national council and by other provincial associations. Over the next two to four years, other provincial associations will be increasing the EIT requirement period. The aim of the EIT program "is to ensure that candidates for membership are sufficiently exposed to the various experience elements to progress to the level of maturity required to make reliable professional judgements" (APEGBC, 1993, p. 6).

5. In B.C. and most other provinces, the exam is a three hour exam which can be taken as many times as is required to pass. The APEGBC Director of Registration states that the exam is "not intended as a screening device" but is intended to expose students to certain information (the Engineering Act, Bylaws, Code of Ethics, Contract Law and Liability, Negligence, Intellectual Property, Business Associations, and Builders' Liens); the Director states that there is a low failure rate on this exam (Wiseen, personal communication, June 1, 1993).

6. In fact, to become accredited, engineering programs must include nontechnical bodies of knowledge among their requirements. Non-technical requirements are labelled as "complementary studies"; prior to 1984 this component was called "Humanities, Social Sciences and Administrative Studies." The CCPE Assistant Director, Accreditation and Qualifications indicates that in recent years the CCPE Canadian Engineering Accreditation Board (CEAB) has been placing more emphasis on "central issues, methodologies and thought processes of humanities and social sciences" (personal correspondence, March 18, 1993). In 1994, the purpose and criteria for accreditation was modified to include the concept of sustainable development (CCPE-CEAB, 1994, p. 13).

7. An engineer can only dissociate his/herself from obligations if a more qualified engineer formally assumes responsibility for the work (CCPE-CEQB, 1994).

CHAPTER 5

ENGINEERING AS IF SUSTAINABLE DEVELOPMENT MATTERED

> Today, the greatest opportunities and challenges for the engineering profession are in the support of development that is economically and environmentally sustainable. . . . Sustainable development will be the dominant economic, environmental, political and social issue of the 21st century. (Hatch, 1993, p. 216)

The previous chapter identified a number of factors interfering with engineers' ability to fulfil the parallel ideals of engineering and sustainable development. The limiting factors include lack of familiarity with reports of sustainable development; narrow problem definitions; organizational structures and work arrangements which inhibit free exchange of information and ideas; deficiencies in knowledge (e.g., knowledge of actual limits, ecosystems, management) and skills (e.g., group process, mediation, conflict resolution); doubt and conflict about engineers' responsibilities; weaknesses in education and training. Chapter 4 also described some of the negative consequences of these limiting factors.

There are essentially three general approaches for reducing the gaps between the real and the ideal. One approach is to redefine the ideals of the profession and the obligations of engineers such that there is a greater possibility of success. Since engineers are designated as "professionals," this does not mean that obligations can be so restricted that discretionary judgement is eliminated or that engineers become little more than technicians bound by legislation. Rather, what may be needed is increased clarity about the kinds of responsibilities to be assumed in what contexts, for whom, and over what range of potential impact. A second approach is to increase engineers' knowledge and skills so that they can more adequately fulfil responsibilities consistent with ideals. That is, to bring available knowledge and skills more in line with those that are ideally required. A third approach is to increase dialogue and sharing of responsibility among various participants and stakeholders in sustainable development. To increase the effectiveness and benefits of engineers' contributions to sustainable development and society, it is recommended that all three avenues of approach be pursued.

Consistent with these general approaches, this chapter offers more specific recommendations and suggestions for addressing the problems and better preparing engineers to address sustainable development. Some of the recommendations are such that they have the potential to assist in ameliorating several problems at once; others attend more specifically to one problem. The first six recommendations call for changes which have implications for all those involved in engineering (engineering governing bodies, employers, practitioners, education faculty and students); those that have primary responsibility for each of the recommendations are identified. The remaining recommendations focus more specifically on engineering education; responsibility for these recommendations rests primarily, but not exclusively, with those directly involved in engineering education (particularly course instructors, curriculum designers and program directors). Evidence in support of recommendations is offered where available. For some recommendations, however, further study is needed to demonstrate the effectiveness of suggested changes. The second section of Chapter 5 offers suggestions for further study.

Recommendations

1. Increase discussion of the concept and ideas of sustainable development

> Sustainable development is a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations. (WCED, 1987, p. 46)

Although there are some indications that engineers' awareness of sustainable development is increasing, evidence suggests that (a) engineers' are relatively unfamiliar with reports of sustainable development; (b) few engineers are involved in discussions of sustainable development; (c) practitioners are confused about their roles and responsibilities regarding sustainable development; and (d) there are a number of problems translating sustainable development into engineering practice. The 1994 change in the CCPE's accreditation criteria, requiring engineering programs to address the concept of sustainable development, holds a promise of increases in future engineers' understanding of sustainable development. This is a good beginning but, especially since sustainable development is "not a fixed state" (WCED, 1987, p. 9), discussions must extend into the community of practitioners; if APEGBC study participants are any indication, such discussion is both valuable and welcomed.

The APEGBC study demonstrated that discussions of sustainable development have a number of benefits. For example, discussions provide opportunities to (a) increase engineers' awareness and understanding of sustainable development; (b) help engineers reflect on their potential roles and responsibilities as professionals; (c) identify new needs to be met within the context of engineering practice; and (d) identify and develop interdisciplinary knowledge needed to effectively contribute to sustainable development. As demonstrated by some APEGBC study participants, involvement in discussions may also result in engineers' becoming more interested in and familiar with reports and accounts of sustainable development. The benefits may be even greater if discussions involve engineers and non-engineers from various backgrounds and perspectives.

Responsibility for this recommendation should be extended to engineering educators, professional associations, corporations and individual engineers. Discussions of sustainable development can be engaged in the context of other recommendations (e.g., Recommendation 3 regarding role clarification) and/or be a vehicle to further other recommendations (e.g., Recommendation 2 regarding developing linkages with stakeholders; Recommendation 6 regarding communication skills). Other ways to facilitate and increase discussion of sustainable development include, for example:

- Sponsor lectures, seminars or workshops on sustainable development which focus on the six sustainable development principles;

* Initiate one or more discussion groups which meet monthly to explore various pre-determined topics and which report back to the professional community through Association journals;

* Establish a discussion group/message board on Internet;

* Publicize events and vehicles which further discussion of sustainable development (e.g., lectures, seminars, conferences, publications).

2. Forge linkages and develop dialogues within the stakeholder/client system

> The process of change requires the expertise and responsibility of all disciplines in cooperation at all levels . . . The engineering profession must play a major role in seeing that change is implemented. . . . [Engineers] must actively engage with all disciplines and the public to start the process of change for a more secure, stable and sustainable world. (Hatch, 1993, p. 218)

The stakeholder/client system includes engineers of various disciplines, other professionals, members of government and non-governmental organizations, policy and decision makers in the public and private sectors, immediate clients, potential clients, unions, educators, and the public in general. By forming linkages and dialogues within the stakeholder/client system, it is likely that engineers will (a) gain a better understanding of the needs and expectations of the recipients of their work; (b) become better informed about the skills and knowledge they may need to increase their value to clients and society as a whole; (c) be seen as concerned and interested parties in the social enterprise; (d) have opportunities to expose others to an engineering perspective on complex problems; and (e) have greater opportunity to participate in and influence decision-making and problem-solving. Further, the interaction of concepts and ideas among those with a variety of active service and context experiences is likely to expand the possibilities available for successful problem-solving. In sum, as a result of decreased barriers between stakeholders, increased understanding of interdisciplinary issues and multiple stakeholder interests, and increased access to systems of influence, engineers have the potential to provide more optimal solutions to various problems. Responsibility for this recommendation should rest primarily with professional associations (e.g., by establishing interdisplinary task forces and committees), and with senior engineers.

The trend in engineering toward multi-disciplinary team approaches, especially in international work (e.g., Dickinson & Crofton, 1994; Price Waterhouse, 1994), and reports of the success of team approaches, provides some evidence of the benefits of forging linkages and relationships. Evidence of benefits is also provided by, for example, the success of cooperative education programs and approaches (e.g., Barchilon & Kelley, 1994; Esdale & Ens, 1994; Porteous & Swanson, 1994; Van Gyn, 1994); outcomes of various cross-disciplinary or multi-stakeholder approaches (e.g., BCRTEE, 1992; Crofton, 1992b; WEPSD, 1992); and improvements to engineering solutions (e.g., Akrich, 1993).

These examples also illustrate ways linkages can be created: industry-education linkages can be formed through cooperative programs and internships; cross-disciplinary linkages can be formed through team approaches (e.g., team teaching; multi-disciplinary project teams); linkages and dialogue among diverse stakeholders can be created through discussion of particular issues or problems. In additions to suggestions offered under Recommendation 1, other suggestions to facilitate the development of linkages and relationships include:

* Identify (a) individuals and organizations working on cross-cutting issues of common interest; (b) key contact people within government and various stakeholder groups; (c) engineers who will initiate and maintain contacts with people/organizations identified;

* Initiate and maintain contact with clients, representatives from various interest groups, legislators and regulators, etc. to whom position statements, technical data or offers of assistance can be provided;

* Attend conferences, seminars, and other kinds of meetings which provide opportunities for increased range of personal contacts;

* Volunteer to serve on local, regional or national task forces or advisory committees.

3. Clarify the roles and responsibilities of professional engineers

> In the age of continuous innovation, specialization and the explosion of knowledge, the demand for clearly identified responsibilities is rapidly increasing. . . . The engineering profession must take charge of itself and direct this effort or we must settle for the regulations developed by others. . . . If our work is defined, controlled and regulated by others, then clearly engineering is not a profession. (Pennoni, 1993, p. 344)

To guide engineering practice, the CCPE has provided "sets of underlying principles as codes of professional ethics which form the basis and framework for responsible professional practice"; engineers are to "interpret the essence of the underlying principles within their daily decision-making situations" (CCPE-CEQB, 1994, p. 20). The guidelines are responsive to changes in technology and societal interests. For example, the guidelines include discussion of the ways computer technology may or may not be considered part of professional engineering (CCPE-CEQB, 1994, p. 19); protection of the environment was added to engineers' responsibilities in recent years; in 1994, the engineer's role in the environment was more clearly articulated. Evidence from the APEGBC study suggests that sustainable development requires further clarification of a number of elements of the engineers' Code. For example, what is the nature of engineers' responsibility to safeguard economic, societal interests or other substantive public interests? How far does the responsibility extend? What role is an engineer to assume in serving multiple clients or "publics" effected by engineering work especially if conflicts exist within the client system?

The CCPE states that the guidelines are not intended to be "a detailed and specific set of rules couched in legalistic or imperative terms to make them more enforceable" (CCPE-CEQB, 1994, p. 20). Some engineers in the APEGBC study expressed desire for rules of this kind; others expressed concern about the effect such rules would have on the application of discretionary judgement and, given the variety of contexts within which engineers operate, about the practicality of implementation. Nonetheless, whether in the form of strict rules or other forms of guidance, evidence suggests that most engineers have a desire for clearer direction regarding their various roles and responsibilities. Responsibility for clarifying engineers' roles and responsibilities should rest primarily with professional engineering associations and, most particularly, with the CCPE.[1] Specific suggestions to further the process include:

- Involve various stakeholders in discussions of engineers' roles and responsibilities for sustainable development to explore expectations and to determine in what ways engineers can reasonably fulfill those expectations. For example, what knowledge and skills are required to fulfill various expectations? To what degree do these exist among engineers?

- Clarify the meaning of "societal interests," "other substantive public interests," "economic interests";

* Clarify engineers' role in assessing client/public needs and determining priorities among them;

• Build an illustrative case file to show the ways engineers' environmental, economic and social responsibilities are or could be fulfilled;

• Develop additional "interpretive articles which . . . discuss some of the more difficult and interrelated components of the Code" (CCPE-CEQB, 1994, p. 21);

* Build on Recommendation 2 and become actively involved in shaping policy and legislation which have implications for engineering and sustainable development.

4. Refine support and accountability systems for the enactment of engineers' roles and responsibilities

> Engineers have a duty to speak up and to add their knowledge to the debate. (Coates, 1993, p. 228)
>
> We are playing catch up. We are about 20 years late in seizing the initiative. We have followed, not led. . . . Engineers [must] work to create an environmentally enlightened image among their publics that reflects an honest determination to support sustainable development. (Hatch, 1993, p. 219)

The roles and responsibilities engineers are expected to assume include protection of the public and the environment, being a faithful agent of clients, maintaining competence and knowledge, and providing opportunities to further the professional development of engineers-in-training, subordinates and colleagues (CCPE-CEQB, 1994). Evidence suggests there are a number of problems regarding competence and professional development; recommendations specific to these problems will be the focus of other recommendations (particularly recommendations 6-13) which follow. This recommendation is focussed on responsibilities to the 'client,' that is, responsibilities which may extend beyond the immediate client and which are concerned with the protection of the public and the environment.

As professionals, engineers are commited to serve and protect the public in all engineering endeavors, that is, "where engineering principles are involved, and where there are any effects on any 'public' or on society in general" (CCPE-CEQB, 1994, p. 19). They are obliged to practice engineering "with concern for societal and environmental needs, while maintaining responsibility to clients, employers, colleagues, subordinates, themselves, and the profession at large" (CCPE-CEQB, 1994, p. 18). The previous recommendation calling for clarification of engineers' roles and responsibilities will likely provide some guidance in determining for whom, how far, and to what effect engineers are expected to respond to their various responsibilities. Nonetheless, the study indicates that engineers remain concerned about the implications of offering advice or criticisms in the name of "safeguarding societal interests." Several claim that without legislation and regulations, they "don't have a leg to stand on"; they are concerned that they will lose their jobs or their clients "to the guy down the street." Some are also concerned that, by speaking out, they may violate some other tenets of the code and suffer censure from the profession or even lose their license to practise. Cohen and Grace (1994) provide evidence that their concerns are not unwarranted. In two instances cited, engineers spoke out in the public interest and in so doing criticized the work of other engineers; both engineers were censured (for criticizing other engineers) and in one case, professional membership renewal was refused; in neither case was the substance of the criticisms investigated.

Primary responsibility for refining support and accountability systems should rest with professional associations. If engineers are to safeguard societal interests, they will need to have support for speaking out in the public interest (Coates, 1993). The profession can provide support by, for example, taking a public stand on controversial issues; finding ways to interpret the Code so that individual engineers who seek to behave ethically are not censured (e.g., by ensuring that the proprieties of professional etiquette do not preempt or soften the obligation of engineers' to protect the public or the environment); ensuring that the parallel standards of sustainable development and engineering are reflected in the Acts of provincial and territorial engineering associations; encouraging professionalism in all its aspects not only those specifically related to the technical aspects of engineering; and providing resources (e.g., financial, legal) in defense of "whistle-blowers."

The profession might also consider introducing additional accountability mechanisms (see also Recommendation 13) to ensure that engineers are providing sufficient and appropriate information to 'clients' regarding potential societal and environmental consequences of engineering work. For example, Coates (1993) suggests that when reporting to clients

> it must become normal for engineers to put before the client the best option for sustainable development within the terms of reference. If an even better environmental solution is available outside the terms of reference, then the report must bring this to the attention of the client, with cost implications and all other factors so that a rounded and fully informed decision can be taken before going ahead. (p. 226)

If attention to sustainable development was a required element of every solution response, whether or not it is explicitly stated within problem or task solutions, engineers would (a) need to become more aware of the implications their solutions have for sustainable development and (b) be freer to speak out in the public interest. In effect, limitations of narrow problem definitions and concern about speaking out could be ameliorated simultaneously.

5. Examine organizational structures and work arrangements and improve their effectiveness

> [An] organization's officers and bureaucratic structure have the potential to implement acceptable suggestions. . . . they often do not. Good ideas fall through the cracks, the cracks widen, and frustration and apathy follow. (Pletta, 1988, p. 168)

Organizational structures and working relationships in engineering are in the process of change and such things as Total Quality Management (TQM) and ISO-9000 programs[2] are altering organizational and social systems within organizations (Bellamy et al, 1994; Dickinson & Crofton, 1994). Nonetheless, although there is an increasing demand for holistic approaches to problem-solving and collaborative, team-based approaches, it appears that work continues to be fragmented and that traditional hierarchical structures and behavior patterns continue to prevail among engineers (Dickinson & Crofton, 1994). For example, APEGBC study participants report that their work is usually very narrowly defined (with little latitude for applying discretionary judgement or extending terms of reference), that they are often distant from or left out of decision-making pertaining to the larger project to which their activities contribute, and that little communication occurs across various groups working on a project. As a consequence, information or ideas which may improve engineering activities may be lost or distorted and engineers' ability to fulfil broader professional responsibilities can be undermined.

It is therefore recommended that engineers critically examine current organizational structures and work arrangements to determine the ways in which these may negatively impact on communication, problem-solving, learning, the taking of responsibility and the overall ability of the organization to provide effective solutions for sustainable development. Organizational leaders (e.g., CEOs, managers) should have primary responsibility for initiating this activity. Detailed descriptions of programs or systematic methods to undertake organizational analysis[3] is beyond the scope of this paper but some basic building blocks can be suggested:

- Gather information about organizational assessment and improvement approaches;

- Establish clear organizational goals and objectives;

- Involve all organizational members in identifying the ways the organization supports or impedes communication, problem-solving, learning, individual ability to take responsibility, contributions to sustainable development, and the meeting of overall organizational goals and objectives;

- Brainstorm improvement initiatives and select and implement those most appropriate to the organization;

- Develop a system for ongoing effectiveness assessment and maintenance to ensure activities and outcomes are consistent with goals and the changing demands and contexts of the organization's work.

6. Increase emphasis on interpersonal and group process knowledge/skills

> The engineers of the world must engage more actively in the political, economic, technical, and social discussion and decision processes. They must help set the new direction, not just follow. (Hatch, 1993, p. 218)

Strong interpersonal and group process knowledge/skills (e.g., communication, team-building, negotiation, conflict resolution) may well be considered the currency needed for change; they are essential for building effective working relationships within an organization, for developing and maintaining appropriate relations with immediate clients and various other stakeholders, and for participating effectively and with confidence in discussion and decision-making regarding sustainable development. Evidence from the APEGBC and CEI studies suggest that engineers believe such knowledge/skills are critical and likely to be even more important in the future; evidence also suggests, however, that engineers are weak in these areas and that opportunities to overcome these weaknesses are limited. At present it appears that technical knowledge/skills are easier to demand and obtain than "softer" knowledge/skills.

In order to build more effective working relationships, efforts are needed at several levels – the individual, the work group, the organization and the profession as a whole. Individuals need to develop foundational skills (e.g., interpersonal skills, group process skills, conflict management); work groups need to understand and have skills in team development, team building and team effectiveness; organizations and/or the profession as a whole need to provide leadership by emphasizing the importance of these efforts through policy and allocation of resources. It is recommended that a stronger commitment be made to the development of "softer" knowledge/skills and that a variety of workshop, seminar, conference and other such programs be developed and delivered to address these needs. The effectiveness of these approaches is demonstrated in various reports (e.g., Dickinson & Crofton, 1994; Price Waterhouse, 1994) and in organizational and human resource management literature (e.g., Covey, 1989; Ketchum & Trist, 1992; Weisbord, 1987, 1992).

It is suggested that programs focus on conditions for interpersonal and group effectiveness and such skills as reflective listening, values clarifying, and promoting thinking (see, for example, Gazda et al, 1977; Johnson & Johnson, 1982; Raths et al, 1967). Programs may be developed by engineering educators (e.g., special certificate programs, part of undergraduate education programs), by employers, by professional associations or by independent service providers. Programs will be most effective if (a) they are designed to specifically address the kind and range of interactions engineers encounter with engineers, other professionals, clients, and various stakeholders; (b) employers, employees and educators are involved in the design process; (c) they are not confined to technical issues alone (e.g., technical presentations and technical report writing that tend to be one-way communications); and (d) learners are actively involved in practicing the skills. Employers and the profession itself must communicate the importance of increased interpersonal competence to career progression and involvement in a broader range of activities. Some specific suggestions include:

* Develop a foundations course for undergraduate programs which focusses on reflective listening skills. This course could either stand alone or incorporate contents of existing writing and oral presentation skills courses;

* Develop a series of courses (short courses, distance education courses, self-study or ongoing certificate programs) that are accessible to individuals or organizations (see Recommendation 12) and focus on various interpersonal, team, and public participation skills and processes;[4]

* Encourage participants in meetings and project teams to evaluate interpersonal and group effectiveness;

* Increase involvement with various stakeholders (refer to Recommendation 2) where engineers may be exposed to diverse ways of interacting and working with others;

* Provide support mechanisms (refer to Recommendations 4 and 13) to encourage engineers to further develop interpersonal and group process knowledge and skills.

Reshape engineering education to serve society as well as the engineering community and its immediate clients

The sustainable development principles described in Chapter 2 provide some guidelines and strategies for moving toward the goal of human health and well-being. Achievement of this goal will rely heavily on peoples' attitudes, perceptions and knowledge of what is prudent and in our collective best interest and on peoples' ability to contribute to sustainable development. Discussions in Chapters 3 and 4 indicate that a number of problems exist which interfere with the effectiveness of engineers' contributions to sustainable development. Since education is consistently identified as one of the key strategies for facilitating sustainable development,[5] it is reasonable to look to engineers' education for ways to ameliorate problems and increase the effectiveness of engineers' contributions to sustainable development.

In many ways the effectiveness of engineering education is beyond dispute. Engineers have responded to societal needs for transportation, sanitation, health care, communication, energy production, waste management, and pollution control systems. Today, however, the problems to be addressed are more complex, clients are more differentiated and extend beyond the immediate user/client of engineering services, and there is an increasing demand for engineering solutions which respond to a variety of challenges (APEGBC, 1992; Bugliarello, 1991; Coates, 1993; Cutliffe et al, 1992; Hatch, 1993; Whitman, 1991). Given the demand for different kinds of knowledge and skills and dissatisfaction with current undergraduate and continuing engineering education programs, recommendations cannot be complete without attention to the need for reform in engineering education. Although the prior recommendations are among those that may improve engineers' ability to respond to sustainable development and can be useful in guiding educational reforms, the following recommendations are more specifically attentive to the engineering education context.

7. Reassess and clarify the goals of each phase of engineering education

> If only we knew what we were about, perhaps we could get about it better. (Abraham Lincoln quoted in Pratt, 1980, p. 145)

When I began to review documents and articles concerned with engineering education, specifically undergraduate education, I expected to get a clear and consistent picture of the purpose of engineering education (beyond fulfilling a licensing requirement) and the kinds of competencies expected of graduates. Instead I found 'goals' variously attentive to skills, knowledge, expansion of laboratories and research facilities, improvement of pre-entry programs, faculty training and such; 'goals' that were the equivalent of long lists of multiple and various intended competencies;[6] goals that were so vague as to provide little information as to their substance;[7] and different perspectives of the importance of various educational objectives.[8]

Some of the information gained was helpful. For example, there is general agreement that undergraduate engineering education must provide both specialized and general knowledge and skills; that knowledge/content areas should include mathematics, natural and physical sciences, engineering sciences and design, management, economics, communication and ethics; and that technical, organizational, managerial, interpersonal, problem-solving and planning skills should be included. Further, it appears that undergraduate engineering education is to fulfill three somewhat different functions: (a) provide a general, basic education for the professional engineer (CCPE requirement); (b) prepare graduates for immediate productivity (industry requirement);[9] and (c) prepare graduates for advanced study (academic requirement). It is less clear, however, what emphasis should be given to each knowledge, skill or function area, what kinds or degrees of competency are expected (and how they are related to the various functions), how the knowledge and skill areas are to be integrated, or how they serve to prepare engineers to fulfil professional obligations defined by basic tenets of the CCPE Code of Ethics.

Answers to these questions might be gleaned from a more detailed examination of a diversity of engineering programs each influenced by such things as local needs, institutional constraints (e.g., funding, facilities, human resources), and faculty member interests and values; Vanderburg's (1992) study of the University of Toronto program provides one example. Engineering educators, however, are continually challenged by (a) new advances in science, technology and engineering; (b) shifting societal demands; (c) different and changing expectations and priorities for engineering education revealed by industry, practicing engineers, colleagues, and students (Betts et al, 1993; Dickinson & Crofton, 1994; Smith et al, 1981); and (d) reports that today the "half-life" of engineers' body of knowledge is about five years and shrinking (Pennoni, 1993; Poirot, 1993). It is clear that lifelong learning is required to keep pace with changes, but what should be learned, when and for what ultimate end? What should the overall structure and composition of curriculum look like?

Without a long-term vision of the professional engineer, it is difficult to enter into discussion of where engineering education should go from here (Coates, 1993). Evidence that engineers lack certain knowledge and skills they believe are necessary to effectively respond to sustainable development suggests changes are required. It is not reasonable, however, to expect that all knowledge and skills required can be obtained through conventional education -- and certainly not through undergraduate engineering programs alone -- or to expect engineering faculty to resolve various problems without assistance from others. As a starting point, therefore, it is recommended (a) that a long-term vision of the professional engineer be established to guide all phases and stages of engineering education; (b) that current goals and contents of each phase of engineering education (e.g., undergraduate, EIT, continuing education) be re-examined and aligned with the vision; and (c) that involvement in establishing goals and determining relevant content and the means by which engineering education can be furthered, extend beyond members of the engineering profession.

a. *Vision.* Given the parallel ideals/requirements of sustainable development and professional engineering practice, the paramount obligations of professional engineers, and studies which reveal current deficiencies in engineers' ability to effectively undertake their professional responsibilities, I propose that the profession adopt a vision of the professional engineer as one where consideration of sustainable development is an integral part of an engineer's training and, subsequently, an integral part of every engineer's general practice. What is needed are goals that can (a) guide the curriculum designer in developing an effective curriculum; (b) guide the teacher in choosing or creating appropriate learning experiences; (c) inform the student about what they are expected to learn; and (d) provide a basis for evaluating the success of a program. Thus, adapting the BCRTEE (1993) goals of education for sustainability to engineers, it is proposed that the goals of engineering education should be to ensure that engineers:

understand the systemic nature of the world and the interconnectedness of natural and human systems;

understand the global nature of the world and how local and regional issues are part of the whole;

understand a variety of perspectives and recognize that perspectives and worldviews reflect values and beliefs that may not be universally shared;

have the skills necessary for constructive participation in local, national and global communities;

be prepared to take responsibility as contributing professionals and global citizens;

have knowledge and skills to apply engineering knowledge in ways which fulfil their professional responsibilities and are consistent with their broader understandings (as above);

have specialized expertise in a particular engineering discipline area.

b. *Reassessment.* It is recommended that goals of engineering education be assessed and clarified for each phase of engineering education -- undergraduate, EIT programs, and continuing education -- consistent with the prior vision. Further, the goals need to be tied to the roles and responsibilities engineers can be expected to assume at each stage of their career, and then translated into programs for action. In the process, a number of questions will need to be considered. For example: How will sustainable development principles be incorporated at each phase of education? What primary needs are to be addressed in an undergraduate program? What kinds of specific knowledge from various bodies of knowledge is important for students to learn? What specific skill areas should be included and what degree of emphasis should be given to various areas and/or goals? What kinds of competencies are to be expected, and what level of competency should be achieved? What remains to be achieved and should be a focus in the experiential, engineers-in-training phase of preparatory education? What goals are to be met in the continuing education of professional engineers at each stage of their career development? Questions about effective approaches for increasing engineers' understandings and skills will also require attention as these may have bearing on how much can be achieved within a particular program or time frame. With regard to undergraduate programs, it is further recommended that the CEAB, in future, ongoing reviews of its' accreditation criteria and approach, give consideration to the vision, suggestions and questions contained in this recommendation and make appropriate modifications to accreditation criteria and approach.

c. *Involvement*. It is also recommended that, in the process of goals formulation (and the evaluation of current programs and educational approaches that may be required), engineering educators work collaboratively with industry employers, EIT supervisors, and non-engineers. Employers and those supervising EITs will likely have insights about specific knowledge/skills needs that are not easily available to academics more focussed on teaching and research. Non-engineers should include education professionals (those with special competencies in teaching, learner development and curriculum design), and individuals with knowledge/skills specific to the "complementary studies" component of engineering education. Ideally, these individuals will also have understanding of engineering education and practice. In collaboration, the non-engineers will be able to assist engineering educators to define the specific areas of knowledge/skills within the humanities and social sciences that would most benefit engineers, the competencies that could be expected, and the ways knowledge/skills might be incorporated into engineering education. Collaborations of this kind are likely to have such additional benefits as reinforcing the importance of working and learning from each other, increasing the potential for future collaborations (e.g., team teaching), and providing instructors with new and innovative ways to improve pedagogical approaches (Barchilon & Kelley, 1994; Bellamy et al, 1994; Hutzler & Baillod, 1994).

8. Expand, diversify and collaborate in providing practical experiences[10]

Students in the CEI study complained about the lack of course connection to the real world and APEGBC participants expressed difficulty translating sustainable development into practice. APEGBC and CEI study participants reported that theories are often not easily understood or not seen to be relevant unless they were applied in a real situation; they also often spoke the old adage about experience being the best teacher. In spite of the recognized importance and benefits of practical knowledge and experience,[11] participants suggest that instructors often lacked practical experience (or at least did not share it) and that access to co-op programs was limited; alternative means of obtaining practical experiences are limited and are rarely credited toward completion of an undergraduate program. For these reasons it is recommended that educators:

* Expand work experience programs through collaborations with industry, users of engineering works, technology suppliers, and professional associations (collaborations might be built out of Recommendation 2);[12]

* Explore non-traditional, engineering-related experience placements, such as participating in a Major Project Review Process or similar processes involving public consultation (refer also to Esdale & Ens, 1994), of either an extended or part-time nature;

* Explore possibilities for providing students with a diversity of practical experiences and ensure students have exposure to contexts which facilitate students' ability to understand and meet parallel requirements of sustainable development and engineering;

* Collaborate with other educational institutions to develop bridging programs (e.g., between universities and more practically-based technical institutes) and alternative qualification pathways;

* Increase the involvement of practitioners or "pracademics" in the design and delivery of engineering courses (for examples, see Hartman, 1994; Lewis, 1994; Poirot, 1993);[13]

* Encourage all faculty members (not just those coordinating student co-op programs) to increase contacts and engineering work experiences outside of the educational institutions (e.g., through exchange programs, consultation).[14]

9. Re-examine and (if necessary) reform engineering faculty and student selection criteria

a. Faculty Selection. Faculty members tend to be hired for their research and publication success within narrow engineering specialties. Most faculty members have small acquaintance and limited experience in complementary studies and few have had any teacher training (Brannan, 1994; Crofton, 1993; Johnson et al, 1988; Karbhari, 1989; McCuen, 1990; Tadmore et al, 1987). Further, given a "culture of publication and academic reward based on fame in particular narrow subjects" (Lucky, 1990, p. 17), an "uncommon satisfaction with technical work" (O'Neal, 1990, p. 33), and the importance of research in promotion and tenure (McCuen, 1990), faculty are often reluctant, indifferent, or unconvinced of the need to change their programs or practices. For example, McCuen (1990) found that faculty were reluctant to try to incorporate ethical issues into courses because they have no formal education in the subject, have limited exposure to the subject in a practical setting, and are not familiar with available educational resources. One professor unconvinced of the need to address sustainable development – since "it is of interest to just a tiny fraction of the population" and "it's not even a political issue in Canada" – stated "it is certainly not an issue for engineering education" (Faculty member in CEI study, Dickinson & Crofton, 1994).

There are also indications of outright resistance to involvement in areas outside of engineering. For example, students continue to see their professors pursuing narrowly defined technical areas and as indifferent, sometimes hostile and rarely enthusiastic about social science and humanities courses. (Dickinson & Crofton, 1994; Holstein and McGrath, 1960). One professor stated that "engineering education is too valuable to waste 12.5% on non-technical areas . . . let's get out of advanced recess!" (Faculty member, [Respondent X29], Crofton, 1993). This less than enthusiastic response is also reflected in attitudes toward pedagogy. Beasley et al (1994) state that faculty members "are not drawn to educational psychology or philosophy by inclination or interest. They often greet such matters with meager enthusiasm and sometimes with outright skepticism" (p. 1407).

Obviously engineering schools require a faculty with strong technical expertise to help students obtain technical knowledge and skills, to further research and, admittedly, to obtain funding. Nonetheless, whether for reasons of lack of knowledge about subjects outside their area of specialty, lack of involvement in business and industry, lack of familiarity with educational resources, lack of awareness or understanding of effective pedagogy, or indifference, it appears that many faculty members are unable to assist students to obtain and apply a broader base of knowledge and skills. Although Recommendations 2 and 8 may help overcome some of the problems, it is also suggested that faculty selection criteria increase focus on:

* Candidates with some teacher training and/or willingness to acquire some teacher training prior to or immediately after appointment;

* Candidates with strengths in complementary studies areas (e.g., psychology, sociology, management, communication);

* Candidates with interest, knowledge and/or experience in environmental science and sustainable development.

b. Student Selection. It is also suggested that student selection criteria be re-examined. Enrolment limits make entry into engineering programs highly competitive. Academic achievement, especially in mathematics and science, is given primary weight in selecting candidates; "little weight is specifically given to such qualities as creativity, leadership or communication skills although these qualities are essential" (CCPE & National Committee of Dean of Engineering and Applied Sciences [NCDEAS], 1992, p. 18). It also appears to be the case that most engineering students choose engineering because they like math and science (Crofton, 1993; Myers, 1994).

Older studies of students (e.g., Perrucci & Gerstl, 1969; McCaulley, 1976; several studies reported by the Center for Policy Alternatives at M.I.T, 1975) suggest that engineering students value task completion over task initiation, are not people-oriented, are intolerant of uncertainty and ambiguity, prefer structured work and are less than enthusiastic about social sciences. If the students who participated in the CEI study (Dickinson & Crofton, 1994) are any indication, these observations may be at least somewhat less true today. For example, students in the CEI study often expressed a desire for exposure to issues beyond the strictly technical and for greater access to social science courses; students in another study (Crofton, 1993) also indicated that it was important to learn about cooperation, human needs, social issues, environmental issues, ethics and interpersonal skills. Nonetheless, it was also not uncommon for students to say things like "I got into engineering so I wouldn't have to deal with people and fuzzy values stuff" or "What has all that [interpersonal skills, sustainable development, public consultation, politics, qualitative research] got to do with engineering? If I wanted to learn about that stuff I would have gone into some other department!" (Student comments, Crofton, 1993).

In the absence of other more recent and detailed studies, it is difficult to draw conclusions about the characteristics of students currently entering engineering programs. Nonetheless, studies using the Myers-Briggs Type Indicator to explore psychological types[15] of engineering students are revealing (e.g., Bernold et al, 1994; Felder et al, 1993; McCaulley, 1976; McCaulley et al, 1983). According to Jungian theory, thinking types (as opposed to feeling types) "typically draw conclusions or make judgement objectively, dispassionately and analytically" (McCaulley et al, 1983, p. 395); "preference for thinking leads to a skeptical, somewhat critical attitude, especially for anything 'out of line' or 'fuzzy'" (McCaulley, 1976, p. 732). Feeling types "take the human side of problems into account and . . . ensure that important long-range values are not jeopardized by immediate short term solutions" (McCaulley, 1976, p. 732). Judging types "prefer to collect only enough data to make a decision before setting on a direct path to a goal, and typically stay on that path"; others (called "perceiving types") "are attuned to changing situations, alert to developments which may require a change of strategy or even a change of goals" (McCaulley et al, 1983, p. 395). McCaulley et al (1983) found that engineering students markedly prefer thinking and judging;[16] the more recent studies by Bernold et al (1994) and Felder et al (1993) report distributions similar to McCaulley's findings though their samples are much smaller. Bernold et al question whether engineering programs "weed out" or are unsuccessful in reaching a larger number of other types. It may be that engineering schools are selecting students that are already disinclined to learn broader knowledge and skills or concern themselves with subjective factors involved in engineering work.

The studies reported in the previous paragraph were of engineering students in the United States; there is very little information available regarding the characteristics or inclinations of Canadian engineering students. Nonetheless, given current emphasis in student selection (CCPE & NCDEAS, 1992), students' primary motivation for entering engineering (liking math and science), and the demand for engineers to be more widely interested, experienced, and skilled, a reassessment (at least) of current student selection criteria seems warranted. Van Gyn (1994) noted that co-op students were more successful than non-coop students; she also noted that, at the beginning of the program, co-op students had higher academic standing (more first class standings), higher test scores on the College Outcomes Measures Program tests (6 outcome areas: communication, problem-solving, values clarification, ability to function in social institutions, ability to use science and technology, and ability to use liberal arts areas), and more work experience than non-coop students. It is therefore suggested that, where necessary, student selection procedures be modified to ensure consideration of:

* Academic performance in the arts as well as the sciences;

* Work experience and other indications of successful interaction with others such as work on student council, volunteer work, and participation on committees;

* Demonstrated interest in broad societal issues that include engineering but extend beyond strictly technical concerns (interest could be demonstrated either by work experience as above, recent books read, or by knowledge of various societal issues).

Another way to draw a greater diversity of students to engineering might be to develop an orientation program for prospective students which highlights the breadth as well as depth of content expected to be learned and outlines the kinds of approaches that will be used. Further, a course teaching non-engineers about engineering (Myers, 1994) may also encourage students who might not otherwise have chosen an engineering career, to move into engineering programs.

10. Develop interdisciplinary knowledge and skills

Since sustainable development involves more than just one field of study it is considered an 'interdisciplinary' area of study. APEGBC study participants and others (e.g., CCPE Task Force, 1994; WCED, 1987) emphasize that, to effectively respond to sustainable development, therefore, requires the development of interdisciplinary knowledge and skills (IKS hereafter). It is here assumed that IKS is demonstrated by (a) understanding principles, concepts and practices of a number of disciplines; (b) understanding the ways knowledge and skills from various disciplines bear on a particular problem; and (c) the ability to integrate and apply these undertandings to the solution of problems.

The APEGBC, CEI and Vanderburg studies indicate that undergraduate engineering education is primarily focussed on the technical and there is little opportunity to develop broader knowledge and skills. Given that technical engineering expertise is insufficient for responding to the complexity of problems associated with sustainable development, and that engineers both need and demand knowledge and skills from multiple disciplines, interdisciplinary efforts are essential. Launching interdisciplinary efforts in an environment dominated by departments built around discipline specialties, and where technical values of efficiency, utility, order, control and precision are primary (Franklin, 1985 & 1990; Johnson et al, 1988; O'Neal, 1990), will be difficult. There are essentially three approaches for developing IKS and, more specifically, for incorporating sustainable development knowledge and skill requirements into engineering programs: (a) students can take courses offered by departments outside of engineering; (e.g., courses in philosophy, business, economics, sciences/ecology); (b) special courses can be offered within engineering; and (c) the content and skills can be integrated within existing courses.

Smorgasbord programs where students merely select from a number of courses offered outside the engineering school are not sufficient. First, engineering students, immersed in very demanding, grades competitive, technically oriented courses, tend to choose courses that will give them "easy credits" (Crofton, 1993; Dickinson & Crofton, 1994; Hartley, 1994). Second, even if students have interests in particular courses, course schedules or program demands prevent them from enrolling in them (Dickinson & Crofton, 1994; Esdale & Ens, 1994; Hutzler & Baillod, 1994). Third, courses provided by faculty external to engineering are not specifically designed for or attentive to engineering issues and concerns; as a result, students may be unable to transfer their learning to the engineering context (Hutzler & Baillod, 1994; McCuen, 1990).[17] In addition to recommendations which follow, suggestions for improving this approach include:

- Identify courses offered outside of engineering that legitimately and effectively contribute to the development of IKS and ensure that these courses are dominant among courses chosen to fulfil students' complementary studies requirements;

* Identify or develop interdisciplinary courses which, though they may be offered outside of engineering, address technology and are appropriate for the education of engineers and non-engineers alike. Such courses might include, for example: Politics of Innovation and change (drawing on e.g., psychology, sociology, political science); Critical Perspectives of Technology (drawing on e.g., philosophy, history, sociology); Human Ecology, Social Consciousness and technology (drawing on, e.g., environmental science, ethics);

The second approach, development of special courses within engineering, is one that is already utilized by engineering programs. Many engineering programs include such courses as Writing skills for Engineers; Engineering Communication (usually limited to technical writing and oral presentations, i.e., one way communication); History of Engineering; Technology and Society; Environmental Engineering. Some schools are now initiating courses in Sustainable Development (e.g., the Georgia Institute of Technology and the University of British Columbia both offered their first course in January 1995).[18] This approach requires faculty members with resources and experience to develop such courses (see Recommendation 9a). The addition of courses in an already crowded curriculum, however, must be considered carefully; this approach, given the problems of coping with changing demands and growth in knowledge, could result in a continuous expansion of programs. If the objective is to develop students' abilities rather than simply add knowledge, the approach will only be relevant if new courses are consistent with the educational goals (refer to Recommendation 7) and overall structure and composition of the curriculum.

New approaches are needed (e.g., see Beasley et al, 1994; Catalano, 1994; Devon, 1994); it may even be, as Vanderburg (1990b) suggests, that "a new body of knowledge must be created to deal with the human and social context of technology from an engineering perspective" (p. 705). The third alternative, integrating sustainable development and non-technical knowledge and skills into existing programs, appears to be both practical and effective (Beasley et al, 1994; Bernold et al, 1994; Betts et al, 1994; McCuen, 1990). The following suggestions are offered to assist in the development of new approaches and the creation of a new body of knowledge:

* Define and represent the overall composition of existing curriculum (technical components and broader aspects of students' professional development);

* For each course, define linkages, topic by topic, to other courses in the curriculum, and trace fundamental principles and key concepts throughout the curriculum;

* Focus on issues, problems and/or solutions related to sustainable development in which engineers may be involved or may be expected to contribute (Recommendations 1, 2 and 3 may be useful here), and highlight the ways that course content (knowledge or skills) is needed to understand and effectively respond to sustainable development;

* Increase the use of cooperative learning and collaborative teaching approaches (Barchilon et al, 1994; Bellamy et al, 1994; and Hutzler & Baillod, 1994 are among those who discuss the advantages of these approaches; see also Recommendation 8);[19]

* Since design courses are an obvious place to consider economic, environmental and social objectives and ethical issues (Devon, 1994), increase emphasis on design problems by incorporating design problems into existing courses (including first year courses), and by increasing the number of design courses in undergraduate programs;[20]

* Identify, develop and use cross-disciplinary problems, case studies,[21] projects and simulations[22] that are likely to help develop interdisciplinary knowledge and skills;

* Identify individuals and/or programs (workshops, seminars, courses) as examples of exemplary treatment of the complementary study/non-technical objectives of engineering education. In particular, those that have integrated various disciplinary interests, knowledge and skills, should be identified;

* Develop professional re-training materials, based on exemplary models, to provide engineering faculty with ideas for incorporating social, environmental and leadership issues, and communication and group process skills within existing programs.

11. Reform engineers-in-training (EIT) programs

Since it is impossible to teach all that one may need to know in a four-year university program, prospective engineers are expected to gain additional knowledge and skills from their EIT experiences. The Canadian engineering profession believes that two years (the previous EIT requirement) is not enough time to gain the additional knowledge and skills; as a result, registration requirements now (or will soon) require a four-year EIT period. Unfortunately, since prospective engineers have limited practical 'field' experience and a background focussed on the technical, they are ill-prepared to determine what kinds of experiences they should seek or what kinds of knowledge/skills they should attempt to acquire. As a result, the value and effectiveness of EIT experiences is dependent on the kinds of job placements EITs obtain and the kind of guidance or mentorship provided. The candidate's past and present direct supervisors and/or "a person in authority at the candidate's place of employment or of a client firm" are expected to (a) "ensure that the candidate has sufficent exposure to a significant majority" of the components of EIT requirements; (b) "provide guidance, encouragement and support . . . during the internship period"; and (c) evaluate the candidate's competence (CCPE-CEQB, 1994, pp. 12-13).

Given prospective and practicing engineers' reports of their EIT experiences and evidence of certain knowledge and skill weaknesses among engineers, there is reason to question the effectiveness of EIT programs in furthering the professional development of prospective engineers. Many of the supervising engineers may themselves lack particular kinds of knowledge and/or skills and may not be competent evaluators in those areas.[23] In sum, there is no assurance that employers, supervisors and persons "in authority," by being professional engineers and by virtue of their positions, are sufficiently knowledgeable, competent, or effective as guides in the professional development of prospective engineers. For these reasons, and in addition to the previous recommendation that goals of the EIT phase of preparatory education need to be made clear (Recommendation 7b), the following recommendations are offered to improve the effectiveness and value of the EIT experience.

* Identify knowledge and skill needs, preferably particular to each candidate, to be addressed during the EIT experience (particular emphasis should be placed on areas of weakness already identified by professional engineers);

* Develop guidelines for ways to obtain knowledge and skills; support, monitoring and accountability mechanisms (for sponsors and candidates) should also be developed or refined;[24]

* Identify knowledge and skills required for effective mentoring and develop guidelines for the selection and/or training of qualified mentors;

* Although employers, direct supervisors and persons in authority who are familiar with a candidate's work should have a role (perhaps even a mentor role) in guiding and evaluating a candidate, it is recommended that selection of the primary supervisor/mentor of the EIT's experience not be limited to these individuals;[25]

* Develop an orientation (and possibly a training) program for those assuming primary supervisor/mentor roles;

* Provide opportunitites for primary supervisors/mentors to meet together (e.g., workshops, seminars, conferences) to discuss problems and successes, share ideas, receive information about current knowledge and skill demands, and to further develop the EIT component of engineering education; at times, EITs might also be invited to participate in these activities.

12. Increase the range and accessibility of continuing education opportunities

APEGBC and CEI study participants were generally satisfied with opportunities to maintain or improve technical competence; in other areas of professional development (e.g., management, communication, leadership), however, they complained that opportunities were either not available, not accessible (due to location, timing, time requirements or costs), or not sufficiently specific to the engineering context. Since the maintenance of technical competence is seen to be less problematic, continuing education should increase emphasis on knowledge/skills areas outside the narrowly technical (e.g., environmental science, leadership, communication, management).

Although important and useful, continuing education opportunities should not be limited to formal programs, courses, workshops or seminars. Continuing education opportunities could include: participation on boards, task forces, or planning committees that are concerned with issues related to, but generally outside of, an individual's usual engineering practice; public consultation/involvement activities; making presentations or providing courses to people outside of the usual areas of engineering practice; involvement in active community service groups (see also Recommendations 1 and 2). It is recommended that such less formal activities be included among strategies for promoting continuing competence among professional engineers. Further, professional associations should both publicize and initiate such less formal continuing education activities. Some additional suggestions for increasing the range and accessibility of continuing education opportunities include:

- Increase involvement of universities in providing continuing education opportunities through, for example, involving practitioners in the design and delivery of courses or course components; providing practitioners with access to specialized courses (e.g., a course on sustainable development) by scheduling certain lectures or courses in the evenings or on weekends;[26]

- Increase engineers' awareness of opportunities for professional development that are alternatives to traditional approaches (such as those noted above);

- Identify or develop distance education programs (including, e.g., televised or computer-assisted programs) which may help engineers develop a broader knowledge and skill base;[27]

- Develop a library or database of useful references, case studies and programs that engineers can access to obtain information and guidance for their continuing education;

• Publicize information on emerging concerns (e.g., environmental, legal) in Association journals and identify sources for further information.[28]

13. Develop a system of ongoing accreditation

To encourage professional engineers to maintain and increase their professional competence through ongoing education and professional development, engineers should be made aware of emerging knowledge and skills required for career development and to better fulfil professional obligations.[29] It is recommended that a system be put in place which credits engineers for their professional and continuing education activities. Credits should be provided for formal and informal activities, include corporate training and industry experiences, and recognize activities which demonstrate the enactment of the broad range of responsibilities mandated by the codes of ethics (e.g., furthering professional development of colleagues; safeguarding the public or the environment). It is further recommended that these credits become part of a program that requires engineers be more formally accountable for ensuring career-long continuing competence as mandated by the code of ethics (CCPE-CEQB, 1994).[30] The Certified General Accountant (CGA) Maintenance of Standards Program and Chartered Accountants Maintenance of Competency Program are examples of programs that are similar to what is being recommended here and may be useful models for developing an ongoing accreditation program for engineers (the CGA requirement that members earn 100 credits in each three year period on a moving total basis is one idea that may be particularly useful).

Resistance to establishing such a program may occur if engineers feel the program is intended to police their activities or that control over their professional development activities is being taken from them. It must be clear, therefore, that the primary purpose of this recommendation is to encourage and reward professional development rather than to police engineers; further, it must be clear that choice of activities remains the responsibility of the individual engineer. Objections might also be made on the grounds that engineers "do this anyway," that it is time consuming (for the individual engineer and for those monitoring the program), and/or requires an infusion of additional resources. The following is offered in response to these objections. First, if engineers are "doing it anyway," then participating in professional development activities does not represent any additional burden; it should be noted, however, that evidence indicates that many engineers are not "doing it anyway" and that certain weaknesses in engineers' knowledge/skills continue to persist (as revealed by APEGBC and CEI studies). Second, while it may be time consuming for engineers to record, report and monitor their collective activities, it is likely that such recording and monitoring will help engineers become more self-reflective, more attentive to career planning, and more focussed on developing and maintaining a range of professional competencies.

Finally, it is true that establishing and maintaining a system of ongoing accreditation will require time and resources.[31] If done properly, however, the investment is not without benefits. For the profession as a whole, competency requirements will be more clearly defined, a diverse and expanded set of vehicles for obtaining knowledge/skills will be established and recognized, and the profession will become more committed to ensuring that a broad range of knowledge/skills are acquired. Individual practitioners gain by receiving guidance and recognition for their continuing education efforts and are likely to be internally (as well as externally) motivated to develop competencies beyond the merely technical.[32] For these reasons, it is suggested that investment in a system of ongoing accreditation is warranted; responsibility for the recommendation should rest with professional associations. In sum, recommendations included in this discussion are as follow:

* Publicize information about the kinds of knowledge, skills and activities that are particularly relevant to engineers' expanding roles and to career development;

* Develop a system which credits engineers for their informal and formal continuing education activities;

* Require continuing education for maintenance of license to practice.

Suggestions for Further Study

The conclusions and recommendations suggest a number of possibilities for further study:

1. The CCPE states that professional engineers need to be aware of "the impact that engineering in all its forms makes on the environmental, economic, social and cultural aspirations of society" (CCPE-CEAB, 1994, p. 14); as of 1994 they have added the need to understand the concept of sustainable development. Given the increasing need and demand for engineers to acquire such awareness and understanding, and the recent inclusion of sustainable development in the guidelines for accreditation of engineering education programs, it is suggested that the impact the policy guideline has on engineering faculty, students and curriculum be investigated. That is, to what degree is this policy recommendation operationalized and with what effects?

2. It is becoming increasingly clear that multiple disciplines are involved with sustainability concerns and that sustainable development has implications for engineering. In order to better determine ways to incorporate sustainable development into engineering education, and to increase linkages across disciplines, it is suggested that a survey be conducted to identify courses and programs currently being offered or developed which are specifically attentive to sustainable development.

3. Knowledge and skills that extend beyond the technical areas of engineering are reported to be weak (e.g., environmental science, business, communication). It is therefore suggested that an investigation be conducted to (a) identify courses and programs (within and outside of engineering) that strengthen knowledge/skills in these areas and, more specifically, which encourage the development of interdisciplinary knowledge/skills; and (b) determine what elements of the curriculum content and methods of these courses are critical to their success.

4. Since not all expected knowledge/skills can be acquired in an undergraduate engineering education program, and since the required experience component of engineering education has been extended to four years, a detailed investigation of EIT programs is warranted. Questions of importance to this investigation would include, for

example: What types of employers sponsor EITs? What were the employers' reasons for offering sponsorship and what were the students' reasons for accepting sponsorship? (For example, what priorities are given to training opportunities or recruitment/employment agendas?) What understanding, priorities and vehicles do sponsors/mentors have in guiding EITs and ensuring EITs gain experience across the components of the EIT requirement? How do EITs describe their EIT experience in terms of kinds of activities, usefulness of their undergraduate education and the supervision/guidance received? What similarities/differences exist across experiences (e.g., is gender a factor?)? Does the EIT experience influence choices for future activities in terms of disciplinary interests or continuing education? From the various perspectives of employers, supervisors, mentors, and students, what are the problems and benefits of the EIT program? To what degree does the EIT experience extend knowledge and skills required for sustainable development?

5. There is evidence to suggest that engineers are at times uncertain or in conflict about their professional responsibilities regarding sustainable development. It is suggested that a study be conducted which (a) explores a range of specific contexts or cases within which engineering knowledge/skills impacts sustainable development directly (e.g., products, processes and design solutions) or indirectly (e.g., testimony, consultation, products or solutions used within a larger projects); (b) identifies the ways engineers have or have not accounted for the economic, environmental, and social effects of their work; (c) reveals conditions under which engineers experience uncertainty or conflict in fulfilling their responsibility to safeguard public interests or the environment; and (d) explores ways engineers have overcome their uncertainty and/or resolved conflicts in ways that enable them to provide effective solutions for sustainable development and fulfill their various professional responsibilities.

6. Although the CCPE documents, as consensus documents, indicate alignment between the standards of sustainable development and professional engineers, it is not clear how well these standards are incorporated by engineering acts in each province and territory. Many engineers complain that, in the absence of legislation or other legal authority, they often "don't have a leg to stand on" to argue for approaches more supportive of sustainable development. It is suggested that a study be conducted to (a) determine the ways in which the parallel standards of sustainable development and

engineers are or are not incorporated in current engineering Acts; (b) explore the reasons why standards are or are not included or enforceable; and (c) identify the ways current civil and criminal laws within each jurisdiction may help to facilitate the meeting of the standards.

7. It has been suggested that an ongoing accreditation system would benefit the profession and individual engineers in a number of ways: the kinds of knowledge/skills that might be expected for various roles and stages in an engineer's career would be more clear; the kinds of activities that might be engaged to maintain and develop professional competence would be identified; and the profession and individual practitioners would be more motivated to be involved in professional development/continuing education activities. The implication is that these benefits would increase the breadth of engineers' actual competencies and enable them to more effectively participate in a range of activities associated with sustainable development. Although these claims are intuitively reasonable, it is suggested that (a) a study be undertaken to investigate the problems and benefits of similar systems, and (b) a comparative study be conducted to determine the degree to which the benefits are similarly attainable in professions who do not have such competency maintenance programs.

Summary

> I am a caterpillar. The leaves I eat taste bitter now. But dimly I sense a great change coming. What I offer you, humans, is my willingness to dissolve and transform. I do that without knowing what the end-result will be; so I share with you my courage too. (Macy quoted in Roberts & Amidon, 1991, p. 280)

Sustainable development demands new ways of thinking, valuing and acting. But there is no simple blueprint. As we learn more about the interconnectedness of human and non-human systems, as we become more receptive to alternate perspectives, as we challenge our assumptions, and as we attempt to make changes, we may, like the caterpillar, have to eat 'bitter leaves' as part of our transformation. This chapter has suggested some ways that engineers can become better prepared to address sustainable development and begin to transform engineering practice.

The recommendations stem from evidence that (a) the engineering profession believes it has, and is willing to assume, professional responsibility for sustainable development, and (b) that current understanding, skills and practices fall short of the ideals and limit engineers' ability to effectively respond to sustainable development. The profession has performed extraordinarily well in responding to technical challenges; however, it has been less vigorous in responding to complex socio-technological issues. Engineers recognize that they need to better understand sustainable development and the interaction between engineering considerations and broader societal interests, and be more actively involved in the mediation of competing demands and in decision-making regarding the resolution of complex socio-technical problems. Unfortunately, evidence provided by this study suggests that (a) deficiencies in engineers' existing knowledge and skills inhibit engineers' ability to gain better understandings; (b) engineers rarely participate in other than technical discussions or activities related to sustainable development; (c) the engineering profession and engineering practice is "highly partitioned or fragmented" and that this renders its members "somewhat impotent in influencing external decision makers" (Hatch, 1993, p. 216); and (d) that current engineering education and training programs have thus far been more effective in ensuring technical competence of engineers than in facilitating the development of a broader knowledge and skills.

If these problems are unaddressed, engineers may find themselves excluded from or relegated to the background in the making of important decisions about our collective lives; we all would suffer the loss of their voices. In effect, these weaknesses and problems do a disservice to society by confining engineers to a mainly technical role and conceding responsibility for basic strategies to others who may lack technical insights and expertise. Perhaps more than ever before, the effectiveness of engineers' solutions and the value of their contributions to achieving sustainable development will depend on engineers' capacity for continued learning and retraining, and on the strength of their communication skills. Engineers need to be self-reflective, aware of changing needs, diligent in acquiring the knowledge and skills required to respond to a variety of demands and expectations, and committed to responding to sustainable development.

The recommendations are intended to help engineers' develop knowledge and skills required for sustainable development; encourage their involvement in a broad range of activities related to sustainable development; alter organizational structures, work arrangements and systems of support and accountability in ways that support sustainability efforts; and realign engineering education with the parallel goals and requirements of professional practice and sustainable development. In essence, the recommendations are intended to facilitate engineers' ability to develop and successfully undertake a more "macro role" (Coates, 1993) and to assume greater leadership responsibility for sustainable development. As Bugliarello (1985) notes: "Until engineering is prepared to assume greater leadership, it will remain a most honorable and skillful profession but it will renounce its legitimate role [in the] . . . manifestation of humankind's will to control its destiny" (p. 85).

Endnotes

1. Although the CCPE does not have legislative or disciplinary authority, the documents it prepares serve to guide the work of constituent associations. As previously noted (see Chapter 1, Endnote 6), documents defining responsibilities and roles are the result of an iterative process involving the participation of engineers from private, public and academic sectors, different regions and disciplines, and constituent associations. The CCPE can provide a key leadership and facilitative role in clarifying roles and responsibilities currently included in CCPE documents, furthering the consensus process, and developing a clearer guide for the work of provincial and territorial associations.

2. ISO-9000 is a series of quality standards which outline the requirements for quality management systems. ISO-9000 was developed by the International Organization for Standardization in 1987; it is an internationally accepted system of rating quality management and quality assurance intended to improve organizational effectiveness. Canada has adopted the ISO-9000 series as its national standard. ISO standards are under continual development (e.g., environmental standards are now being developed; one group is looking at ways to incorporate ethics into the standards programs). In the international arena, the demand for companies which are ISO-9000 certified is increasing (Dickinson & Crofton, 1994). Further information can be obtained from Canadian Standards Association offices.

3. Several people have (a) described types of organizations and work arrangements; (b) analyzed their effectiveness in various contexts; and (c) described intervention approaches (e.g., Bolman & Deal, 1991; Burrell & Morgan, 1988; Frost et al, 1991; Mintzberg, 1979; Mohrman et al, 1989; Peters & Austin, 1985); their work can provide guidance for organizational analysis of the kind recommended here. Reliable and valid instruments to assess organizational effectiveness are also available. For example: Human Synergistics produces group and interpersonal style inventories and

an organizational culture assessment tool; Pacific Leadership Inc., in cooperation with T. Gerstl, has developed an Organizational Health Inventory (OHI) to assess various organizational effectiveness factors.

4. Undergraduate and graduate courses developed by Dr. Wassermann for the Faculty of Education, Simon Fraser University, are good models of courses being suggested. Wassermann, with the assistance of others, also developed a graduate level, distance education program which included Values Clarifying, Empathy Training, and Promoting thinking. Audio-video demonstrations were among the materials making up the program; students were required to prepare their own audio and video-tape skill demonstrations, analyze and transcribe their work, and provide samples for evaluation.

5. For example: the United Nations Environment Program (UNEP) was formed out of the 1972 Stockholm Conference to promote the idea of environmentally sound development; the UNEP (with UNESCO) then founded the International Environmental Education Program (IEEP) in 1975. The 1980 World Conservation Strategy called for training, public participation and education in order to foster attitudes and behavior consistent with a "new ethic" emphasizing the need for harmony with the natural world. The WCED also stated that public participation and education would be necessary to set us on a new, sustainable course. Agenda 21, the "blueprint for action" for sustainable development of the planet, called for "commitment to training and educating scientists worldwide," environmental education as part of every student's course of study, curricula review, teacher and administrator training, cross-disciplinary university courses, and more (Preparatory Committee for UNCED, 1992, p. 29). In Canada, the NRTEE initiated the Sustainable Development Education Program which would be "key in promoting awareness . . . and commitment to the proposition that future development must integrate environmental, economic, social and cultural needs" (NRTEE, 1992, p. 8). In B.C., from the very beginning, the BCRTEE identified public information and education as key elements in building sustainability. The position that "education must be a major part of the overall sustainable development strategy" (BCRTEE, 1991, p. 1) is reflected in Towards a Strategy for Sustainability (BCRTEE, 1992) and is emphasized in Towards Sustainability: Learning for Change (BCRTEE, 1993).

6. For example: The Future of Engineering Education in Canada focussed on a series of recommendations including expanded programs, lower student-to-staff ratios, transition programs, etc. (CCPE & NCDEAS, 1992). The CCPE-CEQB (199), while not stating goals explicitly, provides a rather lengthy list of necessary understandings and competencies in their clarification of the requirements for qualification as a professional engineer (pp. 11-26); Smith et al (1981) generated lists of goals (as competencies) for coop programs in engineering education.

7. "Problem-solving" is one example of a generally agreed upon competency requirement though it is not entirely clear what kind of problems may be the focus or what kind of strategies might be included in their solutions.

8. For example, Smith et al (1981) presents two prioritized lists of goals – one generated by academics; the other by industry. The differences in priorities are immediately apparent. A study by Betts, Liow and Pollock (1993) also challenges the assumption of agreement about educational objectives among staff, students and employers.

9. While there have been debates about the extent to which university education should have a utilitarian purpose, "that a major purpose of university education is preparation for the world of work in no longer in dispute" (Commission of Inquiry on Canadian University Education, 1991, p. 71). The establishment of schools and programs intended for preparing students for the "professions" make it abundantly clear that career education is part of the educational landscape.

10. In keeping with the notion of experience incorporated by others, experience does "not necessarily refer to longevity or length of time in a position; rather, it refers to a very active process of refining and changing preconceived theories, notions and ideas when confronted with actual situations" (Benner in Tillman, 1990, p. 182). The case method and project work can also be used to facilitate this process. See Recommendation 10 and Endnotes 21 & 22.

11. Evidence of the importance and advantages of practical experience during undergraduate education can be found in literature on COOP engineering education. Evidence indicates that COOP students have better communication, problems-solving, values clarification and social skills, are better at applying their academic knowledge, fail fewer courses, extend their programs less often, and perform better academically than students completing traditional programs (see for example: Porteous & Swanson, 1994; Russell, 1991; Van Gyn, 1994). Further, Van Gyn (1994), referencing studies done by others, states that "Tacit knowledge is acknowledged as providing the basis for *appropriate* application of formal knowledge . . . COOP experience of as little as 5 months has a demonstrable and measurable impact on the tacit knowledge base of students" (p. 88, italics in the original). COOP programs are also believed to develop in students a clearer sense of career objectives and motivation to further their education (Russell, 1991); industry believes students exposed to hands-on, applied theory approaches can more readily adapt and are more effective than other students (Dickinson & Crofton, 1994; Tomovic, 1994). Further, Koehn's (1993) study concerning ethics and professionalism shows that "students with minimum work experience tend to rate the frequency and seriousness of ethical issues lower than students with work experience, members of the Consulting Engineers Council, and faculty" (p. 402).

12. Examples of successful partnering initiatives are provided by Gooding et al (1994); Haughton and Bibby (1994); Hill (1994); Pickles (1994); Verma et al (1994).

13. Lewis (1994) suggests that in addition to the value to students' education that "pracademics" or "boundary-spanning professionals" provide (e.g., introducing professional norms, values and information into the curriculum; meshing the world of education with the world of professional work), such "adjunct faculty represent enrichment, diversity, scheduling flexibility, short-term contractual obligations, and a degree of economic savings" (p. 820).

14. Reports by several individuals in the CEI study indicate that some educational institutions have developed successful exchange programs; one technical school in Alberta has developed a COOP program for their instructors; many technical schools require that their instructors are "in the field" regularly (one requires instructors to return to the field every two years).

15. The exploration of psychological types is based on the work of C.G. Jung and is concerned with the "conscious aspects of personality that determine how people take in information and how they decide what to do about what they perceive"

(McCaulley, 1976, p. 729). The Myers-Briggs Type Indicator is one of the best known instruments used to assess psychological type. Psychological types (and there is variability within each type) are determined in terms of subject preferences assessed on each of four scales: (1) general approach: extroversion-introversion; (2) information gathering: sensory-intuitive; (3) making judgements: thinking-feeling; (4) data collection: judging-perceiving.

16. McCaulley et al (1983) report that 74% of students are thinking types; 61% are judging types. McCaulley et al also report that the greatest loss of engineering students were the "enthusiastic, insightful types sharing intuition and feeling (types frequently attracted to the behavioral sciences and communications)" (p. 397). Earlier, Feldman summarized a number of studies (Feldman, reported in CPA, 1975) and concluded that students withdrawing from engineering programs show less stereotyped thinking, less need for external structure, greater social awareness, feel more at ease with complex issues, and tend to have a more intellectual rather than practical orientation than those who complete engineering programs. The students that drop out of engineering (and many of those who choose not to enter) may be those who have the interest and capacity to develop and demonstrate those competencies currently seen to be inadequate among engineering graduates; they also may be those who could best deal with the ambiguities of a great number of engineering problems.

17. McCuen (1990), in his discussion of professionalism and ethics, states that "the educational background of those who teach such courses [outside of engineering] is rarely the least bit oriented toward engineering practise so the students may not learn to transfer the general knowledge of ethics to application in engineering practice" (p. 251). Hutzler and Baillod (1994), concerned with educating engineers for the environment, state that environmental science or ecology courses are typically "descriptive and qualitative in nature with little engineering content and are <u>not</u> adequate for problem solving" (p. 2689). Cambel and Schuh (1989) suggest that the external course approach can be more effective if an engineering faculty member participates in the non-engineering course (thereby assisting students with the transfer); except for a few special cases, however, there are a number of logistic problems with this approach.

18. The Department of Civil Engineering at the University of British Columbia has developed a lecture-style course on sustainable development where speakers drawn from various sectors speak on limits, social structures, economic well-being, ethics, fundamental economic-environmental conflicts (case studies from fisheries and forestry), governance and democracy, public consultation, involvement of grassroots organizations, environmental policy development, environmental law, and professional responsibility. The course consists of 35 lectures and is one of the "core" (i.e., required) courses for graduation from civil engineering. The Georgia Tech course is the first of a planned three-course sequence. Titled "Introduction to Sustainable Development" it focusses on "economic, ethical, technological and ecological dimensions of sustainability"; it does not, however, address social issues or issues of governance and public consultation.

19. For example: Barchilon and Kelley (1994) report that faculty collaboration (in program design and delivery) reinforced the importance of working together and learning from each other, provided role models for students, provided opportunities to observe others' teaching styles, resulted in "greater mutual respect for our fields

and each other" (p. 2669), and strengthened pedagogical approaches. They also report that student collaboration increased learning: in particular, students reported seeking out opinions more often, being more open to other opinions, listening and involving themselves more, and becoming more socially involved. Bellamy et al (1994) report that, as a result of collaborative efforts to introduce a *Quality* culture (i.e., from TQM approaches) into the school, a teaming atmosphere is emerging, teachers now lecture less frequently, use pedagogy that requires active participation of students and often act as coaches or facilitators of learning; there is shift in emphasis from teaching to learning. Hutzler and Baillod (1994), reporting on collaborative course design and development, state that "The most valuable outcomes of this phase was to learn about the barriers of communication between engineering disciplines and to see how different engineering specialties approach a common problem" (p. 2691).

20. Devon (1994) states there is dearth of design courses in undergraduate programs. McCuen (1990) provides examples of how ethics can be incorporated into a design course and prefers this approach to special ethics courses outside or within engineering programs; he also illustrates ways design questions can be addressed in first year. Gooding et al (1994) are working to improving their instructional program by integrating design concepts throughout the undergraduate curriculum including the introduction of design problems in first year. Their objectives include: enabling students to realize value of subject content by applying it to realistic, comprehensive problems; showing students how subjects covered in different courses are related; promoting team work and interaction among students and faculty.

21. The case method recognizes the context within which knowledge is understood and applied; case studies describe and present problems in their real context. "Case studies can be an effective tool that brings engineering practice into the theoretical environment of the classroom" (Russell & McCullouch, 1990, p. 172). Papers by Harding (1988) and Russell & McCullouch (1990) are useful orientations to the case method. They explain the method and its advantages and disadvantages, describe kinds of cases, provide case examples, and provide guidelines for selecting or developing cases and for using cases in the classroom. McCuen (1990) provides an outline of the application of the case study approach in engineering design classes. (EUREKA, an on-line library service, is a good source of engineering-related case studies.)

22. Projects are another way to expose students to real world problems (Bernold et al, 1994; Verma et al, 1994); since real world problems tend to require more than technical knowledge for their solutions, students are challenged to develop broader knowledge and skills. Simulations can also bring the real world into the classroom and provide experiences that add to what one already knows. Simulations are useful for increasing understanding about a diversity of issues and problems, and for developing and assessing problem-solving, decision-making, leadership, team and interpersonal skills (Fripp, 1984; Lederman, 1984).

23. For example, Tillman (1990), with regard to ethics, states: "Too often, supervising engineers seem to concentrate on the technical requirements and ignore the ethical dimensions of the assignment" (p. 185).

24. The Professional Development model in the Faculty of Education at Simon Fraser University may be useful in establishing support, monitoring and accountability mechanisms. In this model a "faculty associate" (someone working at

the university) and a "school associate" (a teacher working with the student at the practicum site) work collaboratively to support, guide and monitor student practice. Similar arrangements might be established for the EIT by establishing a primary "on site" contact and another outside associate (from the university or other site) who work together to guide, encourage and evaluate EIT experiences.

25. The Association of Professional Engineers of New Brunswick (APENB) is one Association that allows for this possibility. S. Stairs, Assistant Registrar, reports that APENB requires that all EITs have a mentor; however, since the APENB recognizes that EITs may be engaging in engineering work but are not working under the supervision of a professional engineer, mentors may be selected from outside the workplace (personal communication, January 24, 1995).

26. The UBC course on sustainable development (see Endnote 18) is one example of how practitioners from various fields can be involved in course design and delivery. SFU offers a number of courses in the evenings and on weekends specifically targeted to meet the needs of people working fulltime (e.g., almost graduate courses in the Faculty of Education are scheduled in the evening).

27. A videotape version of the UBC sustainable development course (Endnote 18) might be one way to get these ideas out to a broader audience. See also Endnote 4.

28. Something of this kind has been done by the Institute of Mechanical Engineers in Britain through their <u>Green Engineering: A Current Awareness Bulletin</u> (reported in Devon, 1994); the Environmental Law Group at Russell & DuMoulin produce the <u>Environmental Law Bulletin</u> which, in clear language (it is intended for non-lawyers) highlights changes and potential changes in environmental law and provides information about publications, seminars and conferences.

29. For example, Pennoni (1993) in his argument for mandatory continuing professional development for relicensing engineers notes that the half-life of an engineer's knowledge is decreasing and that today's "engineers must be knowledgeable in a much broader range of subjects. Environmental issues are probably the most obvious. However, legal and societal issues as well as technical concerns must likewise be fully understood by the practitioner. Additionally, political, financial, and aesthetic concerns also significantly impact today's engineering projects" (p. 342).

30. Pennoni (1993) reports that in the U.S., "five states now require CPD [continuing professional development for professional engineers] and that nine others are considering enactment of enabling legislation. . . . The public is demanding that all providers of products and services be properly qualified, continuously measured, and policed. If the engineering 'profession' doesn't enact these requirements, the public . . . will so enact them" (p. 344). He believes that "relicensing is upon us and will continue to spread" (p. 344). Given the diversity of engineering disciplines, it is likely that requirements will vary across disciplines; California, for example, has five categories of engineering licenses (Pennoni, 1993).

31. Finding funds for initiatives such as this is always problematic and, given information provided by APEGBC study participants, engineers are concerned about professional membership fees and how they are used. It should be noted, however, that compared to fees for membership in other professional associations (e.g., teacher,

accountant, law associations), fees for membership in professional engineering associations are relatively low.

32. I was unable to find evidence of the effectiveness of mandatory continuing education other than that which was reported by Pennoni (1993). Pennoni reports finding only one program that evaluated the effectiveness of mandatory continuing education; this was conducted by the State Education Department of New York for licensed accountants. According to Pennoni, the study provides clear evidence of an increase in knowledge proficiency with the program. Further, two-thirds of the accountants favored the program; about one third of the accountants said they would reduce their level of participation in continuing education if it was not mandatory.

AFTERWORD

During the course of this research and writing, the world and my thoughts have continued to evolve. Not everything I might have said has been said. The journey of learning and discovery is ongoing and, if I had not stopped somewhere, this dissertation would never have been completed. After the successful defense of my work, the examining committee encouraged me to write and include an "afterword" in the dissertation before final submission to the library. This afterword was to give me an opportunity to say more about some of things I have said, to include my reflections on discussion generated during defense, and to speak more personally about my perspective at this stage of the journey. To be honest, I both resist and welcome the opportunity.

I was drawn to undertake this study because of my desire to know and understand, and my wish to facilitate change and to help improve conditions in the world. But perhaps most importantly, I was drawn my values. My values are strongly tied to the natural world -- to the plants and animals; to the land, the sea and the sky; to earth, air, fire and water, what some people call "the four sacred things." My concern for the well-being of life, human and non-human, was a primary motivator for the study. Over the years I have observed that more people are becoming aware and concerned about conditions of the environment and the ways humans impact on it. Yet awareness and concern are not enough. We need to find ways to contribute to the building of a sustainable world; we need to change old behaviors and learn new behaviors; and we need to be assisted by enabling institutions.

Key among potentially enabling institutions for engineers are educational institutions and professional associations. In the past, it has often been one association or one engineering school or one particular engineering program that has initiated and led change. As a result, they have enabled others to acquire new understandings and behaviors. For example, Normal Ball identifies the University of Waterloo as the first university to incorporate co-op programs within their engineering school.[1] Although this move was not taken very seriously by some at the time, benefits were forthcoming and co-op programs are now part of most undergraduate engineering programs. Some schools have established special centers of education and research to focus on particular issues. Centers at the University of Toronto and the University of Waterloo, for example, focus attention on the relationship between technology and society. Some schools are leading efforts to increase participation of women in engineering. The University of British Columbia's civil engineering department, by developing and requiring a course on engineering and sustainability, may spur further work and change in this area.

Professional associations also help to develop new understandings and behaviors. It is not the case that every association decides at once to change their ways of doing things. In fact, when inquiring about various issues, I was often directed to a particular association who was "taking the lead," "spearheading the work," or "furthest along" in a particular area. For example, the Association of Professional Engineers of New Brunswick (APENB) was identified as the one furthest along in developing guidelines for EIT and EIT Mentor programs. The association in Ontario (APEO) was the first to grant limited licenses; APEGBC expects to do the same by September of this year and other associations are watching.[2] APEGBC is clearly identified as the association that took the lead in the area of sustainable development. Initiatives from the various associations are often reflected in documents subsequently produced by the CCPE and are so carried to other provincial and territorial associations. As previously discussed, the change in CCPE-CEAB accreditation criteria requiring programs to ensure students understand the concept of sustainable development, if taken seriously, may also initiate positive change.

All this is to say that initiative and leadership is an essential component of creating change. We can expect that the changes we desire will occur gradually; we should not expect that the changes will occur in the absence of such initiative and leadership. Engineering schools and associations can do much to support and encourage initiative and leadership, to set new standards, and to help engineers more effectively contribute to sustainable development. If sustainable development is to be achieved, however, support from society's larger legislative and political infrastructure is also required. Some changes in regulations and legislation may give engineers the "teeth" they need to argue for better, more effective engineering solutions. Environmental legislation, for example, helps ensure that environmental concerns are addressed by both engineers and their clients. Where legislation requires that the public be consulted and review projects, there is at least the potential for increased understanding among engineers and non-engineers and for more satisfactory outcomes.

Questions about the effects of increased legislation or, alternatively, de-regulation – as in, for example, de-regulating professions – still need to be addressed. Liability questions, for example, need to be resolved. Questions of the effects of issuing limited licenses under an engineering Act, or introducing exemptions into the Act also need to be further explored. Do such changes dilute the profession or potentially endanger society as some claim? And who is affected when professional engineers, in their desire to respond to new and emerging concerns, extend their areas of responsibility and expand definitions of professional practice? Might such changes, if not well-considered, mean that people with experience and specialized knowledge in these "new" areas would be made less effective? Might competent, conscientious people who previously provided valuable or specialized services in these "new" areas find themselves marginalized or excluded from participation? These are complex questions. When we answer them, we must be careful that neither resistance to change nor eagerness for change will undermine, forestall or detract from collective efforts to achieve sustainability.

The transition to a more sustainable world will not be easy nor is success assured. Those who are eager to move as quickly as possible may be disappointed when people will not listen or when progress is slow. It often seems that many individuals and modern society must first experience considerable crisis, failure or conflict before being awakened to the need for change. The need for change and for improved understanding must be felt deeply before there is a willingness to be open to alternative ideas and to search for better ideas. This is all about learning. Perhaps one of the greatest challenges to educators is to develop within students this deep need to learn and understand. It is why I strongly recommend both the development of sophisticated interpersonal and group process skills and discussion with a diversity of people.

When meeting with a group of people with different values, expectations, and ways of seeing, those with well-developed interpersonal and group process skills behave differently than those with less competency in these areas. Competent individuals work to build trust among participants and ensure that the environment is sufficiently "safe" for people to express themselves openly even if this means taking certain "risks." Rather than merely presenting or arguing for their own position or point of view, they listen carefully to what others are saying and actively seek to understand another person's point of view. Rather than leaping to conclusions that may be based on misunderstandings or faulty assumptions, they will check to ensure that their understanding is correct by asking questions, paraphrasing and reflecting back what they have 'heard.' Rather than avoiding or squashing potential disagreement or conflict, they encourage the expression of different ideas. Rather than allowing disagreement and conflict to interfere with process, they identify points of agreement and similarity and root out the specifics of disagreement or conflict so that productive discussion can continue. Individuals who learn to participate with each other in these ways usually come away from the experience with a broader understanding and a somewhat changed way of seeing.

And that brings me to the issue of practical experience. Knowledge and skills are not enough; understanding and competency comes with "hands-on" practice and with experience. Developing strong interpersonal and group process competencies, for example, is not merely a matter of learning about interpersonal styles, group dynamics, or effective room arrangements, nor is it about learning and following step-by-step interaction strategies for communicating with others. Learners must *use* this knowledge and their beginning skills in situations that challenge their beliefs, that engage them emotionally, and that cause them to question their thinking. We must pay attention to the kinds of practice and experiences we offer to students. Co-op programs, immersion programs, practicum experiences, apprenticeship models and the like, expose students to the context and practice of professional engineering. We can hope that these experiences will expose students to both traditional and innovative approaches, to approaches which are common and those which are outstanding, and to both broad and narrow ways of seeing problems and solutions. We should also hope, perhaps even expect, that students will be exposed to effective and ineffective practices, to approaches which further sustainable development and those that do not, and that they can tell the difference.

Unless a tension exists, unless engineering students are aware of and disturbed by the disparity between the real and the ideal, we take the risk that students' will accept beliefs, assumptions, and things as they are without question. While experience is an essential part of the learning process, it is important to guard against the negative effects of students' engineering "acculturation." Franklin (1985), expressing her observations of the effects on female students, says "It was painful for me to see how most, though not all of them, were trying so hard to become part of the 'tribe' that they were losing their own identity, their common sense, and their judgement" (p. 9). We should not be surprised if engineering students, male and female, begin to develop a new identity and new kinds of "common sense" and judgement. We should be concerned, however, if as a consequence of working hard to enter and maintain a place in the engineering milieu, students (and practicing engineers) become less rather than more critical and reflective of their own practice.

Students, educators and practicing engineers alike must seek out opportunities to have their assumptions challenged and guard against meek or resigned acceptance of beliefs and practices that can and should be changed. Awareness and understanding cannot be taken for granted. It has to be cultivated through reflection and then translated into action. Taking time is the key. Reflection takes time. Learning takes time. Everything I have talked about which can contribute to a more sustainable world takes time. "While we must be patient . . . we must also be serious about our intention to learn and take time to make more learning settings available" (Boulding, 1988, p. 162). There will be difficulties and obstacles on the path to achieving sustainability. We cannot ignore them or put them aside merely because they are hard to overcome. So what do we do in the meantime? Of course many of my answers to that question have already been outlined in the recommendations section of this dissertation. Milbrath (1989) suggests:

> We do not need to sit idly by. Some people achieve a sense of satisfaction by becoming politically active. Another tactic is to do everything we can to promote social learning. We can try to reorient or redesign our institutions so that they learn more readily. We can study and do research. We can speak up against injury, foolishness, selfishness, injustice, waste, and tyranny. (pp. 379-380)

We can also identify learning and action settings – family, neighborhood, community centers and events, workplace, organizations, places we shop, and so forth. We can try to help our friends, neighbors and colleagues to think anew about things. If we want to achieve sustainability, we must participate in guiding and facilitating change; we cannot shrink from this responsibility.

In the near future, I will continue to seek to strengthen the sense of professionalism among engineers by facilitating change in the ways engineers look at problems and the ways they enact professional responsibilities, by encouraging engineers to take broader kinds of responsibilities, and by helping to enable them to meet and enforce the standards of sustainable development and engineering as articulated in this dissertation. I know that engineers often look askance at, and can be somewhat suspicious of, non-engineers. Since I am not an engineer I can only hope that my arguments are presented sensitively enough and are sufficiently convincing that engineers will be open to hear and reflect on what I have said, and that they will be motivated to take action.

Presenting arguments in favor of the maintenance of professional status of engineers is another task I see ahead. In this case, not being an engineer may give me some advantage; people are less likely to assume a bias they might attribute to a professional engineer. We must all be prepared to question our own beliefs and behaviors and interrogate our assumptions about technology, development and the environment. Next steps may include: (a) increasing non-engineers' understanding of the role professional engineers can play in furthering sustainable development; (b) pointing out the dangers of diluting the profession; and (c) further encouraging the development of ways for non-engineers and professional engineers to work together for their mutual benefit and increased benefits to us all.

My final words must be set apart from the rest. Overall, I hope that more and more of us will dedicate our curiosity, our will, our courage, our silences and our voices to achieving sustainability. Perhaps we will meet along the way.

Endnotes

1. Dr. Ball made this comment during my dissertation defense.
2. Information provided by Frank Willis, Director, Professional Ethics, APEGBC.

APPENDIX A

Additional Information on Library Searches
(Refer to Chapter 2: Increasing Currency of the Idea)

As an indicator of the currency of the terms of sustainability, several title and subject word searches were conducted at the University of British Columbia libraries. ***Subject word*** included subject words "sustainable," "sustainable agriculture," "sustainable communities," "sustainable development," "sustainable economic development," and "sustainable forestry." It is interesting to note that these subject words were only issued by the Library of Congress very recently. For example, the February 1993 search for subject word = sustainable, yielded 94 citations (there was one duplication in this list and 43 citations listed also appeared in the results list for title word = sustainable). Only two of the citations were dated prior to 1987; both of these were published in 1986 as a result of conferences concerned with sustainable agriculture.

Title word searches included title words "sustain," "sustained", "sustaining", "sustainable", and "sustainability." For title words "sustain," "sustained," and "sustaining," many of the citations included references to topics not directly related to the idea of sustainability explored in this paper. For example, only two of the citations listed for title word "sustain" were directly relevant; other citations included such topics as substance abuse treatment, organizational excellence, creativity and innovation, prayer meetings, etc. All citations resulting from title and subject word searches for "sustainable" and "sustainability" were directly related to the focus of this paper. Understandably, some citations appeared in more than one search.

In examining citations, it was discovered the citation lists sometimes included duplicate citations (e.g., sustainable forestry, 2 duplications; subject word sustainable, 1 duplication). The raw number of citations (i.e., not adjusted for duplication) resulting from each of these subject and title word searches is provided in the table below.

Table A-1

Number of Citations By Title/Subject Word Searches

		2.93	12.93
Subject word:	Sustainable	94	175
	Sustainable agriculture		57
	Sustainable communities		3
	Sustainable development		111
	Sustainable economic devt		44
	Sustainable forestry		23
Title word:	Sustain	11	
	Sustained	140	
	Sustaining	82	
	Sustainable	427	589
	Sustainability	55	

The relevant searches were profiled by topic area and year of publication. A sample profile and related analyses of the search for Title word = sustainable (2.93) is provided in Tables A-2 to A-5 in the following pages. These Tables are described below.

Table A-2: Profile of Citations

Table A-2 profiles the 334 citations remaining after eliminating 85 duplications and 19 undated citations and adding 11 journal citations that cross years. The numbers in boxes next to each topic area identify individual citations. Proceedings of conferences and symposia are identified by a 'P' preceding the number; journals are identified by 'J' preceding the number. To identify citations which cross topic areas, one or more asterisks (*) follow the number and indicate the number of *main* topic areas to which the citation refers. Angle brackets (< >) around a citation indicate that the citation deals with more than one topic within the main topic area in which it appears. The total number of citations referring to a main topic area, by year, are presented underneath each topic area.

Table A-3: Topic Coverage

Table A-3 shows the distribution of citations, by topic area, according to whether the citation focussed on one or more than one topic area. This provides an indication of the way in which sustainability discussions cross topic, issue or discipline areas. The totals provided at the bottom of Table A-3 summarize the number of citations which are specific to a main topic area and those that cross topic areas. (Table A-5 provides percentages.)

Table A-4: Topic Linkages

Table A-4 profiles citations in terms of number of linkages made between one main topic area and each of the other topic areas. Linkages between economics and environment dominate. A summary of these linkages by year is provided in Table A-5; a comparison of the years 1987-1992 and the years prior to 1987 is also provided. This comparison was intended to explore possible influence of the publication of the WCED report in 1987.

Table A-5: Summary Information

Table A-5 provides summary statistics Topic Coverage and Topic Linkages with particular focus on economic-environmental linkages.

The dominance of topics and of certain topics over time lends support to the key concerns and suggested seed, roots and growth of the idea of sustainable development. For example, the agriculture/food production topic appears to have received the most consistent attention over time: publications are cited each year and, prior to 1987, there are more citations listed for this topic area than for others (though numbers of citations under environment and economics run a close second and third). This lends support to the idea that sustainability notions are rooted in concern about food production. Overall, environment, economics, and agriculture/food production rank first, second and third (respectively) in numbers of citations. (It is interesting to note that, although agriculture/food production may be considered a rather narrower topic area than "environment" or "economics," it still ranked third in number of references.) Although the social issues are less well identified by topic areas arising from searches, such topic areas as human settlements, economics, and international development do capture social concerns as do some citations in other topic areas.

There are several possible explanations for the fact that social issues are less explicitly identified in titles and related subject listings of citations. One explanation may be that the idea and language of sustainability are only beginning to enter into debates about social issues (refer to human settlements/communities; education; and public involvement in Table A-2). Some might suggest that the lack of explicit mention of social concerns may be explained by the fact that the voices of developed rather than developing nations dominate the publications. While voices of developed nations do dominate publications, another explanation is that poverty, unemployment, welfare, and other social issues are so strongly linked to both economic and environmental conditions that they are subsumed by economic and environmental discussions. Closer reviews of various citations warrant this latter explanation. In sum, if the profiles of citations generated by title and subject word searches are an indication, environmental, economic, and social issues are primary in sustainable development.

Recognizing that the profiles limit indications of topic coverage to content of titles and the related subject headings provided by each citation, there is nonetheless one further observation resulting from the preparation and review of the profiles: it appears that the number of topic areas addressed by a single citation has increased. Referring once again to the profile of citations for title word "sustainable," prior to 1987 only 33% of citations covered more than one topic area and almost all of these referred to only one additional area; from 1987 on, a greater percentage (50%) of the citations addressed more than one topic area and many of these addressed three or more topic areas. This suggests and supports the idea that achieving sustainability requires attention to a number of interconnected issues and seems to suggest a greater recognition of and interest in interconnections among issues. Of particular note are the ***linkages between economics and environment over time: prior to 1987, only 10% of cross-topic citations represented economic-environment linkages; from 1987 to 1992, economic-environment linkages were indicated in 53% of cross-topic citations.*** Although the 1972 Stockholm Conference was criticized by developing nations for the dominance of developed nations' "green agenda" (BCRTEE, 1993, p. 21), that is, for the primary focus on environmental rather than economic issues, the profiles suggest that there is greater awareness of the connectedness of these issues and that the "green agenda" is not exclusive of economic concerns. (Refer to Tables A-3, A-4 and A-5 for details of topic coverage and linkages.)

Taken together with the historical review, the profiles suggest a number of things about sustainability/sustainable development. First, the origin of the idea of sustainable development is firmly located in concerns about natural resources and the environment and has a longer history than the term we now use to capture the idea. Second, achieving sustainability requires attention to environmental, economic and social issues. Perhaps more to the point, sustainable development is "concerned with the limits which nature presents to human beings [and] ... with the potential for human material development which is locked up in nature" (Redclift, 1992, p. 199). Third, given the international attention the idea has received and the rapid increase in title and subject references to sustainable, sustainability or sustainable development, there is reason to expect that sustainable development will increasingly capture the attention of various stakeholders in the human-environment enterprise.

Table A-2: Profile of Title Word=Sustainable

CONTENT AREA	1992	1991	1990	1989	1988	1987	1986
AGRICULTURE	P2/18/22/23/ 28/30**/35*/ J263/J264/ P348/391	45**/46/P68/97*/ 112/J263/J264/ P390**	94/P100*/161/ 164/P165/166**/ 178**/P191**/ P192/195/198/ J263/J264/383	P104/218/ 219*/243*/256/ J263/J264	P187/J264/ 286*	P170/289**/ 292*/	P279/309*
& food prodn	37*/			P177/257*/		291*/ 296**	
	12	8	14	9	3	5	2
HUMAN SETTLEMENTS (community)	13*/	47**/48**/58**/91*/ <105*>/392*	141/P146*/ <152*>/P162/ 183	240**/246*/ P254**/		P268***	307*/
municipalities	24/						
cities/urban devt	7/16/17*/38**/ J345/386	<105*>/<77>	144**/P149**/ <152*>			P189/	
reg. planning general	6**/<P8>/394/ 397/P401	53**/106***	145/176**	204*/		P190*	
housing	<P8>/P20*/	67/73-75/<77>					
	14	13	9	4	0	3	1
ECONOMICS/ECONOMY	3***/6**/9**/10*/ 11*/15**/26**/ 27*/29***/30**/ 31*/32**/33**/ 34*/37*/43/347*	45**/47**/48**/54*/ 66*/70**/72**/ 99*/106***/110**/ 111**/114**/117*/ 120*/ P390**/ 404*	P96*/128*/129*/ 130*/131**/132*/ 133*/P137*/144**/ 166**/169*/ 174**/181**/184*/ 188**/P191**/ 194**/196*	P172**/197**/ P201*/202*/203/ 208*/217*/219* 222*/235**/ 239**/240**/246*/ 248*/ 250**/254**/380	P253**/260*/ 262*/266**/ P274/ 280**/281**/ 282**/ 285*/	P268***/289**/291* 293**/299**	305*/
envtal acctg , assessment indicators		51*/56*/61**/98*/ 115**		206*/P211* 220*			
& trade	40/351	101**/414*					
entrepreneurs			P146*	216***			
business/taxation/lending/etc	P20*/402/	95(jobs)/118*	134*/403	247/			
	21	25	21	22	9	5	1

CONTENT AREA	1985	1984	1983	1982	1981	1980	other yrs	# citns
AGRICULTURE	311/	P306/P312/ 315	318/	320/321-*x5	P316/P322- P325/		(79):P339	
& food prodn					P327			
	1	3	1	2	6	0	1	67
HUMAN SETTLEMENTS (community)								
municipalities								
cities/urban devt	310/							
reg. planning general								
housing								
	1	0	0	0	0	0	0	45
ECONOMICS/ECONOMY		313*/		321*x5/	329*/330/	P319**/	(79):P328* (77):341*/ 342***	
envtal acctg, assessment indicators								
& trade								
entrepreneurs								
business/taxation/lending/etc								
	0	1	0	1	2	1	3	112

CONTENT AREA	1992	1991	1990	1989	1988	1987	1986
ENVT GENERAL (Rsces etc)	<4**>/6**/<9**>/ 15**/17*/26**/ 27*/29***/30**/ 31*/32**/34*/35*/ 38**/347*/399/ 405*	45**/47**/48**/ 51*/52*/54*/56*/ 59*/99*/P101**/ 102/106***/P109*/ 110**/ 111**/114**/115**/ 118*/404*/ 412*/414*/	P96*/123*/126/ 152*/160*/163/ 169*/174**/181**/ 184*/188**/ P191**/194**/ 378/417/ 423*/ P426*/	197**/199/206*/ P211*/213/ 216***/220*/ 239**/240**/ 248*/250**/ 252*/P254**/382	266**/272*/277*/ 280**/282**/ 285*/288*	290*/293**/296**/ <298*>/ 299**	304/305*/
& waste/pollution	3***/<4**>/33**	<65>/<71>/	124/167/P149**				
& impact assessment			127/	<377*>	260/P261/		
land use	<4**>/<42>/	<49>/	<178**>/	(<202*>)/<205*>/ 235**/243*/			302/
water use	<4**>/<42>/346*	<49>/ 119/120*/	136/<178**>	<205*>/	258/	P300*/	
transboundary issues (ozone +)			P100*	<215*>/			
conservation/protection/management	<9**>/10*/11*/ 12*/13*/14*/25*/	50*/53**/57/60**/ 61**/P62*/64* <65>/66*/69/70**/ <71>/72**/98*/ J384	128*/129*/130*/ 131**/132*/133*/ 134*/135/P137*/ 138/139/144**/ 196*/J384	P172**/P201*/ <202*./207/208*/ 209*/210 /212/214/<215*> / P222*/<377*>/ J384	P238**/253**/ 259*/262*/P269/ J384	P268***/<298*>/ 301*	
	27	39	38	30	16	8	3
FORESTRY	19/25*/390*	55/60**/103/113/ 390**	P93/P125/142/ 173/ 178**/395	209*/216***/237/ 252*/	P190*/P238**/	296**/297/	
	3	4	6	4	2	2	0
ENERGY	1/3***/4**	50*/70**/83/107*	131**/176**/		278*/		307*/309*
	3	4	2	0	1	0	2
SD GENERAL	9**/12*/15**/ 398/	58**/86/406/ 408/409/412*/ 415	160*/180/186/ P373/379/418/ P426*	227/230/241/ 250*/382	P253**/265/ 266**/275/276/ 287/288*/	293**/301*	
defns/principles		72**		204*/		299**/	
indicators/decision-making		59*/61**/P62*/108/ P109*/110**/ 114**/349		377*			
	4	16	7	7	7	3	0

CONTENT AREA	1985	1984	1983	1982	1981	1980	other yrs	# citns
ENVT GENERAL (Rsces etc)		313*				P319**/	(77):342***/	
& waste/pollution							(78):340	
& impact assessment								
land use							(79):P326*/ 338*/	
water use							(79):336	
transboundary issues (ozone +)								
conservation/protection/management				321*x5		332/	(79):337**	
	0	1	0	1	0	2	6	171
FORESTRY				321*x5			(79):P326*	
	0	0	0	1	0	0	1	23
ENERGY				321*x5	P317/331/		(79):337** (77):342***	
	0	0	0	1	2	0	2	17
SD GENERAL								
defns/principles								
indicators/decision-making								
	0	0	0	0	0	0	0	44

CONTENT AREA	1992	1991	1990	1989	1988	1987	1986
INTERNATIONAL DEVELOPMENT	3***/26**/29***/ 38**	101**/106***/	166**/176**/ 194**	239**/381/	238**/277*/278*/ 280*/281**/ 282**/286*	289**/290*/292*/ P300*	
	4	2	3	2	7	4	0
OTHER MISC	landscape 4**; transportation 5; poverty 393; politics 32**	architecture 107*; tourism 79/385; mining 76; transport 392*; politics 111**	ethics:P149*	tourism 216***		peace 295	
sustainable society				<250**>		P268***	
sustainable futures				217*/P44			
population	33**/405*	115**				115/	
technology	346*/	117*/			<259*>/281**		
education	14*/	52*/<63>/97*/ 416	427/	200/<250**>	<272*>/		
indigenous people	39/		423*	235**/	<272*>/		
public involve't/sector/interests	29***	53**/58**/60** 64*/91*/105*	123*	/P172**/205*			
growth	411/	81/	174**/				
law		<63>/80/	181**/188**	P197**/257*	<259*>/	298*/	
	11	20	7	9	3	4	
Actual number of citations	58	76	67	51	27	16	6

Total Citations = 427 - (85 duplications & 19 undated citations) + 11 journal citations that cross years = 334 citations profiled

KEY: #s reference citations;

P indicates proceedings of conferences, symposiums etc.; proceedings are classified by year activity occurred

J indicates citation is a journal

* indicates number of additional topic areas covered by this citation

<> indicates the citation occurs in more than one sub-topic of larger topic area

CONTENT AREA	1985	1984	1983	1982	1981	1980	other yrs	# citns
INTERNATIONAL DEVELOPMENT							(79):338*	
	0	0	0	0	0	0	1	23
OTHER MISC						politics <334>	politics:(77): 341* fisheries:(75): 343; (68):344	
sustainable society					329*	<334>)/	(79): P328* (78):340* (77):342***	
sustainable futures								
population				321*x5				
technology						P319**/	(79):337**/	
education								
indigenous people								
public involve't/sector/interests								
growth								
law								
				1	1	2	7	65
Actual number of citations	2	4	1	2	10	3	11	334

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Table A-3
Distribution of Citations for Title Word = Sustainable: Single versus Multiple Topic Coverage

Topic Area	# Citations	92	91	90	89	88	87	86	85	84	83	82	81	80	<80	TTL
Agriculture	Main topic only	9	5	10	6	2	1	1	1	3	1	1	6		1	47
	>main topic	3	3	4	3	1	4	1				1				20
	Total Citations	**12**	**8**	**14**	**9**	**3**	**5**	**2**	**1**	**3**	**1**	**2**	**6**	**0**	**1**	**67**
Human	Main topic only	9	5	4			1		1							20
Settlements	>main topic	5	8	5	4		2	1								25
	Total Citations	**14**	**13**	**9**	**4**	**0**	**3**	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**45**
Economics	Main topic only	4	1	1	3	1							1			11
	>main topic	17	24	20	19	8	5	1		1		1	1	1	3	101
	Total Citations	**21**	**25**	**21**	**22**	**9**	**5**	**1**	**0**	**1**	**0**	**1**	**2**	**1**	**3**	**112**
Environment	Main topic only	2	8	12	8	5		2						1	2	40
	>main topic	25	31	26	22	11	8	1		1		1		1	4	131
	Total Citations	**27**	**39**	**38**	**30**	**16**	**8**	**3**	**0**	**1**	**0**	**1**	**0**	**2**	**6**	**171**
Forestry	Main topic only	1	3	5	1		1									11
	>main topic	1	2	1	3	2	1					1			1	12
	Total Citations	**2**	**5**	**6**	**4**	**2**	**2**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**1**	**23**
Energy	Main topic only	1	1										2			4
	>main topic	2	3	2		1		2				1			2	13
	Total Citations	**3**	**4**	**2**	**0**	**1**	**0**	**2**	**0**	**0**	**0**	**1**	**2**	**0**	**2**	**17**
SD general	Main topic only	1	7	5	4	4										21
	>main topic	3	9	2	3	3	3									23
	Total Citations	**4**	**16**	**7**	**7**	**7**	**3**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**44**
International	Main topic only				1											1
Development	>main topic	4	2	3	1	7	4								1	22
	Total Citations	**4**	**2**	**3**	**2**	**7**	**4**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**23**
Other	Main topic only	4	7	1	2		2							1	2	19
	>main topic	7	13	6	7	3	2					1	1	1	5	46
	Total Citations	**11**	**20**	**7**	**9**	**3**	**4**	**0**	**0**	**0**	**0**	**1**	**1**	**2**	**7**	**65**
TOTAL	Main topic only	31	37	38	25	12	5	3	2	3	1	1	9	2	5	174
	>1 topic	27	39	29	26	15	11	3	0	1	0	1	1	1	6	160
	Citations	58	76	67	51	27	16	6	2	4	1	2	10	3	11	334

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Table A-4: Topic Linkages: Title Word=Sustainable

			92	91	90	89	88	87	86	85	84	83	82	81	80	<80	TTL	
AG-HS																	0	
AG-EC			1			1		1									3	
	ENV		1	1	1												3	*
	ENV-FOR-ENR-OTH	popn											1				1	*
	FOR			1													1	
	ID				1			1									2	
AG-ENV			1		1	1											3	
	FOR				1			1									2	
AG-FOR	see AG-EC-ENV-FOR & AG-ENV-FOR																	
AG-ENR									1								1	
AG-SD																	0	
AG-ID							1	1									2	
AG-OTH		law				1											1	
		educ		1													1	
HS-EC			1		1	1											3	
	ENV		1	2	1	2											6	*
	ENV-ID			1													1	*
	ENV-OTH	educ						1									1	*
HS-ENV	see also HS-EC-ENV		2		1												3	
	ID		1														1	
	OTH	ethics			1												1	
		public		1													1	
HS-FOR								1									1	
HS-ENR									1								1	
	ID				1												1	
HS-SD						1											1	
	OTH	public		1													1	
HS-ID	see HS-EC-ENV-ID & HS-ENV-ID																	
HS-OTH		public		2													2	
		transport		1													1	
	see also HS-EC-ENV-OTH , HS-ENV-OTH, HS-SD-OTH																	
EC-ENV	see also AG-EC-ENV & HS-EC-ENV		6	10	12	8	3		1		1						41	*

			92	91	90	89	88	87	86	85	84	83	82	81	80	<80	TTL	
	ENR			1	1												2	*
	ENR-ID		1														1	*
	FOR-OTH	tourism				1											1	*
	SD		2	4		1	2	2									11	*
	ID		1	1		1	2										5	*
	ID-OTH	public	1														1	*
	OTH	tech													1		1	*
		public				1											1	*
		law			2	1											3	*
		indig				1											1	*
		growth			1												1	*
		politics	1	1													2	*
		popn	1	1													2	*
EC-FOR	see AG-EC-ENV-FOR, AG-EC-FOR & EC-ENV-FOR																	
EC-ENR	see EC-ENV-ENR																	
EC-SD	see EC-ENV-SD																	
EC-ID	see AG-EC-ID, HS-EC-ENV-ID, & EC-ENV-ENR-ID & EC-ENV-ID																	
	OTH	tech					1										1	
EC-OTH		sus.soc												1		1	2	
	see also HS-EC-ENV-OTH	politics														1	1	
		sus.fut				1											1	
		tech		1													1	
ENV-FOR			1			2										1	4	
	see also AG-EC-ENV-FOR, AG-ENV-FOR & EC-ENV-FOR																	
	ID						1										1	
	ENR-OTH	sus.soc														1	1	
	OTH	public		1													1	
ENV-ENR	see also EC-ENV-ENR			1													1	
	OTH	tech														1	1	
		landscap	1															
ENV-SD			1	4	2	1	1										9	
ENV-ID							1	2								1	4	

			92	91	90	89	88	87	86	85	84	83	82	81	80	<80	TTL
	see also HS-EC-ENV-ID, HS-ENV-ID, & EC-ENV-ENR-ID, EC-ENV-ID, ENV-FOR-ID																
ENV-OTH		law						1									1
		tech/law					1										1
		tech	1														1
		indig			1												1
		ed/indig					1										1
		educ	1	1													2
		public		1	1	1											3
		popn	1														1
	see also HS-EC-ENV-OTH, HS-ENV-OTH & EC-ENV-FOR-OTH, EC-ENV-ID-OTH, EC-ENV-OTH,																
	& ENV-FOR-ENR-OTH, ENV-ENR-OTH																
FOR-ENR	see ENV-FOR																
FOR-SD																	0
FOR-ID	see ENV-FOR																
FOR-OTH	see EC-ENV-FOR-OTH, , ENV-FOR-OTH																
ENR-SD																	0
ENR-ID	see also HS-ENR-ID & EC-ENV-ENR-ID						1										1
ENR-OTH		architec		1													1
	see also AG-EC-ENV-FOR-ENR-OTH, ENV-FOR-ENR-OTH, & ENV-ENR-OTH																
SD-ID																	0
SD-OTH	see HS-SD-OTH																
ID-OTH	see EC-ENV-ID-OTH, EC-ID-OTH																

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Table A-5: Summaries of Cross-Topic and Linkage Information

	92	91	90	89	88	87	86	85	84	83	82	81	80	<80	TTL	
Summary of Cross-Topic Information																
Number of citations crossing topic areas	27	39	29	26	15	11	3	0	1	0	1	1	1	6	160	
Total number of citations	58	76	67	51	27	16	6	2	4	1	2	10	3	11	334	
% crossing topic areas	47	51	43	51	56	69	50	0	25	0	50	10	33	55	48	%
% crossing topics: 1987-1992 & prior to 1987						50								33		%
Linkages between Environment & Economics Topic Areas																
Total # of economic-environment linkages	15	22	16	15	7	3	1	0	1	0	1	0	1	0	82	*
% linkages in cross-topic citations	56	56	55	58	47	27	33	0	100	0	100	0	100	0	51	*%
% linkages 1987-1992 & prior to 1987						53								10		*%

Appendix B: Sustainable Development Principles: A Sample of Sources

ref	human needs	ref	ecol integrity	ref	equity/soc justice	ref	particn/coopn
	Barnaby 88		Barnaby 88		Barnaby 88	E	Andrews 91
TD	Borgmann 84	•	*BCTFEE 89	•	*BCRTEE 92		Barnaby 88
•	*BCRTEE 92	•	*BCRTEE 90, 92	$	Daly 77		Bartlett & Baber 89
•	*BCTFEE 89	M	Burhoe 73	•	*Envt Canada 90		Bartlett 89a,89b
M	Burhoe 73		Capra 88	•	*FAO 92		Barto 90
•	*FAO 92	$	Daly 77	T	Franklin 90	TD	Borgmann 84
E	Devall & Sessions 85	E	Devall & Sessions 85	•	*Garbarino 88	•	*BCTFEE 89
•	*Envt Canada 90	E	Drengson 80	•	*Gardner 89	E	Drengson 80
•	*Garbarino 88	•	*Envt Canada 90	•	*Gardner & Roseland 89	•	*Envt Canada 90
•	*Gardner 89	•	*Faby 84	•	Goodland et al 92	•	*Faby 84
•	*Gardner & Roseland 89	•	*FAO 92	E	Heinegg 79	•	*FAO 92
•	Goodland et al 92	T	Franklin 90		Henderson, 78,88	T	Franklin 90
E	Heinegg 79	•	*Garbarino 88	•	*Jacobs et al 87	•	*Gardner 89
E	IUCN 80	•	*Gardner 89	•	*Jenkins & Codner 90	•	*Gardner & Roseland 89
•	*Jacobs et al 87	•	*Gardner & Roseland 89	•	*Manning 90		Henderson, 78,88
•	*Jenkins & Codner 90	E	Heinegg 79	C	Mendlovitz 77	E	IUCN 80
•	*Khosla 87		Henderson, 78,88	•	Milbrath 89	•	*Jacobs et al 87
	Leiss 78	E	IUCN 80	•	*Nalder 91	•	*Jenkins & Codner 90
	McHale & McHale 78	•	*Jacobs et al 87	•	*NTFEE 87	•	*Khosla 87
•	*Manning 90	•	*Jenkins & Codner 90	•	*Nelson 82, 90	O	Kotter 86
•	*NTFEE 87	•	*Khosla 87	$	Newton 90	E	Langton 84
OP	Pasmore 88	•	*Manning 90	E	Oelhaf 79	M	Laszlo 73
TS	Rickover 72	C	Mendlovitz 77	P	Parenteau 88	•	*Manning 90
TD	Sibley 66	C	Morrison 76	•	*Redclift 87	C	Mendlovitz 77
•	*Simonis 90	•	*Nalder 91	TS	Rickover 72	•	*Milbrath 89
•	*WCED 87	•	*NTFEE 87	•	*Ruitenbeek & Fields 92	•	*Nelson 82, 90, 91a
		•	*Nelson 82,90,91a	•	*Sadler & Hull 90	P	Parenteau 88
		$	Newton 90	ET	Schnaiberg 85	OP	Pasmore 88
		•	*Redclift 87		Schrader-Frechette 89	•	*Ruitenbeek & Fields 92
		•	*Rowe 90	•	*Simonis 90	•	*Sadler & Hull 90
		•	*Ruitenbeek & Fields 92	C	Starr 77		Schrader-Frechette 89
			Russell 83	•	* WCED 87	DT	Sclove 91
		•	*Sadler & Hull 90			TD	Sibley 88
		•	*Shiva			O	Srivasta et al 86
		E	Wandesforth-Smith 89			O	Srivasta & Barrett 86
		E	Watts et al 81			E	Wandesforth-Smith 89
		•	*WCED 87			E	Watts et al 81
						•	* WCED 87

Please note:
All sources listed incorporate more than one of the sustainable development principles in their discussions

- • Sources which specifically refer to sustainability/sustainable development
- C Civilization/society
- D Democracy
- E Environment, eco-philosophy, environmental ethics
- M Systems, systems modelling
- O Organizational literature
- P Participation, cooperation
- T Technology
- $ Economics

ref	orgnal sys/struc	ref	approp technol	ref	quality (growth/life)
E	Andrews 91		Barnaby 88		Barnaby 88
	Bartlett & Baber 89	TD	Borgmann 84	TD	Borgmann 84
TD	Borgmann 84		Commoner 90	•	*BCTFEE 89
	Boulding 88	T	Cutcliffe 92 (series in)	$	Daly 77
•	*BCRTEE 90,92	T	DeGregori 85	•	*Envt Canada 90
$	Daly 77	E	Devall & Sessions 85	$	*Faby 84
E	Devall & Sessions 85	E	Drengson 80	•	*Gardner 89
E	Drengson 80	•	*Faby 84	•	*Gardner & Roseland 89
•	*Envt Canada 90	T	Franklin 90	•	Goodland et al 92
T	Franklin 90	•	*Garbarino 88		Henderson, 78,88
•	*Garbarino 88	•	*Gardner 89	E	Kuhn & Johnson 89
•	*Gardner 89	•	*Gardner & Roseland 89	E	IUCN 80
•	*Gardner & Roseland 89	•	Goodland et al 92	•	*Jenkins & Codner 90
E	Heinegg 79		Henderson, 78,88	•	*Manning 90
•	*Jacobs et al 87	•	*Hyde 92	•	*Milbrath 89
•	*Jenkins & Codner 90	•	*Jacobs et al 87	S	Morrison 76
EO	Johnson 81	•	*Jenkins & Codner 90	E	Oelhaf 79
•	*Khosla 87	•	*Khosla 87	•	*Redclift 87
O	Kotter 86	E	Langton 84	•	*Ruitenbeek & Fields 92
E	Langton 84	M	Laszlo 73	•	*Simonis 90
•	*Manning 90	EP	Nelson 82	C	Starr 77
C	Mendlovitz 77	$	Newton 90	•	* WCED 87
•	*NTFEE 87	E	Potter & Norville 81		
•	*Nelson 82, 90, 91a		Randolph 92		
$	Newton 90	TS	Rickover 72		
E	Oelhaf 79	•	*Ruitenbeek & Fields 92		
OP	Pasmore 86	•	*Sadler & Hull 90		
•	*Redclift 87	ET	Schnaiberg 85		
TS	Rickover 72	DT	Sclove 91		
•	*Ruitenbeek & Fields 92	TD	Sibley 66		
•	*Sadler & Hull 90	•	*Simonis 90		
911	Schrader-Frechette 89	ET	Skolimowski 91		
DT	Sclove 91	C	Starr 77		
TD	Sibley 66	TS	Whelchel 86		
•	*Simonis 90	•	*WCED 87		
O	Srivasta & Barrett 86				
C	Starr 77				
E	Wandesforth-Smith 89				
E	Watts et al 81				
•	* WCED 87				

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Appendix C: Characteristics of the APEGBC Population and Study Participants

	Population		Questionnaires		Interviews		Focus Groups	
	N	%	N	%	N	%	N	%
Disciplines								
Civil	3800	27.61%	168	32.75%	11	36.67%	19	33.33%
Mechanical	2660	19.32%	116	22.61%	** 5.5	18.33%	8	14.04%
Electrical	2424	17.61%	80	15.59%	5	16.67%	5	8.77%
Other*	3633	26.39%	135	26.32%	** 8.5	28.33%	12	21.05%
Uncoded/missing	1248	9.07%	14	2.73%	0	0.00%		
Special focus							*** 13	22.81%
Total	13765		513		30		57	

* members included in other discipline categories range from 1-837 (.01-6.08%) per discipline area
** in 4 cases, 2 discipline areas were identified (e.g., civ/chem); each was counted as .5
*** a special focus group for geoscientists was held to ensure their voice as new members of the Association

Year of Graduation	Population		Questionnaires		Interviews		Focus Groups	
1911-1920	3	0.02%		0.00%				
1921-1930	69	0.53%	2	0.39%				
1931-1940	337	2.58%	8	1.56%				
1941-1950	1291	9.88%	49	9.55%	2	6.67%	3	5.26%
1951-1960	1967	15.06%	99	19.30%	8	26.67%	5	8.77%
1961-1970	3116	23.86%	123	23.98%	12	40.00%	26	45.61%
1971-1980	3408	26.09%	115	22.42%	5	16.67%	8	14.04%
1981-1990	2871	21.98%	109	21.25%	3	10.00%	14	24.56%
missing			8	1.56%			1	1.75%
Total	13062		513		30		57	

Gender	Population		Questionnaires		Interviews		Focus Groups	
Male	N/A	est 96%	492	95.91%	28	93.33%	45	78.95%
Female	N/A	est 4%	16	3.12%	2	6.67%	* 12	21.05%
Missing			5	0.97%				
Total			513		30		57	

* a special focus group for women was held

Age	Population		Questionnaires		Interviews		Focus Groups	
0-35	N/A	N/A	119	23.20%	4	13.33%	16	28.07%
36-45	N/A	N/A	125	24.37%	4	13.33%	10	17.54%
46-55	N/A	N/A	112	21.83%	12	40.00%	17	29.82%
56-65	N/A	N/A	86	16.76%	6	20.00%	11	19.30%
66+	N/A	N/A	56	10.92%	1	3.33%		0.00%
missing			15	2.92%	3	10.00%	3	5.26%
Total			513		30		57	

Population data (effective May, 1991) was provided by the APEGBC.

Appendix D

SUSTAINABLE DEVELOPMENT QUESTIONNAIRE

F ☐☐☐☐

CUT HERE

We would like to get some idea of what you are thinking about sustainable development and ask that you complete the following questionnaire and return it to the APEGBC office (by mail or FAX) by July 2, 1991. Thank you for your participation.

For the purposes of this study, we do need some information on your background. No attempt will be made to identify you personally.

Please enter your responses to the following in the boxes provided.

Gender: If male, enter '0'; if female, enter '1' ☐ Age: ☐☐

Year engineering degree completed: 19 ___ ☐☐

Approximate number of university non-technical/ non-science courses taken ☐☐

Please answer the following on the lines provided:

My degree was in ____________ (eg, civil, mining, etc)

My practice is mostly in __________ (eg, civil, mining, etc)

The most common types of work/projects in which I engage include:

____

On average, I supervise approximately ______ employees.

The following statements pertain to your thoughts and attitudes about sustainable development. Unless otherwise directed*, please indicate whether or not you agree with each statement by using the following scale and placing the appropriate scale number in the box to the left.

1	2	3	4	5	6	7
strongly agree			neither agree or disagree			strongly disagree

☐ 1. I am very familiar with the contents of the Brundtland Report and/or other similar reports.

☐ 2. Sustainable development means ensuring policies and practices support economic growth and development projects and land uses.

☐ 3. Sustainable development means protecting environmental quality while permitting economic development.

☐ 4. Sustainable development means recognizing limits to growth, population and consumption and learning to do better with less.

☐ *5. If you had to pick *only one* of the above 3 statements to represent what you believe, which would it be? Please put the number of the statement (2, 3 or 4) in the box at the left.

☐ *6. Several strategies have been suggested to address sustainable development. Of the following, which do you think needs most attention? 1) Resource management; 2) development of controls and safeguards; 3) altering consumption expectations and behaviors. Please put the number of your choice in the box at the left.

7. As engineers we are responsible for the technical adequacy of our engineering work. In order to foster sustainable development, we also have a professional responsibility to:

☐ a) formulate sustainable development **guidelines** for engineering practise

☐ b) support and/or promote **economic** development

☐ c) account for the **environmental** effects of our engineering work

☐ d) account for the **social** effects of our engineering work

☐ e) participate in formulating appropriate codes, legislation and policy *in society in general*

☐ f) actively work to increase **public awareness** of engineers' role in improving the quality of life and in protecting the environment

☐ g) participate in **professional development** opportunities related to the broader (not specifically technical) issues of sustainable development

☐ 8. Our Code of Ethics requires "proper regard for the safety, health and welfare of the public." Current environmental awareness has expanded this concept and we are now bound to consider the effect of our work and its by-products **beyond immediate users.**

☐ 9. The Engineering *Association* should take responsibility for establishing a set of membership guidelines for sustainable development (assuming that such guidelines are subsequently accepted and endorsed by the membership)

☐ 10. Assuming sustainable development is achievable, it is achievable in BC without considering events outside BC.

☐ 11. Inherent in sustainable development are a number of concerns. I am well prepared to address:

	by virtue of my formal education	experience
a) the environmental concerns	☐	☐
b) the economic concerns	☐	☐
c) the social concerns	☐	☐
d) the technical concerns	☐	☐

☐ 12. I would be willing to pay higher annual fees to support sustainable development efforts.

Please cut out the completed survey and MAIL or FAX to: F S Crofton, APEGBC, 2210 W 12th, Vancouver, BC V6K 2N6 FAX: 736-2984. BY JULY 2, 1991. Thank you for your participation.

Appendix E:

Interviews/focus group Discussion Guide

Interviews and focus groups will attend to the content of the questionnaire, however, in order to ensure that respondents are not biased by what we have determined to be the issues of importance, nor overly directed by our questions, I propose a more open-ended topical discussion as follows:

1. (a) What led you to agree to participate in this study?

   (b) Have you had particular experiences that motivated your interest in this topic area? If so, what were they?

2. (a) What do you perceive to be the essential issues of sustainable development? What factors promote or limit the achievement of sustainability?

   (b) Given the issues you've identified, how would you define sustainable development?

3. (a) What knowledge, skills or training do you think are needed to address the issues of sustainable development?

   (b) How can engineers participate? What skills do they offer? What additional areas of education/training might assist engineers in participating?

   (c) How can engineers assist in the integrated & inter-agency decision-making required to achieve sustainable development?

4. One way the Task Force has proposed to address Sustainable Development is by the formulation of guidelines for the membership.

   (a) Is this a direction you support? Why or Why not?

   (b) What would you want to see included in such guidelines? What concerns would you have?

   The Task Force has attempted to draft some guidelines. Please take some time now to review these.

   (c) What do you like about the guidelines that have been formulated? What concerns do you have?

5. Are there any other comments/suggestions/questions you have that have not yet been addressed?

Appendix F:
APEGBC Focus Group Participants Background Information

Focus Group #1: Kelowna n=9

Discipline	Grad Yr	Gender	Age
civil	56	m	61
civil	58	m	56
civil	78	m	36
civil	69	m	47
civil	69	m	55
civil	75	m	38
elec	55	m	60
civil	84	m	35
civil	79	m	38

Focus Group #2: n=9

Discipline	Grad Yr	Gender	Age
chem	67	m	na
chem	89	m	30
civil	88	m	30
forestry	48	m	65
industrial	65	m	48
mech	80/85	m	33
metal	65	m	49
mining	48	m	64
mining	55	m	62

Focus Group #3: Geoscientists n=13

Discipline	Grad Yr	Gender	Age
geol	62	m	50
geol	63	m	49
geol	66	m	46
geol	66	m	48
geol	65	m	50
geol	60	m	51
geol	64	m	62
geol	62	m	50
geol	69	m	45
geol	55	m	58
geol	na	f	38
geop	67	m	60
mining	66	m	47

Focus Group #4: n=9

Discipline	Grad Yr	Gender	Age
civil	74	m	39
civil	84	m	28
civil	63	m	52
civil	54	m	58
civil	68	m	48
civil	48	m	65
mech	72	m	42
mech	87	f	28
chem	66	m	47

Focus Group #5: Women Only n=10

Discipline	Grad Yr	Gender	Age
bio-rsce	89	f	26
geop	86	f	28
bio-rsce	89	f	28
civil	61	f	54
metal	70	f	43
mech	80	f	33
mech	66	f	50
mech	89	f	25
chem	86	f	28
elec	74	f	na

Focus Group #6: n=7

Discipline	Grad Yr	Gender	Age
civil	83	m	30
chem	84	f	31
elec	90	f	25
civil	86	m	29
geol	70	m	42
geol	70	m	42
civil	61	m	na

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