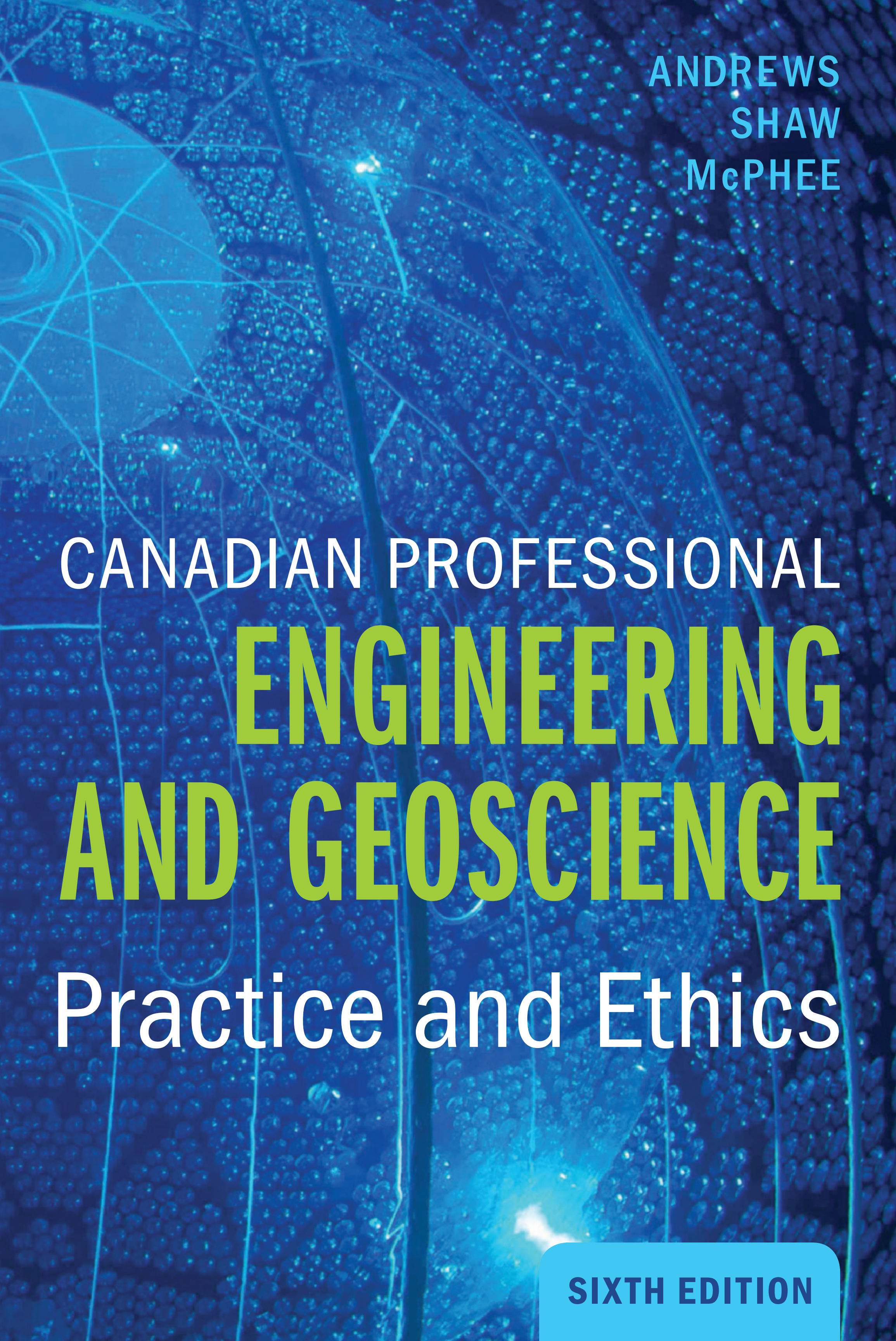

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CANADIAN PROFESSIONAL ENGINEERING AND GEOSCIENCE

Practice and Ethics

SIXTH EDITION

CANADIAN PROFESSIONAL

ENGINEERING AND GEOSCIENCE

Practice and Ethics

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SIXTH EDITION

Gordon C. Andrews
University of Waterloo
Patricia Shaw
MotionPro Inc.
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University of Waterloo

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IN MEMORIAM

Gordon C. Andrews
(1937–2014)

Gordon C. Andrews spent 33 years of his career as a professor at the University of Waterloo. I had the privilege of working with him as a master's student, and later as his colleague and co-supervisor of Ph.D. students. Gord came to the University of Waterloo in 1968 with several years of engineering experience with the Royal Canadian Air Force and The Boeing Company. Throughout his career at Waterloo, he collaborated with companies such as Rapid Gear, Eagle Press, Diemaco, and Redpath Industries; these projects became case studies in the machine design courses he taught. He was extremely gifted at covering the theoretical basis for machine design, followed up by personal experiences with real-world applications. Students loved his approach to teaching, and Gord enjoyed some of the highest teaching evaluations from students in Waterloo Engineering.

Gord took his teaching a step further, with classroom discussions of the ethical implications of the decisions made by engineers. His interest in professional engineering practice and ethics was so great that he eventually wrote a textbook on the subject—the one you are now reading.

His personal interest in ethical behaviour guided him during his many years of administrative service to the university. He served on the Board of Governors for 11 years and on the University of Waterloo Senate for 12 years, where he was always an outspoken defender of the rights of students and professors, especially academic freedom of speech. It was natural that Gord should become president of the Faculty Association of the University of Waterloo, where he worked tirelessly to protect the rights of academics.

In terms of research, Gord was an inspiration to many of us working in the field of machine design. He was a pioneer in the use of mathematical graph theory and computers, and their application to dynamic analysis. Today, the

Photo Credit: University of Waterloo Library, Special Collections & Archives/University of Waterloo Archives ideas that he proposed are embedded into software programs that are used by thousands of engineers who are designing robots, airplanes, automobiles, and other mechatronic systems.

It was a privilege to have studied and worked with Gord, and a great honour to contribute to the newest edition of this textbook.

—John McPhee, Professor
Systems Design Engineering
University of Waterloo, Ontario, Canada

ABOUT THE COVER AND FRONTISPIECE

The cover and frontispiece illustrate Canadian engineering and geoscience achievements, which range from the ocean floor to outer space.

COVER—SUDBURY NEUTRINO OBSERVATORY

The cover shows the Sudbury Neutrino Observatory (SNO), a complex feat of engineering that has generated scientific discoveries that have changed our fundamental understanding of the nature of matter.

Nobel Prize winner Dr. Arthur McDonald has provided the following description of the engineering and science behind the SNO facility. “The detector . . . was built 2 km under ground, in INCO’s Creighton mine near Sudbury, Ontario, Canada. SNO was a heavy-water Cherenkov detector designed to detect neutrinos produced by fusion reactions in the sun. It used 1000 tonnes of heavy water loaned from Atomic Energy of Canada Limited (AECL), and contained by a 12 meter diameter transparent acrylic vessel. Neutrinos reacted with the heavy water (D2O) to produce flashes of light called Cherenkov radiation. This light was then detected by an array of 9600 photomultiplier tubes mounted on a geodesic support structure surrounding the heavy water vessel. The detector was immersed in light (normal) water within a 22 meter diameter by 34 meter high barrel-shaped cavity (the size of a 10 story building!) excavated from Norite rock. Located in the deepest part of the mine, the overburden of rock shielded the detector from cosmic rays. The detector, with the heavy water replaced by liquid scintillator, is continuing as the SNO+ experiment in the new SNOLAB facility. The laboratory and detector are extremely clean to reduce background signals from radioactive elements present in the mine dust which would otherwise hide the very weak signals from neutrinos and the rare radioactive process known as neutrino-less double beta decay.”[1]

[1]http://www.queensu.ca/physics/arthur-b-mcdonald

FRONTISPIECE—THE CONFEDERATION BRIDGE

The frontispiece is a photograph of the Confederation Bridge, which opened to traffic in May 1997 and links New Brunswick and Prince Edward Island across the Northumberland Strait. The bridge is 12.9 km (8 miles) long, which makes it the world's longest saltwater bridge subject to ice hazards. Strait Crossing Inc. of Calgary, Alberta, designed the Confederation Bridge to survive the harsh climate of the Northumberland Strait for at least a century. The bridge has two highway traffic lanes (and emergency shoulders). The distinctive arches provide a clearance of 60 m (197 ft.) for seagoing vessels. The bridge approach on Prince Edward Island has seven spans (totalling 580 m; 1,903 ft.); the central bridge portion has 44 spans (11 km; 7 miles); the bridge approach in New Brunswick has 14 spans (1,300 m; 4,265 ft.). The water is as deep as 35 m (115 ft.) at the support piers, which are protected by conical ice shields to resist the severe scouring of floating ice. For further information, travel advisories, tolls, current weather, wind speed, and a photo gallery, see the Confederation Bridge website at www.confederationbridge.com.

ABOUT THE AUTHORS

Dr. Gordon C. Andrews, P.Eng., was a professor emeritus of the Department of Mechanical and Mechatronics Engineering at the University of Waterloo. He was a graduate of the Royal Military College (B.Sc.), the University of British Columbia (B.A.Sc., M.A.Sc.), and the University of Waterloo (Ph.D.). He was a licensed Professional Engineer (Ontario), certified to provide engineering advice to industry. He worked on many engineering projects in machine design, dynamics (projectiles and vehicles), and gear train strength analysis. Prior to his doctoral studies, he served as an engineering officer in the Royal Canadian Air Force and as a stress analyst at the Boeing Airplane Company on the Boeing 747 design team.

During his career, Dr. Andrews taught university courses from first year to graduate level in machine design, dynamics, kinematics, and computer-aided design. He was the author or co-author of more than one hundred publications, including journal papers, conference papers, technical reports, manuals, and two textbooks. He developed the Vector-Network Method that applies graph theory techniques to computer formulation of equations of motion of dynamic systems. A paper describing the theory received the Best Paper award at the 19th Mechanisms Conference of the American Society of Mechanical Engineers (1986). He was retained as an expert witness in 10 legal cases involving engineering failures.

Dr. Andrews was a member of the Academic Requirements Committee of Professional Engineers Ontario (PEO); for several years, he set and graded the PEO licensing exam in Advanced Machine Design. Dr. Andrews also served for many years on the Senate and Board of Governors of the University of Waterloo.

Patricia Shaw, P.Eng., is a mechanical engineer and a graduate of Queen's University in Kingston, Ontario (B.A.Sc.). She is a licensed Professional Engineer in Ontario, where she has worked as a project engineer for Monenco and as a sales engineer for Quadro Engineering Corporation of Waterloo. At Monenco, she developed engineering designs and analyses of co-generation facilities; she also worked on the construction planning for the Sudbury Neutrino Observatory, pictured on the cover. Ms. Shaw is currently the president of a software engineering company, MotionPro Inc.

Dr. John McPhee, P.Eng., is a Canada Research Chair and professor in Systems Design Engineering at the University of Waterloo. He is a graduate of Acadia University (Cert.A.Sc.), the Technical University of Nova Scotia (B.A.Sc.), and the University of Waterloo (M.A.Sc., Ph.D.). He is a licensed Professional Engineer (Ontario) and a Fellow of the Engineering Institute of Canada, the Canadian Society of Mechanical Engineers, and the Canadian Academy of Engineering. He has collaborated with many industry partners on dynamics and control, including Toyota, Maplesoft, Magna, Multimatic, Cleveland Golf, aboutGolf, the Canadian Space Agency, Bombardier, and the Canadian Sport Institute Ontario. Dr. McPhee has published more than 250 peer-reviewed papers, supervised 80 graduate students and researchers, and served as an expert witness to the Federal Court of Canada. In 2014, he received the Natural Sciences and Engineering Research Council of Canada (NSERC) Synergy Award for Innovation from the Governor General of Canada.

PREFACE

This textbook introduces readers to the structure, practice, and ethics of the engineering and geoscience professions in Canada. It is a comprehensive reference for practising professionals, recent graduates, senior undergraduates, and immigrants who want to practise engineering or geoscience in any province or territory. This book is the recommended study guide for the practice and ethics part of the Professional Practice Examination (PPE) required for licensing in every province and territory. The five parts of the book cover all practice and ethics topics recommended by the Engineers Canada syllabus and also offer personal advice to help readers quickly become effective professionals.

ORGANIZATION AND OUTLINE

Part One: Professional Licensing and Regulation

Part One describes the history, structure, and administration of engineering and geoscience in Canada, including academic and experience requirements; the licensing process, the licensing Acts (or laws); the Associations that enforce those Acts; and how the Associations discipline unethical, negligent, or incompetent practitioners.

- **Chapters 1 and 2, "Introduction to the Professions" and "Regulation of Engineering and Geoscience,"** describe many inspiring achievements of both professions and explain how two tragic cases—the Quebec Bridge collapse and the Bre-X fraud—led to demands for effective licensing.
- **Chapter 3, "Disciplinary Powers and Procedures,"** defines professional misconduct and the disciplinary process. The chapter includes five discipline case studies and closes with the case history of the Elliot Lake Algo Centre rooftop parking lot collapse.

Part Two: Professional Practice

These five chapters give essential, basic, practical knowledge needed by professionals.

- **Chapter 4, "Basic Concepts of Professional Practice,"** describes professional working conditions, salary expectations, responsibility levels, promotion options, and the significance of the professional seal and how and when to use it.
- **Chapter 5, "Consulting, Private Practice, and Business,"** describes private practice and business as career options and explains licensing, business formats, assistance available, and the Qualifications-Based Selection (QBS) process for consultants.
- **Chapter 6, "Hazards, Liability, Standards, and Safety,"** urges professionals to avoid hazards and liability by following standards. The chapter also discusses occupational health and safety (OHS) legislation and two key case histories—the Rivtow Marine and the Westray Mine—in which unsafe practices led to loss and death.
- **Chapter 7, "Computers, Software, and Intellectual Property,"** explains liability and ethics problems related to computers, commercial software, and software piracy. The chapter briefly summarizes intellectual property laws—copyright, patents, industrial designs, integrated circuits, and trademarks. The Therac-25 radiation therapy accidents, the Hartford Arena collapse, and various instances of patent infringement are featured in four case histories.
- **Chapter 8, "Diversity in the Professional Workplace,"** explains that diversity enhances a work environment and that harassment and discrimination are unacceptable and illegal under the Canadian Criminal Code and human rights legislation. Three illustrative case studies follow.

Part Three: Professional Ethics

These four chapters explain the basic principles of ethics and justice, and how to apply them to common employment situations. The principles are illustrated in many case studies and case histories.

- **Chapter 9, "Principles of Ethics and Justice,"** explains four well-established ethical theories and the basic principles of justice. The chapter discusses the Codes of Ethics mandated by the licensing Associations and proposes a six-step strategy for solving ethical problems. The chapter describes the classical ethical "trolley dilemma" and illustrates it with an occurrence of the dilemma in the Second World War.
- **Chapter 10, "Ethics Concepts and Cases: Employment,"** examines typical ethics issues such as conflicts of interest, union activities, and dishonest managers. The chapter includes seven case studies, plus the history of the *Challenger* space shuttle—a disaster that occurred when a manager overruled an engineer's advice.

- **Chapter 11, "Ethics Concepts and Cases: Management,"** examines management issues, such as hiring, dismissal, performance review, conflict of interest, and adhering to the licensing Act. Six case studies, plus the history of the Vancouver Second Narrows Bridge collapse, illustrate the concepts.
- **Chapter 12, "Ethics Concepts and Cases: Consulting,"** examines ethics in consulting, such as client–consultant relationships, advertising, competitive bidding, confidentiality, and conflict of interest. Seven case studies are included, as well as the inspiring story of consultant William LeMessurier and the Citicorp Tower.

Part Four: Environmental Practice and Ethics

These chapters encourage sustainable thinking by showing that ignoring the professional duty to protect the environment can lead to disaster.

- **Chapter 13, "Environmental Ethics,"** reviews the professional's duty to protect the environment, the various laws and guidelines that apply, and the duty to report unethical behaviour (often called "whistle-blowing"). It includes a brief description of the negligence that led to the sinking of the Ocean Ranger floating oilrig.
- **Chapter 14, "Environmental Threats and Disasters,"** surveys the many threats to the environment. The chapter includes four histories of toxic pollution and three histories of nuclear disasters, all instances in which negligent practices led to tragedy.
- **Chapter 15, "Environmental Sustainability,"** defines sustainability and gives a brief history of climate change and the depletion of fossil fuels. It suggests how to make our lifestyle sustainable and discusses the ethical dilemma posed by the oil sands.

Part Five: Obtaining and Maintaining Your Professional Status

All Acts require professionals to pass a licensing exam and to maintain their competence. Every Association has some form of competence assurance program.

- **Chapter 16, "Writing the Professional Practice Exam,"** describes the Professional Practice Examination (PPE) syllabus and format. The chapter suggests a technique for answering ethics questions and includes 28 practice questions with answers.
- **Chapter 17, "Maintaining Your Professional Competence,"** stresses the importance of continuing professional development (CPD) in maintaining competence.
- **Chapter 18, "Benefiting from Technical Societies,"** discusses the key role of technical societies, lists many societies, and describes the Iron Ring and Earth Sciences Ring rituals that welcome new members into our professions.

FEATURES

This comprehensive textbook is a reference for practising engineers and geoscientists and is suitable for individual study or classroom use.

- The writing style is logical and readable.
- The coverage includes every province and territory in Canada.
- All chapters have been recently checked, revised, and updated.
- The chapter on environmental sustainability includes recent issues.
- More than 20 histories of actual events illustrate that unethical practices can lead to personal tragedy or disaster.
- More than 20 case studies pose realistic ethical problems and ask readers to suggest an appropriate course of action or recommend a solution.
- About 28 typical examination questions, from several provinces, assist readers who are preparing for the Professional Practice Examination.
- More than 30 photographs illustrate issues discussed in the text.
- Personal advice guides young professionals in planning their careers.
- Advice and situations show the professional as employee, manager, or consultant.
- Assignments are found at the end of each chapter, with much more on the website.

WEBSITE

The website accompanying the textbook is at nelson.com/andrews6e. The website contains more than 300 pages of additional material in six appendixes:

- **A—Links and addresses** for all provincial and territorial licensing associations;
- **B—Important excerpts** from the Acts that regulate engineering and geoscience, including Codes of Ethics, admission criteria, definitions of professional misconduct, and disciplinary powers for all provinces and territories;
- **C—Codes of Ethics** from many technical societies;
- **D—NSPE guidelines** on working conditions for professional employees;
- **E—Over 100 more assignments** and discussion topics, organized by chapter; and
- **F—Twenty-five additional case studies**, with the authors' recommended solutions.

ACKNOWLEDGMENTS

Sixth Edition

We are very grateful to everyone who patiently answered our many questions as we took over the writing of this sixth edition. In particular, we thank Elke Price, Jackie Wood, and Paul Fam of Nelson, for their tireless guidance

and support. Dr. Jennifer Boger, P.Eng., wrote the Therac-25 case history in Chapter 7. Elizabeth Shaw, P.Eng., contributed to Part Two: Professional Practice. Charlotte Dyck checked the many references for accuracy. We appreciate their significant contributions. We would also like to thank each of the reviewers who provided us with many insightful and constructive comments and suggestions: Rémi Alaurent, Concordia University; Said Easa, Ryerson University; Eldo Hildebrand, University of New Brunswick; Raj Rajan, The Professional Practice Examination Committee (PPEC); Marc Rosen, University of Ontario Institute of Technology; and Robert Stewart, The Professional Practice Examination Committee (PPEC). We also thank Greg Pope and Mohamed El Daly of APEGA, Oliver Bonham, P.Geo., of Geoscientists Canada, Alain Liard, P.Geo., of the Ordre des géologues du Québec, Nanci Lines of the Canadian Academy of Engineering, and Sarina Cotroneo of CFES for their many helpful suggestions and statistics. We are especially grateful to Isobelle Andrews and Nelson for entrusting us with Gord's legacy. Finally, we thank our children Mary, Jonah, and Michael, for their encouragement and support while we were working on this book.

Patricia Shaw and John McPhee
December 2017

FIRST FIVE EDITIONS

I am indebted to many people for assistance and advice in writing the first four editions of this textbook. The list is too long to include their affiliations, but I would like the following individuals to know I sincerely appreciate their past help: Scott Duncan, Sarah Duncan, Semareh Al-Hillal, Su Mei Ku, John D. Kemper, Ken Nauss, Grant Boundy, Stephen Jack, Georges Lozano, Wendy Ryan-Bacon, G.A. Bernard, E.R. Corneil, Dennis Brooks, John Gartner, C. Peter Jones, Harold Macklin, Gordon Slemon, Al Schuld, Kent Fletcher, Elvis Rioux, Anita Direnfeld, Larry Gill, Laurie Macdonald, Chris Lyon, Jerry M. Whiting, Norman Ball, Dr. Dick van Heeswijk, Judith Dimitriu, David Frost, Gilles Y. Delisle, Richard Thibault, Andrew Latus, Deborah Wolfe, Karen Martinson, Marie Carter, Marc Bourgeois, Dr. David Burns, the late Dr. Alan Hale, Dr. Beth Weckman, Dr. Herb Ratz, Dr. Roydon Fraser, the late Kathy Roenspiess, Evelyn Veitch, Anthony Rezek, Joanne Sutherland, Terri Rothman, Susan Calvert, Matthew Kudelka, Brian Orend, A.O. Abd El Halim, N.S.W. (Norm) Williams, Dr. Milt Petruk, Deborah Wolfe, Samantha Colasante, Marc Bourgeois, Dr. Gordon D. Williams, Wanda Howe, Stephanie Gray, the late Richard Furst, Harry McBride, the late Dennis Burningham, Dr. Dwight Aplevich, Dr. Carolyn Macgregor, Dr. Harold Davis, Steven Brown, Toivo Roht, Jon Legg, Elke Price, and Paul Fam.

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Gordon C. Andrews
May 24, 2013

CONTENTS

List of Web Appendixes

The website accompanying this textbook (nelson.com/andrews6e) consists of more than 300 pages of additional information in the following appendixes:

Chapter 1
Introduction to the Professions

Welcome to a challenging, creative, and rewarding career! Engineering and geoscience are highly respected technical professions that protect our safety, generate prosperity, and enrich our lives. This textbook is an overview and a guide for these two professions, which have very similar organizations.

The creativity of engineers and geoscientists is all around us: in the graceful structure of bridges; in the speed and accuracy of digital devices; in the rapidly advancing technology of new automobiles; and in the wealth that flows from our natural resources and manufacturing. Canada prides itself on immense open space and on resources that are envied by the world: for example, reliable electricity, a secure supply of natural gas, safe vehicles and aircraft, and a dependable supply of pure and abundant tap water. Geoscientists discovered these rich resources, and engineers designed structures and systems to put them to use. Their expertise, efforts, and teamwork are essential to making Canada a great place to live.

Chapter 1 reviews many Canadian engineering and geoscience achievements and gives a brief overview of both professions. It also describes critical events that changed the engineering profession: the tragic 1907 and 1916 collapses of the Quebec Bridge. Even today, the 1907 Quebec Bridge disaster remains Canada's most lethal industrial accident. These events galvanized governments to pass laws to regulate professional engineering. In Chapter 2, we see a sad parallel: laws to regulate professional geoscience were also precipitated by tragedies. This sixth edition of the text includes more examples of the disciplinary process that deals with corruption, negligence, incompetence, and inefficient use of resources. Despite Canada's impressive record for honesty and fairness, we are not immune from vice.

1.1 AN INSPIRING LEGACY

Canada is a huge country, and our history is an exciting chronicle of great achievement in a harsh climate. Early settlers were faced with dense forests, rough and rocky terrain, and vast distances that obstructed travel, trade, settlement, and agriculture. Engineers and geoscientists responded willingly to the challenge. Two famous technical leaders of that era are Lieutenant Colonel John By of the Royal Engineers (1779–1836) and William Logan (later Sir William Logan, 1798–1875) of the Geological Survey of Canada (GSC).

Lieutenant Colonel John By of the Royal Engineers supervised the construction of the Rideau Canal, built in 1832 to connect Ottawa and Kingston. The Canal, Canada's first megaproject, is an ingenious linkage of dams, locks, rivers, and lakes that extends for 202 km (126 miles). It was built by manual labour in only five years—a remarkable achievement, considering the primitive tools of the time. In Colonel By's honour, what is now Ottawa was called Bytown for almost three decades before being renamed in 1855.

In 2007, the United Nations Educational, Scientific and Cultural Organization (UNESCO) designated the Rideau Canal and the fortifications in Kingston (Fort Henry and the Martello towers) as a World Heritage Site on the 175th anniversary of their completion. The Rideau Canal joins 800 other sites on the World Heritage list, such as the pyramids of Egypt and the Great Wall of China. Furthermore, it is the only North American canal system of its era that remains in use today. Almost all of its original structures are intact, a lasting tribute to John By.[1]

Within a decade after completion of the Rideau Canal, the Province of Canada (which included Quebec and Southern Ontario at that time) granted £1,500 sterling for a geological survey. In 1842, William Logan was appointed as the first director of the GSC. Logan, born in Montréal but raised in Scotland, devoted the rest of his life to this task. As Canada became a nation extending from the Atlantic to the Pacific, and to the Arctic, the GSC grew to become Canada's principal agency for geoscientific information and research. The GSC is now part of Natural Resources Canada (NRCan), a government department that provides outstanding expertise in geoscience surveys and the development of Canada's resources. NRCan also encourages environmental protection and stimulates innovative geoscience technology.

Logan's immense influence lives on in many geoscience achievements, discussed briefly in this text. He received dozens of medals and honours for his achievements and was knighted by Queen Victoria in 1856. In 1898, Canada named Mount Logan in southwestern Yukon after him. At 5,959 m (19,551 ft.), Mount Logan is Canada's highest peak—a symbol of Logan's immense influence on the discovery, analysis, categorization, and development of Canada's resources.[2]

The "Top Ten" Canadian Engineering and Geoscience Achievements

The Rideau Canal is only part of a great legacy that inspires us, even today. In 1987, the centennial year of the Engineering Institute of Canada (EIC), a jury of prominent Canadians identified Canada's "top ten" engineering and geoscience achievements. (Many of these projects involve geoscience expertise and should be recognized as such, but they occurred before the term "geoscience" came into widespread use.) More than 110 projects were nominated, and the jury compared the projects based on the significance of the achievement, the contribution to Canadian well-being, international recognition, management required, and, of course, originality, ingenuity, and creativity or uniqueness.[3]

As the list below shows, each was important and uniquely Canadian; most are simply massive! These achievements represent only a sample of thousands of projects in which we may all take pride.[4] Photographs of some are included in this text, and more can be found in *Mind, Heart, and Vision: Professional Engineering in Canada 1877–1987*,the impressive pictorial history book by Norman Ball.[5]

THE TRANSCONTINENTAL RAILWAY NETWORK

The importance of (and the huge investment in) the transcontinental railway cannot be overemphasized. The railway connected the country from Atlantic to Pacific, making Canada a viable social, economic, and political entity. The federal government signed a contract with the Canadian Pacific Railway (CPR) in 1880, and by 1885, the "last spike" had been hammered in. The first train from Montréal arrived in Port Moody, British Columbia, in July 1886.

THE ST. LAWRENCE SEAWAY

The St. Lawrence Seaway (also known as the "Great Lakes Waterway") permits ocean-going ships to travel up the St. Lawrence River and through the Great Lakes, an almost unbelievable distance of almost 3,800 km (2,400 miles). Construction began in August 1954, and the Seaway was open for commercial ships in April 1959. The Seaway made the Great Lakes accessible to industry and trade, and it is a major route for shipping bulk products, such as grain, iron ore, coal, petroleum, cement, and rolled iron and steel.

THE POLYMER/POLYSAR SYNTHETIC RUBBER PLANT IN SARNIA

During the Second World War (1939–1945), the shortage of natural rubber led to the rapid construction of the Polymer synthetic rubber factory in Sarnia, Ontario. The plant was incredibly successful and efficient and helped the Allied forces win the war. It became a Crown corporation after the war ended and was renamed Polysar in 1976. Polymer's war contribution was recognized by the inclusion of an image of the plant on the 1971 Canadian $10 bill. The plant was eventually sold to Bayer AG of Germany.

THE ATHABASCA COMMERCIAL OIL SANDS DEVELOPMENT

The Athabasca oil sands in Alberta contain bitumen, the heaviest, thickest form of petroleum. Alberta's oil sands have the third largest oil reserves in the world, after Venezuela and Saudi Arabia. In its natural state, however, bitumen is so dense and viscous that it is suitable only for paving roads. Creating oil from bitumen is expensive and complicated. Compared to conventional crude oil, bitumen's carbon-to-hydrogen ratio is too high, so special refining processes had to be invented to remove the mineral content and to adjust the carbon–hydrogen ratio. The successful research in separation methods in the 1950s, and the first successful large-scale commercial plant at Fort McMurray in the 1960s, proved that oil extraction was viable.

THE HYDRO-QUÉBEC VERY-HIGH-VOLTAGE TRANSMISSION SYSTEM

Electric power is critically important to our standard of living, but transmitting electricity over long distances from remote hydroelectric generators can be costly and wasteful. Energy loss is proportional to the square of the current, so voltage must be high and current, low. When the 735 kV Manicouagan transmission line was electrified in 1965, Hydro-Québec became the first electrical power producer to transmit electricity at voltages over 500 kV (AC).

THE CANDU NUCLEAR POWER SYSTEM

The CANDU nuclear power system produces electricity using natural uranium, moderated by heavy water. The uranium does not need enrichment, thus making the system safer in many respects than other nuclear generators. The first CANDU Nuclear Power Demonstration (NPD) reactor was built in 1962; a 200 MW Douglas Point prototype was built in 1966, which delivered electricity to the grid; and four commercial 500 MW Pickering-A units came into service from 1971 to 1973. Although nuclear power is controversial, as discussed later in this text, it has some advantages over coal-fired generators.

THE DE HAVILLAND BEAVER DHC-2 AIRCRAFT

The Canadian designed and built De Havilland Beaver DHC-2 first flew in 1947. It carries six passengers and cargo, in addition to the pilot, and can take off and land in very short distances. When equipped with floats or skis, it can fly into remote locations. The Beaver was a crucial aid to developing northern Canada, and many are still flying.

THE ALOUETTE I ORBITING RESEARCH SATELLITE

In 1962, Canada became the third nation to have a satellite in orbit (after the Soviet Union and the United States). Alouette I was designed and built in Canada and was launched on a U.S. rocket. It completed its mission successfully, investigating the ionosphere as part of International Satellites for Ionospheric Studies from 1963 to 1969.

THE BOMBARDIER SNOWMOBILE

Joseph-Armand Bombardier began experimenting with snow machines in 1922, and in 1937, he invented the endless-track vehicle that we know as the snowmobile. Its speed over snow-covered ground makes it essential in remote parts of Canada, and it has changed the hunting methods of the Inuit. In fact, the snowmobile changed winter life in most of Canada, although concerns about noise, environmental damage, and safety have led to laws restricting its use.

THE TRANS-CANADA TELEPHONE SYSTEM

The Trans-Canada Telephone System (now known as "Stentor") is an association of telephone companies formed in 1931 to integrate national telephone service. Previously, Canada relied on U.S. transmission facilities for most cross-Canada communication. Stentor expanded in 1969 to include Telesat Canada

(Canada's sole domestic satellite carrier). In 1972, Anik A-1 was launched, followed by Anik A-2 in 1973, and Canada became the first country in the world to use satellites for domestic communications.

Canadian Engineering Achievements of the 20th Century

The five most significant Canadian engineering achievements of the 20th century, chosen using objective criteria by the 1999 National Engineering Week committee, are listed below.[6]

THE CPR ROGERS PASS PROJECT

The CPR transcontinental railway, built in 1885, crosses the Rocky Mountains via the Rogers Pass, but over the years, avalanches and steep grades have been constant problems. (Snow depths reach 15 m [50 ft.] per year in this area.) In 1989, the CPR completed the 34 km (21-mile) Rogers Pass project, including six bridges and two tunnels. The Mount Macdonald Tunnel under the Rogers Pass is 14.7 km (9 miles) long, making it North America's longest railway tunnel. The project was a major achievement in railway safety and reliability.

THE CONFEDERATION BRIDGE (NORTHUMBERLAND STRAIT)

The Confederation Bridge links New Brunswick and Prince Edward Island across the Northumberland Strait, and it opened to traffic in May 1997. The bridge is 12.9 km (8 miles) long, which makes it the world's longest saltwater bridge subject to ice hazards. The distinctive arches provide a clearance of 60 m (197 ft.) for seagoing vessels. The frontispiece of this textbook bears a photo of the Confederation Bridge.

THE CANADARM REMOTE MANIPULATOR SYSTEM

Canadian engineers from many disciplines designed and developed the Canadarm for the U.S. space shuttle. The Canadarm flew on the second shuttle flight in 1981. It proved essential for deploying and retrieving satellites from the shuttle cargo bay. After the disastrous *Columbia* accident in early 2003, the Canadarm was fitted with a 15 m extension for examining the shuttle's underside for thermal damage. A larger version, the Canadarm2, is part of Canada's contribution to the International Space Station (ISS). Canadian Space Agency astronaut Chris Hadfield installed the Canadarm2 in April 2001. Canada also contributed the Mobile Servicing System (MSS) to the ISS. The MSS has three parts: a movable base, the Canadarm2, and Dextre, the Special Purpose Dextrous Manipulator (SPDM).

THE IMAX SYSTEM (MOTION PICTURE PHOTOGRAPHY AND PROJECTION)

Canadian mechanical engineer William Shaw perfected the "rolling loop" film transport mechanism in the IMAX projector, which projects images that are 10 times the size of conventional motion-picture images onto huge screens, without vibration or streaking. IMAX theatres are now in operation around the world.

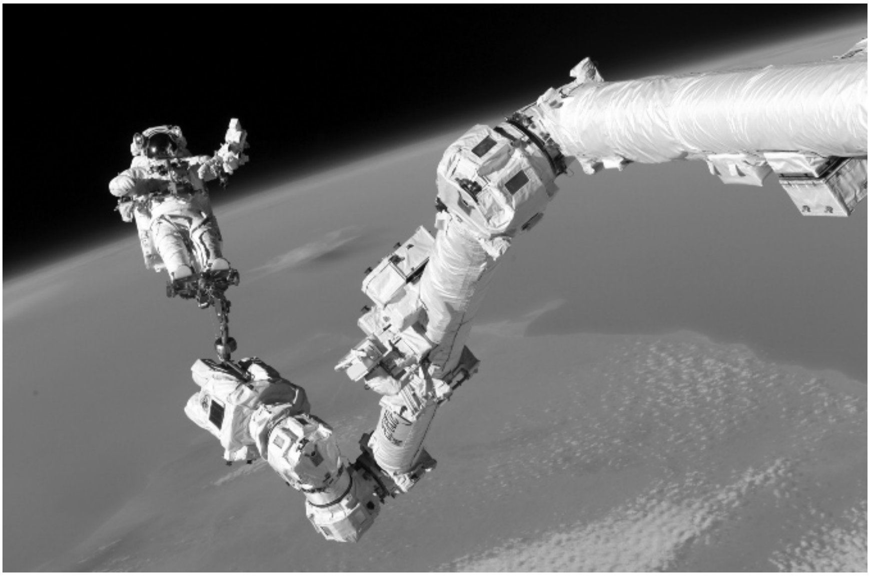

Photo 1.1 — CANADARM2. *This photo shows an astronaut at the end of the Canadian robot arm "Canadarm2" on the International Space Station (ISS), in orbit about 400 km (250 miles) above Earth. MD Robotics designed Canadarm2 for the Canadian Space Agency (www.asc-csa.gc.ca/eng) as part of Canada's significant contributions to the ISS. Canadarm2 has been used to build and maintain the space station, move equipment and astronauts, and perform "cosmic catches" of unpiloted spacecraft.*

Source: NASA/Getty

THE HOPPS PACEMAKER

Canadian electrical engineer Dr. John A. Hopps, working with medical colleagues at the Banting and Best Institute in Toronto in 1949, discovered that a gentle electrical stimulus would restart a heart that had stopped beating. In 1950, Hopps developed the first heart pacemaker at the National Research Council. The pacemaker helps millions of people to lead normal, healthy lives. Hopps was in the vanguard of biomedical engineering in Canada.

Canadian Geoscience Discoveries and Achievements

Canadian geoscientists can take pride in the achievements of their profession. Canada plays a central role in developing the world's resources, bringing prosperity to Canada and benefits to us all. The following seven discoveries and achievements are only a small sample of these important contributions.

OIL AND GAS DISCOVERIES IN ALBERTA

Canada's most valuable natural resources are its oil and gas reserves, located mainly in Alberta. These resources were discovered as early as 1910 and attracted international oil companies to the province in the 1930s. Development increased dramatically in 1947, however, with the discovery of oil at Leduc, Alberta. The Leduc discovery made Calgary the centre of Canada's oil industry. Further exploration yielded many new oil and gas deposits, including Pembina in central Alberta, one of Canada's largest conventional oil fields.

The following quote explains the importance of Alberta oil and gas production:

> Canada is the third largest natural gas producer in the world with over 80 per cent of the country's gas being produced in Alberta. Alberta produces approximately five trillion cubic feet of natural gas a year which is enough natural gas to heat every Albertan home for 35 years. Almost 70 per cent of natural gas produced in Alberta is exported to other provinces and the United States.*

Although the consumption of fossil fuels creates ethical dilemmas (explored at length later in this textbook), the oil industry generates immense wealth for Alberta. It has made Canada self-sufficient in oil consumption and a net exporter of oil.

OFFSHORE OIL AND GAS DISCOVERIES

In addition to the oil and gas discoveries in Alberta, huge oil and gas reserves are also located beneath the ocean on Canada's east, west, and Arctic coasts. Three major oil projects are located off Newfoundland and Labrador—the Hibernia, Terra Nova, and White Rose oil fields—and the Sable Offshore Energy Project, which produces natural gas, is off Nova Scotia. Hibernia, Canada's largest offshore oil field, has been producing oil since 1997. The field produced its one billionth barrel of oil in December 2016.[7] During the first half of 2016, the field's production averaged 195,000 barrels (31,000 m^3) per day.[8]

In the Arctic, offshore oil drilling is under way, adhering to the current Canadian environmental assessment process. Oil drilling in the Arctic has special problems, including the difficulty of transporting the oil to the markets and the cleaning up of spills in the frigid Arctic waters.

SUDBURY NICKEL BASIN

The Sudbury Basin in Ontario is the world's second-largest impact crater, created by a comet that collided with Earth 1.85 billion years ago. It is Canada's most productive mining site, with total past production and current reserves of over 1.7 billion tonnes of nickel, copper, cobalt, platinum, palladium, gold, and silver ore, by 2007 estimates.[9]

Railway workers discovered the crater in 1885, during the construction of the Canadian Pacific Railway. The original crater is estimated to have been about 200 km in diameter. (This size indicates a meteorite larger than that which led to extinction of the dinosaurs.) Over the centuries, however, many geological processes have deformed the crater into a smaller oval that is now 60 km long, 30 km wide, and 15 km deep.

* Alberta Energy, 2008, *Natural Gas*, brochure, https://open.alberta.ca/.../4281332-2008-Natural-Gas-Brochure-2008-10.pdf (accessed August 20, 2017).

Meteorite craters are an important source of metals and minerals. It is curious that the craters do not include the meteorite's metal content—meteorites typically vaporize upon impact. The collision, however, heats up Earth's surface at the point of impact. The heat melts the metal ores near the impact point, which collect at the bottom of the crater.

ATHABASCA BASIN URANIUM

Canada has an enormous amount of energy in the form of uranium. Canada is one of the top three producers, along with Kazakhstan and Australia, and these three countries produce over 60 percent of the world's uranium. The richest Canadian uranium ore body is the Cigar Lake deposit in the Athabasca Basin near Great Slave Lake in northern Saskatchewan. This deposit, discovered in 1981 and only now being developed to its full potential, is believed to be the richest uranium deposit in the world, with an average ore grade of 18 percent uranium oxide (U_3O_8). It is also one of the largest uranium deposits, with geological reserves of 103,000 tonnes of uranium oxide. Canada's uranium is used exclusively to generate electricity at nuclear power plants, and this is strictly enforced by international nuclear nonproliferation agreements and Canadian export restrictions. Nuclear power has grown in importance during recent years and now provides 14.8 percent of Canada's electricity. As a result, uranium is one of Canada's largest non-carbon-emitting sources of energy in use today.[10]

N.W.T. DIAMONDS

Diamond mining is a major source of income for the Northwest Territories. The Diavik Diamond Mine is the largest in Canada, followed by the Ekati and the Snap Creek mines. All three mines are located about 200 km to 300 km northeast of Yellowknife, Northwest Territories.

Prospector Charles Fipke and geologist Dr. Stuart Blusson made the diamond discovery. The pair searched northern Canada for many years, looking for Kimberlite "pipes" of volcanic rock in which diamonds are found. Their persistence paid off with a discovery near Lac de Gras (north of Yellowknife). The mines are very productive. In 2011, the Diavik mine produced 6.7 million carats; the Ekati mine produced 3 million carats, and the Snap Creek mine produced 882,000 carats.[11] The Canadian Mining Hall of Fame inducted Charles Fipke in 2013.

AIRBORNE ELECTROMAGNETIC SURVEYING

Although prospectors experimented with airborne electromagnetic (AEM) ore detection methods in the 1920s, it was not until the end of the Second World War that the availability of pilots, aircraft, and electronics encouraged the development of the concept. The successful Canadian test flights during the summer of 1948 are generally recognized as the birth of AEM systems. AEM detection enabled the discovery of the Heath Steele lead-zinc-copper deposit in New Brunswick in 1954. This, and several other successful surveys, encouraged the Ontario and Quebec governments to fly AEM surveyors to search for minerals in the Abitibi region. The whole region is now mapped by AEM surveys.[12]

Walter Holyk, a Canadian geoscientist, made one of the first and most impressive ore discoveries using AEM detection. Holyk applied his geoscientific knowledge to AEM anomalies in the Canadian Shield and discovered a massive 100 million ton sulphide deposit near Timmins, Ontario. The site, now the Kidd Mine, is one of the world's greatest zinc-copper-lead-silver mines. Holyk received many awards for his pioneering AEM work and was inducted into the Canadian Mining Hall of Fame in 1997.[13]

CANADIAN OCEAN-FLOOR RESEARCH

Ocean Networks Canada (ONC), established at the University of Victoria in 2007, is a world-class Canadian nonprofit research institute dedicated to ocean research. ONC operates the Victoria Experimental Network Under the Sea (VENUS) and the North-East Pacific Time-series Underwater Networked Experiments (NEPTUNE) undersea laboratories and research facilities, consisting of a network of advanced sensors that observe and report conditions on the ocean floor. They monitor undersea conditions and events and send data in "real time" via computer links to researchers, teachers, industries, and interested individuals around the world.

These facilities offer a unique opportunity for ocean and earth sciences research. Scientists have the ability to respond to rare oceanic events, observe ocean changes, and conduct experiments on the Internet. NEPTUNE Canada's major research themes include earthquakes and plate tectonics, seabed fluid dynamics and gas hydrates, marine life and climate change, deep sea biodiversity and ecosystems, as well as engineering and computational research.[14]

The Challenge of the 21st Century

Today's engineers and geoscientists have knowledge and capabilities that previous generations could barely imagine. Every professional office now has computer hardware and software for analysis, design, and visualization. The tools to get the job done are also more powerful and versatile than ever before: giant excavators and cranes, numerically controlled machine tools, satellite positioning and instant wireless communication, and so forth.

However, the current generation will face some serious challenges: climate change may make life more difficult and expensive for all of us (as explained in Chapter 15). Fortunately, engineers and geoscientists have the technical expertise to overcome these challenges. We must discover efficient methods to use resources, reduce waste, and avoid needless consumption. For example, we must improve the efficiency of transportation, building insulation, resource extraction, and the transmission of electricity over long distances. Improving energy efficiency and reducing waste may, however, also require lifestyle changes, and these may be the toughest obstacles.

The changing global economy, volatile commodity prices, and immigration offer challenges and opportunities for engineers and geoscientists to creatively address societies' needs.

Photo 1.2 — The Avro Arrow Fighter–Interceptor. *The Avro Arrow, a Canadian-designed all-weather fighter–interceptor, was a technological marvel and decades ahead of its time. The Arrow, which first flew in March 1958, could exceed Mach 2 at 50,000 ft. (15,240 m) in normal flight. On September 28, 1958, the government of Prime Minister John Diefenbaker cancelled the Arrow program in a scandalously abrupt manner, on the basis that manned fighters were obsolete and too costly. Avro's 14,000 employees were immediately laid off. Avro was ordered to destroy the two prototypes.*

Source: CP Images

1.2 OVERVIEW OF ENGINEERING AND GEOSCIENCE

Engineering and geoscience are well-respected professions, and their roots go back centuries in Canada. As the previous pages show, both professions exhibit impressive achievements. Provincial governments did not regulate engineering as a profession until the 1920s, and in 1955, Alberta was the first province to regulate geoscience (specifically, geology and geophysics). All provinces and territories now recognize, license, and regulate both engineering and geoscience, typically under the same laws (although Yukon and Prince Edward Island do not yet regulate geoscience). The next few pages are an overview of the professions and the roles they play in the technical team. To start, consider this laconic characterization of how the professions differ:

- **Engineering** involves the design, manufacturing, and installation of man-made solutions (often within or for use in natural systems) that rely on the application of engineering and scientific principles—solutions over which the engineer has almost complete control.

- **Geoscience** is a science (largely observational) that uses the scientific method to investigate, map, model, and predict the behaviour of Earth's natural systems (in the past, present, and into the future)—the actual behaviour of which the geoscientist absolutely cannot control.[15]

Engineering and Geoscience Licensing Laws

The provincial and territorial governments regulate engineering and geoscience. Each province and territory has passed a law, or "Act," that establishes engineering and geoscience as professions, with the exception of geoscience in Yukon and Prince Edward Island. Each Act, in turn, creates an Association of Professional Engineers and/or Geoscientists (in Quebec, the Associations are called the *Ordre des ingénieurs du Québec* and the *Ordre des géologues du Québec*). These Associations are licensing bodies (or "regulators") that set and enforce standards of practice in engineering and geoscience. To practise engineering or geoscience, you must obtain a licence from the Association in your province or territory. (Appendix A lists contact information for these Associations.)

The importance of the Associations (or *Ordres*, in Quebec) cannot be overemphasized. They set the qualifications for admission into the profession, determine the standards of professional practice, and discipline members who fail to meet these standards. The Associations also prevent the misuse of titles and prosecute illegal practice by unqualified individuals. In addition, two nonprofit organizations, Engineers Canada and Geoscientists Canada, are also vitally important: they assist the Associations in coordinating licensing policies and procedures across Canada.

Entering the Professions

The academic qualifications and experience required to practise engineering or geoscience are stringent. Applicants typically require both a four-year university degree and an internship—usually three to four years of acceptable experience. (Chapter 2 explains licensing rules in detail.)

Distribution of Engineers and Geoscientists in Canada

About 287,000 individuals were on engineering membership lists in 2015, according to Engineers Canada.[16] As Table 1.1 shows, however, only about 206,000 were licensed professionals. Associations include engineers in training and retired engineers on their membership lists, and many engineers are licensed in more than one province or territory.

About 10,500 professional geoscientists held licences in 2015, according to Geoscientists Canada.[17] The number of individuals is approximate because some engineers and geoscientists are licensed in more than one province or territory or are licensed as both engineers and geoscientists.

TABLE 1.1 — Licensed Professional Engineers and Geoscientists in Canada

Province or Territory	Professional Engineers Practising in 2015	Professional Geoscientists Practising in 2015
Ontario	68,014	2,013
Alberta	46,776	4,412
Quebec	43,976	839
British Columbia	18,914	1,617
Saskatchewan	8,143	597
Manitoba	5,261	228
Nova Scotia	4,387	132
New Brunswick	4,191	136
Newfoundland and Labrador	3,800	331
Northwest Territories	1,439	239
Yukon	761	0
Prince Edward Island	525	0
Totals	**206,187**	**10,544**

Sources: Geoscientists Canada; Engineers Canada, *National Membership Report, 2017*. Found at https://engineerscanada.ca/reports/nationalmembership-report. Data reproduced with permission of Geoscientists Canada and Engineers Canada.

Note 1: Professional Engineers: The number of professional engineers does not include non-practising engineers, engineers-in-training, or engineering students, but includes restricted, temporary, "licence to practise," and some duplicate members, since about 12 percent of professional engineers are licensed in more than one jurisdiction.

Note 2: Professional Geoscientists: The number of professional geoscientists does not include non-practising geoscientists, geoscientists-intraining, or geoscience students, but includes restricted, temporary, "licence to practise," and some duplicate members, since many professional geoscientists are licensed in more than one jurisdiction.

The distribution of professionals is not uniform across Canada. As Table 1.1 shows, most engineers practise in Ontario, Alberta, and Quebec, whereas most geoscientists practise in Alberta, Ontario, or British Columbia.

Employment Prospects

Two factors predict positive employment prospects for graduate engineers and geoscientists. First, the baby boom generation (born after the end of the Second World War in 1945) is now aging. Many senior engineers and geoscientists are retiring, creating opportunities for younger professionals. Second, concern about climate change is convincing thoughtful consumers to demand increased energy efficiency and reduced pollution. This demand is stimulating research activity, investment opportunities, and jobs. Although a period of adjustment may lie ahead, the outlook is promising.

ENGINEERING EMPLOYMENT A report prepared for Engineers Canada in 2013 by Randstad, a leading engineering recruiting firm, predicts that a shortage of experienced engineers will occur over the next two decades. This 100-page report estimates that 95,000 professional engineers will retire by 2020, and they cannot be replaced fast enough by experienced Canadian or internationally trained engineers. Canada will, therefore, face an engineering skills shortage. The report gives an overview and assesses labour markets in all 10 provinces.[18]

GEOSCIENCE EMPLOYMENT The federal department Employment and Social Development Canada (ESDC) has a suite of computer models, called the Canadian Occupational Projection System (COPS). The COPS system predicts labour supply and demand for all employment categories across Canada. The following is the COPS employment prediction for geoscientists and similar physical science professionals:

Employment (non-student) in 2014:	31,900
Median Age of workers in 2014:	42.7 years old
Average Retirement Age in 2014:	64 years old

> For Physical Science Professionals, over the period 2015–2024, new job openings (arising from expansion demand and replacement demand) are expected to total 10,200, while 9,900 new job seekers (arising from school leavers, immigration and mobility) are expected to be available to fill them.
>
> As job openings and job seekers are projected to be at relatively similar levels over the 2015–2024 period, it is expected that the balance between labour supply and demand seen in recent years will continue over the projection period.*

OBTAIN A PERSONAL EMPLOYMENT PREDICTION Labour predictions are freely available on the COPS website for most occupations. To obtain a personal labour prediction, simply specify your profession and specialty using the four-digit National Occupational Classification (NOC). The process involves two steps:

1. Find your occupation code (NOC) at http://noc.esdc.gc.ca.
2. Insert your NOC code into the COPS system at http://occupations.esdc.gc.ca/sppc-cops/.

The result is a two-page overview of your occupation, listing the number employed in Canada, the median worker age, average retirement age, a brief employment history, and statistical predictions of job openings and job seekers.

It is important to emphasize that job predictions may change quickly and drastically, depending on political events, monetary policies, wars, changes in government, and so forth.

* Government of Canada, 2016, "Canadian Occupational Projection System (COPS)." Found at http://occupations.esdc.gc.ca/sppc-cops/occupationsummarydetail.jsp?&tid=67. Used with permission.

JOB PLACEMENT Note that, in addition to labour predictions, the government (ESDC) also sponsors a free job placement website, called Job Bank,to assist Canadians seeking jobs. See www.jobbank.gc.ca/home-eng.do?lang=eng. (Note: The above websites are valid as of May 2, 2017.)

A Brief Discussion of Professional Status

The public holds the engineering and geoscience professions in high regard. In Canada and the United States, opinion surveys consistently rate them near the top for honesty and integrity. However, this question still arises: Are engineering and geoscience really professions? To answer this question, we need to define the term "profession" more precisely. What is a profession? How does it differ from a job? The following dictionary definition of a profession helps to answer these questions:

> **Profession:** A calling requiring specialized knowledge and often long and intensive preparation including instruction in skills and methods as well as in the scientific, historical, or scholarly principles underlying such skills and methods, maintaining by force of organization or concerned opinion high standards of achievement and conduct, and committing its members to continued study and to a kind of work which has for its prime purpose the rendering of a public service.*

Engineering and geoscience certainly require "specialized knowledge," "intensive preparation," and "instruction in skills and methods as well as in the scientific, historical, or scholarly principles underlying such skills and methods." In fact, licensing requires at least four years of formal education and three to four years of relevant work experience before engineers or geoscientists can practise. This requirement equals the preparation required in medicine and law—two professions that serve as a useful basis for comparison.

Engineering and geoscience also have a "force of organization." Laws and regulations have been enacted in every province and territory in Canada (except Prince Edward Island and Yukon, where geoscience is not yet a regulated profession). The Acts, laws, and regulations include Codes of Ethics, committing practitioners to "high standards of achievement and conduct" (as discussed in detail in Chapter 9).

It is significant that, like medicine and law, engineering and geoscience are "self-regulating" professions. In other words, the government delegates the responsibility for admission, for standards of practice, and for discipline, to the members of the profession. Some differences exist. Unlike medical doctors and lawyers, who are generally self-employed and work with clients on a one-to-one basis, most engineers and geoscientists are employees of large companies, where they work in teams. This team spirit adds to professional status.

* By permission. From *Merriam-Webster's Unabridged ® Dictionary* ©2017 by Merriam-Webster, Inc. (http://unabridged.merriam-webster.com/).

1.3 THE TECHNICAL TEAM

Today's complex projects need specialized skills and knowledge, so most engineers and geoscientists work in technical teams. A survey of engineers, sponsored by Engineers Canada, showed that the majority (79 percent) worked on teams. Most of the teams (three out of four) were formed on a project-by-project basis. Engineers were the main team members (69 percent), but almost half of the teams (46 percent) included a technician or technologist, and a quarter of the teams (25 percent) included a non-engineering technical person.[19] These survey data are believed to include geoscientists. Although many geoscientists work as independent prospectors or consultants, the need for expensive electronics and aircraft encourages a team approach.

Engineers and geoscientists must work effectively with other team members. Respect for each team member's expertise is essential for a productive work environment. The full technical spectrum includes research scientists, geoscientists, engineers, architects, urban planners, chemists, biologists, healthcare professionals, technologists, technicians, and skilled workers, some of which are described in the next few paragraphs. Note that this categorization is a gross approximation, and many exceptions will exist.

- **Research scientist:** Scientists develop ideas that expand the frontiers of knowledge—ideas that may not have practical applications for many years. A doctorate is typically the basic educational requirement, although a master's degree is often acceptable. A scientist is rarely required to supervise other technical personnel except research assistants and usually is a member of several learned societies in his or her field of interest.

  Generally, the task of the research scientist is to generate new knowledge, whereas the task of the engineer is to apply that knowledge. Many geoscientists, however, are research scientists. The roles of the scientist, the geoscientist, and the engineer thus often overlap, and in some projects, the boundary may be invisible. Most scientists work in government agencies, universities, or institutes, and their results are usually published in scholarly technical journals. Such new knowledge is frequently very valuable to industry.
- **Geoscientist:** Geoscience is a fairly new name for the well-established fields of geology, geophysics, and related Earth science disciplines. Geoscientists are mainly concerned with the study, measurement, and analysis of Earth and the systems, such as petroleum and hydrology, which operate within Earth. The main role of the geoscientist is the practical application of scientific ideas, not the study of natural science. For example, geoscientists analyze seismic, gravitational, magnetic, and other data to discover minerals and fuels, locate stable foundation sites for structures, and identify dangers related to the dynamic movement of Earth. Geoscientists are licensed, under a provincial Geoscience Act, in order to practise. A bachelor's degree in geoscience (typically geology, geophysics, or a related discipline) is the minimum educational requirement.

It is important to note that geoscientists and engineers play a key role in any exploitation of Earth (such as resource extraction) that affects life, health, property, or the welfare of the public because a "qualified person" (as defined in Chapter 2) must approve such activities.

- **Engineer:** Engineers are mainly concerned with the practical application of science. They link theory to practice, so design is a key area of employment—that is, creating plans for devices, systems, and structures for human use. Many engineers are also involved in construction, testing, and manufacturing, and a few focus on the discovery and distribution of natural resources. In these activities, engineers make many decisions that affect life, health, property, or the welfare of the public, so they must be licensed under a provincial Engineering Act in order to practise. They need to have extensive theoretical knowledge, the ability to think creatively, and a knack for obtaining practical results. A bachelor's degree in engineering is the minimum educational requirement.
- **Architect:** Architects are mainly concerned with the planning, aesthetic design, and construction management of buildings, including residences, offices, and institutional and industrial buildings. Architects, geoscientists, and engineers often work together since each has a specialty that may apply to such buildings. For example, an architect may conduct the aesthetic design and layout plan for a large building; may engage professional geoscientists to assess the foundation strength and seismic problems; and may engage professional engineers to design the structural, heating, ventilation, and air conditioning systems. Architects also make decisions that affect life, health, property, or the welfare of the public, so they must be licensed under a provincial Architects Act in order to practise. These Acts typically contain several clauses that define the boundary between the responsibilities of engineer, geoscientist, and architect. A bachelor's degree in architecture is the minimum educational requirement.
- **Technologist:** Technologists work closely with engineers and geoscientists, and often perform key tasks, such as design, testing, computing, solving problems, supervising, and project management, under the direction of a licensed practitioner. The basic education needed is a diploma from a technology program at a community college, technical college, *Collège d'enseignementgénéral et professionel* (CEGEP), or college of applied arts and technology (CAAT). Many technologists, however, have a bachelor's degree (usually in science, mathematics, or technology). Technologists often supervise the work of others.

  Associations of engineering technicians and technologists have been established in all 10 provinces (although not in the territories) to certify their qualifications. Certification as a technologist requires an assessment of the candidate's education. The candidate must also document at least two years of relevant experience. The technologist designation is a "right to title." That is, the professional technologist designation confers the right to use the technologist title, but does not limit the right of an unlicensed technologist to practise. Certification is voluntary, so it is not required to work as a technician or technologist in Canada; however, only certified technologists are entitled to use the following designations: Certified Engineering Technologist (C.E.T.), Applied Science Technologist (A.Sc.T.), Registered Engineering Technologist (R.E.T.), or Technologue Professionnel (T.P.). Which title is used depends on the province in which certification is granted.

- **Technician:** Technicians usually work under the supervision of engineers or technologists in the practical aspects of engineering tests or equipment maintenance. The basic educational requirement is usually a diploma from a community college, CEGEP, or CAAT. In most provinces, the title Certified Technician (C.Tech.) may be awarded by the provincial associations of technicians and technologists after the applicant completes the appropriate education and acquires two years of appropriate experience. Certification is voluntary and is not essential to work as a technician.
- **Skilled worker:** Typically, skilled workers apply highly developed manual skills to carry out the designs and plans of others. Master artisans train skilled workers, and the quality of a worker's apprenticeship is more important than the worker's formal education. Each type of trade worker (e.g., electrician, plumber, carpenter, welder, pattern maker, brick and stone mason, machinist) comes under a different certification procedure, which varies from province to province.

Each member of the technical team has a different task, but in a large project, everyone in this technical spectrum may be required at some time. Mutual respect for these diverse skills and training is key to creating a productive work environment.

1.4 INTRODUCTION TO CASE HISTORIES

As Canadians, we can be proud of many spectacular achievements, examples of which are mentioned above. We tend to take success for granted when well-designed structures and devices work properly. In contrast, when a structure or project fails, we ask why it happened and how similar failures can be avoided. When a failure involves injury or death, an investigation panel or a coroner's inquest (or even a Royal Commission) studies the failure impartially and publicly. As a result, we often learn more from failures than from successes, although at great cost. Remember that failure itself is not proof of unethical or incompetent practice. Many projects push the limits of knowledge. New projects always involve risk, and even determined, ethical professionals cannot guarantee success every time.

The case histories in this textbook typically involve negligence, incompetence, conflict of interest, or corrupt practices. Many cases had tragic results, but they are presented here to help avoid similar tragedies in future.

CASE HISTORY 1.1

THE QUEBEC BRIDGE COLLAPSE

The first case history describes the negligence that led to the collapse of the Quebec Bridge in 1907. This case is important because the huge death toll from this industrial accident prompted the creation of laws for the professional licensing of engineers. Moreover, even a century later, similar cases of negligence occur occasionally—lessons are still being learned.

AN OVERVIEW OF THE PROJECT

The Quebec Bridge, which had its official opening in 1919, is the longest cantilever span in the world, with a centre-distance between supports of 549 m (1,800 ft.). The bridge is a very impressive structure. In fact, you must see it in person to comprehend its grandeur and massive size. The Quebec Bridge is, however, infamous for the many lives lost in the harrowing accidents that occurred during its construction. *The Canadian Encyclopedia* summarizes these tragic losses succinctly:

> **Quebec Bridge Disasters:** Construction on the Quebec Bridge, 10 kilometres above Quebec City, officially began in 1900. On 29 August 1907, when the bridge was nearly finished, the southern cantilever span twisted and fell 46 metres into the St. Lawrence River. Seventy-five workmen, many of them Kahnawake (formerly Caughnawaga), were killed in Canada's worst bridge disaster. An inquiry established that the accident had been caused by faulty design and inadequate engineering supervision. Work on a new bridge began in 1913, but on 11 September 1916 tragedy struck again when a new centre span fell into the river as it was being hoisted into position, killing 13 men. The bridge was completed in 1917 and the Prince of Wales (later Edward VIII) officially opened it on 22 August 1919.*

The residents of Quebec City advocated building a bridge over the St. Lawrence River as early as 1852, and a site had been chosen where the river narrowed, just upstream of the city. Designs were prepared, but construction did not begin until 1900. The success of the cantilevered Forth Bridge, built in 1890 in Scotland, was a factor in the choice of a cantilever design for the Quebec Bridge. The Forth Bridge has two spans of 521 m (1,710 ft.) each. At the time, these were the world's longest unsupported (cantilevered) bridge spans, and they would remain so until the Quebec Bridge was completed.

At the time of the 1907 accident, two major companies were involved in constructing the Quebec Bridge: The Quebec Bridge & Railway Company (known simply as the "Quebec Bridge Company") was responsible for the project and had contracted with the Phoenix Bridge Company in Phoenixville, Pennsylvania, to design and construct the superstructure. The Phoenix Iron Company had a subcontract to fabricate steel components.

* H.A. Halliday, "Quebec Bridge Disasters," The Canadian Encyclopedia Plus, http://www.thecanadianencyclopedia.com/articles/quebec-bridge-disasters (accessed May 11, 2008). Used by permission of Historica-Dominion.

The Quebec Bridge Company employed a chief engineer, Edward Hoare, on the site, as well as many hundreds of erection and inspection staff. They also hired Theodore Cooper, a consulting engineer from New York, as chief design engineer. In technical terms, Cooper was highly competent, and early in the design work, it was decided that Cooper's decisions on technical matters would be final. Cooper insisted on this, so the government gave him full technical authority, in writing, as an order-in-council.[20] Astonishingly, although Cooper was the ultimate technical authority, he visited the Quebec site only while the supporting piers were being built and was never on site thereafter. Furthermore, over the many years that the bridge components were being fabricated, he visited the Phoenix Iron Company shops only three times.[21]

Norman McLure was the Quebec Bridge Company's inspector of erection. Cooper had appointed him, with Hoare's agreement, and McLure received instructions from both men. He reported to Hoare mainly on "matters regarding monthly estimates, and to Cooper on matters of construction."[22]

The Phoenix Bridge Company's chief engineer was Mr. Deans, who was an experienced bridge builder but was more accurately described, after the accident, as its "chief business manager."[23]

The design engineer of the Phoenix Bridge Company was P.L. Szlapka, a German-educated engineer with 27 years of experience in designing many similar projects. Szlapka was responsible for generating the design details and had the full confidence of Cooper.[24]

A competition for the design was held in 1898. Cooper reviewed the submitted plans and recommended the Phoenix Bridge Company's design, which showed a span of about 488 m (1,600 ft.) between the supporting piers. Cooper requested further investigation of the riverbed to find the best locations for the supporting piers. After much study, he recommended that the piers be located closer to shore, thus lengthening the unsupported span to 549 m (1800 ft.).

THE FIRST COLLAPSE

In 1907, with the first span of the cantilever now reaching out over the water, it became obvious that some parts of the structure were deforming in unexpected ways. The deformation was communicated by letter to Cooper in New York. In a dramatic series of misunderstandings and oversights, however, his return message to stop work arrived but was not read until it was too late. Henry Petroski summarizes these fatal days concisely in his highly readable book *Engineers of Dreams*:

> The south arm of the Quebec Bridge had been cantilevered out about six hundred feet over the St. Lawrence River by early August 1907, when it was discovered that the ends of pieces of steel that had been joined together were bent. Cooper was notified, by letter, by Norman R. McLure, a 1904 Princeton graduate who was "a technical man" in charge of inspecting the bridge work as it proceeded, who suggested some corrective measures. Cooper sent back a telegram rejecting the proposed procedure and asking how the bends had occurred. Over the next three weeks, in a series of letters back and forth among Cooper, chief engineer Deans, and McLure, Cooper repeatedly sought to understand how the steel had gotten

bent, and rejected explanation after explanation put forth by his colleagues. Cooper alone seems to have been seriously concerned about the matter until the morning of August 27 when McLure reported that he had become aware of additional bending of other chords in the truss work and, since "it looked like a serious matter," had the bends measured; he explained that erection of additional steel had been suspended until Cooper and the bridge company could evaluate the situation.

Yet, even as McLure went to New York to discuss the matter with Cooper, Hoare, as chief engineer of the Quebec Bridge Company, had authorized resumption of work on the great cantilever. As soon as McLure and Cooper had discussed the bent chords, Cooper wired Phoenixville: "Add no more load to bridge till after due consideration of facts." McLure had reported that work had already been suspended, and so contacting Quebec more directly was not believed to be urgent, but when McLure went on to Phoenixville, he found that the construction had in fact been resumed. Some conflicting reports followed, thanks in part to a telegraph strike then in progress, as to whether Cooper's telegram was delivered and read in time for Phoenixville to alert Quebec.

In any event, the crucial telegram lay either undelivered or unread as the whistle blew to end the day's work at 5:30 P.M. on August 29, 1907. According to one report, ninety-two men were on the cantilever arm at that time, and when "a grinding sound" was heard, they turned to see what was happening. "The bridge is falling," came the cry, and the workmen rushed shoreward amid the sound of "snapping girders and cables booming like a crash of artillery." Only a few men reached safety; about seventy-five were crushed, trapped, or drowned in the water, surrounded by twisted steel. The death toll might also have included those on the steamer *Glenmont*, had it not just cleared the bridge when the first steel fell. Boats were lowered at once from the *Glenmont* to look for survivors, but there were none to be found in the water. Because of the depth of the river at the site, which allowed ocean liners to pass, and which had demanded so ambitious a bridge in the first place, the debris sank out of sight, and "a few floating timbers and the broken strands of the bridge toward the … shore were the only signs that anything unusual had happened." The crash of the uncompleted bridge "was plainly heard in Quebec," and the event literally "shook the whole countryside so that the inhabitants rushed out of their houses, thinking that an earthquake had occurred." In the dark that evening, the groans of a few men trapped under the shoreward steel could be heard, but little could be done to help them until daylight.*

THE REPORT OF THE ROYAL COMMISSION

Within hours of the accident, a Royal Commission was established to determine the cause. The Commission prepared a thorough report containing

* "Cooper," from ENGINEERS OF DREAMS: GREAT BRIDGE BUILDERS AND THE SPANNING OF AMERICA by Henry Petroski, copyright © 1995 by Henry Petroski. Used by permission of Alfred A. Knopf, an imprint of the Knopf Doubleday Publishing Group, a division of Penguin Random House LLC. All rights reserved. Any third party use of this material, outside of this publication, is prohibited. Interested parties must apply directly to Penguin Random House LLC for permission.

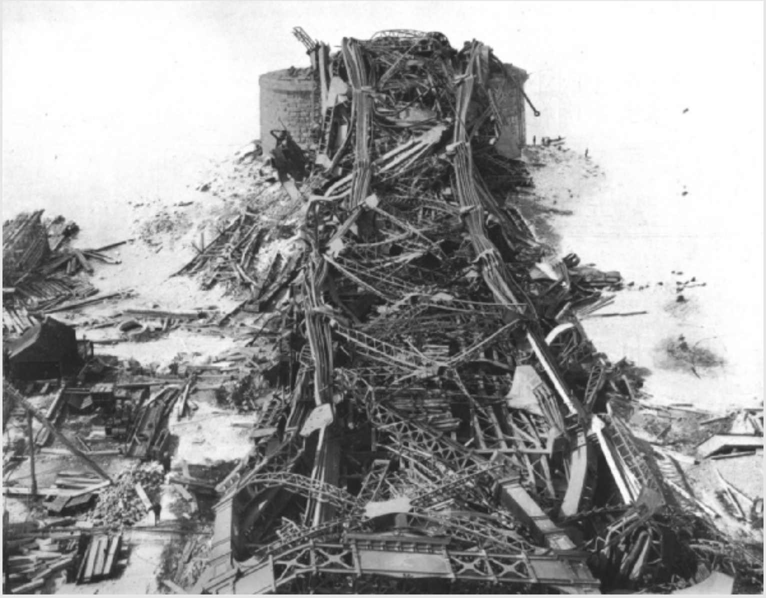

Photo 1.3 — The Quebec Bridge (1907 collapse). *The twisted wreckage of the Quebec Bridge (Phoenix design) stretches out toward the south pier, after the collapse on August 29, 1907.*

Source: The Quebec Bridge over the St. Lawrence River near the City of Quebec: *Report of the Government Board of Engineers*, Department of Railways and Canals, Canada, 1919.

lessons—learned at great cost and still worth reading today—that have benefited structural engineers and bridge designers in Canada and around the world.

The report concluded that appointing Hoare (who had ordered work to resume on the day of the collapse) as chief engineer of the Quebec Bridge Company was a mistake. Although he had a "reputation for integrity, good judgement and devotion to duty," he was not technically competent to control the work. Regarding Deans, chief engineer of the Phoenix Bridge Company, the report concluded that his "actions in the month of August, 1907, and his judgement … were lacking in caution, and show a failure to appreciate emergencies that arose." However, the Commission assigned most of the blame for the bridge's collapse to errors in judgment made by Cooper and Szlapka.[25]

DESIGN AND COMMUNICATION DEFICIENCIES

The Commission's report identified several serious deficiencies in the bridge's design and in the construction. Specifically, the design loads were underestimated, and the engineers failed to investigate even when the bent members showed that very high compressive stresses existed.

The stresses were originally calculated by Szlapka using an estimate of the total dead weight of the bridge—an estimate made by Cooper at the start of the design process; however, as the detail design progressed and as the precise shapes of the members were determined, the dead weight changed. The stresses should have been recalculated using more accurate estimates of the dead weight. They were not. It is especially noteworthy that the bridge span had originally been specified as 488 m (1,600 ft.), but Cooper later recommended moving the supporting piers, which increased the span to 549 m (1,800 ft.). When the bridge's span was increased, the dead weight increased significantly, yet this increase was not included in the calculations.

Other human failures also contributed to the collapse, and addressing them might have prevented the tragedy or lessened its consequences. Because of advancing age and declining health, Cooper had been unable to visit the construction site during the two final years of construction. Furthermore, Szlapka criticized Cooper for making the bottom chords curved "for artistic reasons" and for failing to visit the Phoenixville plant where the bridge parts were being fabricated.[26]

Cooper's distance from the construction site and his inability to travel created a communication problem that played a critical role. In a project of this magnitude, it is unimaginable that the key consulting engineer would neglect to ever visit the construction site—especially when that engineer has ultimate technical authority of the sort that Cooper wielded.

ORGANIZATIONAL DEFICIENCIES

The Royal Commission also criticized both the Quebec Bridge Company and Cooper for the way in which the project had been organized:

> Mr. Cooper assumed a position of great responsibility, and agreed to accept an inadequate salary for his services. No provision was made by the Quebec Bridge Company for a staff to assist him, nor is there any evidence to show that he asked for the appointment of such a staff.... The result of this was that he had no time to investigate the soundness of the data and theories which were being used in the designing, and consequently allowed fundamental errors to pass by him unchallenged. The detection and correction of these fundamental errors is a distinctive duty of the consulting engineer....[27]

This problem persists even today, as shown by the 1988 Burnaby supermarket roof collapse (see photo in Chapter 3). Moreover, in the case of the Quebec Bridge, it seems that this lesson was not fully learned by the government's Board of Engineers. When the bridge reconstruction began, the Board spent more than two years and half a million dollars preparing specifications for the bridge. Having expended so much time and money already, it then expected engineering companies to prepare detailed competitive bids within four months, with no remuneration.[28]

REDESIGN AND RECONSTRUCTION

In 1908, the Government of Canada recognized that the bridge was an essential link in the transcontinental railway and decided to redesign and reconstruct it. Removing the twisted steel and debris from the 1907 disaster took two years. After that, new supporting piers that went down to bedrock were built. The St. Lawrence Bridge Company of Montréal designed, manufactured, and erected the superstructure. The final (St. Lawrence) bridge design was intended to instill confidence in the structure: the massive compressive chords are almost 2.5 times as heavy (per unit length) as those on the Forth Bridge.[29]

THE SECOND COLLAPSE

During the reconstruction, a second disaster occurred. The erection plan was to build the cantilevers only partway out from the shore. Meanwhile, the central part of the span would be assembled onshore. At the appropriate time, it would be floated out and raised into position. On September 11, 1916, the weather and tides were suitable. All went smoothly, and by mid-morning, the span had been lifted about 7 m (23 ft.) above the water. At about 11 a.m., a sharp crack was heard, and the centre span slid off its four corner supports into the river. Thirteen men were killed and 14 more were injured.

An investigation found that the accident was unrelated to the design and was caused by a material failure in one of the four bearing castings that supported the central span temporarily while it was being transported and hoisted. The St. Lawrence Bridge Company assumed the responsibility for the failure, a second span was constructed, and the design of the support bearings was changed from a casting to a lead "cushion." The new middle span was successfully lifted into place, over three days, in August 1917. The bridge was opened to traffic in 1918, and the Prince of Wales attended the formal inauguration on August 22, 1919.

AFTERMATH: SOME HARD LESSONS LEARNED

In the decade after the Quebec Bridge disasters, provincial governments passed the first Acts to license professional engineers. The Ritual of the Calling of an Engineer (described in Chapter 18) was introduced, and there arose the myth that the chain and iron rings used in that ritual are made from the steel from the wreckage that claimed the lives of so many men in the cold waters of the

Photo 1.4 — The Quebec Bridge (1916 collapse). *The collapse of the centre span of the Quebec Bridge (St. Lawrence design), photographed at the instant it hit the water on September 11, 1916.*

Source: *The Quebec Bridge over the St. Lawrence River near the City of Quebec: Report of the Government Board of Engineers*, Department of Railways and Canals, Canada, 1919.

St. Lawrence. Canada's worst bridge disasters taught engineers a few lessons that still ring true today, these among them:

- Provide adequate funding for projects.
- Hire capable and competent professionals.
- Define clearly the duties, authority, and responsibility of personnel.
- Discuss design decisions and technical problems openly.
- Monitor work on the site adequately.
- Ensure that communication is rapid and accurate.
- Provide adequate support staff and remuneration for professional people.

Provincial regulation of engineering helps achieve these goals. The professional engineer's stamp on engineering plans and specifications identifies unambiguously who is responsible for the accuracy of the documents and for the computations on which they are based. These lessons were learned at great cost.

WHERE TO LEARN MORE

The two-volume book cited below describes the Quebec Bridge in impressive detail. The book is a classic of project documentation, and is well worth reading, even a century after the disaster, by anyone interested in structural design. It is available in most university libraries.

> *The Quebec Bridge over the St. Lawrence River near the City of Quebec: Report of the Government Board of Engineers*, Department of Railways and Canals Canada, printed by order of the Governor General in Council, 31 May 1919.

(For more reading suggestions about Canadian engineering history, see Web Appendix E.)

DISCUSSION TOPICS AND ASSIGNMENTS

1. The section "An Inspiring Legacy" in this chapter summarizes more than 20 Canadian engineering and/or geoscience achievements. Select one of these achievements and investigate it in more detail, using the Internet or your library. Write a brief description of the project (not more than two or three pages). Be sure to include the motivation for the project; the name of the key person or group responsible for the project; and any major technical or financial problems facing the designers or builders. What was (or is) the major impact of the project on Canada?
2. The Avro Arrow was a supersonic interceptor aircraft designed and built in Canada in the 1950s. Although the Arrow was decades ahead of other military interceptor aircraft of the time, it was cancelled in 1958. Write a brief description of the project (not more than two or three pages), using the Internet or your library. Be sure to include the factors listed in the previous question, as well as an explanation of the reason why the Arrow was abandoned and the effect of the cancellation on the Canadian aircraft industry.

For additional assignments, see Web Appendix E.

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[13] Canadian Mining Hall of Fame, Walter Holyk (1921–2004), inducted 1997. The hall's six locations include the University of Toronto and the Royal Ontario Museum. mininghalloffame.ca/inductees/g-i/walter_holyk (accessed June 18, 2017).

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[17] Oliver Bonham, email correspondence, June 19, 2017.

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[19] Engineers Canada, *National Survey of the Canadian Engineering Profession, 2002*,10.

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[21] Ibid., 50–52.
[22] Ibid.
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[24] Ibid.
[25] G.H. Duggan, *The Quebec Bridge*, bound monograph, prepared originally as an illustrated lecture for the Canadian Society of Civil Engineers, January 10, 1918.
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[29] Duggan, *The Quebec Bridge*.

Chapter 2
Regulation of Engineering and Geoscience

A key role of government is to protect the public. Therefore, when the government confers the privilege of professional status on any group, the public welfare must be protected by licences and by regulations that

- admit only qualified people to the profession,
- establish standards of professional practice and Codes of Ethics, and
- discipline negligent, incompetent, or unscrupulous practitioners as necessary.

As professionals, engineers and geoscientists are governed by strict licensing rules. This chapter explains the licensing process and the organization of these professions. The licensing was initiated by tragic events, including the collapse of the Quebec Bridge (see Chapter 1) and the Bre-X fraud (described in this chapter). Since you are, or likely will be, a licensed member of a "self-regulating" profession, read this chapter critically. How should you regulate your profession?

2.1 EVOLUTION OF ENGINEERING AND GEOSCIENCE LICENSING

Professional Engineering

Efforts to place engineering on the same professional footing as law and medicine began as early as 1887, when the Canadian Society of Civil Engineers (CSCE) held its first general meeting. The campaign to regulate the engineering profession was led by the CSCE. In the years after Confederation, most of Canada followed the British model: engineers entered the profession after a period of apprenticeship, and few engineers were university graduates. However, from its very start, the CSCE established and maintained high standards for admission to the Society with the goal of improving professional engineering practices. Applicants were required to be at least 30 years of age and to have at least 10 years of experience, which could include an apprenticeship in an engineer's office or a term of instruction in a school of engineering acceptable to the CSCE Council. Each applicant also had to show "responsible charge of work" for at least five years as an engineer, designing and directing engineering works.[1]

Despite this early Canadian initiative, the United States was, in fact, the first country to regulate the practice of engineering. The State of Wyoming enacted a law in 1907 after many instances of gross incompetence were observed in a major irrigation project.[2] In Canada, the deadly collapses that occurred during the construction of the Quebec Bridge (see Case History 1.1) emphatically reinforced the need to regulate the profession.

It would, however, be many years before Canadian engineers overcame professional rivalries, business competition, class barriers, and other impediments to agree to improve professional standards—and, indirectly, the status of engineers. In August 1918, at a general meeting of the CSCE held in Saskatoon, an Alberta engineer named F.H. Peters called on the Society to seek licensing legislation. In his view, engineers had developed the nation's resources but had yet to receive the remuneration and the respect they deserved.[3] At that time, the First World War was drawing to an end, and the flood of returning soldiers—some of whom had been involved in various aspects of military engineering—was dramatically increasing the number of engineers. This was depressing salaries, increasing competition, and putting quality at risk.

The CSCE, which changed its name to the Engineering Institute of Canada (EIC) in 1918, drafted a Model Act and published it in the *EIC Journal*. In September 1919, the *Journal* announced that 77 percent of EIC members had approved the Model Act by mail ballot. By the spring of 1920, all provinces except Ontario, Saskatchewan, and Prince Edward Island had passed licensing laws. In Ontario, a joint advisory committee redrafted the bill, and it became law in 1922. The laws enacted in British Columbia, Manitoba, Quebec, New Brunswick, and Nova Scotia were "closed," which meant that engineers would require a licence either to practise engineering or to use the title Professional Engineer (P.Eng.). In Alberta and Ontario, the laws were "open," which limited the use of the P.Eng. title, but since licensing was voluntary, unlicensed people could still practise engineering. Alberta amended its Act to "close" it in 1930; Ontario closed its Act in 1937.

In the years that followed, all of Canada's provinces and territories and all the American states amended or passed licensing laws to regulate the engineering profession and the title of P.Eng. Prince Edward Island, in 1955, was the last province to enact closed legislation. A licence is now mandatory to practise engineering or to use engineering titles in every province or territory. This specification differs from practice in the United States, which remains "open." A Canadian licence confers both the right to practise the profession as well as the right to the title (P.Eng. or P.Geo.). In the United States, licensing confers only the right to use the title. As a result, anyone can practise. This well-known loophole, sometimes called the "industrial exception," permits entire industries to function with unlicensed professionals in the United States.

There is another key difference between the Canadian and U.S. engineering laws. In Canada, the engineering profession is "self-regulating": each province or territory has passed an Act to create an Association of professional engineers, which, in turn, regulates the profession.

The importance of self-regulation cannot be overemphasized. Each Association's governing council must enforce the Act, regulations, and bylaws, but the licensed members of the Association elect (most of) the Council members. This practice ensures that well-informed engineers are involved in the regulation of the profession. By contrast, in the United States, the profession is not self-regulating. State governments appoint licensing boards to license engineers, and the governments establish the regulations that engineers must follow. Therefore, politicians typically play a more significant role in establishing and enforcing regulations in the U.S. system than they do in Canada.

In some countries, engineering is not a licensed profession, and anyone may use the term "engineer." In those countries, the possession of a degree or membership in a technical society may be the only guide to the person's competence. In the United Kingdom, for example, licensing is not compulsory and the title of Engineer often means *mechanic*—the sign "Engineer on Duty" hangs outside many garages. British engineering societies award the title of Chartered Engineer to members who join voluntarily and meet their admission requirements.

Professional Geoscience

Geoscience is an important profession, respected for centuries. In our early history, geoscience was the work of solitary explorers, prospectors, and miners. The profession gained great recognition, however, through the establishment of the Geological Survey of Canada in 1842 and the tireless work of Sir William Logan. Laws for licensing of geoscientists date back more than 80 years. The following provides a brief history:

> The engineering professions were regulated in Canada in the early decades of the twentieth century. From the outset, it was recognized that the work of many geoscientists also affected the public welfare through their involvement in oil, gas and ore reserves estimation, exploration and mining activities, and construction of major engineering works such as dams and bridges. More recently, geoscientists have become major players in the broad area of environmental practice.
>
> Initially, geoscientists whose work impacted the welfare of the public were licensed as engineers, usually as mining engineers. In Alberta, John A. Allan, a prominent geoscientist and founder of the Geology Department at the University of Alberta, took an active role in establishing the Association of Professional Engineers of Alberta (APEA) in the 1920s and became its president in the 1930s. In the 1950s, the discovery of oil and gas in Alberta focussed attention on the geoscience professions, with the result that geologists, and the practice of geology and geophysics, were explicitly identified in the Engineering Act in Alberta in 1955. Separate designations for geologists and geophysicists (*P.Geol.* and *P.Geoph.*) were introduced in 1960 and, in 1966, APEA changed its name to become the Association of Professional Engineers, Geologists and Geophysicists of Alberta (APEGGA) [and as of 2012 is the Association of Professional Engineers and Geoscientists of Alberta (APEGA)].

> Following the pattern in Alberta, geoscientists are now licensed in most Canadian provinces and territories by Associations of engineers and geoscientists, established by legislative acts covering the professions of engineering and geoscience.[4]

Tragically, scandal and disaster precipitated the creation of licensing laws. The Bre-X fraud, exposed in 1997, spurred the regulation of geoscientists in the same way that the collapse of the Quebec Bridge, 90 years earlier, spurred the regulation of engineers. (A case history of the Bre-X fraud is found at the end of this chapter.)

In 2000, the Walkerton tragedy reinforced the Bre-X lesson. Seven people died and more than 2,300 became ill from contaminated drinking water in Walkerton, Ontario. A Public Inquiry revealed "omissions or failures to take appropriate action" on the part of Ontario's Ministry of the Environment, which is responsible for monitoring the operation of municipal water systems.[5]

Shortly thereafter, Ontario passed the Professional Geoscientists Act (2000), Quebec passed the Geologists Act (*Loi des géologues*—2001), and Nova Scotia passed the Geoscience Profession Act (2002). Prince Edward Island and Yukon do not yet regulate geoscience.

Photo 2.1 — The Canadian National Seismograph Network. *The Geological Survey of Canada operates almost 100 seismographs that transmit their data via satellite, radio, and telephone lines to central locations. More than 1,000 earthquakes is located and catalogued each year, mainly in western Canada, and the data is publicly available from Natural Resources Canada at www.earthquakescanada.nrcan.gc.ca. Most seismologists have a postgraduate geoscience degree and typically work in oil and gas exploration, earthquake measurement, or nuclear explosion monitoring.*

Source: © Victoria Times Colonist

Qualified Persons—An Important Role for Engineers and Geoscientists

Some of the regulations made after the Bre-X fraud and the Walkerton tragedy introduced the term "qualified person" (QP). This term now appears in legislation, and it is defined below as it applies to professional engineers and geoscientists. QPs are required to be independent. If unqualified people assist a QP to prepare a technical report, the QP must assume responsibility for the report and must ensure that all information is correct. A QP must always visit the site on which the report is based.

- **Mineral discoveries:** The Canadian Securities Administrators (CSA), an umbrella body for provincial securities regulators, issued a document titled *National Instrument 43-101*, a revised version of which came into effect on June 30, 2011. This document specifies the (mandatory) format for providing oral statements or written disclosures of scientific or technical information to the public concerning mineral projects. The document is extremely specific—it even lists the headings for technical reports. The CSA also states that only a QP can disclose scientific or technical information to the public regarding a mineral project. The CSA defines a QP as an individual who

  a) is an engineer or geoscientist with a university degree, or equivalent accreditation, in an area of geoscience, or engineering, relating to mineral exploration or mining;
  b) has at least five years of experience in mineral exploration, mine development or operation, or mineral project assessment, or any combination of these, that is relevant to his or her professional degree or area of practice;
  c) has experience relevant to the subject matter of the mineral project and the technical report;
  d) is in good standing with a professional association; and
  e) in the case of a professional association in a foreign jurisdiction, has a membership designation that
     i) requires attainment of a position of responsibility in their profession that requires the exercise of independent judgment; and
     ii) requires
        A. a favourable confidential peer evaluation of the individual's character, professional judgement, experience, and ethical fitness; or
        B. a recommendation for membership by at least two peers, and demonstrated prominence or expertise in the field of mineral exploration or mining....[6]

  In addition, *NI 43-101* recommends several publications to guide the QP, prepared by the Canadian Institute of Mining, Metallurgy and Petroleum (CIM). These are listed on the CIM website at www.cim.org/en.aspx.
- **Oil and gas discoveries:** The CSA periodically amends *National Instrument 51-101, Standards of Disclosure for Oil and Gas Activities*. This document specifies the (mandatory) format for providing oral statements or written disclosures of scientific or technical information to the public concerning oil and gas discoveries.[7] (Readers are warned that *NI 51-101* is a complicated document that usually requires interpretation by legal advisers and reserves experts.)

- **Coal discoveries:** *National Instrument 43-101* specifies that estimates on coal deposits should be prepared according to GSC Paper 88-21, which outlines definitions, concepts, and parameters used to determine coal resources.[8]
- **Brownfields:** The restoration of "brownfields" (contaminated properties), which are a "legacy of a century of industrialization," requires the supervision and approval of a QP. Canada has an estimated 30,000 brownfields, typically sites of former gas stations, toxic storage dumps, or abandoned mines. Most jurisdictions have legislation to monitor the decontamination of brownfields. Professionals in the role of a QP in brownfield restoration are governed by the provincial/territorial Environmental Protection Act.[9]

2.2 REGULATORY ACTS

The provincial and territorial governments regulate engineering and geoscience by Acts of provincial legislatures (in the provinces) or legislative councils (in the territories). These important Acts are the legal basis for professional regulations. Eight provinces or territories regulate engineering and geoscience in the same Act, and three provinces regulate engineering and geoscience in separate Acts. Two jurisdictions (Prince Edward Island and Yukon) regulate engineering, but do not yet regulate geoscience. The following is a list of the regulatory Acts:

TABLE 2.1 — Regulatory Acts by Province and Territory

Alberta	Engineering and Geoscience Professions Act
British Columbia	Engineers and Geoscientists Act
Manitoba	Engineering and Geoscientific Professions Act
New Brunswick	Engineering and Geoscience Professions Act
Newfoundland and Labrador	Engineers and Geoscientists Act
Northwest Territories	Engineering and Geoscience Professions Act
Nova Scotia	Engineering Profession Act and Geoscience Profession Act
Nunavut (N.W.T. administers this Act.)	Engineers and Geoscientists Act
Ontario	Professional Engineers Act and Professional Geoscientists Act
Prince Edward Island	Engineering Profession Act
Quebec	Engineers Act (*Loi sur les ingénieurs*) and Geologists Act (*Loi sur les géologues*)
Saskatchewan	Engineering and Geoscience Professions Act
Yukon	Engineering Profession Act

Contents of the Acts

These Acts establish the legal basis for the engineering and geoscience professions. The Acts define basic terms; create the Association as a legal entity; define the extent of its powers; and set standards for admission, practice, and discipline of professionals. The following clauses are typical in each Act:

- the purpose of the Act (which, in every case, is to protect the public)
- the legal definition of engineering and/or geoscience
- the authority to establish a provincial (or territorial) Association
- the purpose (or objects) of the Association
- standards for granting licences (or for admission to the Association)
- procedures for establishing regulations to govern professional practice
- procedures for establishing bylaws to govern the Association itself
- Code of Ethics to guide the personal actions of the licensees (or members)
- disciplinary procedures

Every Act is available on the websites for the Associations. (Appendix A lists all of the Associations and their websites.)

Self-Regulation of the Professions

The Acts establish engineering and geoscience as self-regulating professions, just as law, medicine, and dentistry are. The term *self-regulating* means that the licensed members elect most of the Association's Council. The Council administer the Act, following democratic procedures. Doing so ensures that the best-informed people are in a position to establish and enforce the standards of practice, Codes of Ethics, and discipline procedures that protect public safety and the environment. The public also benefits because the Associations run without government funding. Licensing fees pay administrative staff, and licensed members serve voluntarily on the admission, discipline, and other committees.

A Note about Nomenclature

- Several Associations use the term "licensed" to indicate admission to the profession, but other jurisdictions use "registered." The terms are equivalent, but this text uses "licensed" to avoid any misunderstanding that membership is voluntary or that the Associations are trade unions or special interest groups.
- The terms "licensee," "practitioner," and "member" are interchangeable.
- The term "professional Act," "provincial Act," or simply "Act" refers to the relevant Act or law (as listed above) in each province or territory.
- The term "Association," "regulator," or "licensing body" refers to the Association of Professional Engineers and/or Geoscientists (or *Ordre des ingénieurs* or *Ordre des géologues*) created under the Act in each province or territory.

2.3 DEFINITION OF ENGINEERING

The terms "engineer" and "ingenuity" come from the same Latin root, *ingenium*, which means talent, genius, cleverness, or native ability. Ancient Roman armies marched with a complement of engineers to design and build roads, fortifications, and weapons of war. Over the centuries, *civil* (non-military) engineers evolved to design the structures needed in a modern society. Engineering now includes dozens of branches and sub-disciplines.

Model Definition of Engineering

Engineers Canada (the working name of the Canadian Council of Professional Engineers [CCPE]) proposed a model definition for "the practice of engineering." The goal is to assist governments to adopt consistent definitions in their Acts and thus permit engineers to practise across Canada more easily. The Engineers Canada model definition is as follows:

> The Practice of 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.[10]

This definition is similar to the wording in most engineering Acts; it is, however, a circular definition (since it uses the term "engineering" within the definition), so it needs further clarification. The difference between *engineering* principles and *scientific* principles is an emphasis on useful applications. The Canadian Engineering Accreditation Board's criteria explain the difference: "The engineering sciences primarily involve the creative *application* of the principles developed through the natural sciences in the *solution of engineering problems* [emphasis added]."[11]

In other words, engineering includes almost any act that puts science and mathematics to creative, practical use and that concerns the safeguarding of life, health, property, economic interests, the public welfare, or the environment. This definition is a broad one; some Acts further clarify the boundaries with scientists and architects.

Legal Definition of Engineering

The most important definition of engineering is in the Act for your province or territory, because that definition applies to you. Most Acts are similar to the model definition (above), although a few Acts list the types of machinery or structures (such as railways, bridges, highways, and canals) that are within the engineer's area of practice. (For example, see the APEGBC definition in Web Appendix B.) This makes the definition clear and specific, but also long and difficult to read. Also, as time passes, such lists become obsolete as old components (such as steam engines) disappear and new areas (such as nanotechnology) emerge. Ontario's Act is probably closest to the national definition:

> The Practice of Professional Engineering: means any act of planning, designing, composing, evaluating, advising, reporting, directing or supervising that requires the application of engineering principles and concerns the safeguarding of life, health, property, economic interests, the public welfare or the environment, or the managing of any such act; ("*exercice de la profession d'ingénieur*") …[12]

In Alberta, the definition of engineering is similar but not identical:

> "Practice of Engineering" means
>
> (i) reporting on, advising on, evaluating, designing, preparing plans and specifications for or directing the construction, technical inspection, maintenance or operation of any structure, work or process
>
> (A) that is aimed at the discovery, development or utilization of matter, materials or energy or in any other way designed for the use and convenience of humans, and
>
> (B) that requires in that reporting, advising, evaluating, designing, preparation or direction the professional application of the principles of mathematics, chemistry, physics or any related applied subject, or
>
> (ii) teaching engineering at a university.[13]

Note that the Alberta definition does not say that the engineer is responsible for protecting life, health, safety, and welfare of the public. The Alberta Code of Ethics and the Act, however, state this clearly. (The legal definition for your province or territory is in the Act, on your Association's website. Excerpts are in Web Appendix B.)

Note that the "factor of safety" (the ratio of load capacity to expected load on a component, system, or structure) is typically the key calculation that decides whether a design protects the "life, health, property or the public welfare." The duty of the professional engineer is to ensure that the factor of safety is adequate and is calculated correctly. Unqualified people cannot assume this responsibility.

2.4 DEFINITION OF GEOSCIENCE

Model Definition of Geoscience

Each province and territory (except Prince Edward Island and Yukon) has an Act that regulates "professional geoscience" (including geology and geophysics). These Acts define the boundaries between geoscience, engineering, and other professions. The definitions vary slightly among the provinces and territories. The advisory body, Geoscientists Canada (the working name of the Canadian Council of Professional Geoscientists [CCPG]), has proposed the following model definition:

> The "practice of geoscience" is when a person who, through specialized education, training and experience advances knowledge of the Earth and earth-forming processes through scientific investigation and interpretation.[14]

Legal Definition of Geoscience

Of course, the key definition of geoscience is in the Act for your province or territory, because it applies to you. The province of Alberta has the largest enrolment of professional geoscientists, so let us examine the definition in its licensing Act:

> "practice of geoscience" means
>
> (i) reporting, advising, evaluating, interpreting, processing, geoscientific surveying, exploring, classifying reserves or examining related to any activity
> (A) that relates to the earth sciences or the environment,
> (B) that is aimed at the discovery or development of oil, natural gas, coal, metallic or non-metallic minerals, precious stones, other natural resources or water or that is aimed at the investigation of surface or subsurface conditions of the earth, and
> (C) that requires, in that reporting, advising, evaluating, interpreting, processing, geoscientific surveying, exploring, classifying reserves or examining, the professional application of the principles of mathematics, chemistry, physics or biology through the application of the principles of geoscience, or
>
> (ii) teaching geoscience at a university.[15]

2.5 LICENSING ASSOCIATIONS

Each province and territory has an Association of Professional Engineers and/or Geoscientists, which administers the Act. In Quebec, the Associations are called *Ordres*. In eight jurisdictions, the Associations include both engineers and geoscientists, but three provinces (Ontario, Quebec, and Nova Scotia) have separate Associations for engineers and geoscientists. (Appendix A lists all Associations/Ordres, with addresses and websites.)

The Acts are provincial/territorial laws, but the governments delegate the responsibility for implementing the Acts to provincial or territorial Associations. Each Association, in turn, has developed regulations, bylaws, and a Code of Ethics, all of which derive their authority from the Act:

- **Regulations** are rules that clarify the Act or define procedures, such as admission, professional conduct, and disciplinary procedures.
- **Bylaws** are rules for running the Association itself and typically include election procedures, financial matters, committee requirements, and meetings.
- **The Code of Ethics** is a set of rules of personal conduct. Every engineer and geoscientist must be familiar with the relevant Code and endeavour to obey it.

As mentioned earlier, the professions are self-regulating because members, who are licensed professionals, establish and enforce these rules. In addition, members serve voluntarily on the admission, discipline, and other committees; members elect the majority of the Association's governing council (the government also appoints some councillors); and members usually must confirm (by ballot) any regulations recommended to the government and bylaws passed by the Council. Obviously, for self-regulation to work effectively, members must be willing to serve in these volunteer and elected positions.

2.6 PROFESSIONAL LICENSING: GENERAL RULES

The licensing standards for engineers and geoscientists are similar across Canada and follow guidelines published by Engineers Canada (*Guideline on Admission to the Practice of Engineering in Canada*)[16] and by Geoscientists Canada (*Geoscience Knowledge and Experience Requirements for Professional Registration in Canada*).[17] These guidelines, summarized below, are recommendations, not law, so provincial and territorial laws take precedence (and may vary slightly).

Basic Requirements

Although engineering and geoscience are distinct disciplines, the basic requirements for licensing are similar. To obtain a licence, every applicant (engineer or geoscientist) must satisfy the following six basic requirements:

- **Education:** The applicant must have adequate academic engineering or geoscience qualifications, such as a university degree from an accredited program (engineering) or a Bachelor of Science (B.Sc.) degree (geoscience), or equivalents.
- **Experience:** The applicant must satisfy the experience requirement, which is four years of suitable engineering or geoscience experience in the area of qualification. (Quebec requires three years of experience.)
- **Knowledge of local practices:** Applicants must understand local practices and conditions. For example, work experience should demonstrate knowledge of local Canadian "laws, practices, standards, customs, codes, conditions, climate, and technology." To satisfy this requirement, at least one year of practical experience must be in a Canadian environment.
- **Language:** The applicant must be able to communicate effectively, both orally and in writing, in the working language of the province or territory.
- **Good character:** The applicant must be of good character, as determined mainly from references. Evidence of criminal conviction, fraud, or false statements on applications may affect admission.
- **Knowledge of professional practice and ethics:** Typically, every applicant must write and pass the Professional Practice Exam (PPE) on Canadian law and ethics. The exam tests non-technical knowledge of professionalism, ethics, self-regulation, governance of the professions, law, and legal concepts. (Chapter 16 explains the PPE in detail and includes sample questions.)

Note: A few Associations require more than what Engineers Canada and Geosciences Canada recommend. For example, PEO (Ontario) requires applicants to be at least 18 years of age. APEGA (Alberta) requests citizenship or landed immigrant status for full membership (licensing), but non-citizens may enrol as Foreign Licensees.

Types of Licences

Licensing is similar across Canada. Each Association typically issues about five types of licences (or grades of membership), but the names may vary. Table 2.2 lists the names of the various licences. Equivalent licences are grouped together. (Check your Association's website for possible changes. The licensing bodies have collaborated on a project called the "Canadian Framework for Regulation," which simplifies and coordinates current practices.)

TABLE 2.2 — Summary of Canadian Engineering and Geoscience Licences

1	**Professional Engineer (P.Eng.) Professional Geoscientist (P.Geo.) ingénieur (ing.) or géologue (geo.) or géoscientifique (géosc.).**	These fully qualified professionals have satisfied the licensing requirements (above) and are licensed to practise.
2	**Provisional Member Provisional Licensee**	A provisional member has a satisfactory academic record and at least four years of approved experience outside Canada, but lacks Canadian experience and is working to gain that experience. The rights and responsibilities of these licensees vary across Canada.
3	**Temporary Licensee (B.C., Ont., Man., Sask., Que.)**	Licensed Canadian engineers living outside the province may usually apply for a temporary licence to practise. A temporary licensee may not take part in Association elections and must renew the licence annually. Rights and responsibilities vary across Canada.
4	**Limited Licence, Engineering Licensee (Eng.L.) Geoscience Licensee (Geo.L.)**	Most but not all Associations issue a limited licence to practise engineering or geoscience in a specified scope of practice. The licensee usually has several years of specialized experience and good academic qualifications (but not in engineering or geoscience).
5	**Licensee (Alta.), Licence to Practise (P.E.I.), Non-Resident Licensee (B.C., Nfld. and Lab., N.W.T.)**	An applicant who is not a Canadian citizen or permanent resident (landed immigrant) must apply as a Non-Resident Licensee in some provinces.

6	**Engineer-in-Training (EIT), Geoscientist-in-Training (GIT), Engineering Intern (EIT), Member-in-Training (MIT), Ingénieur junior or Géologue junior**	The individual is qualified academically, but must work under a licensed professional to obtain the specified experience for licensing. The rights and responsibilities vary across Canada.

Note: You might want to circle the licence names that apply in your province or territory. You should also check your Association's website for a full explanation of the rights and responsibilities associated with your licence.

2.7 LICENSING OF ENGINEERS

Applications may be submitted online in many Associations, but applicants must submit originals (or certified copies) of all grade transcripts and academic documents. Note that Engineers Canada sponsors a website to assist applicants:

https://engineerscanada.ca/become-an-engineer/overview-of-licensing-process

Academic Requirements

Academic qualifications are the key requirement for admission. The Association's Board of Examiners (or Academic Requirements Committee) will evaluate these documents to determine if the applicant is academically qualified.

- **Graduates with CEAB-accredited degrees:** Graduates of university engineering programs accredited by the Canadian Engineering Accreditation Board (CEAB) are exempt from exams (but must write the PPE, required of all applicants). The CEAB publishes a list of accredited programs. A few international degree programs are also CEAB-accredited.[18]
- **Mutually recognized degrees:** Engineers Canada has negotiated international agreements with about a dozen countries. These agreements recognize that Canadian and foreign accreditation procedures (for these countries) are substantially equivalent and that graduates satisfy the academic requirements for admission to professional engineering. For example, the U.S. Accreditation Board for Engineering and Technology (ABET) accredits university engineering programs in the United States. Engineers Canada recognizes engineering degrees from ABET-accredited programs as equivalent to Canadian degrees. If, however, an Association's Board of Examiners judges an applicant's academic record to be deficient, the Board may overrule the agreement and assign exams. A full list of the countries recognized in these agreements is on the Engineers Canada website, under "International Mobility."
- **Non-accredited degrees:** Applicants with degrees that lack CEAB accreditation or mutual recognition are normally required to write confirmatory or technical exams. The Association's Board of Examiners examines each case carefully. The exam program assigned to the applicant (and its purpose) may vary, as explained next.

Internationally Educated Graduates

All applicants must provide the Association with originals (or certified copies) of all transcripts and diplomas. An applicant from an international university must also provide notarized translations, if needed. The assessment process usually follows this path:

- **Application:** The Association's Board of Examiners (or Academic Requirements Committee) assesses all documents. When an applicant's degree is from a non-accredited program, the Association must obtain and evaluate other evidence to justify admission. This request for corroborating evidence of academic ability does not imply any lack of respect for the individual or the individual's university. The Association evaluates each case carefully.
- **Qualifications accepted:** Several "mobility" agreements, such as the Washington Accord, recognize some foreign qualifications and university programs as equivalent to accredited Canadian university programs and grant exemption from the exam program.
- **Confirmatory exams required:** If an applicant's degree is not accredited or equivalent, however, the Association will ask the applicant to write a set of confirmatory exams, even when the applicant's academic record from the non-accredited university appears to be equivalent to the *Examination Syllabus* published by Engineers Canada. Confirmatory exams cover the advanced topics in a portion of the engineering program. Their purpose is to validate the quality and standards of the applicant's university. If the applicant obtains good grades on the first two confirmatory exams, the Association normally waives the rest of the exams.

In the case of a senior, experienced foreign applicant, the Association may be "looking to exempt" the applicant from exams, but some additional evidence must be provided. Associations normally interview senior applicants (with more than 10 years of experience) to evaluate their academic qualifications and engineering achievements, and may then waive some (or all) of a confirmatory exam program.

In addition, Associations may waive some confirmatory exams if applicants can provide other evidence of engineering competence. For example, applicants who have completed a master's degree (or advanced undergraduate courses) at an accredited Canadian university may receive some exemption from the confirmatory exams.

In Alberta (and a few other provinces), engineering applicants assigned confirmatory examinations by APEGA's Board of Examiners have the option of satisfying this requirement by writing the Fundamentals of Engineering (FE) examination, administered by the U.S. National Council of Examiners for Engineering and Surveying (NCEES). The FE examination is a comprehensive eight-hour technical examination covering basic concepts of engineering (with 120 basic general questions in a four-hour morning session, followed by 60 discipline-specific questions in a four-hour afternoon session). The FE examination is the first step to Professional Engineering (P.Eng.) licensing in all U.S. states. APEGA arranges for the FE examination to be held in Alberta on specific dates. More information about the FE examination is available from APEGA or from the NCEES website at www.ncees.org.

Applicants whose engineering degrees are judged not to be equivalent to the *Examination Syllabus* published by Engineers Canada may still enter the engineering profession but will be required to write technical examinations, as described below.

Technical Examinations

Applicants who have non-accredited engineering degrees, or engineering-related degrees (such as the B.Tech. or B.Sc.), or three-year technology diplomas may enter the engineering profession by writing technical exams, based on the *Engineers Canada* syllabus.[19]

For each branch of engineering, there are about 14 to 18 three-hour technical examinations. After a detailed evaluation of the applicant's academic transcripts, the Association assigns a subset of these technical exams to make up academic deficiencies. Associations normally do not admit applicants to the exam program if the subset exceeds nine exams. Some Associations permit applicants to take equivalent university courses in lieu of the assigned exams. (Contact your Association for more specific information; Appendix A lists the Web addresses for all Associations.)

The possession of a postgraduate degree may reduce the number of exams assigned, but the postgraduate degrees must be relevant to engineering. Moreover, the accredited programs teach important engineering subjects in their undergraduate courses, and this undergraduate knowledge is essential for licensing.

Permission to enter the examination system varies slightly across Canada. For example, in Ontario the examination system is open to those who hold, as a minimum, one of the following: a three-year engineering technologist diploma from a college of applied arts and technology; a technologist-level certificate from the Ontario Association of Certified Engineering Technicians and Technologists (OACETT); or equivalent acceptable education as determined by the Association.

The examination system provides an alternative route into the profession, but it is not an easy route. Applicants must prepare themselves to write and pass the exams. The Associations do not offer classes, laboratories, or correspondence courses.

2.8 LICENSING OF GEOSCIENTISTS

Applicants may apply online but must also submit originals (or certified copies) of all grade transcripts and academic documents. The Association's Board of Examiners (or Academic Requirements Committee) needs these documents to assess the applicant's academic qualifications.

Academic Requirements

Geoscientists Canada has published a reference for geoscience applicants, titled *Geoscience Knowledge and Experience Requirements* (GKE). The GKE defines the academic requirements in each of the three disciplines of geoscience. Geoscientists Canada has also published *Framework for Assessment in the Licensing of Professional Geoscientists in Canada*, which explains the evaluation criteria.[20] Some Associations (e.g., APEGS and APEGNS) offer an online self-assessment that helps applicants to show the Academic Review Committee how their education compares to the GKE (see, for example, www.apegs.ca and http://ees.acadiau.ca/tl_files/sites/ees/pdfs/apgns_self-assessment.pdf). Students should undertake this investigation early in their geoscience studies, to ensure that their courses meet the evaluation criteria.

However, no accreditation process exists for geoscience degree programs in Canada (or in the United States), so licensing bodies must examine the undergraduate transcripts for each applicant and make a course-by-course comparison with the GKE syllabus. Therefore, it is particularly important that each applicant submit complete original transcripts (or certified copies) directly to the Association. If you received your bachelor's degree from a university located outside of Canada, or even outside your current province or territory, the Association may request detailed course descriptions. The Board of Examiners will consider every university-level course taken by the applicant, including postgraduate courses and theses written. Relevant university-level courses taught by the applicant should also be included.

When an application is complete, a course-by-course assessment determines if the applicant meets the geoscience knowledge required by the GKE. If so, then the applicant is academically acceptable and may move on to satisfying the other admission requirements (such as experience and the PPE).

Internationally Educated Graduates

All geoscience applicants undergo the same course-by-course evaluation.

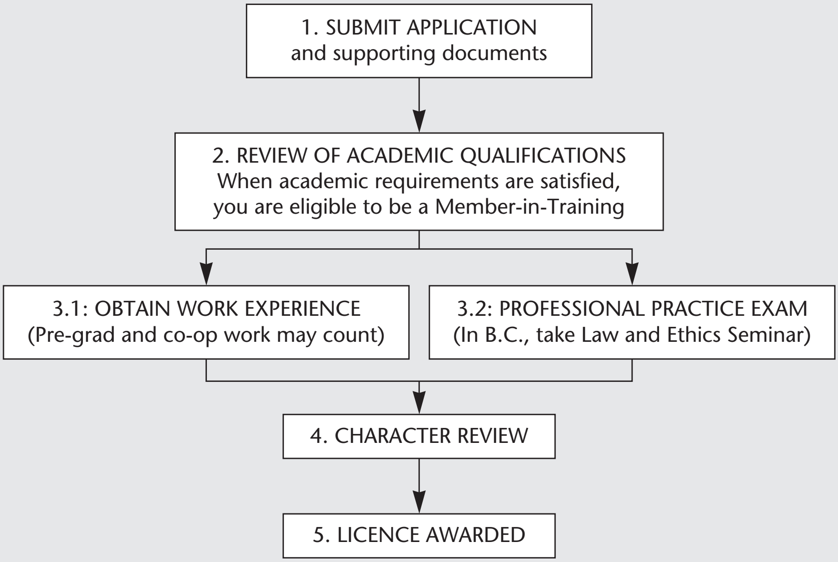
Technical Examinations

If the Board of Examiners determines that the applicant has academic deficiencies, the Board will usually assign confirmatory exams or an examination program to remedy these deficiencies. Under certain circumstances (such as outstanding performance by an applicant in completing exams), these programs may be waived or reduced. However, policies vary on waiving assigned exams, so specific cases must be addressed to your Association's Board of Examiners.

2.9 PROFESSIONAL PRACTICE EXAMINATION

Almost all applicants, whatever their academic qualifications, must pass the PPE in professional practice, law, contracts, liability, and ethics. British Columbia also requires applicants to participate in its Professional Engineering

FIGURE 2.1 — Five Steps in the Licensing Process



Note: You usually write the Professional Practice Exam (step 3.2) during the second or third year of your work experience (step 3.1).

and Geoscience Practice in BC Online Seminar, available online at www.apeg.bc.ca. Applicants transferring their licences from elsewhere in Canada do not need to write the PPE if they passed it in the previous Association. Figure 2.1 illustrates the Five Steps in the Licensing Process. (The PPE is explained, in detail, in Chapter 16.)

2.10 EXPERIENCE REQUIREMENTS

On graduation, applicants are expected to enrol in an engineer-in-training or geoscientist-in-training program to obtain the experience required for a licence. Applicants must submit a summary of this experience for assessment by the Association's Experience Requirements Committee (or Registration Committee). Each Association has a preferred format for summarizing the experience, so contact your Association as soon as you are eligible academically for licensing.

Although the experience requirements for engineering and geoscience are different, the nature, duration, currency, and quality standards of the required experiences are similar. This parallel is evident when comparing *Geoscience Knowledge and Experience Requirements for Professional Registration in Canada* (cited earlier) with *National Guideline on Assessing Engineering Work Experience*.[21]

Rules for Experience

Follow your Association's guidelines when you prepare your experience documentation.

NATURE OF EXPERIENCE

Acceptable engineering or geoscience experience must normally be in the same area as the applicant's academic study. When the experience differs from the academic study—for example, if an engineering graduate is working in a geoscience job—the Association will require additional experience or studies before granting a licence. Furthermore, some jobs may have similar descriptions but, depending on the activities performed, may have different credit as professional experience. An applicant should not presume that his or her area of employment will automatically be accepted (or rejected) as valid experience.

In particular, an applicant should consult the Association for advice when employment is in postgraduate studies, teaching, sales, government service, consulting, or experience that varies sharply from the field of study.

DURATION AND CURRENCY OF EXPERIENCE

Engineering and geoscience both have a four-year experience requirement (except Quebec, which requires three years). The experience must be recent, because engineering and geoscience evolve quickly. An applicant must show that old experience is still relevant.

PRE-GRADUATE AND POSTGRADUATE EXPERIENCE

Most Associations grant up to 12 months' credit for work experience obtained before university graduation. The pre-graduate experience (preferably obtained after the midpoint of the academic program) must satisfy the quality standards listed below.

Most provinces grant up to 12 months' work experience for completing a postgraduate degree in a relevant discipline. In fact, some provinces permit even more credit (up to the total time spent in postgraduate studies), depending on how well the postgraduate experience satisfies the five quality criteria, listed under "Engineering Experience" (see next page).

CANADIAN EXPERIENCE

All Associations require applicants to obtain 12 months' work experience in a Canadian environment. This usually means working in Canada under the direction of a licensed professional. The work may be outside Canada—for example, in a Canadian company with foreign contracts—providing that the applicant is working with Canadian laws, practices, standards, customs, codes, conditions, and climates. (Quebec requires at least 12 months of work experience within Canada.)

Quality of Experience

ENGINEERING EXPERIENCE

In *Guideline on Admission to the Practice of Engineering in Canada*, Engineers Canada defines the engineering work experience requirement as demonstrating the core engineering competencies. The competencies are:

- apply engineering knowledge, methods and techniques;
- use engineering tools, technology and equipment;
- protect the public interest;
- manage engineering activities;
- communicate engineering information;
- work collaboratively in the Canadian environment; and
- maintain and enhance engineering skills and knowledge.

> Applicants demonstrate that they meet the core engineering competencies by providing descriptions of situations from their engineering work experience where they have used each competency. The core engineering competencies allow the regulators to assess the quality of engineering work experience by looking not just at *what* an applicant has done, but by also looking at *how* and *why* tasks are completed."[22]

While APEGBC has adopted a similar competency-based assessment (and APEGA in mid-2017), many Associations continue to expect the applicants to demonstrate that their experience satisfies the following five criteria for engineering quality:

- **Application of theory:** analysis, design and synthesis, testing methods, and implementation methods (such as engineering cost studies, optimization). The application of theory is mandatory, and it must involve substantial experience (though not necessarily all of it). Theory must be supplemented by experience in the other four criteria.
- **Practical experience:** site visits, application of equipment, opportunities to experience practical limitations (such as manufacturing tolerances), and importance of time (e.g., scheduling, wear-out, replacement scheduling).
- **Management of engineering:** project management, planning, scheduling, budgeting, supervision of staff, project control, risk analysis, and so on.
- **Communication skills:** preparation of written work, correspondence, record-keeping, report writing; oral reports or presentations to colleagues, supervisors, senior management, clients and regulators; public presentations; and so on.
- **Social implications of engineering:** demonstration of awareness of dangerous conditions threatening life, limb, property, or the environment; understanding of the role of regulatory bodies; knowledge of legislation concerning health and safety in the workplace.[23]

Check with your Association to see how to demonstrate that your work experience meets all requirements.

GEOSCIENCE EXPERIENCE

Geoscience practice experience should involve the following six components:

a) **Practical experience**, which may include field/lab data collection, project function and operation, evaluation of geoscience limitations, project time constraints, project costs, data reliability and uncertainty; equipment maintenance, safety, environmental impact, and hazard and risk recognition;
b) **Application of geoscience theory**, which may include development of concepts and hypotheses, analysis/evaluation of data (maps, graphs or tables), result integration/synthesis and testing or implementation;
c) **Geoscience project management**, which may include planning, scheduling, budgeting, supervision, project control, safety and risk management, and leadership;
d) **Communication skills**, which may include written work and oral presentations to a variety of audiences (supervisors, co-workers, government regulators, clients and general public) and on a variety of scales (from daily record-keeping to major reports);
e) **Professional accountability and ethical responsibilities to the public**, profession, and client or employer; and
f) **Awareness of the societal implications of geoscience**, which may include the recognition of geoscience value and benefits, the interrelationship between society and the planet Earth, government regulations, environmental impacts, economic well-being, safety issues, geoscience education, and geoscience industries.[24]

2.11 MOBILITY AGREEMENTS

National Mobility

Professional engineers and geoscientists in Canada enjoy full mobility in all provinces and territories under the government's Agreement on Internal Trade (AIT). This agreement, which is federal law, enables any worker qualified for an occupation in any part of Canada to work in that occupation in any other province or territory. In other words, licensed professionals in good standing can be licensed easily in other jurisdictions.

International Mobility Agreements

ENGINEERING

Engineers Canada, on behalf of all Canadian engineering Associations, has agreed with several foreign countries to reciprocal recognition of qualifications. Canadian engineers who wish to work in those countries (or immigrants to Canada from these countries) may be interested in learning more about these agreements on the Engineers Canada website.[25] Canadian engineers may register with the *Engineers Canada Mobility Register* at https://engineerscanada.ca/services/mobility-register. This registration indicates that an engineer has met the standards and is prepared to conduct engineering practices internationally.

International engineers who would like to practise engineering in Canada can find information on the Engineers Canada website: Roadmap to

Engineering in Canada at https://newcomers.engineerscanada.ca/. Another organization for engineers interested in mobility is the International Engineering Alliance (IEA). The IEA is an organization that includes 26 countries subject to seven international agreements. These agreements establish and enforce internationally benchmarked standards for engineering education and expected competence for engineering practice.[26]

GEOSCIENCE

Geoscientists Canada, the national organization for geoscience licensing, has established links with many international institutes with similar objectives concerning professional practice in the geological sciences. These institutes and the agreement details are listed on the Geoscientists Canada website.[27]

PRIOR LEARNING ASSESSMENT RECOGNITION

To facilitate mobility of engineers and geoscientist, regulators may consider the use of prior learning assessment and recognition to evaluate an applicant's learning and experience.[28]

2.12 LICENSING OF CORPORATIONS

A corporation, as a legal entity, may obtain a licence to practise engineering or geoscience. The purpose of licensing, however, is to protect the public against incompetence, negligence, and professional misconduct, and these are qualities of human beings. A key question arises: if a corporation is licensed, who is providing the engineering or geoscience services, and how is the public protected?

In almost every province and territory, the Act solves this problem by requiring each corporation to obtain a Permit to Practise (also called a "Certificate of Authorization"). To obtain this permit, the corporation must employ a professional engineer or geoscientist who acts in a supervisory capacity, and who assumes personal responsibility for the services provided by the corporation. The corporation must also obtain liability insurance. In addition, the corporation's engineers and geoscientists must normally participate in a continuing competence program (as discussed in Chapter 17).

A professional engineer or geoscientist working for a corporation that has a permit to practise (or certificate) does not have to apply for an individual permit and, obviously, a corporation that does not offer such services to the public does not need a permit. However, some provinces, such as Ontario, require that every entity—be it an individual, a partnership, or a corporation—that offers or provides professional services to the public must obtain a Certificate of Authorization. A professional who plans to provide services to the public should discuss the plan with the Association before providing such services. In Ontario, professionals who "moonlight" or work on weekends without a permit (or certificate) may be breaking the law.

2.13 CONSULTING ENGINEERS

At present, Ontario is the only jurisdiction in Canada that regulates the designation of "Consulting Engineer." To qualify as a consulting engineer, a member must

- have been continuously engaged for at least two years in private practice,
- have at least five years of satisfactory experience since becoming a member, and
- pass (or be exempted from) exams prescribed by the Association Council.

Since applicants for the Consulting Engineer designation must be engaged in private practice and therefore offer their services to the public, they must also be holders of a Certificate of Authorization in Ontario, or they must be associated with a partnership or corporation that is a holder of a certificate.

2.14 THE PROFESSIONAL SEAL

When an Association awards a licence, it also includes a "seal" (usually a rubber stamp), which the professional engineer or professional geoscientist uses to approve documents. The professional must sign, seal, and date all final drawings, specifications, plans, reports, and similar documents before releasing them for action.[29] Write your signature and date next to the seal, but do not obscure the seal. When two or more professionals collaborate on different aspects of a project, both seals are applied. Each professional specifies his or her area of responsibility in writing next to the seal.

The seal has important legal significance—it means that you as the professional have approved the document. A seal identifies the person responsible and provides assurance that the work was competently prepared. Only *final* documents are sealed. *Preliminary* documents are not sealed; they must be marked "preliminary" or "not for construction." Costly errors can occur when preliminary documents are mistaken for approved final designs. Only the professional who prepares or approves a document should seal it. The seal implies an intimate knowledge of and control over the document. Do not use the seal casually.

A professional who knowingly signs or seals a document that has not been personally prepared (or prepared by assistants under supervision) may be charged with professional misconduct. That professional may also be liable for damages if the misrepresentation results in a loss.

Moreover, many disciplinary cases have arisen because professionals signed and sealed documents prepared by others that later proved to have serious flaws. (Chapter 4 gives much more information on seals, and discusses electronic seals.)

2.15 DISCIPLINE AND THE CODE OF ETHICS

The Code of Ethics defines a high standard of personal professional conduct, required by every provincial and territorial Act. The Code includes, in general terms, the duties of the professional to the public, to the employer or client, to fellow professionals, to the profession, and to oneself. The Code protects the public by requiring professional behaviour; it is the basis for disciplining unscrupulous practitioners.

Every professional should read and understand the Code, but it is not necessary to memorize it. Most professionals use common sense in their ethical behaviour, follow the Code intuitively, and never fear charges of professional misconduct. The Code of Ethics for each Act is in Web Appendix B, and Chapter 9 discusses the ethical basis for the codes, including the model Code of Ethics of Engineers Canada.

In addition to the Code of Ethics, there is a much older voluntary oath, written by Rudyard Kipling and first used in 1925, called the "Obligation of the Engineer." The iron ring, worn on the working hand, easily identifies engineers who have taken this oath. Earth science rings, made from precious metal, are part of a comparable ceremony for geoscientists. These ceremonies are described in detail in Chapter 18. Wearing an iron ring or an earth science ring does not mean that the wearer has received a degree, but it does indicate that he or she participated in the ring ceremony and has voluntarily sworn to maintain high standards in professional work. Although the Obligation and the Code of Ethics have the same purpose, be sure not to confuse them. The Obligation is a voluntary commitment to high standards, but infractions of the Code of Ethics are subject to discipline under the Act.

To protect the public welfare, the Associations must ensure that only qualified individuals are practising. In addition, it is sometimes necessary to discipline the few engineers or geoscientists who commit professional misconduct. To enforce the Act, each Association has a staff that receives complaints, prosecutes people practising under false pretences, and administers any complaints against licensed members. Chapter 3 explains these functions in detail, but they are summarized, as follows:

- **Enforcement:** Each Association enforces the Act by prosecuting unlicensed individuals who practise engineering or geoscience, or who use the titles of Professional Engineer, Professional Geoscientist, Professional Geologist, or Professional Geophysicist (or the French equivalents).
- **Professional misconduct and discipline:** Each Act requires the Association to reprimand, suspend, or expel members who are guilty of professional misconduct. *Professional misconduct* means negligence, incompetence, or corruption, including a serious infraction of the Association's Code of Ethics. It is important to distinguish between your Association's Code of Ethics (which is enforceable under the Act) and the codes of ethics endorsed by many technical societies, since the societies' codes are voluntary guides to conduct. Chapter 3 describes the disciplinary process.

2.16 ENGINEERS CANADA

Engineers Canada is a federation of the 12 Associations that license engineers in each province and territory across Canada. Established in 1936 as a federation of the Associations, Engineers Canada does not have individual members; however, every licensed engineer is indirectly a member. Its website is www.engineerscanada.ca.

Engineers Canada coordinates the engineering profession on a national scale by promoting consistency in licensing and regulation. It develops policies, guidelines, and position statements. Although these are not binding, the Associations are encouraged to review and adopt the policies. Engineers Canada holds the Canadian trademarks for engineering titles such as P.Eng., Professional Engineer, Engineer, Engineering, and Consulting Engineer (and others), as well as the French equivalents. Engineers Canada has two important committees (CEAB and CEQB), as described below.

Canadian Engineering Accreditation Board (CEAB)

The CEAB evaluates undergraduate engineering programs offered by Canadian universities. The CEAB develops academic criteria, arranges accreditation team visits, compares engineering programs against these criteria, and recommends (for or against) accreditation. Accreditation ensures that university academic standards are adequate for professional engineering licensing across Canada. CEAB accreditation is important to universities and to Canadian engineering graduates, because it qualifies them academically for licensing as professional engineers.

Canadian Engineering Qualifications Board (CEQB)

The CEQB develops national guidelines for professional engineering to promote consistent licensing, registration, and other regulations across Canada. The CEQB also maintains the *Examination Syllabus*, which describes technical exam programs for the engineering disciplines, as well as basic and complementary studies. The syllabus is the key document for evaluating qualifications of applicants with non-accredited engineering degrees and for assigning exam programs.

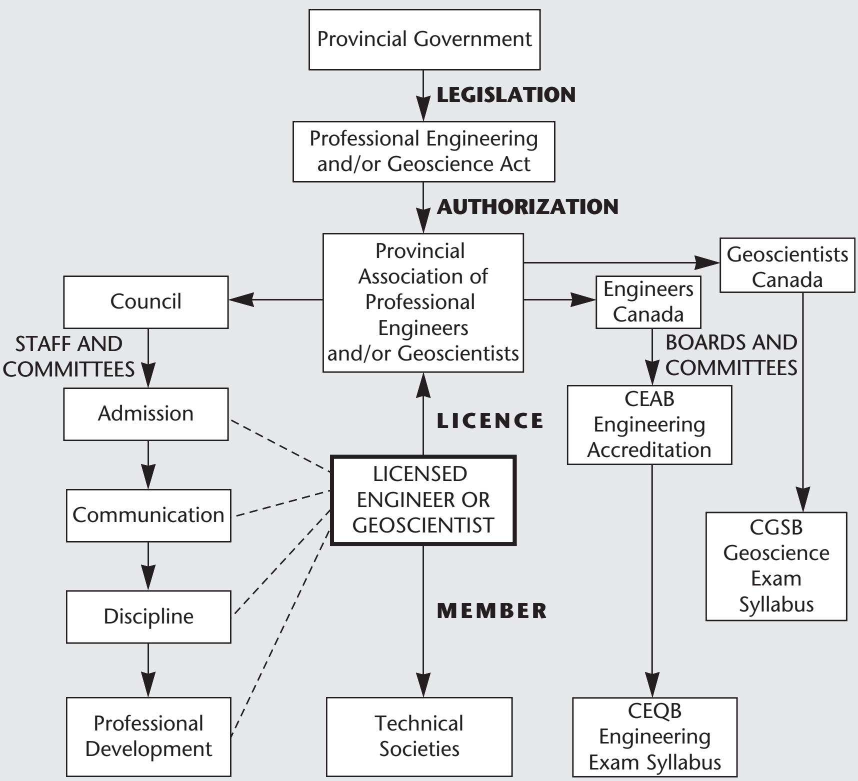
2.17 GEOSCIENTISTS CANADA

Geoscientists Canada is the working name of the Canadian Council of Professional Geoscientists (CCPG), which incorporated in 1996. Its mandate is to coordinate the geoscience profession on a national scale by promoting consistency in licensing and regulation. Geoscientists Canada provides advice to the geoscience licensing Associations. The Canadian Geoscience Standards Board (CGSB), a subcommittee of Geoscientists Canada, develops national guidelines and examination syllabuses for professional registration in geoscience, and assesses geoscience education across Canada. Policies, guidelines, and position statements developed by Geoscientists Canada are not binding on the Associations, but they review and adopt these documents where appropriate. Several key geoscience guidelines are available on their website, including *Geoscience Knowledge and Experience Requirements* and *Framework for Assessment in the Licensing of Professional Geoscientists in Canada*, cited frequently in this chapter. The Geoscientists Canada website is https://geoscientistscanada.ca.

2.18 OVERVIEW OF PROFESSIONAL RELATIONSHIPS

Figure 2.2 illustrates how professional engineers and geoscientists interact with the various organizations mentioned in this chapter. As a professional engineer or geoscientist, you obtained your licence from your provincial Association, and you likely joined at least one technical society (as discussed in Chapter 18). The members of the Association (including you) elect the Council, which hires the staff and appoints the committees. The Association's

FIGURE 2.2 — The Relationship of the Licensed Professional Engineer or Professional Geoscientist to the Provincial Association and Related Bodies



staff members communicate with you regarding admission, professional practice, discipline, professional development, and so forth.

In most provinces, the Association licenses both engineers and geoscientists. All engineering Associations are federated members of Engineers Canada (the national body for engineering), and all geoscience Associations are linked to Geoscientists Canada (the national body for geoscience).

Engineers Canada and Geoscientists Canada are important bodies that affect you indirectly. They probably assessed or accredited your university program, but since their job is to advise the Associations, they rarely interact directly with individual members.

CASE HISTORY 2.1

THE BRE-X MINING FRAUD

In the spring of 1997, Bre-X Minerals Limited, a mining company based in Calgary, became the focus of a spectacular mining fraud, apparently perpetrated by at least one geologist. The fraud convinced Canadians that geology needed professional regulation.

Bre-X claimed to have made a gold strike that was richer than any gold discovery in history, and Bre-X stock prices soared; however, after a mysterious death, the fraud began to unravel. The resulting scandal ruined the reputations of almost everyone involved. More seriously, the fraud caused financial calamity for thousands of investors, some of whom had staked their life savings on the Bre-X geologists' reports. An independent team of investigators from Strathcona Mineral Services later stated: "The magnitude of tampering with core samples … is of a scale and over a period of time and with a precision that, to our knowledge, is without precedent in the history of mining anywhere in the world."[30]

BACKGROUND INFORMATION

For our purposes, the story begins in May 1993, when David Walsh, the founder, chairman, and CEO of Bre-X Minerals, announced the discovery of a gold deposit in Busang, Indonesia. One site, drilled previously by an Australian company, was reported to contain one million ounces of recoverable gold.[31] This modest estimate escalated as the months passed, causing a frenzy that pushed Bre-X stock prices from pennies in March 1994 to the equivalent of over $200 per share in September 1996.[32]

SEQUENCE OF EVENTS

The roles played by various Bre-X geological staff are not completely clear. John Felderhof, a 1962 geology graduate of Dalhousie University, was the chief geologist[33] of Bre-X Minerals, although he has since declared that his role was that of an administrator or commercial manager. Michael de Guzman, a geologist from the Philippines, was "Bre-X's No. 2 geologist." De Guzman was running four Bre-X camps in Indonesia, so a fellow Filipino geologist, Cesar Puspos, reportedly supervised much of the work at the Busang site.[34]

Walsh was actively involved in raising funds in Calgary. Meanwhile, Felderhof was in Jakarta, and de Guzman and Puspos were in Busang. In addition, about 20 others worked as geologists or project managers for Bre-X in Indonesia.

A reputable Australian drilling company was hired to drill core samples to evaluate the gold content of the Busang site. In March 1996, Bre-X reported estimates of 30 million ounces of gold at the Busang site; this estimate soon increased to 70 million ounces, with the potential for 100 million ounces. In early 1997, Felderhof raised the "official" reserve estimate at Busang to 200 million ounces of gold.[35]

The golden glow began to tarnish in January 1997, however, when a storage building containing the core samples at the Busang site burned down, allegedly destroying the records of the drilling results. The unravelling fraud attracted world attention on March 19, 1997, when de Guzman committed suicide by jumping from a helicopter. In his suicide note, he explained that poor health drove him to suicide. A body recovered from the Indonesian jungle was confirmed to be his. At the time, de Guzman had been en route to a meeting with a geological team to discuss discrepancies in the test results. Freeport-McMoRan Copper & Gold, Inc., a company in partnership with Bre-X, had drilled additional test holes next to the Bre-X drill holes and the results were quite different from the glowing results quoted by Bre-X.

Felderhof regularly visited the proposed Busang mine site and made the public estimates of gold content. His final figure of 200 million ounces was worth about $70 billion (at the 1997 gold price). To develop this immense gold find, Bre-X needed the help of a larger company and, under pressure from the Indonesian government, became partners with Freeport-McMoRan to develop the find. Freeport challenged the gold estimates, so Strathcona Mineral Services of Toronto was hired to give an impartial analysis.

Strathcona soon discovered the fraud. The gold, allegedly a type found in local rivers, had been carefully added to the samples to create a false image of the proposed mine's gold content. "The results had to give a very specific three-dimensional picture of a plausible deposit. The whole picture had to make sense. It had to be very well planned and well executed."[36] Moreover, a critical breach of accepted practice was discovered. When drill cores are removed from the ground, they are ordinarily sawn in half along the centreline. One half is tested, but the other half is documented and stored in case it is needed for double-checking. Bre-X, however, did not follow this practice. Suspicion for the salting therefore fell on De Guzman, since he was the senior person responsible for the drill core samples at the Busang site, sent thousands of them to a local laboratory to be assayed, and had the knowledge needed to perpetrate the fraud.

AFTERMATH—CHAOS ON THE STOCK MARKET

After the fraud was discovered, Bre-X hired an investigative team, Forensic Investigative Associates (FIA), to perform an independent audit. The FIA report, published in October 1997, exonerated Bre-X's senior staff and stated that FIA had "reasonable and probable grounds" to conclude that de Guzman and others at the Busang site were responsible for the ore salting.[37]

Many Bre-X employees profited personally by selling shares they had purchased with stock options. The FIA report estimated that de Guzman received $4.5 million in stock sales; Puspos, $2.2 million; and Walsh, about $36 million.[38] Felderhof reportedly sold about $30 million of his shares (later estimated at $84 million).

In March 1997, just before the fraud revelation, the Prospectors & Developers Association of Canada named Felderhof as Prospector of the Year. The award was in honour of the Busang discovery, believed at that time to be the world's largest single gold deposit. Felderhof later agreed to return the award. He was asked to resign from Bre-X, and he now resides in the Cayman Islands. Bre-X was de-listed from the stock exchange, its shares essentially worthless. Many investors are pursuing lawsuits on the basis that the corporation and the individuals who controlled its geological activities should have shown greater diligence in controlling the assay samples and verifying gold estimates. The Ontario Securities Commission charged Felderhof for illegal insider trading and for issuing news releases that he should have known were misleading, but the courts dismissed the case in 2007. Bre-X president David Walsh died in 1998.

Estimates of the total loss to investors because of the Bre-X fraud run as high as $6 billion. The Bre-X scandal seriously damaged the Canadian mining industry. Junior mining companies—even those with no links to Bre-X—found it difficult to raise capital.

COMMENTS ON THE BRE-X FRAUD

The Bre-X scandal is a case of skilled geological fraud, apparently perpetrated by de Guzman. If still alive, de Guzman would be facing criminal charges for fraud, as well as discipline for professional misconduct. In the face of such deliberate fraud, it may seem trivial to refer to the Code of Ethics, but there is a lesson here. The perpetrator ignored the Code, he came to a bad end, thousands of people suffered serious financial harm, and an entire industry was held in contempt.

This case also shows that accurate, unambiguous duties and titles are important. The chief geologist was reportedly Felderhof. He certainly seemed to consider himself qualified for this title when he made estimates of the gold content in Busang and when he accepted the Prospector of the Year award (but later claimed to be merely an administrator). In any case, the chief geologist—whether Felderhof or some other person—had a responsibility to show due diligence in safeguarding the core samples and ensuring that the gold assay was conducted properly; that the gold content, based on the samples, was accurately calculated; and that double-checks were made to confirm the results. As noted above, geologists usually split core samples before testing them and store half of each sample for further confirmation, if necessary. The Bre-X geologists did not do this. Security was loose, and a single individual controlled the testing of all the Busang samples. Consequently, salting could proceed undetected for months.

Stock promoters who encouraged investment of billions of dollars in the fraud may need to question their standards of due diligence. The Bre-X case led the Canadian Securities Administrators (CSA) to issue *National Instrument* 43-101, which now regulates the disclosure of precious metal discoveries. Under this regulation, only a "QP" (defined earlier in this chapter), typically a professional engineer or geoscientist, may make public statements on ore discoveries.

DISCUSSION TOPICS AND ASSIGNMENTS

1. Should the professional person be more concerned about the welfare of the public than the average person? Does professional status impose additional responsibilities? Should people in positions of great trust, whose actions could harm the public, obey a higher code of ethics than the average person obeys? If so, what is the best way to impose such requirements?
2. Compare the U.S. and Canadian systems for regulating professions. For example, much information is available about professional engineers in both countries. In the United States, state boards, appointed by state governments, regulate professions. Engineers are required to write two sets of exams for admission. Everyone, regardless of education, must write the exams. In Canada, the profession is self-regulated by Associations of engineers and/or geoscientists, and graduates of accredited programs are exempt from technical exams. Statistics show that only about 15 percent of the people practising engineering in the United States have licences, whereas about 85 percent of the people practising engineering in Canada have licences. In your answer, respond to these questions: Which system is more effective? Which is simpler to administer? Which is fairer to the applicant? Which is better for protecting the public? Which criterion (effectiveness, simplicity, fairness, or protection) should take precedence?

Additional assignments can be found in Web Appendix E.

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[14] Oliver Bonham (Geoscientists Canada), email to authors, May 8, 2017.

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[31] John Stackhouse, Paul Waldie, and Janet McFarland (with files from C. Donnelly), "Bre-X: The Untold Story," *The Globe and Mail*, May 3, 1997, B1.

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[38] Ibid.

Chapter 3
Disciplinary Powers and Procedures

Self-regulating professions protect the public by ensuring that practitioners are competent and by disciplining those practitioners who prove to be unethical or inept. This chapter explains the procedures for enforcement and discipline in the engineering and geoscience licensing Acts. This basic knowledge may help you to avoid disciplinary problems in your professional career. Moreover, as a member of a self-regulating profession, you share the responsibility for discipline and enforcement.

3.1 INTRODUCTION

Most professional engineers and geoscientists are well-educated individuals with high ideals who want to make a positive contribution to society. Malpractice and corruption are therefore relatively rare in these two professions. In fact, the key message of this textbook is that a competent, ethical professional never needs to worry about such problems. Misunderstandings, disputes, and infractions do, however, occur, so Associations must respond to complaints from the public and resolve disputes among licensed professionals when requested. When complaints arise, the Associations investigate and, where necessary,

- enforce the Act by prosecuting unlicensed people who practise unlawfully, and
- discipline licensed engineers and geoscientists who are guilty of professional misconduct, negligence, or incompetence.

Enforcement and discipline follow different procedures, as explained below.

3.2 ENFORCEMENT: UNLICENSED PRACTITIONERS

The best way to protect the public is to allow only competent professionals to practise. This is the purpose of licensing: every applicant must show high standards of education and experience to obtain a licence. People who practise engineering or geoscience without a licence, or who falsely claim to be licensed, are breaking the law (the Act) and are prosecuted in the law courts. Each Act typically states that it is an offence for an unlicensed person to

- practise professional engineering or professional geoscience, or
- use a term or title to give the belief that the person is licensed, or
- use a seal that leads to the belief that the person is licensed.

Most Associations employ a staff member to receive complaints about offenders. Unlicensed practitioners are usually unaware that they are contravening the Act, and when informed, they promptly stop the offending behaviour.

Some offenders, however, ignore the Association's warnings and persist in practising without a licence. In these cases, the Association's staff member gathers evidence. With the help of a lawyer hired by the Association, the unlicensed offender is prosecuted in court. A trial judge presides and, if the case is proven, the judge usually fines the unlicensed offender. The typical fine is small when compared to the cost of the education needed for a licence. For example, Ontario's fines are $10,000 for the first offence of unlawfully using an engineering title ($25,000 for a second offence), although the fine is $25,000 for practising without a licence ($50,000 for a second offence).

In 2005, a Toronto man was jailed for 30 days and ordered to pay $20,000 in costs after he was found in contempt of an Ontario Superior Court order (issued in 1995) to obey the Professional Engineers Act. The man had never been licensed, but was convicted on four separate occasions, from 1993 to 1998, for repeatedly misrepresenting himself as a "structural engineer" or as "an engineer" on projects in the Toronto area. It is the duty of the court to ensure that unlicensed persons comply with the law (the Act), and the Association merely assists the court. Case History 3.2, presented later in this chapter, discusses a well-known instance of enforcement.

3.3 DISCIPLINE: LICENSED PRACTITIONERS

Under the Act, Associations must also protect the public by responding to complaints of unprofessional activities by licensed members and, where necessary, by taking remedial action. It is therefore important to define what behaviour is subject to discipline and what penalties could result. The licensing Acts typically specify six causes for disciplinary action:

- professional misconduct (also called "unprofessional conduct")
- incompetence
- negligence
- breach of the Code of Ethics
- physical or mental incapacity
- conviction of a serious offence

These terms are defined in the following paragraphs, and Case Histories 3.3 to 3.6 describe typical discipline cases.

Professional Misconduct

Professional misconduct (or unprofessional conduct) is the main type of complaint made to Associations. For example, Alberta's Act defines "any conduct … detrimental to the best interests of the public" or that "harms or tends to harm the standing of the profession generally" as unprofessional conduct.[1] Such general clauses are not specific enough to serve as guidance in individual cases, and we must rely on the Association's Code of Ethics to give more specific guidance.

At the other extreme, Ontario's definition of professional misconduct includes some very specific acts, such as "signing or sealing a final drawing … not actually prepared or checked by the practitioner."[2] Such guidance is clear and unambiguous.

The Acts and regulations cannot, however, define every possible form of professional misconduct, so they typically contain a general clause stating that professional misconduct includes any act that "would reasonably be regarded" as "disgraceful, dishonourable or unprofessional."[3]

Incompetence

Incompetence is a lack of knowledge, skill, or judgment that demonstrates that the member is unfit to carry out duties as a professional. A licensed professional must practise within the limits of competence, and you must judge your own competence as you progress to more difficult tasks. When you move to a new job or project, you must obtain training and experience to ensure that you are competent in the new area. If you do so, the Act gives you wide latitude. Discipline cases often arise, however, when people who are fully competent in one field of practice are judged incompetent when they enter a new field without adequate training.

Negligence

In most Acts, *negligence* means "carelessness," or carrying out work that is below the accepted standard or lacking adequate thoroughness; however, negligence can also include a flagrant disregard for public welfare. Negligence is particularly serious when it involves a failure to safeguard life, health, or property. There is also a fine line between negligence and incompetence; for example, it may be impossible to judge whether a practitioner ignored a safety regulation (negligence) or did not know it existed (incompetence). See Chapter 6, Section 6.2, Professional Liability and Tort Law, for further discussion of standard of care and negligence.

Breach of the Code of Ethics

In four provinces (Alberta, New Brunswick, Newfoundland and Labrador, and Nova Scotia), a breach of the Code of Ethics is specifically defined in the Act to be equivalent to professional misconduct (or unprofessional conduct).

These codes therefore have the full force of the Act. In other provinces (British Columbia, Manitoba, Prince Edward Island, Quebec, and Saskatchewan) and the territories, where the term "professional misconduct" (or "unprofessional conduct") is undefined or defined in general terms, it would usually be understood to include the Code of Ethics, thus making the Code enforceable under the respective Act.

However, the Professional Engineers Ontario (PEO) Code of Ethics differs from all other codes: it is specifically not enforceable under the Act. Instead, a more detailed definition of professional misconduct (in Ontario Regulation 941) contains many concepts that are in the Code, such as "failure to act to correct or report a situation that the practitioner believes may endanger the safety or the welfare of the public," as well as failure to disclose a conflict of interest, and about 16 additional clauses.[4] In other words, the Ontario Code of Ethics describes ideal professional conduct, but a separate definition of professional misconduct identifies the lower limit of acceptable behaviour.

Physical or Mental Incapacity

Most Acts include a "physical or mental condition" as a definition of incompetence, provided the condition is of a nature and extent that, to protect the interests of the public (or the practitioner), the practitioner should not be allowed to practise. Such cases are fairly rare.

Conviction of an Offence

The Acts permit disciplinary action against a practitioner who is found guilty under other laws. That is, if a practitioner is convicted of an offence, and the nature of the offence affects the person's suitability to practise, then the person can be found guilty of professional misconduct. Proof of the conviction must be provided to the Discipline Committee. This clause is used relatively rarely, since convictions for minor offences (traffic violations, local ordinance violations, and so forth) do not affect one's suitability to practise. However, conviction of a serious offence such as fraud or embezzlement, which involves a betrayal of trust and questionable ethics, could be grounds for such action. The standard of conduct for professional people is higher than that expected of the ordinary person.

3.4 AN OVERVIEW OF THE DISCIPLINARY PROCESS

Most complaints against licensed engineers or geoscientists originate from building officials, government inspectors, or other practitioners; however, any member of the public can make a complaint. In fact, Ontario (PEO) places the complaint form online, so that complainants can download and complete the form without a staff member's help.[5]

A serious complaint usually sets in motion a three-stage disciplinary process. The first two stages are confidential, but the third stage—a formal Disciplinary

Hearing—is generally open to the public. To ensure complete impartiality, the three stages of the process are normally carried out by three different groups of people. No one who participates at an earlier stage is permitted to participate (in a decision-making capacity) in the final hearing and judgment. Each licensing Act describes the disciplinary process, which is similar across Canada. Several provinces, including Alberta (APEGA),[6] Ontario (PEO),[7] British Columbia (APEGBC),[8] and Saskatchewan (APEGS),[9] publish summaries of the three-stage disciplinary process.

Stage 1: Gathering Evidence

When an allegation is made against an engineer or geoscientist, the first stage is to collect information. Each Association has trained staff who discuss the allegation with the complainant, explain the Act, answer questions, and give advice on what evidence is essential to support a formal complaint. Complaints must, of course, involve the practice of engineering or geoscience. If the evidence does not support a formal complaint, staff may suggest other solutions. For example, commercial disputes should be resolved by the civil courts and are not suitable for disciplinary action (unless they also involve professional misconduct).

Complainants usually prepare a written complaint and gather evidence with the help of Association staff; however, in technically complicated cases, the Association may hire an independent expert witness. A copy of the signed complaint is sent to the practitioner whose conduct is the subject of the complaint, and a response is requested within a specified time.

Stage 2: Investigation and Review of the Complaint

An Investigative Committee (also called the "Complaints Committee," in some Acts) reviews and evaluates every signed complaint. This Committee is composed of licensed members, typically including at least one of the members appointed to the Association's Council by the government. The investigation covers all evidence, including the complaint, the response from the practitioner, and any expert reports or other evidence. The Investigative Committee, however, does not interview either the complainant or the practitioner at this stage. The Investigative Committee decides whether to

- refer the complaint to the Discipline Committee for a formal hearing;
- refer the complaint to the Discipline Committee for approval of the penalty, when the practitioner admits guilt and signs a voluntary undertaking (also called a "consent," "stipulated," or "recommended" order);
- dismiss the complaint if it is clearly frivolous, vexatious, or if there is insufficient evidence to go further;
- send a "letter of advice" to warn the practitioner about actions that are not professional misconduct, but warrant some concern; or
- direct the Association staff to obtain more information and bring the case back to the Investigative Committee at a later date.

The Investigative Committee is typically empowered to suggest an Alternative Dispute Resolution (ADR) in cases where an agreement between the complainant and the practitioner might settle a dispute. The ADR process is described below. If, however, the complaint proceeds to Stage 3, the Investigative Committee assumes responsibility for prosecuting the case, and the original complainant becomes a witness.

Stage 3: The Discipline Hearing

The third stage is a formal hearing by a Discipline Committee. This Committee is also composed of licensed members, including at least one of the members appointed to Council by the government, but it is totally separate from the Investigative Committee. The Discipline Committee may, at its discretion, conduct a formal hearing to hear the evidence and the response from the accused member, and to render a judgment.

Formal hearings are usually held at the Association's offices and follow procedures similar to a law court, with a court reporter recording a transcript. A panel is selected from the Discipline Committee to act as the "judge." (The panel is typically composed of at least three members.) A delegate from the Investigative Committee acts as prosecutor and presents the case against the accused practitioner.

In keeping with basic concepts of justice, the accused practitioner is entitled to legal counsel (a lawyer or adviser). In addition, the prosecutor (from the Investigative Committee) and the judgment panel (from the Discipline Committee) are acting independently, so they must consult separate, independent legal counsel.

The prosecutor presents the case. Witnesses may be called to testify, and the practitioner is entitled to respond and to call witnesses in defence. The panel from the Discipline Committee makes the final judgment. If the panel finds the accused practitioner guilty of professional misconduct, it assigns a penalty, as discussed below.

This disciplinary process also applies to holders of Temporary Licences, Certificates of Authorization, Limited Licences, Permits, and (in Ontario) designation as a Consulting Engineer; that is, other forms of permits or certificates may be revoked or suspended using this process.

Disciplinary Penalties

The severity of the penalty assigned by the Discipline Committee depends, of course, on the circumstances of the case. Each provincial and territorial Act typically permits the following maximum penalties:

- Revoke the licence of the practitioner (or the permit or certificate of authorization, if a corporation).
- Suspend the licence (usually for up to two years).
- Limit the practitioner's professional work by imposing restrictions on the licence, such as supervision or inspection of work.

- Require the member to be reprimanded, admonished, or counselled, and publish the details of the result with or without names.
- Require the practitioner to pay the costs of the investigation and hearing.
- Require the practitioner to undertake a course of study or write examinations set by the Association.
- Publish any order that revokes or suspends the licence of a practitioner, with or without the reasons for the decision.
- Impose a fine (up to $15,000 in Saskatchewan, $12,500 in Quebec, $10,000 in Alberta, $5,000 in Ontario).

CASE HISTORY 3.1

COLLAPSE OF THE ELLIOT LAKE MALL ROOF

INTRODUCTION

On June 23, 2012, a portion of the rooftop parking lot at the Algo Centre Mall in Elliot Lake, Ontario, collapsed, killing 2 people and injuring 19 more. The failure was due to severe corrosion of a welded connection between a beam and a column of the steel substructure below the parking deck. This corrosion was the result of salty water leaking into the roof for more than 30 years. As the Commissioner of the official inquiry concluded, this sad story is more about human failures than about structural failures.

INTRODUCTION: ALGO FALLS

Elliot Lake is a small city in Northern Ontario, with a population of 10,741 in 2016. It experienced a boom period in the 1950s and 1960s, when it was called the "uranium capital of the world." When the last uranium mines in the area closed in the early 1990s and its population began to decline, the city successfully promoted itself as an attractive retirement location. The Algo Centre Mall hosted multiple services and businesses, and was the economic and social hub of the revived community.

Shortly after its construction in 1979–80, a flaw in the mall design became apparent: the roof leaked. The waterproofing system that was supposed to shed and drain water from the rooftop parking lot was an untested variant of systems used elsewhere. It did not work and, for more than 30 years, water leaked through cracks and expansion joints in the concrete deck into the steel structure of the shopping mall below. Buckets to catch the leaks were a frequent sight in the mall, which became known as "Algo Falls," and the library kept tarps on hand to cover the books overnight.

STEEL + WATER = RUST

To make matters worse, the water leaking onto the structural steel was carrying road salt, accelerating corrosion rates to levels typically experienced by the ballast tanks in ocean-going ships. Despite examinations by professional engineers

Photo 3.1 — Rooftop Parking Lot Collapse in Elliot Lake, Ontario. *On June 23, 2012, a large portion of the rooftop parking lot collapsed into the Algo Centre Mall in Elliot Lake, Ontario. The collapse killed two people, Lucie Aylwin and Doloris Perizzolo, and injured 19 others. The failure was due to severe corrosion of a welded connection in the steel substructure below the parking deck; this corrosion was the result of salty water leaking into the roof for more than 30 years. In the words of Paul Bélanger, the Commissioner of the official inquiry, this tragedy occurred because "Some engineers forgot the moral and ethical foundation of their vocation and profession—to hold paramount the safety, health, and welfare of the public." (Report of the Elliot Lake Commission of Inquiry: Executive Summary, p. 4)*

Source: Courtesy of Ontario Provincial Police. © Queen's Printer for Ontario, 2014. Reproduced with permission.

and architects on some 30 occasions during the 33-year life of the mall, the three different owners did little to fix the faulty waterproofing system except to seal and reseal cracks. Part of the reason for this inaction was the limited scope of the examinations, often just visual and cursory.

Two such examinations deserve special mention, the first in 2009. The city issued to the current owner, Eastwood Mall Inc., an Order to Remedy, which required mall deficiencies related to structural integrity and watertightness to be inspected and remedied. Eastwood was owned by Bob Nazarian, who hired Robert Wood to do the inspection. Wood was an engineer with and owner of M.R. Wright & Associates (MRW). It is noteworthy that Wood was going through the PEO disciplinary process at the time and would lose his engineering licence in November 2011. He inspected the beam that eventually collapsed, noted rust, but reported that there were no visual structural concerns. The city accepted Wood's report.

In April 2012, former engineer Wood conducted another inspection, again at the request of Nazarian who required the inspection to secure a loan. Wood saw rusted steel beams but took no measurements and concluded that "the observed rusting … has not detrimentally changed the load carrying capacities of the structure." Since he was no longer an engineer, Wood asked an engineer at MRW, Gregory Saunders, to review and sign his report. Saunders did so after a 45-minute meeting, but did not affix his engineering seal. Unbeknownst to Saunders, Wood subsequently altered the report at Nazarian's request, to remove a photo and references to the leaks being "of particular concern."

A mere 11 weeks later, the roof collapsed while a car in the parking lot drove over the corrosion-weakened weld connection between a beam and column in the steel structure. Two people were killed, Doloris Perizzolo and Lucie Aylwin, and 19 others were injured. Ontario Premier Dalton McGuinty quickly appointed Paul Bélanger, a retired judge of the Ontario Court of Justice, to lead a Commission of Inquiry into the mall collapse.

FINDINGS FROM THE INQUIRY

Commissioner Bélanger reviewed more than 500,000 documents and interviewed 118 witnesses during his investigation. His 1400-page report, released in October 2014, includes an Executive Summary and two main parts: (1) the events leading to the roof collapse, and (2) the emergency response. Here we list some of his conclusions from the first part:

- The collapse was due to the sudden failure at 2:18 p.m. of a connection between one beam and one column of the steel substructure below the parking deck of the Mall.
- The failure was the result of the continual and uninterrupted ingress of water and chlorides from the parking deck of the Mall ever since its construction in 1979, resulting in severe corrosion of the connection.
- The ingress was the result of a faulty initial design combined with inadequate and incompetent maintenance and repair of the surface of the parking deck.…
- Municipal authorities ignored repeated complaints and warnings about leaks and material failure.…
- Owners chose cheap and ineffective repairs or opted to sell the Mall when faced with significant repair bills. They actively concealed their knowledge of the parking deck's condition from the City and from subsequent purchasers.
- The last owner (Eastwood Mall Inc.) actively misrepresented the repair work it engaged in and resorted to subterfuge and falsehood to mislead authorities, tenants, and the public.*

* *Report of the Elliot Lake Commission of Inquiry: Executive Summary*, Paul R. Bélanger, October 15, 2014. Found at https://www.attorneygeneral.jus.gov.on.ca/inquiries/elliotlake/report/ES/ELI_ES_E.pdf (accessed July 14, 2017). Queen's Printer for Ontario, 2014. Reproduced with permission.

In his summary of the conclusions, Commissioner Bélanger made the following poignant remarks:

> Although it was rust that defeated the structure of the Algo Mall, the real story behind the collapse is one of human, not material, failure. Many of those whose calling or occupation touched the Mall displayed failings—its designers and builders, its owners, some architects and engineers, as well as the municipal and provincial officials charged with the duty of protecting the public. Some of these failings were minor; some were not. They ranged from apathy, neglect, and indifference through mediocrity, ineptitude, and incompetence to outright greed, obfuscation, and duplicity. Occasional voices of alarm blew by deaf and callous ears. Warning signs went unseen by eyes likely averted for fear of jeopardizing the continuing existence of the Mall—the social and economic hub in Elliot Lake.
>
> Some engineers forgot the moral and ethical foundation of their vocation and profession—to hold paramount the safety, health, and welfare of the public. They occasionally pandered more to their clients' sensitivities than to their professional obligation to expose the logical and scientific consequences of their observations. Some of their inspections were so cursory and incomplete as to be essentially meaningless. Others were fundamentally flawed because they were based on false assumptions or calculations.…
>
> Based on any fair and objective analysis of the history of the Algo Mall as it unfolded during the Commission's hearings, it is difficult to resist the conclusion that, if any one of the owners, engineers, or officials who were involved with the Mall over its 33 years of existence had insisted, "Enough—this building will fail if it isn't fixed," two lives would not have been senselessly and tragically lost. A few people did just that, but they were ignored. Instead, faced with the clearest of warning signs, owners sold or attempted to sell the problem instead of fixing it. They opted for the narrowest of interpretations of engineering reports—always the least expensive solution that merely repeated past feeble and ineffectual remedies. Many witnesses averred that they were unaware of one of the most basic and widely understood tenets of material science: a combination of water, air, and chlorides makes steel rust; and continuously rusting steel gets progressively weaker as time goes by.*

RECOMMENDATIONS OF THE INQUIRY

Professional Engineers Ontario requested and was granted official standing at the inquiry, to which it proposed 11 recommendations. Nine of these recommendations to address many of the factors leading to the Algo Mall roof collapse were adopted in the final report by Commissioner Bélanger. Here we list his summary of some of the key recommendations:

- There should be a mandatory province-wide requirement that buildings covered by my recommendations [large mercantile buildings] be maintained to a minimum standard to ensure public safety.

* *Report of the Elliot Lake Commission of Inquiry: Executive Summary*, Paul R. Belanger, October 15, 2014. Found at https://www.attorneygeneral.jus.gov.on.ca/inquiries/elliotlake/report/ES/ELI_ES_E.pdf (accessed July 14, 2017). Queen's Printer for Ontario, 2014. Reproduced with permission.

- All such buildings should be inspected by properly qualified structural engineers. These inspections should occur when a building is sold and, at a minimum, at a frequency that is commensurate with the risk of harm from a failure to meet the standard.
- Information about whether these buildings meet these minimum public safety standards should be available in an easily accessible and understood form to owners, the public, and prospective purchasers.
- The standards should be enforceable by a simple and practical process which requires that the responsible public authorities are accountable for the decisions they make and the actions they take.
- Those charged with determining whether buildings meet these standards, as well as with enforcing them—including professional engineers and municipal building officials—should be appropriately trained and certified. In addition, owners and the public should have easy access to relevant information about their training, certification, and any discipline against them ...*

The Commissioner also recommended that PEO establish a mandatory system of continuing professional education for its members.

PEO ACTIONS

In November 2012, PEO sent to all its members a Professional Practice Bulletin "Structural Assessments of Existing Buildings," and recommended to the Elliot Lake Inquiry that the Bulletin be enforced as a Performance Standard. To do so would require a legislative change to the Professional Engineers Act (PEA); the same would be required to enforce three other recommendations made by PEO[10]:

- The structural Performance Standard should require a report from a Structural Engineering Specialist, whose qualifications should be prescribed in the PEA.
- A performance standard should be developed and enforced for engineers who are supervising non-engineers or former engineers.
- Findings of professional misconduct or incompetence should be included in the PEO Register (which may be inspected by any member of the public under current law).

PEO is working with the Ontario Attorney-General to develop potential amendments to the PEA as well as the Ontario Building Code. In its November 2012 Bulletin, PEO reminded its members of their legal obligation to seal final engineering reports.

A mandatory program of continuing professional education for PEO members would also require legislative changes to the Act. In the meantime, a new

* PEO, *Submissions of the Association of Professional Engineers of Ontario (PEO)*, August 8, 2013, 31, https://www.attorneygeneral.jus.gov.on.ca/inquiries/elliotlake/submissions_l/Professional_Engineers_of_Ontario/PEO_Written_Submissions_Aug_8_2013.pdf. Queen's Printer for Ontario, 2014. Reproduced with permission.

Practice Evaluation and Knowledge (PEAK) program (www.peopeak.ca) was developed and launched in March 2017 to monitor the continuing professional development of Ontario engineers. This voluntary program requests PEO members to update their professional development each year and complete an online refresher course on ethics and professionalism.

As for disciplinary actions related to the Algo Centre Mall tragedy, PEO disciplined Saunders for not properly checking and sealing a final report and Wood's company (MRW) for allowing the unlicensed Wood to perform an inadequate engineering inspection. These discipline results are published by PEO,[11] which has updated its website so that the licence status (and PEAK updates) of any member can be viewed. Under the proposed legislation, additional details of the member's qualifications and status will be made available to the public.

Wood himself was not disciplined by PEO, since his licence had already been suspended in November 2011 and revoked in 2012. Instead, he was arrested and tried for two counts of criminal negligence causing death and one count of criminal negligence causing bodily harm. He was acquitted of all charges on June 1, 2017, by Superior Court Justice Gareau, who cited insufficient evidence to convict him.[12]

Four years after the Algo Centre Mall collapse, a new shopping centre opened in Elliot Lake.

CONCLUSIONS

This history contains many sober lessons for practising engineers. It clearly establishes that many of the engineers and architects who performed inspections of the Algo Centre Mall fell short of expected standards for professional practice and ethics. The case emphasizes the primary ethical obligation of the professional engineer to place public safety above all other concerns. In the words of Commissioner Bélanger, had one engineer "insisted 'Enough—this building will fail if it isn't fixed,' two lives would not have been senselessly and tragically lost."

3.5 FEE MEDIATION AND ALTERNATIVE DISPUTE RESOLUTION (ADR)

Many complaints involve fee disputes or contractual breaches; however, Associations cannot compel practitioners to pay compensation or repair their work. Similarly, legal disputes over breach of contract, revoking of offers, or substandard performance are not usually deemed professional misconduct or breaches of the Code of Ethics. These disputes require a lawsuit against the practitioner in the civil courts.

Because of their authority, however, Associations are in a key position to help settle disputes using mediation and arbitration. A few Associations do so, either informally or actively. For example, the Ontario Professional Engineers Act specifically establishes a Fees Mediation Committee with the power to mediate and (where all parties agree) to arbitrate fee disputes. This option greatly reduces the number of complaints in the disciplinary process.

Photo 3.2 — Roof Collapse in Burnaby, British Columbia. *The Save-on-Foods supermarket in Burnaby, British Columbia, opened on the morning of April 23, 1988. A parking lot on the roof of the supermarket provided extra convenience to shoppers. Within minutes of the supermarket's opening, however, a main beam supporting the roof collapsed, dumping 20 automobiles into the store's produce section. Fortunately, no lives were lost. The subsequent Inquiry discovered basic errors in the design, which led to changes in licensing procedures for engineers.*

Source: © Glacier Media

Some Associations offer a voluntary ADR process to resolve disputes where professionalism and contractual matters overlap. Allegations of professional misconduct are referred to the complaints process, but contractual disputes that appear to be minor breaches of the Code of Ethics are encouraged to go through the ADR process. This process involves a confidential mediated negotiation that may lead to a solution satisfactory to all concerned, unlike civil courts or disciplinary hearings, which almost always result in a win-lose arrangement. If, however, the mediation reveals evidence of professional misconduct, the ADR stops, and a formal complaint is considered in order to protect the public interest.

3.6 A FINAL PERSPECTIVE ON DISCIPLINE

Fairness and Confidentiality

Disciplinary procedures must be fair and must be seen to be fair, both by the public and by the practitioner. It is important to emphasize that the

Investigative Committee and the Discipline Committee are independent. The accused practitioner, the prosecutor (from the Investigative Committee), and the judgment panel (from the Discipline Committee) are all acting independently, so each must be able to consult separate, independent legal counsel.

The first two stages of the disciplinary process are confidential, although in the final stage, hearings by the Discipline Committee are typically open to the public. Verdicts are usually published (with or without names) unless the practitioner is found not guilty, or if there are compelling arguments for privacy. When publication is appropriate, the case is usually summarized in the Association's monthly magazine, and/or on the Association's website.

Some Statistics

Compared to other professions, engineering and geoscience rarely need to apply the full disciplinary process. For example, data from PEO in Ontario (Canada's largest Association) indicate that PEO receives around 70 formal complaints per year, even though PEO has more than 85,000 licence and certificate holders.[13] All of these complaints are investigated, but many complaints are resolved or withdrawn after consultation with PEO staff. Only about five to seven of these complaints go to the Discipline Committee each year for a formal disciplinary hearing.[14]

CASE HISTORY 3.2

ENFORCEMENT: MISUSE OF "SOFTWARE ENGINEER" TITLE

INTRODUCTION

In the mid-1990s, the Microsoft Corporation introduced a technical course called the "Microsoft Certified Software Engineer (MCSE)" course. The use of the term "software engineer" caused some concern in Canada. In the United States, state laws regulate "Professional Engineer" but do not regulate variations such as "software engineer." Canadian laws are different; they clearly restrict the term "engineer" to licensed professional engineers. For example, the Ontario Professional Engineers Act says that an unlicensed person who "uses the title 'professional engineer' … or an abbreviation or variation thereof as an occupational or business designation" is guilty of an offence.[15] Clearly, the "software engineer" variation is an occupational designation.

More importantly, the MCSE title makes confusion possible and likely. Software Engineering is an accredited program at many Canadian universities,[16] and a software engineer would reasonably be expected to be a graduate of such a program, with three or four years of acceptable experience, licensed annually, and constantly subject to professional ethics, discipline, and continuing competence requirements. The MCSE course requires only about 42 weeks, usually in a community college, and costs about $15,000, according to an unconfirmed report in *ITbusiness*.[17] It appears that an MCSE holder has no continuing competence obligations, although upgrades may be required for new specialties.

COMMUNICATION

Representatives from Engineers Canada and several provincial Associations met with Microsoft Canada in 2001, explained that their title contravened Canadian law, and suggested that MCSE (as an acronym) would be acceptable. Microsoft Canada initially agreed to this limitation; however, after speaking to MCSE holders, lawyers, and others, Microsoft apparently decided that the MCSE designation would be less valuable in Canada if holders could not refer to themselves as engineers. In 2002, Microsoft reversed itself and issued a press release stating that the estimated 35,000 Canadian MCSE holders should continue to use the full title.

Microsoft's decision was regrettable since, as one Association said, "we would be in contempt of our own legislation if we did not enforce improper use of title." At the time, one provider of the MCSE course said that it was unlikely that the restriction on the MCSE title would hurt his business, but also stated, "I think it holds a lot more weight to be an MCSE if it is [understood to be] an engineer...."[18]

PROSECUTION

Shortly thereafter, the *Ordre des ingénieurs du Québec* (OIQ) filed penal proceedings against Microsoft Canada for knowingly causing a person who is not a member of OIQ to use the title of engineer, thereby committing an offence under Quebec's Professional Code. In April 2004, Judge Claude Millette of the Quebec court agreed and ruled that Microsoft Canada contravened a provincial professional code by using the word "engineer" in its international software certification program. A very small fine was also levied.

SUPERIOR COURT JUDGMENT

Microsoft appealed the decision, but in June 2005, Justice Carol Cohen of the Superior Court of Quebec rejected Microsoft's appeal. The OIQ president, Gaetan Samson, Eng., stated that "the OIQ is very satisfied with the Superior Court decision, which confirms that the title *engineer,* alone or with descriptors, is reserved by the Engineers Act exclusively for our members."[19]

No other provincial Association has announced plans to prosecute Microsoft, but under every Act, any MCSE holder who practises engineering or who implies that he or she is licensed could be prosecuted. At least one community college has added a note to their MCSE course description explaining that the full title cannot be used under provincial law.

In 2016, Engineers Canada released "White Paper on Professional Practice in Software Engineering" to provide guidance to provincial regulators in identifying activities that could be deemed software engineering. This document identifies two key aspects of an activity that indicate that it falls under the exclusive scope of software engineering:

- It concerns the public interest (life, health, property, economic interests, the public welfare or the environment.
- It requires the application of engineering principles.[20]

CASE HISTORY 3.3

DISCIPLINE: PROFESSIONAL MISCONDUCT

NOTE: Case Histories 3.3 to 3.6 illustrate the disciplinary process using actual events condensed for brevity. Proper names are not essential and are omitted.

INTRODUCTION

"Company W" prepared a preliminary design for a large (2,000 m^3) steel water-storage tank and hired Professional Engineer "Kappa," licensed in British Columbia, to analyze and approve the design. Engineer Kappa signed and sealed the construction drawings. The tank was later constructed by Company W at a location in South America. However, when the huge tank was filled with water, it was unable to resist the hydrostatic forces and failed catastrophically.

INVESTIGATION

An investigation by APEGBC revealed that basic information was missing from the design drawings sealed by engineer Kappa, including the name, date, and issue of the code or standard for the design; the dimensions for spacing the bands that resist the circumferential stress; strut locations; weld sizes; steel material specifications; and the seismic and wind loads and thermal effects.

In addition, engineer Kappa failed to conduct a concept review of the structural design of the storage tank before construction as required by APEGBC Bylaw 14(b)(3). As a result of these shortcomings, the hydrostatic loading on the bands and the connector brackets greatly exceeded the allowable yield stress of the materials, and the tank ruptured. Although the preliminary tank design was prepared by Company W, no evidence was presented to indicate that any professional engineer, other than engineer Kappa, played any part in the design process.

DISCIPLINARY HEARING

In his defence, engineer Kappa stated that Company W asked him not to show dimensions, weld details, and other basic details in order to prevent copying by others, but he presumed that these details would be available to the fabricators from the computer drawing system operated by Company W. The judgment panel rejected this explanation, because sealed drawings must contain sufficient detail to ensure construction according to the design. In fact, the title block for one drawing was marked "Issued for Construction" when the drawing contained seriously inadequate information.

DECISION

The judgment panel ruled that engineer Kappa's failure to ensure that the sealed drawings conformed to accepted design standards constituted unprofessional conduct. An engineer's seal on design drawings means that the design is fully adequate and meets codes and standards. This is a basic rule of professional engineering and one that cannot be overruled by confidentiality.

PENALTY

The judgment panel were unconvinced that engineer Kappa realized the seriousness of his misconduct and ordered him to

- retain a professional engineer to peer-review his services for a one-year period, with regular reports to APEGBC every three months, the costs of which were to be paid by engineer Kappa;
- undergo a Practice Review within nine months, at an approximate cost of $2,000;
- write and pass the APEGBC Professional Practice Exam within six months; and
- accept the immediate suspension of his membership (licence) if any of the above conditions were not met.

In addition, the committee ordered engineer Kappa to pay costs of $30,000 to APEGBC—a sum that represented about 70 percent of the hearing costs, not including legal fees. Unfortunately, Kappa failed to meet some of these requirements, and in 2005, APEGBC suspended his membership (licence) indefinitely.[21]

CASE HISTORY 3.4

DISCIPLINE: INCOMPETENCE

INTRODUCTION

"Company X" hired Professional Engineer "Omega" to conduct an environmental investigation of six former industrial sites. The purpose was to measure the salt contamination of the soil and groundwater. Engineer Omega personally carried out the work and wrote a report for each site. The six reports were similar, containing borehole data, electrical conductivity measurements, and survey results from an electromagnetic device (typically used by geophysicists) to estimate the electrical conductivity to a depth of 5 m to 6 m. The conductivity data could be used to measure salt contamination.

INVESTIGATION

The reports, however, contained basic errors: incorrect and missing units, and discrepancies between data and conclusions. A complaint to the Association of Professional Engineers and Geoscientists of Alberta (APEGA) led to an investigation, confirming that the reports contained errors and inconsistencies in units, and contour plots that were numerically incorrect. The result showed that the reports were undependable and that site contamination might be greatly underestimated.

DISCIPLINARY HEARING

Engineer Omega admitted that he had only minimal experience with conductivity measurements; had no training in the use of the electromagnetic equipment; had inadequate experience to judge the accuracy of the raw data; and was unsure of the units at the time of writing the reports. In his defence, he stated that he had hired an experienced electromagnetic technologist to help him collect the field data, and he had relied on the technologist to establish the survey procedure, including the frequency and spacing of the readings and the background levels of conductivity. He had also tried to contact the company that supplied the electromagnetic device, but it was no longer in business.

The judgment panel rejected these excuses, stating that engineer Omega did not have adequate knowledge or training to use the electromagnetic tools that measure terrain conductivity or to conduct an electromagnetic survey and that he lacked the experience to ensure that data were valid. He had relied too heavily on the technologist, and, at the very least, he should have known the standard measurement units.

Several witnesses testified to the panel that using electromagnetic tools to acquire terrain conductivity data is within the exclusive scope of practice of geophysics and that engineer Omega was therefore engaging in geophysics, contrary to the Act. However, given the specific wording of the charge, the panel concluded that the question was not whether the reports contained geophysical data, but whether the member had the training and experience to make proper and professional use of the data.

DECISION AND PENALTY

The panel concluded that engineer Omega was guilty of unskilled practice, which is a breach of the APEGA Code of Ethics. It ordered that he be reprimanded and that he pay about $4,800 to APEGA (a portion of the hearing costs) or else relinquish his licence to practise. The penalty was modest because of Omega's previously exemplary record and because his conduct did not directly compromise public safety. Engineer Omega paid his debt, and his professional status was reinstated.[22]

CASE HISTORY 3.5

DISCIPLINE: BREACH OF THE CODE OF ETHICS

INTRODUCTION

Professional Engineer "Alpha," who specialized in reserve evaluation in the oil and gas industry, was hired by "Company A" to evaluate the oil and gas resources of "Company B" because the two companies were proposing to merge. Engineer Alpha attended a confidential meeting held by representatives of the two companies in which company operations, exploration projects, and reserves were disclosed. This knowledge placed engineer Alpha in a "special relationship" under the Alberta Securities Act (R.S.A. 2000, c. S-4).

Using this confidential knowledge, engineer Alpha purchased 90,000 shares in Company A through his son's stock trading account. When the merger was publicly announced, the shares of Company A almost doubled in price. Engineer Alpha then sold the shares, making a profit of approximately $28,000.

SECURITIES INVESTIGATION, CHARGE, AND PENALTY

The staff of the Alberta Securities Commission investigated allegations that engineer Alpha had breached the Alberta Securities Act. During the investigation, engineer Alpha admitted that he had contravened the Act. Engineer Alpha's activity is commonly known as "illegal insider trading," and it is a violation of subsection 147(2) of the Securities Act. Insider trading is contrary to the public interest and undermines the integrity of capital markets.

As a penalty for this infraction of the Securities Act, engineer Alpha agreed to pay an administrative penalty of $30,000; to pay $8,000 for the costs of the investigation; and to cease trading in securities for a period of two years.

APEGA INVESTIGATION AND STIPULATED ORDER

His problems did not end there, however. His lapse of ethical judgment caused the APEGA Investigative Committee to question his suitability to practise engineering. A further investigation was conducted by APEGA under the Engineering and Geoscience Professions Act. Engineer Alpha agreed to a stipulated order, so no formal hearing was necessary (see "Stage 2: Investigation and Review of the Complaint").

PENALTY

Engineer Alpha voluntarily agreed that his insider trading created a serious conflict of interest and that he had improperly used confidential information; both acts were in violation of the APEGA Code of Ethics. In accordance with the regulations, he was reprimanded for unprofessional conduct and ordered to write the Professional Practice Exam (PPE) within six months. Engineer Alpha passed the PPE, and APEGA later reinstated his professional status.[23]

CASE HISTORY 3.6

DISCIPLINE: CONVICTION OF AN OFFENCE

INTRODUCTION

A university technician repairing a computer found what appeared to be child pornography on the computer's hard drive. The computer was university property but was in the care and control of Professional Engineer "Delta," who was a professor at the university. The technician reported his suspicions to his immediate supervisor, who instructed him to delete the material, repair the machine, and report any further instances. A few weeks later, the computer again malfunctioned, and while repairing it, the technician again found what appeared to be child pornography on the hard drive. The technician reported this to the chair of the department, who contacted the police.

POLICE INVESTIGATION, CHARGE, AND CONVICTION

The police obtained search warrants for engineer Delta's home and office and seized the computer and compact discs. A forensic study revealed more than 2,700 files or images that the police described as child pornography. The police arrested engineer Delta and charged him with possession of child pornography, contrary to section 163.1(4) of the Criminal Code of Canada. Engineer Delta pled guilty to the offence and received a sentence of 15 months of community service. He subsequently resigned from his university position.

PEO INVESTIGATION AND DISCIPLINARY HEARING

Based on engineer Delta's criminal conviction, which is public knowledge, PEO began an investigation that led to a disciplinary hearing. There was no allegation regarding the qualifications or technical competence of engineer Delta; the purpose of the hearing was to determine his suitability to practise professional engineering. PEO obtained official verification from the Ontario Superior Court of Justice of the criminal charges against engineer Delta, including the evaluation of the evidence by the police, a statement of facts concerning the criminal trial, and a certificate of conviction. This evidence showed conclusively that engineer Delta had been convicted of a serious criminal offence, but the key question was this: "Did the conviction affect his ability to practise engineering?"

The Discipline Committee observed that engineer Delta used his computer at the university to carry out his criminal behaviour, thus linking the work environment to the behaviour. In addition, to be admitted to PEO, the Act requires applicants to be of "good character." Therefore, if a criminal conviction reveals a fundamental defect of character that is so offensive that it undermines the public perception of PEO, then the conviction is relevant to the member's suitability to practise.

DECISION AND PENALTY

The judgment panel noted that the evidence showed that engineer Delta had, indeed, been convicted of a serious criminal offence—possession of child pornography—and concluded that such behaviour was worse than merely "disgraceful." In addition, the panel concluded that the offence was relevant to his suitability to practise. Accordingly, it found engineer Delta to be guilty of professional misconduct as set out in the Ontario Professional Engineers Act, section 28(2)(a). The panel revoked Delta's engineering licence and ordered him to pay $2,500 in costs.[24]

DISCUSSION TOPICS AND ASSIGNMENTS

1. Select any three provinces or territories and compare the disciplinary powers awarded to each Association under the engineering or geoscience Act. Which Act provides the most severe fines and penalties? Would you say that the disciplinary powers in the Acts are generally similar, or do there seem to be serious inconsistencies between them? Point out and discuss these similarities and inconsistencies. The Acts are found on the Association websites. (See the list in Appendix A or excerpts in Web Appendix B.)
2. In your employment as a professional engineer or geoscientist, you discover that two employees who supervise the delivery and storage of materials on the job site (and who are also engineers or geoscientists) have been involved in "kickback" schemes with suppliers. The suppliers invoice your employer for materials that have not been delivered, your colleagues validate the invoices, and the suppliers pay them a hidden commission. Obviously, these schemes violate criminal law. In addition, your colleagues have broken clauses in your provincial Code of Ethics. Which are they? To what types of disciplinary action have they exposed themselves as a result? Suppose you confront them, and they promise they will discontinue these schemes if you agree not to reveal them. If you agree, would your silence be consistent with the Code of Ethics? Could any disciplinary action be brought against you? Describe the course of action you should follow. Would your actions be different if your fellow employees were not professional engineers or geoscientists?
3. You receive a registered letter from the registrar of your provincial Association stating that you are the subject of a formal complaint made by a former client. The letter contains a description of the complaint, which alleges that you are guilty of incompetence because the advice in a report that you wrote was faulty. The client followed your advice and suffered a financial loss. As part of the preliminary investigation conducted by the Association, the registrar asks you to respond to the complaint. Describe the actions you would take to prepare and protect yourself.

Additional assignments can be found in Web Appendix E.

NOTES

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Chapter 4
Basic Concepts of Professional Practice

This chapter gives useful advice for recent graduates and answers questions such as these: When should you apply for a licence? How do you document your experience? What are reasonable salary expectations? More importantly, this chapter provides an overview of many basic duties expected of professionals. These duties are rarely stated, but you are expected to know them. For example, what is your most important duty as a professional? When and how should you use your professional seal? What working conditions should you expect? How can you prepare for promotion? The chapter concludes with a key decision facing most professionals: should you become a specialist in your discipline or develop the “people skills” needed for management?

4.1 ENTERING THE PROFESSIONAL WORKFORCE

Graduating from university and entering the professional workplace is usually exhilarating; you move to a new location, meet new colleagues, and participate in new projects. You apply your knowledge to real problems and see ideas taking shape on the computer screen, on the construction site, on a well site, in the laboratory, or on a production line. But, unless you had exceptional work terms at university, your first professional job will likely be a challenge.

Your first surprise may be how little supervision you receive and how much responsibility you get because you are “a recent graduate and familiar with the theory.” You may have to work hard to justify this confidence, but ask for help if you need it.

A second surprise may be the apparent lack of order and structure. University courses usually have well-defined objectives, but real projects are open-ended and change at any time. New projects may be chaotic but are usually interesting. It is your job to create order from chaos.

A third surprise may be the strong emphasis on obtaining useful results. Products must perform as promised; if they don’t, then you must “find out why and correct it.” If you need information, you must be aggressive in getting it. The focus has changed—your goal in university was to get an education, but now your employer wants results!

Finally, you may be surprised at the importance of deadlines. Late deliveries cost money—especially when contracts have penalty clauses for lateness, or when just-in-time assembly lines have narrow windows for delivering components. Personal time management is much more important in the professional workplace.

The following hints may help you start your employment on a professional note:

- **Licensing:** As soon as you receive your degree, apply to your Association to begin the licensing process.
- **Experience:** Start to document your experience. It is easy to do now, but hard to remember later. Follow the Association's experience guide (see Chapter 2).
- **Preparation for advancement:** If you want to be promoted, think about your next step. Do you have the knowledge and ambition to be a specialist? Do you have the management skills—especially the "people skills"—to lead the organization? Are you sufficiently self-confident to succeed in private practice or entrepreneurship?

4.2 APPLYING FOR A LICENCE

As soon as possible, apply to your provincial or territorial Association for a licence to practise (that is, membership, or registration). Some graduates believe that they must satisfy the experience requirement first, but this belief is mistaken: applicants can apply as soon as they graduate from university. You can usually apply over the Internet. (The Web address of your Association is listed in Appendix A.)

Every Association has an internship program that you may join as soon as you receive your degree (or otherwise satisfy the educational requirements). When your Association accepts you into their internship program, you will receive one of the following titles: Engineering Intern (EIT), Engineer-in-Training (EIT), Member-in-Training (MIT), *ingénieur junior* (ing. jr.), Geoscientist-in-Training (GIT), or *géologue stagiaire* (depending on your province and discipline). These titles may be used on letters, memos, email, business cards, desk plaques, and so forth. As explained in Chapter 2, graduates must not use titles that imply that they are licensed, so avoid internal company titles such as Assistant Engineer, Assistant Geologist, Plant Engineer, or Sales Engineer.

As an intern, you will be guided by the Association through the next step, which is documenting your experience for licensing. You will also be invited to attend Association meetings, and you may be able to participate in group insurance, investment plans, and similar benefit programs. Internship simplifies the licensing process, both for Canadian Engineering Accreditation Board (CEAB)-accredited university graduates and for internationally educated applicants.

4.3 DOCUMENTING YOUR EXPERIENCE

As soon as you begin working, start documenting your experience. You need four years of documented professional experience to satisfy the licensing requirements (except in Quebec, where the requirement is three years). However, you can shorten the experience needed by as much as one year. As explained in Chapter 2, each Association allows credit for up to one year of pre-graduate experience and most grant up to 12 months' credit for a postgraduate degree in a relevant discipline.[1] Engineers Canada publishes an extensive guideline on admission to the practice of engineering in Canada, with instructions for meeting the core engineering competencies requirements.

> Applicants must produce detailed written competency demonstrations from their engineering work experience that indicate not only what they did in a situation, but also how and why they did it. This added detail is essential for the assessment of the engineering work experience. For each competency, applicants must write about situations from their engineering work experience and show what they did, how they did it and why they did it.[2]

These competencies are as follows:

- Apply engineering knowledge, methods and techniques.
- Use engineering tools, technology and equipment.
- Protect the public interest.
- Manage engineering activities.
- Communicate engineering information.
- Work collaboratively in the Canadian environment.
- Maintain and enhance engineering skills and knowledge.[3]

Although some Associations are moving to the competency-based evaluation described above, many Associations continue to follow Engineers Canada's previously established guideline for documenting experience.[4] The guideline suggests that your experience should satisfy the following five quality criteria:

- **Application of theory:** This is the best experience. It includes analysis, design and synthesis, testing methods, and project implementation. Most Associations expect "meaningful participation" (about 20 percent of your experience) in this category.
- **Practical experience:** Practical experience helps you to appreciate the limits of the theory, equipment, systems, procedures, and standards in your discipline. For example, you are much more competent if you know the practical details of the manufacturing equipment, operating procedures, maintenance schedules, computer software, safety codes, design standards, and so forth in your discipline. Fortunately, many activities qualify as practical experience.
- **Management of engineering/geoscience:** Management experience includes planning, scheduling, budgeting, supervision, project control, and risk assessment. New graduates are not usually assigned management duties, so document this experience whenever you have the opportunity.

- **Communication skills:** Professionals must be able to communicate effectively. Your experience résumé should include some effective writing (e.g., formal reports, design specifications or standards, contracts); maps, drawings, or sketches (where appropriate); and oral presentations of any type.
- **Social implications of engineering/geoscience:** This typically includes any experience involving the responsibility to protect life, health, property, or the environment, especially if you had to report dangerous conditions to those responsible. Most of the topics in this book concern the social implications of technical decisions.

4.4 LEVELS OF PROFESSIONAL RESPONSIBILITY

As your experience increases, you will assume greater responsibility. The following list shows typical levels of engineering and geoscience responsibility. Several Associations publish salary statistics based on these levels.[5]

A word of caution: The average number of years at each level varies, depending on your discipline and location. Furthermore, managers and specialists have different but equivalent career paths, so higher levels may be either management or technical. Levels often overlap, and companies may have more (or fewer) levels, depending on size. Most companies (especially in manufacturing) employ more managers than specialists.

LEVEL A—ENTRY LEVEL A bachelor's degree in engineering, geoscience, or applied science, or its equivalent, is usually required. Recent university graduates—usually with little practical experience—receive on-the-job training in office, plant, field, or laboratory work, or (rarely) in classrooms. Level A employees work under close supervision, preparing simple plans, designs, calculations, costs, and bills of material in accordance with established codes, standards, or specifications. This stage may last one or two years.

LEVEL B—ENGINEER/GEOSCIENTIST INTERNSHIP After the first two or three years of work experience, the employee will be assigned tasks of increasing variety, although responsibility is still limited. Typically, the work involves parts of larger projects. Such assignments provide continuing training and development. During this period, the employee is usually registered with the provincial Association at the internship level (with a title such as EIT, MIT, GIT, or *ingénieur junior*, depending on the province and discipline). Level B employees may give technical advice to technicians or to Level A graduates. This stage typically lasts two or three years.

LEVEL C—PROFESSIONAL ENGINEER/GEOSCIENTIST Level C is the first fully qualified professional level. The engineer or geoscientist carries out responsible and varied assignments in a broad field of engineering or geoscience, and is also expected to understand the effects of decisions on related fields. Combinations of standard methods are used to solve problems, and the Level C professional participates in planning. Typically, this stage requires a minimum of five to six years of related work experience after graduation. Level C professionals make independent analyses and interpret results without supervision, so, of course, they must be licensed.

LEVEL D—FIRST SUPERVISORY (OR FIRST SPECIALIST LEVEL) Job titles at this level have many variations, such as project leader, team leader, lead engineer, site geologist, or engineering/geoscience specialist. Level D is the first level that involves direct and sustained supervision of other professionals or the first level of full specialization. This level requires mature knowledge of planning and conducting projects, or of coordinating difficult and responsible assignments. To reach this level, engineers or geoscientists typically require a minimum of seven or eight years of experience in the field of specialization.

LEVEL E—MIDDLE MANAGEMENT (OR SENIOR SPECIALIST LEVEL) Job titles at this level include chief project engineer, chief geoscientist, group head, and senior specialist. This level (in management) involves supervising large groups, containing both professional and nonprofessional staff; alternatively, this level (in specialization) involves authority over a small group of highly qualified professional personnel engaged in complex technical applications. Level E typically requires knowledge of more than one field of engineering or geoscience. The incumbent participates in short- and long-range planning and makes independent decisions on work methods and procedures within a general program. Originality and ingenuity are required for devising practical and economical solutions to problems. The engineer or geoscientist may supervise large groups that include both professional and nonprofessional staff or may direct a small group of highly qualified professionals in complex technical applications. This level normally requires at least 10 to 12 years of engineering, geoscience, and/or administrative experience.

LEVEL F—SENIOR MANAGEMENT (OR SENIOR CONSULTANT LEVEL) Job titles at this level include director of engineering or geoscience, plant manager, and senior consultant. Levels F and F-Plus may overlap, depending on company size (that is, a chief engineer in a large corporation may have essentially the same duties as the vice-president of engineering in a medium-sized corporation). The incumbent usually has a senior engineering or geoscience administrative function, directing several professional groups engaged in interrelated responsibilities; or may be a consultant, recognized as an authority in a field important to the organization. The Level F professional independently conceives programs and problems to be investigated, determines basic operating policies, and devises ways to reach program objectives economically and to overcome problems. The Level F professional makes decisions on policies and expenditures of large sums of money and/or implementation of major programs, subject only to overall company policy and financial controls. The job requires extensive experience, including responsible administrative duties.

LEVEL F-PLUS—SENIOR EXECUTIVE LEVEL Job titles at this level include president, vice-president of engineering or geoscience, vice-president of manufacturing, general manager, and partner (in a consulting firm). At this level, the person receives general strategic guidance but conceives independent programs and problems to be investigated. He or she plans or approves projects that require considerable amounts of human and financial resources. This level requires many years of authoritative technical and administrative experience. Contact with the workforce is usually through subordinate managers. The incumbent is expected to possess a high degree of originality, skill, and proficiency in the various broad phases of the profession.

4.5 SALARY EXPECTATIONS FOR PROFESSIONALS

Salary is not the only motivator for a professional, but it is important. Several Associations conduct annual surveys of their members' salaries and post them on their websites. Some salary surveys follow the job classification descriptions in the previous section. APEGA has developed the Job Classification Flowchart, by level of responsibility, shown in Figure 4.1. Tables 4.1 and 4.2 show salary data for Alberta engineers and geologists, taken from APEGA's 2016 Alberta employer salary survey.[6]

The complete salary surveys are very comprehensive and show incomes by responsibility level (defined earlier in this chapter), discipline, year of graduation, type of industry, city or region, and so on. Check your Association's website for the most recent salary survey applicable to you. Be warned, however, that surveys differ, depending on whether employees or employers provide the data, because employees often report income from several sources. Moreover, salary surveys show past history and may not predict the future.

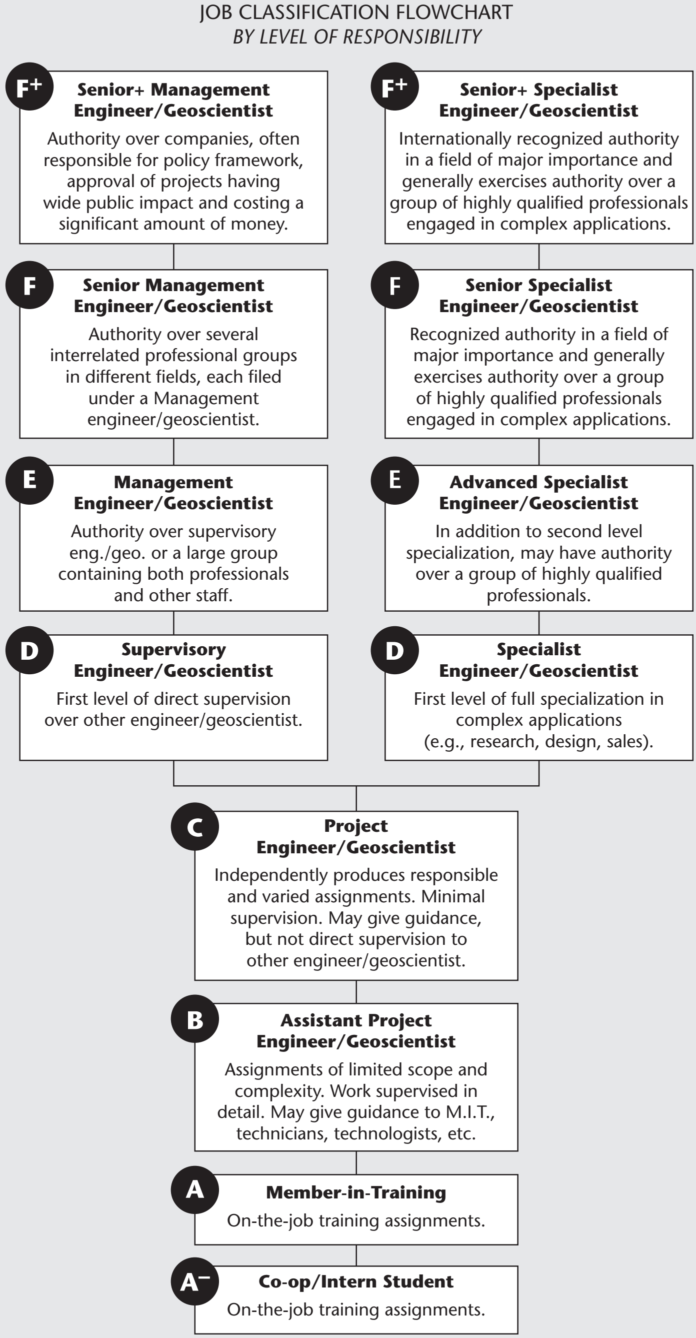
In British Columbia, the salary survey by the Association of Professional Engineers and Geoscientists of British Columbia (APEGBC) gathers data from employees, rather than employers, and classifies salaries by "responsibility point levels." APEGBC provides an online Employment Responsibility Evaluation program to calculate the responsibility point levels. The APEGBC point rating is then compared to ratings for similar job descriptions.[7]

In Ontario, the Ontario Society of Professional Engineers (OSPE) has assumed the responsibility for preparing salary surveys from Professional Engineers Ontario (PEO). Salary summaries are available to OSPE members on the OSPE website.[8]

4.6 YOUR PROFESSIONAL DUTIES: AN OVERVIEW

Of course, the salaries and promotions mentioned above come with duties and responsibilities. Engineers Canada published an overview of these duties in their *Guideline on the Professional Practice Examination*.[9]

Figure 4.1 — Job Classification Flowchart by Level of Responsibility



Source: APEGA, *The Value of Professional Services 2016: Salary Survey Highlights*. Found at https://www.apega.ca/assets/PDFs/salary-survey-highlights.pdf. Used with permission.

TABLE 4.1 — APEGA 2016 Value of Professional Services Salary Survey: ENGINEERS

Job Title	Number of Firms	Number of Cases	Average ($)	Median ($)	Minimum ($)	Maximum ($)
Level A–	26	283	51,918	52,005	36,288	69,852
Level A	106	1,133	72,208	70,294	57,500	95,575
Level B	105	1,788	84,272	83,200	63,538	110,878
Level C	136	2,530	103,910	103,885	70,000	141,650
Level D	133	2,940	127,223	128,000	88,000	170,560
Level E	118	1,984	156,070	156,028	97,746	226,000
Level F	105	1,254	188,677	190,000	124,800	264,960
Level F+	70	380	237,300	230,541	144,000	425,000

Source: APEGA, *The Value of Professional Services 2016: Salary Survey Highlights.* Found at https://www.apega.ca/assets/PDFs/salary-survey-highlights.pdf. Used with permission.

TABLE 4.2 — APEGA 2016 Value of Professional Services Salary Survey: GEOSCIENTISTS (All Industries)

Job Title	Number of Firms	Number of Cases	Average ($)	Median ($)	Minimum ($)	Maximum ($)
Level A–	3	8	58,038	---	56,210	59,124
Level A	13	62	73,659	73,825	55,008	88,953
Level B	14	107	81,933	83,047	65,869	96,250
Level C	22	123	106,754	104,180	84,314	141,375
Level D	25	173	134,852	135,716	93,768	170,000
Level E	22	177	165,039	167,871	117,227	209,917
Level F	25	89	194,738	188,520	152,004	282,000
Level F+	10	36	258,723	244,936	178,299	438,000

Source: APEGA, *The Value of Professional Services 2016: Salary Survey Highlights*. Found at https://www.apega.ca/assets/PDFs/salary-survey-highlights.pdf. Used with permission.

Basic Duties

These duties are based on the Code of Ethics, which is your basic ethical guide. This overview introduces the concepts, and later chapters discuss these ethical issues in detail.

RISK MANAGEMENT (PROTECTION OF THE PUBLIC) The most basic professional duty is to protect the public. Every licensing Act defines this duty, and it is the first clause in every Code of Ethics (although the wording may vary). The professional must put public safety, health, and welfare ahead of any personal gain. The duty to manage risk means recognizing, eliminating, and reducing hazards, and every chapter in this text emphasizes this duty. Advanced hazard reduction and failure analysis techniques are often useful, as explained in Chapter 6, "Hazards, Liability, Standards, and Safety."

CODES AND STANDARDS Professionals must follow recognized codes and standards. Doing so is a simple way to improve safety and prevent harm. Chapter 6 discusses codes and standards and the work of standards organizations, such as the Standards Council of Canada, as well as occupational health and safety (OHS) laws. Environmental codes and standards are discussed in Chapter 13, "Environmental Ethics."

DUTY TO INFORM The professional must communicate truthfully and openly with clients or employers, regulatory agencies, and the public except where patent, legal, or personnel matters require confidentiality. Professionals must also explain clearly what harm may occur if the client (or employer) ignores or "overrules" a technical recommendation. This duty is particularly important when the client (or employer) has little or no technical expertise (see Chapter 10). Under the Code of Ethics, professionals must disclose dangerous or illicit situations. In extreme cases, the professional may need to take exceptional action to protect life, health, or property, as discussed under "whistle-blowing" in Chapters 11 (Ethic Concepts and Cases: Management) and 13 (Environmental Ethics).

DUE DILIGENCE The term *due diligence* literally means "reasonable care." Due diligence is a strategy for guaranteeing success by considering every possible mode of failure and ensuring that a contingency plan is in place for every mode. Due diligence is an important legal defence. For example, consider charges under occupational health and safety (OHS) laws. If a defendant can show that he or she took reasonable precautions to protect health and safety, then the defendant will not be found guilty. (Obviously, if you take reasonable precautions, the workplace should be safe.) Conversely, the absence of reasonable precautions implies negligence. Chapters 6 and 13 discuss occupational health and safety.

LEGALITY—DUTY TO OBEY THE LAW Although this point may be obvious, professionals must practise within the law and uphold the spirit of the law. Chapter 9 offers a concise summary of principles of ethics and the Code of

Ethics. Contravening the Code can lead to serious consequences, as explained in Chapter 3, "Disciplinary Powers and Procedures." Case histories in Chapters 10 to 12 illustrate these ethical principles.

ETHICS IN THE CORPORATE WORLD Corporate duties create pressures (and temptations) that may conflict with professional ethics. For example, insider trading (discussed in Chapter 3) may yield quick profits, but may also end a career. Similarly, the theft or abuse of financial data, computer code, or trade secrets can occur more easily in some corporate environments. Corporations do not cause these unethical activities, but the corporate environments may aggravate them. Chapter 9, "Principles of Ethics and Justice," and the case studies in Chapters 10 to 12 explain and illustrate these ethical issues.

GLOBALIZATION (ETHICS AND INTERNATIONAL ACTIVITIES) The cross-border activities of international corporations create new ethical dilemmas for professionals. For example, when professionals practise across borders and laws differ, which laws should govern? Similarly, when products are manufactured in different countries to different quality standards, whose standards should prevail? These topics are explored in Chapter 12, "Ethics Concepts and Cases: Consulting," under "Foreign Consulting."

SUSTAINABLE DEVELOPMENT Sustainable development means using our natural resources sensibly, so that we do not dissipate them through negligence and do not degrade the quality of life for future generations. Chapter 13, "Environmental Ethics," explores this topic in detail. Chapters 14 and 15 also provide key environmental information.

QUALITY MANAGEMENT Quality management does not focus merely on product quality, but examines the means of achieving it. In other words, quality management programs go beyond an organization's services or products and examine the function of the organization itself. Dozens of quality management programs, known by their acronyms (e.g., ISO, 6Sigma, CSA, LEAN, TQM) have evolved in recent decades. The ISO 9000 family of Quality Management System standards, created by the International Organization for Standardization (ISO), is best known. ISO 9000 standards do not certify the quality of product or service; they certify the organization's systems and processes. Chapter 6, "Hazards, Liability, Standards, and Safety," discusses quality management.

RELATIONS WITH OTHER PROFESSIONALS AND NONPROFESSIONALS Although the wording may vary, every Code of Ethics requires professionals to work together productively. Chapter 1 of this book defines the roles of the technical team. Chapter 5 discusses work relationships in employment, consulting, and business, and Chapter 8, "Diversity in the Professional Workplace," specifically discusses the importance of professional cooperation. Ethics cases in Chapters 10 to 12 illustrate these concepts.

USE OF SOFTWARE, COMPUTERS, AND INTERNET-BASED TOOLS Every professional must be able to use computer technology (in their area of expertise). More pointedly, professionals must use computers ethically and avoid and discourage unethical practices, such as Internet harassment or bullying, hacking, software piracy, and plagiarism. These abuses are contrary to the Code of Ethics, as explained in Chapter 7, "Computers, Software, and Intellectual Property."

DOCUMENT AUTHENTICATION AND CONTROL Professional engineers and geoscientists must prepare legible and complete records of their activities. Key technical documents must be signed, sealed, and dated (a process called "authenticating" the document). Professional seals must be secure, document changes must be properly recorded, and authenticated documents must be property controlled. When requested, documents must be provided for inspection. This chapter describes the use and security of the professional seal (see page 96).

INSURING AGAINST UNFORESEEN EVENTS Although professionals strive to produce accurate work, nothing is perfect; errors sometimes creep in. Professionals must avoid financial disaster by purchasing liability insurance to protect against the costs of negligent conduct. This "errors and omissions" insurance is compulsory for engineering and geoscience firms (and for sole proprietors in some provinces). See Chapter 6 for advice on liability and Chapter 2 for licensing of corporations.

The Critical Importance of Communication

Your ability to communicate is important to career success. A competent engineer or geoscientist must be able to convey ideas to others. Conversely, poor communication may obscure your technical ability. Therefore, always strive to communicate clearly.

If you can perform the following tasks, you likely have good communication skills:

- Explain technical ideas to colleagues and employers.
- Assert yourself and respond adequately in job interviews.
- Inform, motivate, and persuade others.
- Plan for your business, your family, and yourself.
- Correspond effectively with people at all levels of your organization.
- Keep professional records and write reports.
- Make oral reports to colleagues and supervisors.
- Speak publicly at meetings, conferences, and conventions.

Few people have total mastery of these skills, but fortunately, anyone who wishes to improve their communication or language skills can and should be encouraged and enabled to do so. Sometimes, continuing personal development activities can be the key to lifelong change. Of course, engaging in them is a personal decision and depends on individual needs and ambitions.

Digital communication (Internet, intranets and extranets, email, and voice mail) is now widespread and brings new concerns. These technologies may improve speed and accuracy, and this innovation is welcome; however, digital communication also brings new legal and ethical risks. We must not sacrifice accuracy, clarity, or proper legal protection for digital speed. In their legal text, *Practical Law of Architecture, Engineering, and Geoscience*, Samuels and Sanders encourage professionals to prepare written "communications system plans" (CSP) to set out policies for digital communication. Their text lists many common electronic problems that could create serious legal or financial problems for professionals.[10]

In summary, clear communication is more important than ever before, and we must strive to improve our skills. As professionals, however, we must also protect our security.

4.7 PROFESSIONAL WORKING CONDITIONS

Professional employees deserve professional working conditions, including challenging technical work and opportunities for promotion based on merit. Ideally, the workplace should include high-quality computer hardware, state-of-the-art software, high-speed Internet connections, friendly colleagues, and clear communication with management. All of these increase productivity and job satisfaction.

Ideally, a professional should have an employment contract that specifies working conditions (and other job data, as explained in Chapter 10). Most graduates do not have personal contracts; they are typically hired on a letter of appointment, and their working conditions are set by company policy.

Employers should review personal performance and working conditions regularly (at least annually). Failure to review working conditions leads to declining morale, reduced productivity, and turnover of key personnel. Employers must also monitor company employment policies. Two organizations—Canadian Society of Professional Engineers (CSPE) and National Society of Professional Engineers (NSPE)—provide advice on working conditions that may be of interest to professional employees.

The Canadian Society of Professional Engineers (CSPE)

CSPE is an advocacy group for professional engineers. It is not a union and does not face the legal and bureaucratic problems typically encountered by unions. It was modelled after medical associations and bar associations, which work collectively for their members. Although it is intended to be a national advocacy group whose purpose is to coordinate the provincial advocacy groups, it has not yet achieved its potential. The Ontario Society of Professional Engineers (OSPE) remains the only provincial group created under the

CSPE umbrella.[11] Although OSPE is an active advocacy group, it does not yet provide the extensive information offered by the NSPE (the corresponding U.S. organization), discussed below.

The NSPE Professional Employment Guidelines

The NSPE developed professional employment guidelines many years ago. These guidelines may be of interest to Canadian professionals because Canadian guidelines do not yet exist. The NSPE guidelines contain over 60 rules for professional recruitment, employment, development, and termination. They answer practical employment problems and provide good advice for both employers and employees. The NSPE guidelines are explained in Chapter 10 (and listed completely in Web Appendix D).[12]

4.8 USING YOUR PROFESSIONAL SEAL

During your career, you will likely prepare thousands of key technical documents, such as reports, drawings, maps, plans, and specifications. Other people will rely on these documents to make important decisions affecting life, health, safety, or finances. It is standard practice to sign, date, and apply your personal professional seal to these key documents when you issue them in final form. Your seal tells everyone that a licensed professional prepared these documents. The seal increases confidence; it is a sign of quality, and misuse of the seal is serious misconduct.

The seal is usually a rubber stamp, so the terms “seal” and “stamp” are used interchangeably. The licensing Association sends a seal (a rubber stamp) to each newly licensed engineer and geoscientist. The seal identifies the Association, the type of licence, and the name of the licence holder. The rules for using the seal are similar across Canada. The seal remains the property of the Association and must be returned if the professional retires or resigns (or if the Association asks for it). An Alberta (APEGA) guideline explains the purpose:

> A professional stamp or seal affixed to a document is intended to indicate that the document has been produced under the supervision and control of a fully qualified professional member ... or that it has been thoroughly reviewed by a professional member ... who accepts responsibility for it. Professional stamps and seals shall be affixed, signed and dated only after the responsible member is satisfied that the document or component, for which he or she is professionally responsible, is complete and correct.[13]

The process of applying a professional stamp, signature, and date to a document is often defined as “authenticating” the document.

What Does the Seal Represent?

The seal identifies the author of the document, of course, but the seal has a greater significance: It means that the author *approves* it. In other words, the author is confident that the document is accurate and assures others that they can rely on it. Finally, the seal denotes that the author assumes professional responsibility and accountability if the document should later be found to contain errors.[14] The seal is neither an archaic tradition nor a mindless formality—it is a "mark of reliance." It does not guarantee perfection, but it indicates that "the opinions, judgments, or designs were provided by a ... professional held to high standards of knowledge, skill and ethical conduct."[15]

Which Documents Are Sealed?

The Act typically requires all *final* drawings, specifications, plans, reports, maps, and similar documents involving professional practice and issued to the public to be dated, signed, and sealed by a professional engineer or geoscientist. The use of the seal is not optional, and no fee is charged for sealing documents—sealing is standard professional practice, required under every Act. For

Photo 4.1 — Oil Sands Processing. *Mining operations at the Aurora Mine—part of Syncrude Canada's oil sands development near Fort McMurray, Alberta. The Athabasca oil sands in Alberta contain immense amounts of oil in the form of dense, viscous bitumen. To extract the oil, the bitumen must be mined and processed. This development of the oil sands creates an ethical dilemma (as discussed later in this book). The processing of bitumen and the consumption of fossil fuels create carbon dioxide emissions that lead to climate change, which has serious consequences; however, the oil industry creates great wealth for Alberta, indirectly benefits all of Canada, and has made Canada a net exporter of oil.*

Source: Norm Betts/Bloomberg via Getty Images example, Ontario's Regulation 941 requires professionals to "sign, date and affix the ... seal to every final drawing, specification, plan, report or other document prepared or checked" before it is issued to the public.[16] Incomplete or preliminary documents are not sealed.

In the past, Ontario's Professional Engineers Act had a special exemption for industrial machinery: Ontario companies were not required to seal engineering documents for machinery or equipment used to produce a product intended strictly for internal company use. This "industrial exception" is, however, being challenged by Professional Engineers Ontario.[17] All practitioners should be required to seal their work.

Which Documents Are Not Sealed?

Apply your seal only to documents related to professional practice. Do not seal a document that has no technical content, such as business memos, letters, and notes; however, if a memo or letter contains technical data or specifications, you would seal it. Legal documents, such as contracts, are not technical documents, so do not seal them. Signatures are adequate for most business purposes, and if your professional practice is incorporated, use a corporate seal on legal contracts (not your professional seal).

Only *final* documents are sealed. Preliminary documents, rough drawings, or draft specifications are *definitely* not sealed; instead, they are clearly marked "Preliminary," "Not for Construction," "Draft," "For Discussion Only," or something similar to make sure that they are not confused with final documents.

A rare exception occurs to satisfy regulatory agencies, since a preliminary document may need to be sealed for administrative purposes (for example, to get an approval under the building code). In this special case, a document may be "final" for administrative purposes, but *not* final for construction, so it is particularly important that you mark it as "Not for Construction." Expensive and dangerous errors can occur if you mistakenly release preliminary documents for construction—and such errors occur regularly!

Do not use professional seals in company logos, advertising, letterheads, business cards, or other promotional publications. Furthermore, do not apply your seal to government documents, such as applications for passports or birth certificates, even when professional engineers or geoscientists are guarantors.[18]

Document Approval Process

Your seal on a document means that you approved it; therefore, applying the seal is the last step before you release the document. Your company should have a formal document numbering system and an established procedure for preparing, approving, revising, and filing technical documents. If so, follow that procedure (even if it seems cumbersome or bureaucratic). The document system ensures that everyone is working with approved, up-to-date documents, maps, drawings, and data.

Finally, you should routinely verify your documents before you seal them. If you prepared the document, this verification may be done quickly. If you did not personally prepare the document or supervise the preparation, you may need to duplicate some of the work upon which it is based (as discussed below, under "checking").

Professional and Legal Liability

Perfection is not required in technical documents, but reasonable judgment, based on adequate knowledge and experience, is essential. If you do not have confidence in the document, if you have not had time to review it thoroughly, or if it is outside your field of expertise, then you should not seal it. For example, an electrical engineer may be asked to approve the concrete design for a building foundation, because the building is intended to house an electrical transformer. If the electrical engineer has no training or experience in reinforced concrete design, then the request is outside that professional's field of expertise. A colleague experienced in concrete design must be consulted.

An engineer or geoscientist who signs or seals a document without thorough knowledge of the document may be guilty of professional misconduct. In one case, the British Columbia Supreme Court ruled that an engineer was liable in a dispute over an improperly designed residence foundation. The court stated: "By affixing his seal to the drawings and by his letter ... the defendant [engineer] ... certified that the foundation drawings conformed to all the structural requirements of the 1980 National Building Code."[19] It is clear that the court considered the seal on the drawings to be a guarantee that the design conformed with codes.

However, in another case, it is reassuring that the Supreme Court of Canada ruled that there is some room for error—perfection is not essential: "The seal attests that a qualified engineer prepared the drawing. It is not a guarantee of accuracy. The affixation of the seal, without more [evidence], is insufficient to found liability for negligent misrepresentation."[20]

The best strategy is, of course, to avoid these problems. Do not seal a document unless it is correct, complete, within your field of expertise, and you accept responsibility for it.

Adequate Supervision

Every licensing Act allows a professional to supervise the work of others, providing they are under "direct supervision and control." Managing this supervisory relationship requires careful consideration. The supervising professional must ensure that he or she meets the requirements to seal documents prepared with a subordinate's input. Specifically, the licensed professional must demonstrate active involvement in the project, supervise field reviews, be responsible for engineering decisions, and provide the appropriate supervision, given the experience levels of the supervising professional and subordinate.[21]

Reviewing Others' Work

In spite of the above remarks on supervision, professionals often approve work conducted by others, even those who are *not* under their direct supervision and control. This action comes with a serious caveat, though. Before approving work done by others, the "professional member shall only apply his or her stamp to the documents after thoroughly reviewing the documents and accepting professional responsibility for" the work.[22] Accepting this responsibility is occasionally necessary, for example, to cope with staff turnover when staff quit or move to other jobs.

Of course, if you carry out a "thorough review" (which may require duplicating some or all of the work), then it is appropriate for you to accept responsibility for it and apply your seal. The extent of a thorough review depends on the factors listed just above: the same factors needed to judge supervision.

The Hazards of "Checking" Documents

The term "checking" is ambiguous. Does it mean "to point out obvious errors in a document," or does it mean "to accept legal responsibility for the document"? For example, if a colleague asks you to "check," sign, and seal a document, the act is not a formality. You would be accepting full responsibility for the document. You would not be able to do so, though, unless you supervised or made a thorough review of the work.

As a rule, if someone asks you to "check" a document, you must clarify the meaning. Are you merely scanning for errors, or are you assuming responsibility? If you are asked to seal a document that was not prepared under your direct supervision, then you must analyze it sufficiently to assume responsibility for it. The following two scenarios are unprofessional and can lead to discipline:

- **Request from a friend:** Unlicensed practitioners often ask professionals to "check" and seal documents to avoid the cost of a full technical analysis. For example, a friend who is an engineering or geoscience graduate, but is not licensed, approaches you. She asks you, as a favour, to "check, sign, and seal" an engineering or geoscience drawing to satisfy municipal bylaws. She assures you that the drawing is completely correct and that your signature and seal are mere formalities.
- **Pressure of work:** You are the designated professional on the certificate of authorization (or permit to practise) for an engineering or geoscience firm. The firm has many projects, and you are unable to monitor all of them adequately. Your employer asks you to sign and seal the final report for a project of which you were previously unaware. The employer tells you the report is urgent and no further analysis is required, and asks you to sign immediately.

In each of the above situations, you would refuse to sign or seal the document until you had verified the document sufficiently to accept full responsibility for it. Do not be led into a trap by friendships, external pressure, or urgency. For some documents, a proper check might require complete duplication of the analysis. Obviously, if you completely redo the work, it is appropriate for you to assume responsibility for it.

When Professionals Collaborate

The general rule in collaboration is that if one engineer or geoscientist prepares a document and another approves it, then both seals should be affixed. If this is not possible or not expected, then only the approving engineer or geoscientist should seal it. This seal indicates that he or she takes responsibility for the document or drawing. Where final documents concern more than one discipline, the documents should be sealed both by the approving engineer or geoscientist (typically the project leader) and by the design engineer and/or geoscientist for each discipline. The seals should be "qualified" by an explanatory note indicating each person's area of responsibility.

Since electronic collaboration now occurs on a vast scale, maintaining data integrity is essential. When professionals collaborate with large geoscientific or engineering datasets, the authorship of this data (and alterations) must be tracked. Fortunately, software for large electronic datasets usually has these features.

Reports and Multiple Maps or Drawings

Individual pages of a report (and maps or drawings bound in a report) need not be sealed if the report itself is signed, sealed, and dated. The seal is usually placed on the title page near the author's name or at the end (if the report is in the form of a letter).

In large projects, the number of documents to be sealed may be very large. It is not usually necessary to seal every detail drawing on large structural projects, which may have thousands of details. However, the drawings must be prepared under a professional's control and supervision, and he or she assumes responsibility for them whether they are sealed or not. For example, the special case of structural steel is described in Ontario's guideline on the use of the seal:

> Generally applicable design details developed by manufacturers or standards organizations, verified by testing and/or approved by government bodies, do not need to be sealed. However, details or subsystem designs produced by manufacturers or contractors for specific projects, or applications that require professional engineering design or judgment, needed for coordination by the design engineer, must be sealed, to ensure there is consistent delineation of design responsibility for all aspects of the work.
>
> For structural steel shop drawings, the building design engineer designs the members and overall stability system and is responsible to indicate member connection forces as required by professional practice standards. Structural steel detailers use this information to produce shop details and connections for the steel members. Many of the connections use standard details from the Canadian Institute of Steel Construction (CISC) handbook, which have been developed over time by qualified engineers.[23]

The guideline, however, warns that connections may appear to be similar to standard connections but not be identical. Therefore, as a rule, all shop drawings should be sealed or accompanied by a sealed letter to the building design engineer, listing the drawings and stating that all detail drawings were prepared and reviewed under the connection design engineer's supervision.

Seal Security

The seal is important; you must obtain it from the Association and keep it in a secure place. Do not duplicate, lend, or use it unprofessionally. Unlicensed practitioners occasionally make and use illegal seals, but the Associations prosecute this practice under the Act (see Chapter 3).

In the past, the (unsealed) master copies of drawings or maps were usually kept in a secure file, and prints of them were sealed by hand as they were issued. This procedure, still used by many professionals, maintains security while keeping documents up-to-date, since the masters are easily located when revisions are needed.

This manual approval of documents (personally signed, sealed, and dated) provides high security and is acceptable for most small firms; however, the process is labour intensive. Every hard copy must be printed for authentication (signing and sealing) and sent for appropriate signatures. For speed and convenience, professionals in large firms are adopting electronic seals.

Electronic Seals and Digital Certificates

You may be tempted to scan your seal and signature to insert them easily on electronic documents, but this is risky and unprofessional. Do not confuse a digital signature (which has cryptographic protection) with a digitized signature (an image).

For security, electronic seals and digital signatures must be unique to the person using them, under that person's sole control, capable of electronic verification, and attached to the data in such a way that alteration of the data will be immediately recognizable.

Fortunately, electronic seal technology now satisfies these criteria, and professionals can digitally sign and apply an electronic seal to their documents. The approved software ensures secure electronic transmission and legal transactions.

Electronic seals require cryptographic security measures, so you need third-party assistance. However, this service is now available throughout North America. Documents prepared with standard office software and file types (e.g., Word, Adobe) can be digitally "sealed." The documents are legally enforceable. Authorship can be easily verified at any time electronically, and the system ensures that the originals have not been altered. The process permits fully paperless document preparation and approval.

To obtain the agreements and software for digital signatures and electronic seals, you must apply through your licensing Association. Your Association must verify your membership status (as well as the status of the person who witnesses your signature). The Association then grants permission to a third-party software provider to issue an official digital signature and electronic seal. Of course, this convenience comes with a cost and a commitment. The companies providing the electronic seal technology impose a nominal one-time subscription fee and an annual renewal fee. Note that access to documents, for alterations and storage, may be needed for decades. For more information on electronic seals and digital signatures, consult your Association.[24] (See the websites listed in Appendix A.)

Failing to Seal Documents

You may be surprised to learn that applying a seal does not increase the author's legal or professional liability and omitting the seal does not relieve the author of liability: "The courts assign liability on the basis of the facts, not on whether the document is sealed."[25] Omitting the seal is, however, a violation of the Act. Discipline cases often include this charge (even though it is not a serious offence) because a missing seal may corroborate a pattern of negligence or misconduct.

Approval authorities (such as municipal building permit officials) examine unsealed documents closely and routinely reject them. Occasionally, officials may process an unsealed document as a professional courtesy if the author is clearly identified as a licensed professional, and the missing seal appears to be an oversight. However, unsealed documents are always scrutinized more closely.

4.9 PROMOTION TO SPECIALIST OR MANAGER

Promotion is a welcome sign that employers recognize your ability. Usually, about seven or eight years of experience are needed (on average) to supervise other professionals. The first supervisory position is Level D in the responsibility levels (discussed earlier in this chapter). However, promotion paths typically diverge at Level D, leading either to specialization or to management. These are very different destinations.

Specialization versus Management

SPECIALIZATION Specialists are essential. All technical companies need highly qualified experts to give advice to other professionals, solve difficult problems, make discoveries, and create and analyze the new products. Employers must encourage and reward specialists (especially those who achieve world-class levels). Salaries and benefits must match (or exceed!) those of managers. The typical specialist gives advice and solves problems, so a high level of technical knowledge and an advanced degree are definite assets, especially in high-technology industries. If specialization is your goal, develop your technical problem-solving skills, learn codes and standards, join a technical society, and attend its conferences. (Chapter 18 discusses the value of technical societies.)

MANAGEMENT Companies also need good managers, and a basic degree in engineering or geoscience is an excellent preparation. Management means working closely with people, however, so good interpersonal skills are essential. For example, the manager makes key decisions in the "selecting, developing, rating, disciplining and terminating staff." Managers must have "people" skills. An enthusiastic attitude is an asset. These skills can be developed through personal study and practice. (Chapter 5 discusses management tasks.)

Choosing a Management Style

If you plan to enter management, you will want to develop a management style that colleagues support. Douglas McGregor was the first researcher to explain management theory in a popular way. In his classic book, he described the two extremes of management style:

> **Theory X:** Theory X states that work is basically distasteful to most people and that people will avoid it whenever possible. Therefore, employees must be closely monitored and controlled. Furthermore, they must be made to work by threatening or penalties, or by luring them with rewards.
>
> **Theory Y:** Theory Y states that people are naturally inclined to work and merely need favourable working conditions in order to be productive. Furthermore, psychological factors, such as perceived control over one's activities and opportunities for creative work, are important for proper motivation. If they are properly motivated, employees will produce beyond expectations.[26]

McGregor recommended that managers adopt Theory Y. In fact, most managers today would say they try to follow this theory. The "best" management style, however, depends on the situation: a style that works in a software design office may not be effective in managing a police force, a firefighting squad, or even a construction site. The "best" style also depends on the personality and maturity of the manager; the type of corporation; the initiative, creativity, education, or skill level of the employees; and their willingness to achieve the corporation's goals.

The spectrum of management styles ranges from the collegial (where the style is based entirely on Theory Y) to the autocratic (based on Theory X). One view of this spectrum is shown in Table 4.3. Most people like the collegial style best and the autocratic style least. Where is your management style (or your future management style) in this spectrum?

In a professional environment, such as a design office, the manager should adopt a collegial or team-oriented management style. However, an authoritarian style may be needed occasionally—for example, to insist that safety features be added to a design. A good manager adjusts to the situation to ensure that the goals are achieved.

TABLE 4.3 — A Comparison of Management Styles

Management Style	Typical Example
Collegial	Manager treats employees as colleagues and permits them to function independently, within agreed terms of reference. (Theory Y)
Team-Oriented	Manager defines goals, but asks employees to suggest solutions and guides them to a group decision.
Interactive	Manager presents the problem, obtains ideas and suggestions from employees, and then proposes a decision.
Responsive	Manager presents tentative decision to employees and invites questions and discussion. Decision is final only after discussion.
Paternal	Manager presents decision and explains it to employees but will change decision only if serious objections are made.
Authoritarian	Manager makes decision and explains it to employees.
Autocratic	Manager instructs employees. (Theory X)

DISCUSSION TOPICS AND ASSIGNMENTS

1. The discussion of management styles in this chapter implies that authoritarian managers are unable to motivate their workers effectively. Discuss this point. Is this necessarily true? Machiavelli would certainly disagree. History shows that many authoritarian managers have successfully motivated their workers (or followers) in the past, and many will likely do so in the future. Although one may disagree with using authority (that is, fear) to motivate workers, it does sometimes work. Discuss the benefits and disadvantages of an authoritarian management style, and give a few examples (jobs or social situations) where it might be most effective. As a contrast, give a few examples where it might be least effective.
2. The following questions concern management theories:
   a. Two well-known "laws" in management are Parkinson's Law and the Peter Principle. Parkinson's Law states: "Work expands to fill the time available." The Peter Principle states: "People are promoted within an organization until they reach their level of incompetence." Using the Internet, find the sources of these "laws" and explain them in your own words. Can you cite examples where they apply (in politics, in your job, or among friends)?
   b. The president of a famous computer manufacturing company is reputed to have said: "We try to promote people without making them into managers." Explain this, briefly. Is this a positive statement about dual promotion paths (for specialists and managers), or is it a negative statement about managers?

Additional assignments are given in Web Appendix E.

NOTES

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[4] Canadian Engineering Qualifications Board, Engineers Canada, *Guideline for Assessment of Engineering Work Experience* (G09-2009), www.engineerscanada.ca/e/files/Assessment_Guidelines_Final.pdf (accessed June 24, 2012). Excerpt reproduced with permission from Engineers Canada.

[5] APEGA, "Detailed Job Classification Guide," *Value of Professional Services 2011*, 65, www.apega.ca/Members/Publications/salarysurvey.html (accessed June 19, 2012).

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[10] Brian M. Samuels and Doug R. Sanders, *Practical Law of Architecture, Engineering, and Geoscience*, Canadian ed. (Toronto: Pearson Canada, 2016), 291.

[11] Canadian Society of Professional Engineers (CSPE), http://www.cspe.ca/CSPE/Main_Page.html (accessed June 2, 2017); OSPE, www.ospe.on.ca (accessed June 2, 2017).

[12] National Society of Professional Engineers (NSPE), *Guidelines to Employment for Professional Engineers*, 4th ed., June 2006, www.nspe.org/sites/default/files/resources/documents/pei/guidelines_rev4.doc (accessed June 15, 2017).

[13] APEGA, *Guideline for Ethical Practice*, V2.2, February 2013, 10, https://www.apega.ca/assets/PDFs/ethical-practice.pdf (accessed June 2, 2017).

[14] PEO, *Use of the Professional Engineer's Seal*, November 2008, 18, http://www.peo.on.ca/index.php/ci_id/22148/la_id/1.htm (accessed June 2, 2017).

[15] APEGBC, *Quality Management Guidelines—Use of the APEGBC Seal*, October 13, 2013, https://www.apeg.bc.ca/getmedia/4acd4afe-a372-43d5-8111-b05467647dc3/APEGBC-QMG-Use-of-APEGBC-Seal.pdf (accessed June 2, 2017).

[16] Regulation 941, section 53, under the Professional Engineers Act, R.S.O. 1990, c. P.28, https://www.ontario.ca/laws/regulation/900941 (accessed June 2, 2017).

[17] Professional Engineers Act, R.S.O. 1990, c. P.28, section 12(3)(a), https://www.ontario.ca/laws/statute/90p28 (accessed June 2, 2017).

[18] PEO, *Use of the Professional Engineer's Seal*, 8.

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Chapter 5
Consulting, Private Practice, and Business

Engineers and geoscientists in private practice offer their services to the public, typically as consultants. Their preferred business title is Consulting Engineer, Consulting Geoscientist, or simply Consultant. Private practice is entrepreneurial, and although it has more risks than permanent employment, it is often more varied and more rewarding. This chapter provides an overview of private practice and consulting; most topics also apply to many technical businesses.

5.1 THE LURE OF CONSULTING

Consulting offers a stimulating lifestyle, with interesting work and diverse clients at various job sites. Tasks may be new and challenging, for which the engineer or geoscientist is typically well paid. The opportunity to travel attracts people with an independent spirit, and consulting often gives you more direct control over your career.[1] In 2016, the Association of Consulting Engineering Companies—Canada (ACEC) estimated that the gross revenues of its member consulting engineering firms exceeded $21.4 billion.[2]

Of course, there are drawbacks. Your income drops when projects are scarce, you cannot complain if you are your own boss, and travel may interfere with personal relationships. The field is not crowded, but it is very demanding: acquiring knowledge and experience takes years of practice. Professionals usually enter private practice later in life, at the peak of their career. Yet despite the attractions, consulting does not appeal to everyone; only a minority of engineers and geoscientists work as consultants.

5.2 CONSULTING ACTIVITIES

A consultant is usually hired to advise a client (an individual or a company) on a project that needs specialized engineering or geoscientific knowledge. The client owns the project, but the consultant's advice and skills increase the probability of success. Depending on the client's needs, the project may involve any topic—from design, development, management, or construction to mineral exploration, development and mining, remote sensing, water quality, remediation of environmental hazards—and thousands of other activities.

Consultants are generally hired when a project requires specialized expertise for a limited period of time, and their work often involves diverse tasks.

- **Engineering design advice:** Most consulting engineers work on design and construction projects. Tasks may include inspection, testing, quality control, and project management. Consulting engineers may work independently or alongside the client's in-house staff. Consultants may also help to develop inventions or prepare patents. Occasionally, a client may require a forensic analysis of a device or structure that failed in order to redesign it.
- **Geoscience advice:** Many consulting geoscientists advise on resource discovery and development, particularly in petroleum, natural gas, and mining. Specialized services, such as rock and soil sampling, well logging and monitoring, slope stability, erosion, and groundwater and environmental investigations, are typical consulting activities. Advising on natural hazards, seismicity, and volcanism are rare, but extremely important activities when needed.
- **Expert testimony:** Consultants are often hired as expert witnesses. An expert witness provides an independent opinion to a court, commission, board, hearing, or similar government or judicial body. The witness must be impartial and must not be a spokesperson for either side (even if only one side is paying for the expert testimony).
- **Feasibility studies:** Consultants are vital in the early stages of a project when a client needs to know the feasibility, financial justification, duration, and cost of a project. The consultant helps the client decide whether the project goes ahead.
- **Project management:** Consultants often supervise projects, including the design, manufacturing, construction, or assembly phases, or the commissioning (initial start-up) of a large plant.

In summary, engineers and geoscientists in private practice perform any task that requires professional knowledge for a client who lacks the personnel or the expertise to conduct the work.

5.3 ADDITIONAL LICENSING AND INSURANCE REQUIREMENTS

In most provinces, professional engineers or geoscientists may offer their services to the public without additional licensing. However, all provinces and territories (except Quebec) impose rules on partnerships or corporations that offer services to the public. No two Acts are identical on all issues, as is shown in the following overview.

Practice by Partnerships or Corporations

All provinces and territories (except Quebec) require firms (companies, partnerships, or corporations) offering services to the public to have an additional licence. The Associations call the licence a Certificate of Authorization, a Permit to Practise, or a Certificate of Compliance. This licence protects the public by requiring firms to identify the people responsible. The firm must name its qualified, licensed full-time employee(s) who will supervise and accept responsibility for the professional practice. The certificate (or permit) lists their names and holds them personally responsible for the quality of the firm's professional services.

Most provinces and territories permit licensed individuals (sole proprietors) to offer services to the public, but some licensing Associations, such as Ontario (PEO and APGO) and Newfoundland and Labrador (PEGNL), require individuals who offer services to the public to have a Certificate of Authorization (or permit). In Ontario, this certificate requires a minimum of five years of relevant experience.

Designation as a Consulting Engineer

A professional engineer in private practice may use the title Consulting Engineer in most of Canada. In Ontario, however, this title (or any variation with the same meaning) is restricted under the Professional Engineers Act (Ontario). To be a consulting engineer in the province, a licensed professional engineer must apply to Professional Engineers Ontario (PEO) and satisfy several additional requirements:

- **Authorization:** The engineer must obtain a Certificate of Authorization from PEO.
- **Experience:** Consulting engineers must have five years of experience in addition to that required for registration. At least two years of this experience must be in private practice.
- **Liability insurance:** The engineer must give PEO evidence of liability insurance.

Liability Insurance Requirements

Liability—in other words, being sued—is a greater risk for consultants than for employees. As a result, liability insurance (also called "errors and omissions" insurance) is essential for professionals in private practice. The text *Practical Law of Architecture, Engineering, and Geoscience* by Samuels and Sanders has an extensive section on liability insurance. It states: "Even the most competent professionals get sued, sometimes for no valid reason. The cost of defending a frivolous claim can be enormous."[3] Liability insurance typically includes a duty to defend; that is, if the professional is sued, the insurer pays the legal bills.

In spite of this risk, only a few of the Acts require consultants to maintain professional liability insurance. Several Acts do not mention liability insurance, and some Acts require it for partnerships and corporations but exempt sole proprietors. The following summary explains the rules that apply in the provincial and territorial licensing Associations:

- **New Brunswick, Newfoundland and Labrador, Quebec (OIQ and OGQ):** Liability insurance is mandatory for all members.
- **British Columbia, Manitoba, and Saskatchewan:** Liability insurance is not mandatory, but members, licensees, and certificate holders must notify clients in writing whether professional liability insurance covers the services offered and receive the client's acknowledgment before proceeding.
- **Ontario (PEO and APGO):** Liability insurance is mandatory for Certificate of Authorization holders (anyone who offers service to the public) unless they notify clients in writing that no professional liability insurance covers the services offered and receive the client's acknowledgment before proceeding.
- **Alberta, Northwest Territories, Nova Scotia (APENS and APGNS), Nunavut, Prince Edward Island, and Yukon:** Liability insurance is voluntary. The Act does not mention it.

Check the liability insurance rules for your Association, but regardless of the Act's requirements, primary liability insurance is usually essential for consultants.

Secondary Professional Liability Insurance

In every province and territory, professional engineers and geoscientists participate in a Secondary Professional Liability Insurance program begun in March 2002. Engineers Canada administers the insurance plan except in Ontario and Quebec, where the Ontario Society of Professional Engineers[4] (OSPE) and the Ordre des ingénieurs du Québec[5] (OIQ) administer the plans for engineers. The Engineers Canada plan typically provides members with $250,000 in professional liability coverage, as well as defence costs.

The group policy is "secondary" because it is not the main protection against liability claims. Consultants (and design, manufacturing, and similar companies) must maintain separate "primary" liability insurance for professional activities. Secondary insurance typically covers professional engineers and geoscientists who are employees. The secondary plan provides protection for

- claims resulting from actions undertaken as an employee in a firm that does not provide engineering or geoscience services to the public,
- former employees of firms that no longer carry insurance,
- retirees, for past professional acts,
- gratuitous or incidental advice given to others outside of normal employment,
- small consulting jobs (up to $15,000 in fees per calendar year) undertaken outside of normal employment, and
- legal advice up to $75,000 to guide a member for any legal action taken against the member as a result of a whistle-blower action and $75,000 for loss of income related to whistle-blowing action.[6]

The secondary insurance coverage is rather narrow, since it does not cover "moonlighting" activities where the member's fee exceeds $15,000 per calendar year. Nevertheless, secondary coverage provides extra protection to the public. Group coverage increases participation and reduces premium costs. Information on the insurance agreement, coverage, restrictions, and exclusions is available from your Association or OSPE.

5.4 SELECTING A BUSINESS FORMAT

A consulting firm or business must have a recognized structure. The following overview explains the four most common business structures, and the text *Practical Law of Architecture, Engineering, and Geoscience* by Samuels and Sanders explains the advantages and disadvantages of each in more detail.[7] You should, of course, discuss the business plan, structure, legal restrictions, and tax implications with a lawyer or an accountant.

Four Common Business Structures

SOLE PROPRIETORSHIP

A sole proprietorship is a one-person business. It is easily established: the proprietor (owner) simply registers the business name with the provincial or territorial government. The business setup and management are simple, but the proprietor is responsible for all of the business's financial debts and professional problems. For example, if the business should incur large debts, creditors may sue to seize both the proprietor's business and his or her personal property.

GENERAL PARTNERSHIP

A partnership enables professionals to share knowledge, experience, and friendship. Two or more individuals can agree to form a partnership (preferably by a written agreement, but not necessarily). Most often, the partners contribute the capital to start the business and agree to manage it together. They then share the profits and losses. The partners must register the business with the provincial government (as for sole proprietorships). The partners share the work, but each partner is liable for the business debts or obligations incurred by all the other partners. Therefore, the people involved must have absolute confidence in one another's skills, competence, ethical standards, and personalities before entering a general partnership. Errors, omissions, and fraudulent acts by one partner in the name of the partnership create a liability for the innocent partners. In particular, if a partner does unprofessional work, all partners who authorized, permitted, or even acquiesced in the unprofessional work may be subject to discipline.

LIMITED PARTNERSHIP

Investors form limited partnerships when one (or more) of them does not want to participate in running the business. The general partners carry on the business; the limited partners contribute assets for use in the business (typically money, but sometimes property, such as a building or a patent). The liability of the limited partners is restricted to the value of the assets contributed; however, you must register a limited partnership (provincially) to get this liability protection. If a general partner does unprofessional work, only the general partners are required to answer. Limited partners are not involved in the day-to-day running of the partnership—they cannot intervene in the business's operations—and typically are not at risk.

CORPORATION

A corporation has many of the rights of a real person. For example, a corporation can enter into contracts, own property, and conduct business. To establish a corporation, an individual (or a group of people) must apply to the government, something that involves some paperwork and fees. Before doing so, however, you should first consult a lawyer for advice on whether to incorporate under federal or provincial law and for assistance in processing the application. Forming a corporation is usually an effective way to protect personal assets. When a practice is incorporated, creditors (and legal judgments) can seize only the corporation's assets; the personal assets of shareholders are not at risk. A corporation that performs engineering and/or geoscience services must usually obtain a Permit to Practise (or Certificate of Authorization) or must register with the Association. The corporation must designate a licensed professional within the corporation who will take responsibility for the corporation's technical work. The designated professional must have the competence and the authority to ensure that the corporation's work meets professional standards because that person must answer if a charge of professional misconduct is made against the corporation.

Minimizing Risks of Insolvency and Incompetence

Each business structure has advantages and disadvantages. When a professional starts out in private practice, protecting personal assets to the limit possible is wise. The following advice may help:

- Incorporate the practice; this limits your liability against demands from creditors and against civil judgments such as breach of contract should your business go broke.
- Regardless of the form of business organization, get professional liability insurance. This "errors and omissions" insurance will help cover costly mistakes.
- Obtain general liability insurance to cover the risk of accidents within the business premises and product liability insurance to cover the risk of damage claims for dangerous products. (Other forms of liability, accident, and corporate insurance are also available.)

Neither insurance nor incorporation can shield engineers and geoscientists from disciplinary action for negligence, incompetence, or corruption. These personal actions, omissions, or traits are subject to the discipline process described in Chapter 3. Careful, competent, ethical practice is the only protection against these hazards, and the goal of this textbook is to encourage such practice.

5.5 SELECTING AND HIRING CONSULTANTS

Hiring professional services is not the same as purchasing materials. Materials have established quality standards, so the purchaser's goal is simply to obtain the lowest price. However, it is risky to select a consultant based on the lowest price (although not illegal to do so). Studies show that the Qualifications-Based Selection (QBS) process is best for most projects, because QBS separates the evaluation of the consultant's qualifications from the fee negotiation. The client negotiates the fee after selecting the consultant.

This process is logical and amicable, because fees cannot be set without defining the scope of the project, and the client and consultant define the scope together. Good decisions in the early stages of the project can yield large cost savings, so employing the best qualified consultant saves money. Penny-pinching at the design stage almost always results in higher capital, operating, and maintenance costs.

Qualifications-Based Selection (QBS)

Hiring methods for consultants may be broadly categorized as "price based" or "qualifications based," depending on which is the primary factor. In 2001, the federal government initiated a study to determine the best practices for making decisions on Canadian municipal infrastructure projects. The study examined seven common methods for selecting and hiring consultants, and concluded that the QBS process is the best method for most projects. The process is thoroughly described in *InfraGuide—The National Guide to Sustainable Municipal Infrastructure*. It is summarized below.[8]

THE SEVEN STEPS IN THE QBS PROCESS*

QBS is a competitive system for hiring professional consulting services. The seven basic steps in the QBS selection procedure, as described by the *InfraGuide*, are as follows:

1. **Request for qualifications:** The client advertises the general scope of the project to consultants that have (or are believed to have) suitable qualifications for the project. Interested consultants are asked to submit their qualifications and availability for the project.
2. **Evaluate and rank consultants:** The client evaluates and ranks the consultants through interviews, site visits, client references, and so forth, and prepares a short list of (typically three) consultants with the best qualifications.

* "Selecting a Professional Consultant," *InfraGuide—The National Guide to Sustainable Municipal Infrastructure* (Ottawa: Federation of Canadian Municipalities and the National Research Council, June 2006), www.fcm.ca/documents/reports/InfraGuide/Selecting_a_Professional_Consultant_EN.pdf (accessed October 20, 2016).

Photo 5.1 — Mary River Mine Project. *Engineers and geoscientists from equipment suppliers, consulting firms, and the owners were key contributors to the plans, designs, and construction of the Mary River mine project in the North Baffin region, Nunavut. This project, which is the northernmost iron ore mine in the world, required the design and construction of an open pit mine, ore-crushing facility, roads, and a seaport. Designs had to take into account the location (north of the Arctic Circle) and challenging logistics (most equipment and supplies can arrive only during the short summer shipping season each year).*

Source: © Baffinland Iron Mines Corporation

3. **Request for proposals:** The client asks the (three) short-listed firms to submit proposals for the assignment. The client describes the project in sufficient detail to enable consultants to submit proposals that include methods, alternatives, personnel, preliminary schedule, and a basis for fee negotiations, and so on (but fees themselves are not specified at this stage).
4. **Select the highest-ranked consultant:** The proposals are evaluated and ranked by the client.
5. **Define the scope of the project:** The client and the highest-ranked consultant jointly negotiate the scope of the project in detail, assess options and innovations to be explored, life-cycle cost comparisons to be developed, the role of the consultant in processes, approvals, and documentation, and so forth.

6. **Negotiate fee agreement:** When the client and the highest-ranked consultant have defined the scope of the project, they negotiate an appropriate fee. If an agreement is reached, the client and consultant go to the next step and sign a contract. If they cannot agree on the fee, the client goes back to step 5 and negotiates with the second-ranked consultant. This process continues until agreement is reached.
7. **Award contract:** When agreement is reached, a contract is signed, and the client notifies and thanks the unsuccessful consultants.

Standard contract forms are available from the consultant organizations listed in Table 5.1 and from the provincial Associations. In addition, *Practical Law of Architecture, Engineering, and Geoscience* by Samuels and Sanders (cited earlier) has several chapters on contract law, explaining how to draw up good contracts and what problems and pitfalls to avoid.

QBS BENEFITS*

According to *InfraGuide*, the benefits of QBS are as follows:

- **Credible outcomes:** Evaluating qualifications and experience in the absence of price ensures that fees do not influence the outcome.
- **Maximum value for client:** Developing the project scope together allows the client to draw on the consultant's experience and obtain maximum value.
- **Focus on quality:** Developing the project scope together allows deeper study of quality issues, such as design alternatives, life-cycle analysis, sustainability, innovative and creative ideas, and value-engineering analysis.
- **Fair and cost-effective:** Negotiating a fee for service based on a mutually agreed scope of work is seen to be fair and cost-effective.
- **Development of team spirit:** The consultant and client work together, avoiding the adversarial feeling of price-dominated negotiations.
- **Risk reduction:** Risk is reduced when the scope is defined together. The project scope is clearer and claims for extra work occur only if the client modifies the agreed scope.

The Consulting Engineers of British Columbia (CEBC) emphasize the benefits of hiring the engineering consultant early in the project:

> Studies have shown that engineering typically represents only 1.5% of the total cost of a project, while construction costs represent 16.5% of the total cost, and operations are 82% of the total cost. By hiring a consulting engineer at the beginning of the project, good design can cut 10–15% of construction costs—and even more in life cycle costs.[9]

* "Selecting a Professional Consultant," *InfraGuide—The National Guide to Sustainable Municipal Infrastructure* (Ottawa: Federation of Canadian Municipalities and the National Research Council, June 2006), www.fcm.ca/documents/reports/InfraGuide/Selecting_a_Professional_Consultant_EN.pdf (accessed October 16, 2016).

TABLE 5.1 — Engineering and Geoscience Consulting Organizations

Engineering
Association of Consulting Engineering Companies—Canada (ACEC)
Ottawa, ON www.acec.ca
International Federation of Consulting Engineers (FIDIC)
Geneva, Switzerland www.fidic.org
Consulting Engineers of Alberta
Edmonton, AB www.cea.ca
Association of Consulting Engineering Companies—British Columbia
Vancouver, BC www.acec-bc.ca
Association of Consulting Engineering Companies—Manitoba
Winnipeg, MB www.acec-mb.ca
Association of Consulting Engineering Companies—New Brunswick
Saint John, NB acec-nb.ca
Conseil économique du Nouveau-Brunswick inc.—New Brunswick
Moncton, NB www.cenb.com
Association of Consulting Engineering Companies —Newfoundland & Labrador
St. John's, NL www.acecnl.ca
Association of Consulting Engineering Companies—Northwest Territories
Yellowknife, NT www.acecnt.ca
Consulting Engineers of Nova Scotia
Halifax, NS www.cens.org
Consulting Engineers of Ontario
Toronto, ON www.ceo.on.ca
Association of Consulting Engineering Companies—Prince Edward Island
Charlottetown, PE www.acecpei.ca
Association des firmes de génie-conseil—Québec (AFG)
Montréal, QC www.afg.quebec
Association of Consulting Engineering Companies—Saskatchewan
Regina, SK www.acec-sk.ca
Consulting Engineers of Yukon
Whitehorse, YT www.cey.ca
Geoscience
The Canadian Association of Petroleum Producers (CAPP)
CAPP represents large and small companies that explore for, develop, and produce natural gas and crude oil throughout Canada www.capp.ca.

(*Continues*)

TABLE 5.1 — Engineering and Geoscience Consulting Organizations (*Continued*)

Canadian Well Logging Society (CWLS)

The CWLS is for those interested in exploring mineral resources in the Western Canadian Sedimentary Basin, the Canadian Arctic, offshore eastern Canada, and southern Ontario cwls.org.

Mining Association of Canada (MAC)

The Mining Association of Canada (MAC) has been the trusted national voice of Canada's mining and mineral processing industry since 1935 www.mining.ca.

Prospectors & Developers Association of Canada (PDAC)

The PDAC was established in 1932 to represent the interests of the Canadian mineral exploration and development industry www.pdac.ca.

Note: Websites are valid as of August 2017.

5.6 ASSISTANCE FOR CONSULTANTS

Consulting Engineering and Geoscience Organizations

Organizations devoted to assisting consulting engineers and geoscientists exist in every Canadian province and territory (except Nunavut). Table 5.1 lists their names and websites. These organizations also promote the interests of members in several ways.

- **Technical and business information:** These organizations publish a wealth of information on key consulting topics—how to operate a professional practice, write contracts and agreements, and so forth. They provide standard contracts at a nominal charge, usually through the Internet.
- **Communication and representation:** The organizations inform members of current issues that affect the profession. They also represent members before municipal, regional, and provincial governments when requested, or when an issue affects consulting engineers or geoscientists as a group.

Association of Consulting Engineering Companies (ACEC)

Membership in one of the provincial consulting engineering organizations automatically includes membership in the national Association of Consulting Engineering Companies (ACEC), founded in 1925. ACEC comprises about 500 independent consulting engineering firms that belong to 12 provincial and territorial member organizations. The ACEC website notes that Canada's consulting engineering firms "are able to compete successfully at the international level: Canada is now the second-largest exporter of engineering services in the world."[10] ACEC helps to exchange professional, management, and business information; safeguards the interests of consulting engineers when necessary; raises the professional standards in consulting; and provides liaison with the federal government. The American equivalent of ACEC is the American Consulting Engineers Council (also known as ACEC).

International Federation of Consulting Engineers (FIDIC)

Both North American ACECs belong to the International Federation of Consulting Engineers/Fédération Internationale des Ingénieurs-Conseils (FIDIC), founded in 1913, an umbrella group with membership that represents more than 90 countries. The member associations must comply with FIDIC's code as it relates to professional status, independence, and competence. FIDIC publishes an international directory and works on behalf of consulting engineers at the international level. FIDIC also publishes a wide range of documents to help members draft contracts and agreements, manage projects, and operate consulting firms.[11]

5.7 COMPENSATION FOR CONSULTANTS

In the past, professional fees were often set as a percentage of the project costs. This procedure is appropriate in some cases (mainly civil engineering). The drawback, however, is that it penalizes the professional for creating an economical design. A good compensation process should reward efficiency and innovation. Four common methods for calculating consulting fees are found below, adapted from the FIDIC Directory (with permission).*

PER DIEM

Per diem payments are simply daily rates. They are the usual payment method when the scope of work cannot be accurately determined. Studies, investigations, field services, and report preparation are in this category. For example, some consulting companies specialize in short-term overload assistance. When requested, their engineers or geoscientists work side by side with the client's personnel. Doing this allows the client to absorb peak workloads without hiring and training employees who may be surplus when the peak passes. Per diem payment is the best compensation method in this case. Direct out-of-pocket expenses, such as travel costs, are added to the per diem payments.

PAYROLL COSTS TIMES A MULTIPLIER

Payroll costs, multiplied by a factor to cover overhead and profit, are most often used for site investigations, preliminary design, process studies, plant layout, and detailed design. The multiplier is usually in a range from two to three. Under this method, the client essentially pays the personnel costs as they arise, including a sufficient amount to cover overhead and profit. Direct out-of-pocket expenses are also reimbursed in addition to the payroll costs.

LUMP SUM

As the name suggests, the consultant determines, in advance, a "lump sum" fee that includes all costs, overhead, and profit. Many clients prefer this method of

* International Federation of Consulting Engineers (FIDIC), FIDIC International Directory of Consulting Engineers, 1997–1998, Lausanne, Switzerland. Excerpts adapted with permission of RhysJones Publishing Limited.

compensation because it tells them in advance how much they will be paying for professional services. When the services can be determined accurately, this approach is simple. The disadvantage is that the consultant may underestimate time or costs, and incur a serious loss.

FEE AS A PERCENTAGE OF ESTIMATED OR ACTUAL COSTS OF CONSTRUCTION

This method bases fees on total costs and is common for consulting services such as preparing drawings, specifications, and construction contract documents. However, this method is becoming less and less popular because of the difficulty in relating design costs to new and rapidly changing construction technologies and because of the unpredictable market conditions in the construction industry.

5.8 STARTING A PRIVATE PRACTICE OR BUSINESS

Contract Consulting

One way of quickly moving into consulting is by becoming a contract consultant. In this case, an employment agency arranges a contract for you to work as a consultant for a client, usually on a specified project. The agency finds the clients, advertises the jobs, and receives a fee from each client for arranging a contract. Contracts are typically short and terminate when the project ends.

ADVANTAGES

Contract consulting has benefits for both employers and professionals. Employers can quickly build a highly skilled labour force, and professional engineers and geoscientists can try short-term employment opportunities in new locations. Contract consultants are usually paid more than full-time employees. Ideally, the professional chooses between job opportunities (projects, locations, clients, and other job benefits) advertised by the agency. Contract consulting lets you try consulting without committing fully to the lifestyle and may be very helpful to professional employees who have been downsized or laid off.

DISADVANTAGES

Contract consulting is not truly a private practice because the consultant is usually deemed to be employed by the agency (not by the client). A truly independent consultant is usually self-employed (or is a partner or shareholder in a consulting company), provides services directly to a client (without a broker or agency), and assumes full responsibility for administration of the consulting service. This distinction is important because employee status determines whether the agency, client, or consultant is responsible for deducting income tax, employment insurance, and Canada Pension Plan payments, paying severance benefits, and so on. Furthermore, self-employed consultants may deduct business expenses, such as office rent, business travel, and equipment purchases, from their taxable income. Employment status must be clear as tax filing errors can be costly. The Canadian Revenue Agency publishes a lengthy checklist to clarify your status.[12]

HOW TO GET STARTED

Becoming a contract consultant is a career move that depends on the skill, personality, and career goals of the person involved. An excellent, concise guide to contract consulting (and technical employment in general) is published by Randstad Engineering. The guide, suitable for geoscientists and engineers alike, is freely available on the Internet.[13] It helps readers to identify career preferences; compare contract and permanent employment; apply for jobs; negotiate terms; evaluate offers; and, finally, succeed in the career path chosen. In addition, several government and industry websites help entrepreneurs to get started. For example, see the Canada Business Network[14] website and the consulting websites listed in Table 5.1.

Starting a Private Practice

Setting up your own consulting firm is an attractive option, especially for an engineer or geoscientist who has mastered the technical knowledge, has good self-discipline, and wants a challenge. However, even a well-prepared professional may need two or three years to become fully established, and those early years will test the new consultant's determination. Extra hours of work are essential, of course. In addition, most engineers and geoscientists need better business management skills. Working overtime cannot offset poor business sense or inadequate financial reserves.

To succeed as a consultant in private practice, you must have an entrepreneurial spirit! Private practice makes you both boss and employee, and it is impossible to be the boss if you object to working long hours, or if you cannot cope with stress and uncertainty. To succeed, you need a special set of skills and attitudes. The section below lists the characteristics needed to help you to evaluate your potential as a consultant.

Starting a Technical Business

Recent engineering graduates are more likely to start a business than were their earlier counterparts.[15] The present generation is less concerned about job security. They know that staying with one company for a lifetime is now obsolete and that they must adapt to constant change and triumph over it. Many university students held serious jobs during their university years and have some knowledge of the business world. In fact, many university students are already entrepreneurs; a few created companies in high school. Today's graduates are well prepared to be the business leaders of tomorrow.

Nevertheless, before you strike out on your own, evaluate your skills and your opportunities carefully. The following section may help you do this.

5.9 EVALUATING YOUR POTENTIAL AS A CONSULTANT

Regardless of your enthusiasm, consulting is not for everyone. The following checklist of 10 skills, traits, and talents, assembled from various sources, applies to anyone considering a leap into private practice.[16] Do you have all 10 of them?

1. **Education and licensing:** Obviously, the first two requirements before you can start any engineering or geoscience enterprise are a degree and a licence.
2. **Adequate experience and technical knowledge:** You must know the practice or the business well. Leaving a paying job to start a totally new and unknown business is very risky. (For example, if a construction engineer wants to be a machine design consultant, some experience in machine design is essential, even though the fields are related.) If you do not have adequate knowledge, get it first.
3. **A network of contacts:** You need a network of people to guide and help you, particularly during the critical start-up phase. You should list your contacts and check that you have links to all the key groups: potential clients, suppliers, investors, mentors, colleagues, employees, and so on. Government contacts are also useful for advice on new contracts, standards, or regulations.
4. **Determination:** Determination is the most important personal trait you need; consultants and entrepreneurs face many obstacles before they succeed.
5. **Confidence and independence:** Entrepreneurship is often a lonely business, so you must like being your own boss and be able to learn from your mistakes.
6. **Assertiveness:** In addition to self-confidence, you must be able to sell your ideas and promote yourself positively, without embarrassment. Modesty is an admirable Canadian trait, but entrepreneurs must be assertive (but not obnoxious).
7. **Business skills:** Running a consultancy or a business requires discipline and good management skills. Can you manage budgets, business operations, and employees? A basic knowledge of accounting is essential. If simple terms such as "cash flow," "balance sheet," and "profit and loss statement" are not familiar, then you need to upgrade your business skills.
8. **People skills:** You may have innovative ideas, but social skills are also important. Do you like people, and do people like you? Can you say, honestly, that you have a positive personality, enjoy working with people, and can communicate well?
9. **Good health:** Most successful entrepreneurs enjoy getting up early in the morning to attack the day's problems. Good health is important, especially in the early years when the stress and physical demands are greatest.

Photo 5.2 — Ekati Diamond Mine. *The Ekati Diamond Mine is located about 300 km northeast of Yellowknife, Northwest Territories. Two Canadians, prospector Charles Fipke and geologist Stewart Blusson, made the diamond discovery. The pair searched Northern Canada for many years, looking for Kimberlite "pipes" of volcanic rock in which diamonds are found. The Ekati mine opened in 1998. In fiscal year 2016, production was 3.7 million carats of diamonds.*

Source: Copyright © 2016 Dominion Diamond Corporation

10. **Intelligence:** Regardless of their education, successful consultants and entrepreneurs are intelligent, quick thinking, and happy to work with new ideas.

5.10 GETTING YOUR ENTERPRISE STARTED

In addition to the above traits, you need good planning and enough money to survive until the business starts to pay for itself. Your first two steps are to conduct a market survey and prepare a business plan, defined as follows:

- **Market survey:** You must gather as much information as possible about your potential marketplace. When you have solid market research showing that a need exists for your service, product, or idea, you can then prepare a business plan.
- **Business plan:** A business plan describes what you learned from the market research. It also defines your business objectives and outlines a strategy for reaching those objectives. Your business plan should describe every aspect

of your proposal, including business structure, manufacturing, advertising and marketing, and whatever other topics are appropriate.[17] A good business plan is key to raising money—an essential ingredient. In fact, the main obstacle to entrepreneurs is the shortage of investors willing to gamble on a new venture—especially in Canada.

Further details for starting a business are beyond the scope of this text, but much more information is readily available from entrepreneurial and innovation support centres. Resource hubs, such as the Ontario Network of Entrepreneurs (ONE) (see www.onebusiness.ca) and Small Business BC (see www.smallbusiness.ca), direct entrepreneurs to local small business enterprise centres. See also "Checklists and Guides for Starting a Business" on the Canada Business Network website,[18] or APEGA's *Guidelines of Considerations for Establishing a Consulting Practice* and *Guideline for Contract Employees and Independent Contractors*.[19]

DISCUSSION TOPICS AND ASSIGNMENTS

1. Consider the 10 personal characteristics listed above in "Evaluating Your Potential as a Consultant." Rate yourself using those criteria, on a scale of 1 to 10, where

   - zero means you have serious doubts about your ability in the area,
   - 5 means you have reasonable confidence in your ability in the area, and
   - 10 means you have absolute confidence in your ability in the area.

   Sum your scores to get a rating out of 100. Give yourself an additional 5 points for each of the five additional qualifications listed below.

   - You have published three or more technical papers.
   - You have already been involved in consulting.
   - You have a master's degree in your consulting specialty.
   - You have good experience in making presentations and writing technical proposals.
   - You have adequate, current experience in computer software related to your field, and you own computer hardware that runs the software.

   Total your points; they should not exceed 125. If your total is 100 points or more and you have been scrupulously honest in your personal assessment, then you are probably ready to move into private practice or business. If your total is less than 80 points, then you probably need more experience, education, or determination.
2. Try the quiz for entering private practice in question 1. Your score should be between zero and 125.

   a. If your score is 80 or higher, prepare a business plan for your private practice or business. Discuss the plan with your professor (or your banker).

b. If your score is lower than 80, consider whether other career paths (such as management or specialization) are better for you. If private practice is still your objective, make a list of steps that would enable you to move into private practice. Do you need to improve your qualifications, or just obtain more experience? Note: *The Step-by-Step Guide for the Preparation and Implementation of an Individual Continuing Professional Development Plan* by Engineers Canada may help.

3. Imagine that you have decided to enter private practice and that you are trying to become better known so that you can attract more clients. Advertising is a sensitive issue, since it must be consistent with the Code of Ethics. Read the sections in this text on professional advertising (consult the Index); then, devise at least five methods for becoming better known as a consultant that are clearly consistent with your provincial or territorial Code of Ethics.

Additional assignments can be found in Web Appendix E.

NOTES

[1] Randstad Engineering, *Career Resource Guide*, randstadengineering.ca (accessed June 20, 2013).
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Chapter 6

Hazards, Liability, Standards, and Safety

Engineering and geoscience projects are occasionally dangerous to workers, to the public, or to the environment. If a project, process, or product causes injury, damage, or loss, the engineer or geoscientist may be legally liable. Fortunately, you can avoid or reduce the risk of liability and increase safe design and operation by following two simple strategies:

- **For safe design**, follow design codes, standards, and accepted best practices, be aware of safety regulations, and make formal hazard analyses.
- **For workplace safety** in factories, mines, construction sites, well sites, or process plants, learn and follow your province's occupational health and safety (OHS) regulations.

This chapter explains the basic concepts of hazards and liability and examines the importance of safety standards and government regulations—particularly the occupational health and safety (OHS) laws, which are vitally important for workplace safety. The chapter concludes with a description of the Westray mining disaster, which led to a clause in Canada's Criminal Code that imposes penalties for workplace safety violations that result in injury or death. Some readers may find hazards and liability to be unsettling or negative topics; however, the discussion in this chapter may help you to avoid damage, deaths, or lawsuits.

6.1 SOURCES OF PROFESSIONAL LIABILITY

Professional liability often arises when an engineer or geoscientist gives a client negligent or incompetent advice. (Although this situation is unfortunate, it does happen.) If the client follows the advice and suffers a loss or damage, then the professional (and/or their employer or insurance company) may be sued and ordered to pay damages. Similarly, a professional who designs an unsafe product may also be sued to pay damages. Lawsuits may be based on several legal sources: contract law, tort law, or consumer legislation. These laws are discussed in detail in engineering law textbooks[1] and are summarized as follows:

- **Contract law:** Properly negotiated contracts usually run smoothly, but disagreements, misinterpretations, and breaches may sometimes occur.

If they cannot be solved by negotiation, any party to the contract may sue for damages. The contract document is then examined in a court of law, and the judge decides whether the contract has been fulfilled or not, and what damages should be paid. This explanation is, of course, a gross oversimplification, but it stresses the importance of diligence in negotiating and fulfilling contracts. For example, it is usually beneficial for a contract to include bonuses for good results. Conversely, it is also wise to study how a contract could go wrong and to predict the damages that could result. In fact, a cautious person might even specify reasonable payments for damages or set limits on liability. The law books noted above give more advice on contracts.

A personal reminder on liability: Accept work only in the fields where you are competent. If a contract is outside your field of competence, get help with it or decline the contract. (Every Association's Code of Ethics states this rule.)

- **Tort law:** Some readers may be surprised to learn that, even without a contract, a professional may be sued for negligence. Tort law, which is independent of contract or criminal law, entitles a person who has suffered a loss as a direct result of someone's negligence to seek damages from the negligent person.[2] This important concept is explained later in this chapter.
- **Consumer legislation:** If a defective product is manufactured and sold, the designer, manufacturer, dealer, or seller may be liable for damages under provincial legislation, such as the Sale of Goods Act or the Consumers Protection Act. Canadian and American consumer laws differ on a basic premise. Under the "strict liability" concept in American law, the manufacturer is presumed to be at fault unless it can be proved otherwise. In Canada, the manufacturer is not at fault unless the injured party can prove negligence in the design or manufacture of the product.

In addition to the legal liability noted above, negligence, incompetence, or indifference to public safety might also result in disciplinary action by the licensing Association. As explained in Chapter 9, the Code of Ethics obliges professionals to protect the health, safety, and welfare of the public. Note that liability laws in Quebec differ from the rest of Canada, as Quebec's laws are set in the Civil Code of Quebec, rather than common law.

6.2 PROFESSIONAL LIABILITY AND TORT LAW

The word *tort* means "injury or damage." If an injury or damage is caused by wrongful behaviour or by defective merchandise, the plaintiff (the injured party) may sue the defendant (the accused person). The Canadian law of tort is basically fair, because a lawsuit cannot be based on bad luck or a truly random accident. Instead, the defendant's conduct is the key factor. The defendant's conduct may be classified as intentional, negligent, or accidental.[3]

In general, torts must be intentional or negligent to result in liability. Truly random or accidental events may be tragic, but they cannot be the basis for a tort lawsuit. In other words, "There is no liability without fault."[4] To succeed in a tort action, the plaintiff must prove the following:

- The defendant owed the plaintiff a duty of care
- The defendant breached that duty
- The plaintiff suffered loss or damage
- The breach was the proximate (significant) cause of the plaintiff's loss.[5]

If any of these criteria are absent, the tort lawsuit will fail. For example, a negligent act, by itself, is not a basis for a claim under tort law—the plaintiff must have suffered some damage.

Defining the Duty of Care

The term "duty of care" in the preceding discussion may require a clearer definition. Certain actions create a duty of care between people, even in the absence of a contract, and even if the people have never met. The most common example is on our highways: all drivers have a duty of care to avoid injury or damage to other drivers. A driver who negligently breaches this duty of care by causing an automobile accident is therefore liable for the resulting damage. In summary, a duty of care exists when an action satisfies the following two conditions:

- A reasonably foreseeable risk of injury or damage to others exists because of the action.
- Someone is close enough to be affected by the action.[6]

In other words, a duty of care is not owed to everyone but only to those who are likely to be injured by a potentially dangerous act. The scope of the duty of care has, however, expanded over time. For example, legal precedents have extended the duty of care to include people who were not very close during a dangerous act but who suffered damage later (or the danger did not exist or was not apparent until later). For example, poor building design, poor-quality construction, defective products, and environmental pollution may be considered dangerous even if they do not cause damage until many years later.

Other professionals have observed a similar expansion of the duty of care. For example, a psychiatrist who fails to warn others of a dangerous psychiatric patient may be liable for damage caused by the patient. Similarly, a physician may be liable if he or she negligently allows an injured or incapacitated patient to drive an automobile. All provinces now have laws requiring medical doctors to report such patients to the vehicle licence bureau.[7]

Over the years, the law of tort has repeatedly found that engineers and geoscientists have a duty of care for their actions and decisions. When engineers design a device or structure, or when geoscientists plan a mine or drill for oil, they have a duty of care to anyone who may suffer from the harmful effects of these activities, even if the harm occurs years later. The following example demonstrates the duty of care expected from a professional person:

> A house in England was built on a garbage dump, and should have had deep foundations to avoid settling. The foundations were supposed to be inspected by the municipal inspector, but the inspector approved the foundations without inspecting them. Over a period of time, the foundations settled, and could not carry the weight of the building, which collapsed. The municipal authority who employed the inspector was held liable to a later purchaser of the house. In his 1972 judgement, the judge said: "… in the case of a professional man who gives advice on the safety of buildings, or machines, or material, his duty is to all those who may suffer injury, in case his advice is bad." (*Dutton v. Bognor-Regis*)[8]

Defining the Standard of Care

If it is determined that a duty of care existed, the next question in a tort case involves determining what *standard* of care was owed. In other words, was the person negligent? The courts will apply a *reasonable person* test and ask, "What would a reasonable person do under the circumstances?" In the engineering and/or geoscience licensing Acts, the term "reasonable" appears often in the definition of "negligence." For example, Ontario's Professional Engineering Act defines *negligence* as an act or omission that "constitutes a failure to maintain the standards that a reasonable and prudent practitioner would maintain, in the circumstances."[9] Perfection is not required; however, professionals are expected to use reasonable care, established best practices, and well-tested principles.

The best protection against negligence is careful, thorough, accurate work. Professionals can also obtain liability insurance to protect against the costs of negligent conduct. This insurance, typically called "errors and omissions" insurance, is a wise investment for engineers in private practice; in fact, in some provinces, it is compulsory. Professional employees are typically covered by the employer's insurance. Of course, regardless of the insurance, a negligent professional is always subject to disciplinary action by the licensing Association (as discussed in Chapter 3).

Proving Negligence

Canadian tort lawsuits require the injured party to provide evidence of negligence; however, courts may accept circumstantial evidence that negligence must have occurred if the exact cause cannot be defined precisely. For example, the courts will usually assume that negligence has been proved when

- whatever caused the harm was under the sole control of the defendant, and
- the event that caused the harm ordinarily would not occur without negligence.

For instance, when a surgeon leaves a sponge inside a patient during a surgical operation, there is no need to discover precisely how the sponge was left there. The surgeon was in control of the surgery, and had the surgeon not been negligent, the sponge would not have been left behind. This type of circumstantial evidence is described by the Latin phrase *res ipsa loquitur* ("the thing speaks for itself").[10]

The precedent for *res ipsa loquitur* dates back to 1863 and the lawsuit *Byrne v. Boadle*. A barrel of flour fell from a warehouse window above a shop, striking and injuring a passerby, who sued for damages. Although no evidence was produced to explain how the barrel came to fall from the window, the judge (on appeal) stated: "A barrel could not roll out of a warehouse without some negligence, and to say that a plaintiff who is injured by it must call witnesses from the warehouse to prove negligence seems to be preposterous." The judge ruled that the barrel was "in the custody" of the warehouse owner (or his employees) and that he was therefore responsible for the control of it.[11]

This doctrine (*res ipsa loquitur*) affects design engineers because it is often applied to defective products. If an injury results from a product and the cause is so obvious that "the thing speaks for itself," the designers must prove that negligence did *not* occur. In these (*res ipsa loquitur*) cases, Canadian tort law, based on negligence, becomes much like the strict liability in U.S. courts.

In summary, tort law requires professionals to avoid negligence and incompetence, and to eliminate hazards that could endanger others. Failure to do so may create liability for any resulting damage or loss.

6.3 PRODUCTS LIABILITY

We are all consumers, and we expect manufacturers to make quality goods. When a consumer purchases a defective product from a manufacturer (either directly or through the manufacturer's agent, distributor, or retailer), the contract (either written or implicit) permits the consumer to demand reparation (payment or repair). A claim for damages may be made for three reasons:

- defective manufacturing, or
- negligence in design, or
- failure to warn of dangers associated with the product.[12]

Contract Conditions and Warranties

The contract clauses must be examined closely. Contract clauses are typically divided into conditions and warranties. Usually, these terms are identified in the contract.

- **Conditions:** Conditions are key clauses that must be satisfied or the contract may be terminated. Obviously, conditions are important, since they have the potential to end the contract.[13]
- **Warranties:** Warranties are clauses that permit the consumer to demand repairs, replacement, or damages. However, a warranty clause does not permit a contract to be terminated. (The term "warranty" is usually applied to goods and products, whereas the term "guarantee" is usually applied to services or agreements.) Warranties are promises that a manufacturer makes about a product. If the product fails to meet the terms in the warranty, the manufacturer may be liable for any resulting damage.

Government Acts Regulating Products

SALE OF GOODS ACT Every province and territory has a law—typically called a Sale of Goods Act—that may be invoked when a sales contract lacks specific wording. The Sale of Goods Act defines certain conditions and warranties in order to protect the public. For example, typical sale conditions require products to have a basic quality (or *merchantability*), as well as fitness for use. These terms imply that the product must not be defective and must be usable as intended. Thus, a lawn mower must be able to cut grass, and a refrigerator must be able to keep food cold. Regulations for the sale of goods typically apply to product quality, but the courts now interpret Sale of Goods Acts to encompass safety as well.[14]

CONSUMER PROTECTION ACT In addition, every province now has a Consumer Protection Act that imposes further provisions on consumer sales or that ensures that consumers retain certain basic rights. This legislation protects individuals; it does not usually apply to goods purchased for commercial use or resale.

HAZARDOUS PRODUCTS ACT The federal Hazardous Products Act (also mentioned below under workplace hazardous materials) sets standards of safety across Canada for a wide variety of consumer products, from hockey helmets to kettles. In addition, the federal Motor Vehicle Safety Act (R.S.C. 1985, c. M-10) sets safety standards for automobile manufacturers.[15]

U.S. Products Law: Strict Liability

The concept of strict liability applies mainly in the United States. Canadian engineers and manufacturers must be aware of it, however, because the North American Free Trade Agreement (NAFTA) permits a freer flow of products across the border into the United States. Moreover, since Canadian and American laws are both based on the British concept of established precedents, legal decisions made in one country may, over time, be applied in the other country.

Strict liability covers product defects and consumer safety. The focus is on the product itself, and no questions of negligence arise. Donald L. Marston, in his text *Law for Professional Engineers*, states:

> In products liability cases in the United States, a manufacturer may be strictly liable for any damage that results from the use of his product, even though the manufacturer was not negligent in producing it. Canadian products-liability law has not yet adopted this "strict liability" concept, but the law appears to be developing in that direction.[16]

In both Canada and the United States, the requirements for care were set by a 1932 British case, *Donoghue v. Stevenson*. The judgment in this case stated, in part:

> A manufacturer of products which he sells in such a form as to show that he intends them to reach the ultimate customer in the form in which they left him, and with no reasonable possibility of intermediate examination, and with the knowledge that the absence of reasonable care in the preparation or putting up of the products will result in injury to the consumer's life or property, owes a duty of care to the consumer to take that reasonable care.[17]

In the United States, the American Law Institute has published the following two-part rule for products liability, which contains the idea from the British precedent, but applies it more strictly:

1. One who sells any product in a defective condition, unreasonably dangerous to the user or consumer or to his property, is subject to liability for physical harm thereby caused to the ultimate user or consumer, or to his property, if
   a) the seller is engaged in the business of selling such a product, and
   b) it is expected to and does reach the user or consumer without substantial change in the condition in which it is sold.
2. The rule stated in Subsection (1) applies although
   c) the seller has exercised all possible care in the preparation and sale of his product, and
   d) the user or consumer has not bought the product from or entered into any contractual relation with the seller.[18]

The key difference between Canadian and American law is that the American definition specifically states that the rule applies even when the seller has taken all possible care. In other words, it applies even when no negligence can be shown. Instead of the plaintiff being required to prove negligence, the defendants must prove their product's safety and reliability. Moreover, the American law applies to sellers; as a result, everyone in the design-manufacturing-sales chain is included.

Canadian Products Law: Risk–Utility Analysis

The duty to design safe products is well established in Canada, although Canadian liability law differs somewhat from American law. American law focuses on the *reasonable expectations* of the consumer. Osborne makes the following comments regarding this test and illustrates the *risk–utility* approach that is more commonly followed in Canada:

> [In the United States:] If the product is not as safe as a consumer might reasonably expect, the design is defective. This test has, however, proved to be very difficult to apply in a fair and predictable manner. The reasonable expectations of consumers in respect to some products may be unreasonably high and in respect of others it may be unduly low. The test also fails to consider if there is an alternative and safer design available. [A different] test, which is favoured in Canada, is a risk/utility analysis that seeks to determine if the utility of the product's design outweighs the foreseeable risks of the design.

> The risk/utility test was applied in *Rentway Canada Ltd. v. Laidlaw Transport Ltd.* [1989]. The case involved a head-on collision between two trucks, when both of the headlights of one of the trucks failed. The defendant had designed the lighting system of that vehicle. Flying rubber from a tread separation of a tire knocked out one headlight and, because both headlights were on the same circuit, the other one also failed. The plaintiff claimed that the two headlights should have been on independent circuits, in which case, one headlight would have remained on. The trial judge assessed the safety of the design on a risk-benefit analysis and decided that the design was defective. Consideration was given to the degree of danger arising from the design, the availability of a safer design, and the functionality, the costs, and the risks of that alternative design. The ultimate question was whether or not, in the light of these factors, the product was reasonably safe. The Court held that the danger of having both headlights on a single circuit and the availability of a functional and affordable alternative design outweighed the utility of the single circuit system used by the defendant.*

Generally, most product liability lawsuits are brought against the manufacturers and sellers of the products and are usually based on breach of warranty or on strict liability. A lawsuit is usually brought against the design engineer only in the case of alleged negligence. However, some of these lawsuits have been enormously costly, making product safety not only an important value but a good investment. When the designer makes a product safer, both the public and the manufacturer are protected: the public from harm and the manufacturer from financial loss.

6.4 DESIGNING FOR SAFETY

Obtaining Codes, Standards, and Regulations

Many textbooks describing the design sequence emphasize ways to stimulate creative thinking (such as brainstorming). However, few design texts emphasize codes, standards, and safety regulations, which are more important. This key information is available through the Internet.

As a first step in any project, designers should search the Internet for relevant codes, standards, and safety regulations. Do not rely entirely on company standards or textbooks. A general search using a few relevant keywords will find state-of-the-art guidance. However, be careful to cite only dependable sources, such as websites of technical societies or standards organizations. Dependable documents are usually not free, but you can usually purchase them and download them immediately.

Codes and standards may not seem important until accidents occur and lawsuits result. The courts usually see design codes as a "minimum mandatory standard."[19] When a designer deviates from accepted design codes, the

* Philip H. Osborne, *The Law of Torts*, 3rd ed. (Toronto: Irwin Law, 2007), 139–40. Used with permission.

Photo 6.1 — The Transcona Silo Foundation Failure. *On October 18, 1913, the foundation for CP Rail's huge grain elevator in North Transcona, Manitoba, tilted almost 27 degrees from the vertical during its initial loading. The structure was eventually righted and still exists today. However, the accident taught a valuable lesson about bearing capacity and the effects of uneven loading.*

Source: Archives of Manitoba, Foote 1801 N2793

deviation must be explained by a written analysis or by convincing design calculations. As Samuels and Sanders note, codes are intended to guide the designer, so any design that departs substantially from them is obviously "a faulty design, unless it can be demonstrated that it conforms to accepted engineering practice by rational analysis."[20]

Codes change over time, so designers must use up-to-date information, of course. But sometimes (in rare cases), a designer must deviate from a code, such as in the following instances:

- **New information:** Recent failures, accidents, or new research studies may prove that a design code is erroneous, so designers must supplement it with further analysis to show that their designs are safe.
- **Low industry standards:** Some industries set very low standards, and designers must routinely exceed the industry code for reliability or safety. It is unprofessional to follow a code that is widely known to be deficient.

- **No existing code:** Finally, some cutting-edge designs may be so new that no relevant code or standard may exist. In these cases, the designer must use good engineering design principles and follow the Association's Code of Ethics, which puts public health, safety, and welfare ahead of personal profit.

Including Safety in the Design Process

In a tricky design, you may be happy just to find a feasible solution, but your job is not over. The designer is expected to optimize the design, reduce manufacturing costs, and eliminate unnecessary parts (also called "value engineering"). In addition, following these four steps for reducing hazards should be routine.

ELIMINATE KNOWN HAZARDS The Code of Ethics requires professionals to protect the public, so the first step is to eliminate obvious hazards. For example, in building design, a high walkway is obviously dangerous; the designer must include railings for safety. Designers also have an obligation to remove concealed hazards (that is, hazards that are not obvious to the user). When a hazard cannot be eliminated, the designer must shield the user from it, if possible, and warn the user about it. For example, a lawn mower may have a hazardous rotating blade that cannot be seen by the user. The blade is needed to cut the grass, so it cannot be eliminated. Therefore, users must be shielded from the blade, and they must be clearly warned that contact with the blade may be lethal. Another example of a concealed hazard is a random flaw in a key component. For example, aircraft have some parts that, if they fail, will cause the aircraft to crash. The designer must specify that such critical parts must be tested to detect flaws and inspected regularly to ensure that old, worn, or damaged parts are replaced.

FOLLOW ESTABLISHED DESIGN STANDARDS The designer must know and follow (or exceed) the accepted standards—whether they are required by law, are industry standards, or are company design guides—unless there is a convincing analysis to justify deviating from them. As mentioned above, design standards are easier to obtain than ever before.

FOLLOW LAWS AND REGULATIONS Everyone must follow provincial and federal safety laws and regulations. For example, every province has OHS laws to protect workers, and environmental laws to protect the environment. The designer must know (and follow) these laws and regulations, which are easy to find on the Internet.

FOLLOW GOOD ENGINEERING PRACTICE In the absence of design standards or government regulations, the designer must simply use good engineering practice. It is reasonable to expect a designer to examine older designs (particularly if they have failed) to see what lessons can be learned, to conduct a methodical hazard analysis of a new design to find unexpected or potential dangers, and (for a complex system) to conduct a failure analysis. These techniques are described next.

6.5 RISK REDUCTION

Formal Risk Reduction Methods

HAZARD ANALYSIS AND RISK ASSESSMENT A *hazard analysis and risk assessment* should be conducted for every design, and the designer should keep a permanent record of the analysis. (In simple designs, the analysis may be very brief.) The hazard analysis and risk assessment are systematic design reviews in which the design team and other subject matter experts do the following:

- **Identify hazards:** Have we identified all hazards (obvious or hidden)? The analysis should consider both the hazards of normal operation and the hazards that might arise from typical failure or misuse.
- **Assess risks:** Evaluate both the likelihood of a harmful event and the impact of harm. Likelihood typically ranges between rarely, likely, and very likely. Severity ranges from no known impact, minor injuries requiring first aid to serious, and catastrophic (multiple fatalities). The combination of likelihood and severity gives risks that range between none, low (acceptable), medium, and high (unacceptable). A risk matrix (Figure 6.1) can be used to document the assessment.
- **Reduce risks:** Implement the following, in order of preference:
  - Eliminate the hazard or make a substitution.
  - Apply engineering controls (e.g., guards, interlocks).
  - Apply administrative controls (rules, procedures, signs, recall products for repair).
  - Use personal protective equipment and obtain training.[21]
- **Verify effectiveness:** Are residual risks acceptable? If not, work to reduce risks further.

FIGURE 6.1 — A Risk Matrix to Help Determine Level of Risk

		CONSEQUENCES			
		Minor	**Moderate**	**Major**	**Extreme**
PROBABILITY	**Rare**	Low	Low	Medium	Medium
	Unlikely	Low	Medium	Medium	Medium
	Possible	Medium	Medium	Medium	High
	Likely	Medium	Medium	High	High
	Very likely	Medium	High	High	High

FAILURE ANALYSIS AND HAZARD AND OPERABILITY STUDIES A *failure analysis* examines the consequences if a single component of a large system should randomly fail. Failure analysis is intended to find which component failures could lead to a disastrous failure of the whole system. Formal failure analysis techniques are complex, so they are typically applied only to very large systems, such as electrical power plants, aircraft, or computer control systems. Well-known analysis methods include failure modes and effects analysis (FMEA) and fault tree analysis (FTA). Hazard and operability (HAZOP) studies identify issues during the design stage in the chemical, process, and oil and gas industries. A HAZOP study considers hazards, human error, and equipment failures.[22]

In some cases, the risks (or probabilities of failure) can be estimated mathematically, using reliability theory, and the design can be changed until the probability of failure is reduced to an acceptable value. Unfortunately, such complex computations are not feasible in most design situations, and the engineer's judgment must suffice. When in doubt, your bias should always lean toward increasing safety. Hazard analysis, FMEA, and FTA are discussed in most design textbooks.

Designer's Checklist

Hazards exist in normal life and flaws exist in materials. Even the most painstaking attempts by the most diligent design engineers will not prevent all failures; however, following the nine steps listed below can eliminate most hazards:

- Find and apply standards and regulations.
- Conduct formal design reviews.
- Carry out a formal hazard analysis and risk assessment.
- Implement risk reduction measures.
- Carry out a formal failure analysis (when design complexity justifies this).
- Warn consumers and/or clients of hazards.
- Prepare and distribute instruction manuals.
- Use state-of-the-art design methods.
- Maintain complete design records.

Each of these points is explained at length in design textbooks.[23]

Manufacturer's Checklist

Manufacturers want people to buy and use their products; however, if products are unsafe, then damage, injury, or death may occur. These cases often end in court, especially in our increasingly litigious society. The so-called accident analyst conducts an intense review of the design and history of the product. Unless the designer conducted (and documented) a safety or hazard analysis during the design, the manufacturer will likely be found liable for making an unsafe product. Sadly, these "analysts" often find that good designs are "faulty" when, in fact, consumers have grossly misused or abused the product. In hindsight, we often learn that the problem could have been avoided if a fraction of the lawyers' fees had been spent on design safety. Remember the adage "A dollar spent on design safety can save ten dollars on defence lawyers."

Manufacturers, therefore, have an incentive to help their engineers design safe products. The manufacturer's typical responsibilities are listed in the following checklist:

- Establish safety as a company policy.
- Ensure that designers are qualified and competent.
- Require safety reviews and studies during the design stage.
- Conduct adequate quality assurance and testing during manufacturing.
- Review warranties, disclaimers, and other published material for accuracy.
- Act promptly on consumer complaints.
- Inform designers of complaints and failures, so that the designer can find the causes and incorporate changes in future designs. (This measure may seem obvious, but designers are not always informed properly.)
- Warn owners immediately of hazards.[24]

The Rivtow Marine case (below) explains the duty to warn users about hazards.

CASE HISTORY 6.1

THE RIVTOW MARINE CASE: FAILURE TO WARN

This case history illustrates the legal necessity to warn of hazards. Rivtow Marine, a B.C. logging company, chartered a logging barge from a B.C. dealer named Walkem. The barge was fitted with a crane manufactured by Washington Iron Works, an American manufacturer. Washington had (earlier) constructed a similar crane, which had collapsed, killing the crane operator. When Rivtow Marine learned of that collapse, Rivtow stopped operating its own crane and inspected it. Serious cracks were found. These indicated that the Rivtow crane might soon collapse, so it was withdrawn from service. The barge and crane stood idle for some time in the middle of a busy log-harvesting season while repairs were made.

It was later learned that the dealer (Walkem) and the manufacturer (Washington Iron Works) had both been aware for some time of cracks on cranes of this type, yet neither had informed Rivtow Marine. So Rivtow sued both, alleging negligence for failing to provide a warning and claiming damages for the cost of repairing the crane and for economic losses while the barge and crane were idle. The case was appealed to the B.C. Appeal Court and then to the Supreme Court of Canada.

In a unanimous ruling, the Supreme Court awarded damages on the basis of negligent failure to warn. The defendants (Walkem and Washington) had "knowledge of the risk": they knew the business that Rivtow operated, they were aware that the crane was inadequate, they knew it was the busy season, and they knew what harm could arise from having the barge and crane out of operation. Furthermore, the loss was a "direct and foreseeable" consequence of the inadequacy of the crane and not a remote or unforeseeable result, which might not have justified award of damages.

No personal injury occurred to Rivtow personnel; however, the failure to warn them caused economic loss. The Rivtow case is a key part of Canadian tort law because, prior to this case, economic loss was generally considered to be too remote to justify an award. The Rivtow case has been cited and applied in many recent judgments.[25]

6.6 THE STANDARDS COUNCIL OF CANADA (SCC)

Standards are essential for design, manufacturing, and professional practice. Standards define dimensions, tolerances, strengths, voltages, computer protocols, and hundreds of other measurable factors for manufacturing high-quality items. Standards guarantee that products, services, machinery, and equipment work properly and safely. In addition, many standards explain how to test, manage, or control quality. Standards are useful guides for the design, manufacturing, control, and operation of almost anything.

A good starting point in a standards search is the Standards Council of Canada (SCC). SCC represents Canada as the Canadian member of the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC). As well, SCC represents Canada at international accreditation organizations, such as the International Accreditation Forum and the International Laboratory Accreditation Cooperation (ILAC). In addition, SCC participates in regional standardization forums. SCC's involvement in these organizations ensures that the views of Canadian government, industry, and consumers are incorporated in international standards and accreditation practices. The following information is taken from the SCC website, with permission:

> **The Standards Council of Canada:** The Standards Council of Canada is a federal Crown corporation with the mandate to promote efficient and effective standardization. Located in Ottawa, the Standards Council has a 13-member governing Council and a staff of approximately 90. The organization reports to Parliament through the Minister of Industry, and oversees Canada's standardization network.
>
> **What is the national standardization network? (www.scc.ca/en/agl-nss)** The national standardization network is Canada's network of people and organizations involved in the development, promotion and implementation of standards. Through the collaborative efforts of national standardization network members, standardization is helping to advance the social and economic well-being of Canada and to safeguard the health and safety of Canadians. Its efforts are overseen by SCC.
>
> One of SCC's roles is to accredit organizations that develop standards, as well as to accredit those that verify conformity to standards. SCC provides services to over 500

> customers in the area of conformity assessment, including various testing and calibration laboratories. Its accreditation programs are based on internationally recognized standards and guides. SCC operates accreditation and recognition programs for the following: calibration and testing laboratories; good laboratory practice; greenhouse gas validators and verifiers; inspection bodies; management systems certification bodies; medical laboratories; personnel certification bodies; product and service certification bodies; and proficiency testing providers.
>
> More than 12,500 Canadian volunteer members, representing industry, provincial and federal regulators, non-government organizations and consumers, participate in national and international standardization committees. SCC coordinates the activities of individuals and organizations that participate in international and regional standards developments committees and facilitates the participation of approximately 2,600 of these members on technical committees. Even the members of the Council itself are volunteers. The employers who support the work of these volunteers are important contributors and in the broadest sense, anyone who uses or benefits from a standard is part of Canada's national standardization network.*

SCC performs many more functions than this summary shows. For example, SCC manages Canada's participation in two of the world's most important voluntary standardization bodies.

- **International Organization for Standardization (ISO):** ISO is the largest standards development organization in the world, with members representing more 163 countries worldwide. SCC, described above, is the Canadian member. ISO activities are discussed in more detail below.
- **International Electrotechnical Commission (IEC):** The IEC prepares and publishes international standards for electrical, electronic, and related technologies. Its members promote the use of international standards as a means of reducing barriers to international trade and encourage international cooperation on all questions of electrotechnical standards and conformity assessment. Each country has an IEC National Committee. Canadian input to the IEC occurs through the Canadian National Committee of the International Electrotechnical Commission (CNC/IEC), which is the Canadian member body at the IEC.[26] The CNC/IEC is also an SCC advisory committee.

6.7 CREATING NEW STANDARDS

International standards are particularly important for trade, since they help Canadian products to enter foreign markets. However, creating independent standards in every country would be a massive duplication of effort. When international standards are already established, they should usually be adopted.

* Standards Council of Canada (SCC), 270 Albert Street, Suite 200, Ottawa ON K1P 6N7. SCC website at www.scc.ca (accessed January 15, 2013). Reprinted with permission.

The International Organization for Standardization was founded in 1947 with the mandate to "standardize the standards" among countries and make them more available. In its present form, ISO is a network formed by the national standards institutes of 163 countries (with one member per country). Canada, represented by SCC, is a full member and participates in the development and voting in ISO technical and policy meetings. The ISO Central Secretariat, located in Geneva, Switzerland, coordinates the system. ISO is a non-governmental organization, and each member represents his or her national standards organization, not the national government.

Whenever a new standard is proposed, ISO brings together a technical committee comprising experts from the various member countries. Typically, each participating nation sets up an advisory group composed of experts from within its own borders, which then generates a national consensus.

The proposed standard must pass through three drafts. At each draft, members of the technical committee propose differing opinions and alternative wordings. The member countries then vote on the standard. If the final draft standard receives a two-thirds positive vote, it becomes an ISO standard and is translated into the three official ISO languages: English, French, and Russian. Each country can take a further step by adopting the ISO standard as a national standard and publishing it in the language of that country.

ISO has developed more than 21,600 International Standards (as of 2017), which are easily searched through the Internet. In many cases, the listing includes a brief abstract. Paper copies of ISO standards are available through SCC.

6.8 ISO 9000, ISO 14000, AND ISO 26000 STANDARDS

ISO standards usually apply to specific products, but two important standards are different. The ISO 9000 and ISO 14000 series of "generic management system standards" apply to the management of an organization, rather than to its products. The ISO 9000 and ISO 14000 families are among ISO's best-known standards. ISO 9001:2015 and ISO 14001:2015 have been implemented by more than one million organizations in over 170 countries.[27] These standards may be used by any organization, large or small, and are described briefly below.

ISO 9000—Quality Management and Quality Assurance Standards

The ISO 9000 series of standards for managing a manufacturing corporation is intended to maximize the quality of manufactured products to meet customer requirements. "The ISO 9000 family addresses various aspects of quality management and contains some of ISO's best known standards. The standards provide guidance and tools for companies and organizations who want to ensure that their products and services consistently meet customer's requirements, and that quality is consistently improved."[28]

The ISO 9000 standards are very effective and have been widely adopted. Between 1987 (when the first version of ISO 9000 was released) and 2017, more than one million corporations obtained ISO 9001 certification.[29] The automotive industry now expects every supplier to be certified to ISO/TS 16949, a variation of the ISO 9000 standards. ISO 9000 certification is the dominant quality management certification system in the world. It is estimated that an investment in ISO 9000 certification usually pays for itself within three years through increased productivity and reduced scrap.[30]

The ISO 9000 standard is very comprehensive. It requires a corporation to examine almost every aspect of its management, design, purchasing, inspection, testing, handling, storage, packaging, preservation, delivery, and documentation systems. Improving the quality of these systems enables effective evaluation of the manufacturing process and shows where quality improvements are required. An important part of ISO 9000 involves developing a "quality manual" to document the four key aspects of the certification process. The aspects to be documented are as follows:

- quality policies for every aspect of the corporation's operations;
- quality assurance procedures, which involve 20 clauses in the ISO 9000 standard;
- quality process procedures (or practices, or instructions), which include all of the company's production processes; and
- quality proof: a repository for all the forms, records, and other documentation that give objective evidence—or proof—that the quality system is operating properly.

The ISO 9000 quality management system permits and encourages "certification" (internal and external audits). Certification is like an audit in a financial control system, where audits are established, accepted, and routine. Typically, to ensure impartiality, independent quality auditors or "registrars" carry out the certification audit. Every aspect of a company's operations is examined in detail: 15-step processes, which may take more than a year to implement, are common. Re-certification audits should be carried out every third year.[31]

It is important to stress that certification is not necessary to use the ISO 9000 quality management system, but it provides an extra level of assurance. ISO 9000 is now the accepted world standard for quality management.

ISO 14000—Environmental Management Systems

In view of the success of the ISO 9000 series of standards for quality management, many companies also adopted the ISO 14000 series of standards for environmental management. ISO 14000 was developed using the international consensus procedure (as for all ISO standards) and the certification process is similar to that for ISO 9000 certification. ISO 14000 provides the framework that a company can follow to set up an effective environmental management system, providing assurance that the company's environmental impact will be measured and improved.[32] The ISO 14000 process requires the company to examine every function of its operations with the goal of identifying activities with a significant environmental impact. The company then commits to preventing pollution in all its forms. The standard does not set acceptable environmental levels—that is left to regulatory agencies. However, the standard does require that these environmental levels be determined and followed.

Monitoring and measurement are, of course, essential. Procedures for corrective action and emergency response are also required. Each of these activities may require setting performance criteria, defining responsibilities, assigning duties, providing training, and ensuring adequate communication. ISO 14000 does not require developing an environmental management manual; however, most companies would probably prepare it.

The ISO 14000 series was released in 1996, and many major companies immediately committed to implementing the standard.[33] Other standards in the ISO 14000 series concern environmental aspects of product standards, environmental auditing, environmental assessment of sites, environmental labels, environmental performance evaluation and life-cycle assessment, to mention only a few. The ISO 14064 standard for greenhouse gas accounting and verification was published in March 2006. ISO 14064 helps government and industry to manage programs for reducing greenhouse gas emissions and emissions trading.[34]

ISO 26000—Guidance on Social Responsibility

In 2010, ISO released ISO 26000, Guidance on Social Responsibility. ISO 26000 provides guidelines on how businesses and organizations can operate in a socially responsible and transparent way, contributing to the health and welfare of society. ISO 26000 provides guidance rather than requirements, so it cannot be certified, unlike some other well-known ISO standards. Instead, it helps clarify what social responsibility is, helps businesses and organizations translate principles into effective actions, and shares best practices relating to social responsibility, globally.[35]

6.9 GOVERNMENT CODES AND STANDARDS

Designers use standards because it is good professional practice, but sometimes federal or provincial laws and even some municipal bylaws may specify standards. Standards are cited in laws whenever the government wants to guarantee quality or uniformity. For example, laws often require specific standards to be followed to ensure that

- warning and danger signs have standard size, wording, and symbols;
- electric or electronic equipment is safe for public use;
- materials used in government contracts are of proper quality;
- public spaces are suitable for disabled access; and
- buildings, roads, water, sewage, and similar utilities are of adequate quality.

When the law specifies a standard, you must find and follow it. The most common government-specified standards are the building codes, discussed below. Note that "code" is interchangeable with "standard." The difference is subtle: codes usually describe how something is constructed, and standards usually apply to the materials themselves. Therefore, codes often refer to standards, but both serve the same purpose: to improve quality, safety, and reliability.

BUILDING AND CONSTRUCTION CODES Construction codes are often specified in laws. The National Research Council's Institute for Research in Construction (IRC) publishes these codes. For example, the National Building Code was developed in 1941 to consolidate the patchwork of provincial and municipal codes that existed across Canada in the 1930s. The Code was so successful that it has been maintained ever since and is revised every five years. IRC now publishes several other construction codes and user's guides, including the following:

- National Building Code of Canada
- National Fire Code of Canada
- National Plumbing Code of Canada
- National Farm Building Code of Canada
- National Housing Code of Canada
- Model National Energy Code of Canada for Houses
- Model National Energy Code of Canada for Buildings

Building construction is under provincial control, so the national codes are "model codes." However, all provincial governments have adopted these codes, sometimes with modifications, or developed provincial codes based on the national codes. They are widely available from bookstores and the following websites:

- National Research Council: www.nrc-cnrc.gc.ca/eng/solutions/advisory/codes_centre_index.html
- Federal Publications: www.fedpubs.com
- Standards Council of Canada: www.scc.ca
  (valid as of June 21, 2017)

6.10 OCCUPATIONAL HEALTH AND SAFETY (OHS) LAWS

OHS laws protect workers from unsafe work conditions by requiring employers to follow safety regulations. In addition, Canada's Criminal Code now imposes criminal penalties when workplace safety violations result in injury or death. (The Criminal Code amendment was a consequence of the Westray mining disaster, discussed later in this chapter.)

These laws make employers responsible for workplace safety and require them to hire engineers or geoscientists to certify the safety of equipment or processes. To fulfill this important responsibility, engineers and geoscientists must be familiar with the relevant OHS laws and regulations. These vary slightly across Canada:

> Each of the ten provinces, three territories and the federal government has its own OSH [occupational safety and health] legislation. The federal government has responsibility for the health and safety of its own employees and federal corporations, plus workers in certain industries such as inter-provincial and international transportation (e.g., railways and air transport), shipping, telephone and cable systems, etc. Approximately 10% of the Canadian workforce falls into the federal jurisdiction. The remaining 90% of Canadian workers fall under the legislation of the province or territory where they work.[36]

Fortunately, a federal agency helps to make sense of this flood of information. The Canadian Centre for Occupational Health and Safety (CCOHS) provides direct Internet links to all provincial, territorial, and federal health and safety legislation through its website and provides an immense amount of safety advice, training, publications, and links to hazard databases. An auxiliary website, known simply as CanOSH, organizes laws by region. Users can obtain the safety laws for any Canadian jurisdiction easily and directly.

To review the safety laws and regulations for your province, territory, or the federal government, contact either the CCOHS or CanOSH website:

- Canadian Centre for Occupational Health and Safety (CCOHS): www.ccohs.ca
- Canada's National Workplace Health and Safety website (CanOSH): www.canoshweb.org

(valid as of July 10, 2017)

Occupational Health and Safety Regulations

The OHS laws state that every Canadian is entitled to a safe and healthy work environment and that the employer has a duty to provide it. The practical rules for workplace safety are not in the OHS laws, but in the regulations made under the authority of the OHS laws. These OHS regulations are easily found at the CCOHS or CanOSH website (above), or in listings of provincial laws.[37] Some regulations are also available in an inexpensive pocket handbook.[38]

EMPLOYEES' RIGHTS

Federal, provincial, and territorial OHS laws typically give employees three basic rights.

- **The right to know:** Employees must be informed of workplace hazards and must be properly trained to operate or manage dangerous machinery, equipment, processes, or substances.
- **The right to refuse dangerous work:** Employees have the right to refuse dangerous work without the risk of discipline or dismissal. Under specified circumstances, certain members of the health and safety committee can intervene to stop dangerous work.

- **The right to participate:** Employees have the right to participate in making the workplace safer through workplace health and safety committees.

EMPLOYERS' DUTIES

OHS laws place the responsibility for workplace safety firmly on the employer. The employer must ensure that the workplace is safe; provide any needed protective devices, equipment, or materials; ensure that they are used as prescribed by the regulations; and ensure that they are maintained in good condition. Specific guidance is given by comprehensive OHS regulations, which require many potentially dangerous situations to be designed, investigated, and/or certified as safe by professional engineers or geoscientists. This requirement means that professional engineers or geoscientists assume the responsibility for evaluating safety. Obviously, familiarity with OHS regulations is essential.

A typical list of topics in the OHS regulations is shown in Table 6.1, which gives only main headings. (The full regulations are typically 400 or 500 pages long.) As Table 6.1 shows, the OHS regulations establish the workplace health and safety committee and, under 40 or 50 sub-sections, give specific guidance ranging from general safety procedures to procedures pertaining to industries with specialized hazards. Each employer, employee, and professional must be aware of the applicable workplace regulations.

CONTRACTS AND PRIME CONTRACTORS

Owners often hire contractors for specific projects. For example, an owner may hire a builder to construct a building. Contracts should specify clearly who is responsible for public safety and employee safety on the worksite. This person is called the "prime contractor" (or, in some provinces, the "constructor"). The prime contractor must comply with all the OHS regulations on the worksite as if the prime contractor were the employer. It is very important to ensure that the prime contractor is designated in the contract, because if none is designated (or if more than one is designated), then the responsibility for occupational health and safety falls back on the owner.[39]

ENFORCEMENT

The workplace health and safety committee is required to inspect the workplace regularly (typically, monthly) to ensure safety and report potential hazards. In addition, government inspectors employed by the labour ministry visit workplaces to ensure that OHS regulations are being followed. Inspectors have extensive powers under the OHS law to enter and inspect workplaces, examine documents, test equipment, and so on. Where an inspector finds that the OHS Act or an OHS regulation is being contravened, the inspector may order the owner or prime contractor (or whoever is in charge of the workplace) to comply with the OHS Act or regulation within a specified time. Failure to comply with OHS laws or regulations may lead to prosecution in the courts and, upon conviction, fines and/or imprisonment.

ACCIDENT INVESTIGATION

Where an accident causing death or critical injury occurs on a worksite, the owner (or prime contractor) is required to render first aid, preserve the accident scene, and notify the labour ministry and the workplace health and safety committee. The labour ministry (or a related government agency) has authority under OHS laws to investigate workplace accidents, and employers must assist such investigations. Accident investigations may be regulated by the OHS Act or under a separate law, such as the Workers' Compensation Act (discussed below). Professional engineers regularly participate in accident investigations as subject matter experts.

TABLE 6.1 — Occupational Health and Safety Regulations

This table shows typical headings in OHS regulations.

Basic Requirements

- Definitions
- General Safety Precautions
- Joint Workplace Health and Safety Committee
- Hazard Assessment, Elimination, and Control
- First Aid
- Emergency Preparedness and Response
- Workplace Hazardous Materials Information System (WHMIS)
- Specifications and Certifications

Personal Protection Requirements

- Personal Protective Equipment: Eye Protection; Flame Resistant Clothing; Foot Protection; Head Protection; Life Jackets and Personal Flotation Devices; Limb and Body Protection; Respiratory Protective Equipment.
- Toilets and Washing Facilities
- Noise Exposure
- Radiation Exposure
- Lifting and Handling Loads
- Violence
- Working Alone

Common Workplace Protection Requirements

- Fall Protection
- Ventilation Systems
- Entrances, Walkways, Stairways, and Ladders
- Confined Spaces
- Chemical Hazards, Biological Hazards, and Harmful Substances
- Tools, Equipment and Machinery
- Safeguards, Barriers, and Shields

TABLE 6.1 — Occupational Health and Safety Regulations (*Continued*)

- Overhead Power Lines
- Locking Out Dangerous Equipment for Servicing
- Rigging (cables, wire rope, etc., for lifting)

Requirements for Industries with Specialized Hazards

- Forestry
- Oil and Gas Wells
- Residential Roofing
- Tree Care Operations
- Health Care and Industries with Biological Hazards
- Fire and Explosion Hazards (including welding vehicles and pipelines)
- Demolition
- Diving Operations
- Excavating and Tunnelling

Requirements for General Industrial Equipment

- Cranes, Hoists, and Lifting Devices: Cantilever Hoists; Chimney Hoists; Hand-Operated Hoists; Material Hoists; Mobile Cranes and Boom Trucks; Overhead Cranes.
- Personnel Hoists: Roofer's Hoists; Tower and Building Shaft Hoists; Tower Cranes; Underground Shaft Hoists; Vehicle Hoists; Winching Operations.
- Powered Mobile Equipment: Forklift Trucks; All-Terrain Vehicles; Snow Vehicles; Pile Driving Equipment.
- Scaffolds and Temporary Work Platforms: Elevating Platforms; Aerial Devices.
- Explosives: Handling Explosives; Drilling; Loading; Firing; Destroying Explosives; Specific Blasting Activities.

Requirements for Mining

- Division 1—General: Fire Prevention and Emergency Response; Electrical Systems; Rubber-Tired, Self-Propelled Machines; Diesel Power; Conveyors.
- Division 2—Explosives: Transportation; Operational Procedures; Un-detonated or Abandoned Explosives; Blasting Machines and Circuits; Surface Mines; Underground Mines and Tunnels.
- Division 3—Underground Coal Mines: Mine Workers; Mine Equipment; Vehicles; Roof and Side Support; Ventilation System; Gas and Dust Control; Explosion Control.

Workers' Compensation Act

Each province and territory has a law, usually called the Workers' Compensation Act, which establishes a Workers' Compensation Board (WCB), although the name or law may vary in some jurisdictions. (For example, Ontario calls it the Workplace Safety and Insurance Board, and British Columbia combines both OHS and WCB legislation in a single Act.) Workers' compensation is, in simple terms, a form of "no-fault" workers' insurance.

The Workers' Compensation Act typically requires employers to support the Workers' Compensation Board, and each employer is assessed (or taxed) as a proportion of their payroll. The funds collected, typically called the "Accident Fund," are used to pay wage, medical, disability, and related benefits to workers who are unable to work because of a workplace injury. In other words, an employee injured in the workplace may collect compensation from the WCB without having to sue the employer. (In fact, the WCB pays even when the employer is insolvent.) In return for financing the WCB, employers are shielded from employee lawsuits.[40]

In addition, should a worker die because of a workplace injury, the worker's dependants may be entitled to receive benefits. In some provinces, the WCB administers both the Accident Fund and the OHS laws.

Each Workers' Compensation Act typically authorizes the Workers' Compensation Board to require employers to report any accident that involves a serious injury or death, a major structural failure, or the release of a hazardous substance. The Board has the authority to inspect workplaces, investigate incidents, require employers to improve worker safety, and impose penalties.

The CanOSH and CCOHS websites, cited above, are also good sources of information about Workers' Compensation Acts.

6.11 WORKPLACE HAZARDOUS MATERIALS INFORMATION SYSTEM (WHMIS)

Whenever hazardous materials are used in the workplace, they are under strict control by both federal and provincial (or territorial) OHS laws. Workers have a right to know if they are working with hazardous substances and to be assured that they are properly protected. In addition, the federal Hazardous Products Act and the Controlled Products Regulation (made under the Act) apply to material suppliers, importers, and distributors. These laws define which materials (or controlled products) are included in the Workplace Hazardous Materials Information System (WHMIS) and what information suppliers must provide to employers for controlled products used in the workplace. Suppliers who sell or import a hazardous product for the workplace must provide a safety data sheet (SDS) for the hazardous product. They must also ensure that either the hazardous product or its container is labelled with all required information and hazard symbols. Canada has aligned WHMIS with the Global Harmonized System of Classification and Labelling of Chemicals (GHS), and the standard is now referred to as "WHMIS 2015." Rather than replacing WHMIS, WHMIS has incorporated GHS elements, resulting in new standardized

- classification criteria,
- label requirements, and
- safety data sheet (SDS) requirements (formerly material safety data sheet).[41]

WHMIS is an unprecedented example of cooperation among federal, provincial, and territorial governments, and many sources of information are available. The WHMIS.org portal is provided by regulatory jurisdictions across Canada and CCOHS. If you are involved with hazardous substances, check out this website: http://whmis.org/#whmis-carousel.

CASE HISTORY 6.2

THE WESTRAY MINE DISASTER: FAILURE TO FOLLOW SAFETY STANDARDS

This case history shows how a disaster can result when managers sacrifice safety standards to maximize profit. Twenty-six men died when the Westray mine exploded—one of the worst industrial tragedies in Canadian history. As the Inquiry later noted, "Westray was an accident waiting to happen."

INTRODUCTION

Mines are dangerous, and coal mines are the most dangerous, because the rock is soft and because coal dust and methane explode if the mine is poorly ventilated. The first major Canadian mine disaster happened in 1873, and

Photo 6.2 — The Westray Mine. *The Westray coal mine explosion in 1992 killed 26 miners. In his report on the ill-fated mine, Justice Peter Richard blamed the coal company and the provincial government for the disaster, saying that the Westray mine operations were a "violation of the basic and fundamental tenets of safe mining practice."*

Source: © Andrew Vaughan/The Canadian Press thousands of lives have been lost since then. In Springhill, Nova Scotia, 424 miners were killed in the mines between 1881 and 1969. Canada's worst coal mine disaster occurred in June 1914 in Hillcrest, Alberta, when an explosion killed 189 men.[42] As the years passed, people came to believe that modern ventilating, monitoring, and excavating methods made coal mines safe. This belief was shattered on May 9, 1992, when an explosion killed 26 miners at the Westray mine in Plymouth, Nova Scotia. The Inquiry into this disaster revealed a "complex mosaic of actions, omissions, mistakes, incompetence, apathy, cynicism, stupidity, and neglect."[43]

DETAILS OF THE EXPLOSION

The Westray mine explosion occurred on a Saturday at 5:20 a.m. The shaking of the earth was felt by most of the residents of Plymouth. Within hours, mine rescue experts had assembled from neighbouring towns. With oxygen tanks on their backs, they descended into the destroyed mine. It was soon clear that rescue efforts would be pointless—the explosion had killed everyone below ground. Nor could all the dead be retrieved. Ten dead miners are permanently entombed behind rock falls in the mine, much of which was flooded to prevent further explosions.

THE WESTRAY INQUIRY

Within days of the tragedy, anecdotes about unsafe practices were widely reported. One miner described several infractions of the safety regulations: acetylene torches had been used in areas where methane levels could be dangerous; a supervisor had tampered with a methane level monitor to permit higher methane levels; and potentially explosive coal dust had accumulated so thickly that some machinery could not be operated. For fear of retaliation or intimidation, the miners rarely complained about the safety infractions, especially since management seemed to place production ahead of safety.[44]

Amid bitter accusations, the provincial government appointed Justice K. Peter Richard to carry out a far-reaching Inquiry into how and why the 26 miners died. Shortly afterward, the Royal Canadian Mounted Police opened a criminal investigation. In October 1992, the Nova Scotia Labour Department laid 52 non-criminal charges of unsafe practices against Curragh Resources, Inc., the company that owned the mine. These safety charges were later dropped to avoid jeopardizing the police investigation, which resulted in charges of manslaughter and criminal negligence being laid against Curragh Resources and two of its managers. These charges were later "stayed" (or effectively dropped). On appeal, the Supreme Court of Canada upheld an order for a new trial, but prosecutors decided that the evidence was insufficient to proceed, although the average person might think otherwise. No one was ever criminally prosecuted.

Throughout the court proceedings, the Westray Inquiry continued. Justice Richard's final report, *The Westray Story: A Predictable Path to Disaster*, was published in December 1997. Justice Richard commented: "Westray is a stark example of an operation where production demands resulted in the violation of the basic and fundamental tenets of safe mining practice."[45] The following paragraphs constitute a synopsis of the key facts that the Inquiry brought to light. They are excerpted from the report's "Executive Summary."

> **Prelude to the Tragedy**
>
> … In the rush to reach saleable coal, workers without adequate coal mining experience were promoted to newly-created supervisory positions. Workers were not trained by Westray in safe work methods or in recognizing dangerous roof conditions—despite a major roof collapse in August. Basic safety measures were ignored or performed inadequately. Stonedusting, for example, a critical and standard practice that renders coal dust non-explosive, was carried out sporadically by volunteers on overtime following their 12-hour shifts.…
>
> It is clear that the company was derelict in carrying out its obligations for training.… Quite simply, management did not instil a safety mentality in its workforce. Although it stressed safety in its employee handbook, the policy it laid out there was never promoted or enforced. Indeed, management ignored or encouraged a series of hazardous or illegal practices, including having the miners work 12-hour shifts, improperly storing fuel and refuelling vehicles underground, and using non-flameproof equipment underground in ways that violated conditions set by the Department of Labour—to mention only a few. Equipment fundamental to a safe mine operation—from the cap lamp to the environmental monitoring system—did not function properly.
>
> It was equally clear that the Department of Labour was derelict in its duty to enforce the requirements of the two acts.
>
> **The Explosion: an Analysis of Underground Conditions**
>
> … [V]entilation is the most crucial aspect of mine safety in an underground coal mine. Methane fires and explosions cannot happen if the gas is kept from accumulating in flammable and explosive concentrations.… One of the principal functions of a ventilation system is to clear the methane at the working face of the mine and to exhaust it from the mine in non-explosive concentrations. It is clear that the Westray ventilation system was grossly inadequate for this task. It is also clear that the conditions in the mine were conducive to a coal-dust explosion.… The consensus of the experts suggests strongly that Westray was an accident waiting to happen.…
>
> **Responsibility**
>
> As the evidence emerged during this Inquiry, it became clear that many persons and entities had defaulted in their legislative, business, statutory, and management responsibilities.… [T]here is a clear "hierarchy" of responsibility for the environment that set the stage for 9 May 1992, and we ought not to lose sight of this hierarchy.

> The fundamental and basic responsibility for the safe operation of an underground coal mine, and indeed of any industrial undertaking, rests clearly with management. The internal responsibility system merely articulates this responsibility and places it in context. Westray management, starting with the chief executive officer, was required by law, by good business practice, and by good conscience to design and operate the Westray mine safely. Westray management failed in this primary responsibility, and the significance of that failure cannot be mitigated or diluted simply because others were derelict in their responsibility.
>
> The Department of Labour through its mine inspectorate must bear a correlative responsibility for its continued failure in its duty to ensure compliance with the *Coal Mines Regulation Act and the Occupational Health and Safety Act*....
>
> **Compliance with the *Coal Mines Regulation Act***
>
> Much has been said throughout this Inquiry about the inadequacy of the *Coal Mines Regulation Act*. As outdated and archaic as the present act is, it is painfully clear that this disaster would not have occurred if there had been compliance with the act....
>
> If the mine had been "thoroughly ventilated and furnished with an adequate supply of pure air to dilute and render harmless inflammable and noxious gases," then ... the 9 May 1992 explosion could not have happened, and 26 miners would not have been killed. Compliance with these sections of the *Coal Mines Regulation Act* was the clear duty of Westray management, from the chief executive officer to the first-line supervisor. To ensure that this duty was undertaken and fulfilled by management was the legislated duty of the inspectorate of the Department of Labour. Management failed, the inspectorate failed, and the mine blew up.*

The federal government heeded the lessons of the Westray disaster. As a result of the failure to convict anyone for the obvious negligence in this case, the Criminal Code of Canada was amended to hold corporations and individuals criminally responsible if they fail to provide a safe work environment. Section 2.17.1 was inserted into the Criminal Code:

> **2.17.1** Every one who undertakes, or has the authority, to direct how another person does work or performs a task is under a legal duty to take reasonable steps to prevent bodily harm to that person, or any other person, arising from that work or task.[46]

* Justice K. Peter Richard, "Executive Summary," *The Westray Story: A Predictable Path to Disaster, Report of the Westray Mine Public Inquiry*, published on the authority of the Lieutenant Governor in Council, Province of Nova Scotia (December 1, 1997). Copyright by the Province of Nova Scotia, 1997. The report is available on the Internet at www.gov.ns.ca/lwd/pubs/westray (accessed June 7, 2017).

DISCUSSION TOPICS AND ASSIGNMENTS

1. This chapter suggests that the first step in a design project should include a search of the Internet for appropriate technical codes and standards. As an exercise, find at least one design standard for each of the following items: automobile tail-lights, elevators or escalators, buildings, pressure vessels, snowmobiles, children's toys, and the Canadian flag.
2. Using the Internet, obtain the OHS Act for your province or territory. (Try the CCOHS or CanOSH website above. The Act may be included with the regulations or with WCB legislation in some provinces.) Answer the following questions and where appropriate, quote the section in the Act:
   a. What is the precise name and website for the OHS Act?
   b. How does the Act define an "owner" and a "prime contractor" (also called a "principal contractor" or "constructor")?
   c. What is the stated purpose (or "object") of the Act?
   d. What is the maximum fine or penalty for contravening the Act?

Additional assignments can be found in Web Appendix E.

NOTES

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Chapter 7
Computers, Software, and Intellectual Property

Computers are essential for design, visualization, and analysis, and they are indispensable in manufacturing, exploration, refining, and process control; however, computers create unique liability issues. For example, if a key engineering or geoscience decision is based on faulty computer output, who is liable for the damage that may result? This chapter discusses professional liability for computer-generated errors and suggests some simple procedures for validating computer software.

Computers also create new ethical problems, including vandalism, viruses, and software piracy. For example, computers make copying rapid and convenient, so they are ideal tools for copyright infringement. This chapter therefore includes an overview of the laws for intellectual property, including copyright, patents, industrial designs, integrated circuits, and trademarks. The chapter contains three brief case studies.

7.1 THE ROLE OF COMPUTERS IN ENGINEERING AND GEOSCIENCE

Over the past 40 years, computers have drastically changed every phase of our lives. Recent university graduates may not realize how profound these changes have been.

A SHORT BUT AMAZING HISTORY Calculating devices such as the abacus, the slide rule, and the adding machine have existed for centuries, but the first truly electronic computer was not built until 1945, at the end of the Second World War. The initial impetus came from the work of British mathematician Alan Turing, who developed primitive machines to assist in the decoding of German war messages at Britain's Bletchley Park intelligence centre during the war. Although this early computer development was not well known because of wartime secrecy, the story of Turing's impressive achievements and tragic life is gripping, fascinating, and well worth reading[1] or watching in the movie *The Imitation Game*.

The first computers were slow and expensive behemoths by today's standards; they filled rooms, yet they were capable of only primitive calculations.

The invention of the transistor and large-scale circuit integration (LSI) permitted the miniaturization of electronic devices and increased the reliability of components. When the versatile Apple II personal computer came to the market in 1977, it soon replaced the calculator and the slide rule. Over the following decades, the desktop workstation evolved, yielding immense, convenient computing power. Portability and miniaturization followed, leading to today's mobile wireless devices with full Internet capability.

AN INCREDIBLE FUTURE This immense computing and communication power now permits us to visualize and display complex models, such as weather flow patterns, earth modelling, computational fluid dynamics, dynamic finite-element analysis, flexible mechanisms, and many topics once thought to be in the realm of science fiction. In fact, the common term "computer-aided design" is now obsolete, since all design is now "computer aided." Many new fields, such as digital control, mechatronics, and nanotechnology, are based entirely on digital devices.

The computer's incredible speed is creating a dynamic new age for engineering and geoscience. Computer hardware and software have freed designers to be more creative; ideas can be visualized, simulations run, and alternatives analyzed in the earliest stages of any project. Calculations that were once laboriously prepared (by slide rule, and later by calculator) are now displayed instantly. Drawings and maps that were once tediously hand-drawn are now plotted in seconds.

Computers, however, are also creating new problems for professionals: problems such as copyright infringement, errors caused by flaws or "bugs" in computer programs, vandalism by hackers, industrial espionage on the Internet, and the growing problem of identity theft. Engineers and geoscientists must be alert to these problems; they sabotage our security and productivity.

The danger of faulty computer software was emphatically illustrated three decades ago, when the Hartford Arena collapsed—an engineering disaster that was perhaps the world's first large-scale computer-aided failure. The arena's designers used a flawed structural analysis program, as explained in Case History 7.1, which follows.

CASE HISTORY 7.1

THE HARTFORD ARENA COLLAPSE: A COMPUTER-AIDED FAILURE

The Hartford Arena was an impressively large structure when it was completed in 1973. The arena housed a basketball court and seating for 5,000 spectators to watch the games. To minimize obstructions to the view, only four columns supported the roof. Each column was near a corner of the building. The "space-frame" roof was a three-dimensional truss structure about 3 m deep, and approximately 91 m by 110 m in plan size, suspended about 25 m above the floor.

THE ROOF COLLAPSE

At 4:15 a.m. on January 18, 1978, during a heavy snowfall, the huge roof suddenly and violently collapsed onto the central court, with the corners of the roof pointing up into the air. It was fortunate that the collapse occurred in the middle of the night. Earlier in the evening, the arena had been packed with thousands of spectators, and all of them missed death or injury by only a few hours.

THE CAUSE OF THE FAILURE

During the investigation, the snow load at the time of the collapse was estimated to be less than half the rated load for the roof. Attention shifted to the design. The design of the structural steel had several gross errors, as described very well in the case study by Rachel Martin.[2] The basic cause of the collapse was, as Henry Petroski stated, an "oversimplified computer analysis."[3] The Hartford Arena involved one of the earliest applications of computers to the analysis of complex space-frame structures, and the designers made a fateful error. Martin explains:

> The engineers for the Hartford Arena depended on computer analysis to assess the safety of their design. Computers, however, are only as good as their programmer and tend to offer engineers a false sense of security. The roof design was extremely susceptible to buckling which was a mode of failure not considered in that particular computer analysis and, therefore, left undiscovered.[4]

In other words, the stress analysis software overlooked the key fact that compression and tension are different; that is, structural rods will buckle at a much lower compressive stress than the yield strength of the steel, which is the limit for rods in tension. Any engineer could easily have discovered this error, at the earliest stages of the project, by comparing the stress calculated by the computer against the well-known Euler buckling equation—a simple calculation that can be performed in minutes.

ETHICAL IMPLICATIONS

Why the engineers neglected to perform such a simple, obvious check of their computer output is a mystery. Moreover, the design engineers had a strong incentive to double-check their calculations. During the construction, the truss was assembled on the ground and hoisted into place. Large deflections were immediately apparent, and the engineers were informed. In fact, as Kaminetzky reports, the deformations were so much larger than expected that contractors could not insert the windows below the girders. Even the ironworkers commented that the deformations were unreasonably large.[5] Nevertheless, the engineers ignored these warnings and did not double-check their work.

The actions of the design engineers were negligent or incompetent. The Hartford Arena engineers failed to validate the computer output adequately and subjugated their judgment to the computer. Computer program validation should be routine due diligence. The engineers compounded their negligence

Photo 7.1 — Hartford Arena Roof Collapse. *The Hartford Arena was constructed in 1973 and housed a basketball court and seating for 5,000 spectators. On January 18, 1978, during a heavy snowfall, the huge roof suddenly collapsed, only hours after a well-attended game. Engineers traced the collapse to an "oversimplified computer analysis." The arena is known as the first computer-aided failure.*

Source*:* © Bettmann/Getty

when they ignored the excessive deflection of the truss—a warning sign that something was wrong.

The details of the case were never revealed in court. After six years of legal preparation, an out-of-court settlement was agreed upon, avoiding any probing discussion of the causes of the collapse.

An engineer or geoscientist cannot guarantee that every project will succeed, just as a surgeon cannot save every patient, and a lawyer cannot win every lawsuit. However, all engineers, geoscientists, surgeons, and lawyers must guarantee that they possess adequate knowledge and that they will exercise reasonable skill, care, and expertise to meet the client's needs. In the case of computer-aided design, reasonable care requires validation of the computer software.

7.2 LIABILITY FOR SOFTWARE ERRORS

Software engineers aspire to high professional standards, but computer programs occasionally produce incorrect results, as the Hartford Arena collapse shows. Here is the key question: Who is liable if damage results from decisions based on faulty software?

Almost every commercial computer program includes a disclaimer stating clearly that the manufacturer and supplier are not liable for any damage arising from the program's use. Typically, the disclaimer specifically denies responsibility for direct or indirect damages, including loss of business profits, business interruption, personal injury, financial loss, and/or similar losses. In effect, this limits the manufacturer's liability to the price paid for the program.

This disclaimer shifts the responsibility to the user—a fact confirmed by the licensing Associations. For example, the PEGNL (Newfoundland and Labrador) software guideline simply states: "Members are responsible for verifying that results obtained by using software are accurate and acceptable."[6]

The APEGA (Alberta) guideline states the responsibility in a similar way:

> Members are responsible for verifying that any results obtained from computer programs are reliable and valid. Professional members should: examine and understand the methodologies and input parameters, as well as the limitations of the results obtained; and verify, where appropriate, new software releases against a standard certified for general use.[7]

The PEO (Ontario) guideline defines the responsibility more specifically. Under "Use of Computer Software Tools by Professional Engineers," the guideline states:

> The engineer must have a suitable knowledge of the engineering principles involved in the work being conducted, and is responsible for the appropriate application of these principles. When using computer programs to assist in this work, engineers should be aware of the engineering principles and matters they include, and are responsible for the interpretation and correct application of the results provided by the programs.
>
> Engineers are responsible for verifying that results obtained by using software are accurate and acceptable. Given the increasing flexibility of computer software, the engineer should ensure that professional engineering verification of the software's performance exists. In the absence of such verification, the engineer should establish and conduct suitable tests to determine whether the software performs what it is required to do.*

Clearly, all these guidelines hold the user responsible for verifying that the software is operating properly. The user must therefore test or verify the software before using the computer output in engineering design. Such tests, typically called *validation* tests, require independent calculations. Validation tests will vary, depending on the type of analysis and on whether the software was developed in-house (by the user) or was commercially purchased. (Typically, source code is not available for commercial software.) Let us consider these cases separately.

* Professional Engineers Ontario (PEO), *The Use of Computer Software Tools by Professional Engineers and the Development of Computer Software Affecting Public Safety and Welfare* (Toronto: PEO, 1993), 4, available at http://www.peo.on.ca/index.php/ci_id/22078/la_id/1.htm (accessed June 23, 2017). Excerpt reprinted with permission.

7.3 SOFTWARE DEVELOPMENT

Professional engineers and geoscientists often develop software—for themselves or under contract for others. In fact, the demand for skilled professionals in this critical field explains why software engineering is a licensed engineering discipline. According to Engineers Canada, "if an activity both concerns the public interest (life, health, property, economic interests, the public welfare or the environment) and requires the application of engineering principles, the activity falls under the exclusive scope of software engineering."[8] When life, health, or public welfare is placed at risk, governments have a duty to regulate the discipline. Therefore, if you are developing software for internal company use, under a software contract, or for sale to others, it is important that you follow accepted guidelines for accuracy, reliability, documentation, and testing. The first step is to specify the scope of the project, that is, to define precisely what is to be developed and how it will be used.

Specifying the Scope of a Software Project

The PEO guideline is a comprehensive standard for software development. It offers the following advice for specifying the scope of a software project:

> An engineer embarking on the development of engineering software for a client runs the risk of liability if the software does not perform according to the client's requirements, or if its use causes harm to the client or the public. A well-drawn legal contract, which contemplates the development of engineering software for a client and its use by the client, can minimize the engineer's exposure to liability.
>
> It can also define the contractual rights and obligations between the parties to the contract. . . . [P]rovisions addressing at least the following concerns should be included in such a contract:
>
> - What is to be developed;
> - Deliverables;
> - Scope of use of deliverables;
> - Representations and warranties;
> - Ownership;
> - Limitation of liability;
> - Contract price, and
> - Maintenance and escrow.*

The contract terms for limiting liability are very important. In the unlikely event that the contract should be breached, a clause limiting liability will be honoured provided it is a thoughtful and reasonable estimate of the damages likely to result from the breach.[9] It is wise to consult a lawyer when you negotiate a contract with complex legal terms.

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* Professional Engineers Ontario (PEO), *The Use of Computer Software Tools*, 9. Excerpt reprinted with permission.

Software Testing

The PEO guideline includes a discussion of several reviews and tests that should be taken during software development and suggests the following as a minimum:

- software requirements review
- software design review
- code review
- unit testing
- system integration testing
- validation testing*

The early reviews are important because they can save much development time. Furthermore, the final test—that is, the validation—is especially important because it is the last verification step before the software is turned over to the user. The PEO software guideline defines *validation* as "testing the integrated system to ensure that it meets functional and conceptual design requirements." An old engineering adage puts it much more simply: "No important decision should ever be based on a single calculation." In other words, important calculations should always be independently double-checked. This adage dates back to slide rule days but applies equally to computer output. You must validate software before using it to make key decisions.

Software developers must ensure that their work follows a guideline such as the one published by PEO or similar documentation for their province or discipline.

CASE HISTORY 7.2

ACCIDENTAL OVERDOSE: THE THERAC-25 RADIATION THERAPY ACCIDENTS

The Therac-25 computerized radiation therapy machine, created by Atomic Energy of Canada Limited (AECL), constituted a significant technical advance in the field of biomedical engineering and radiation therapy. However, software errors and poor system design resulted in the accidental over-radiation of six people that caused severe injuries and, in three cases, death. The Therac-25 case is an example of how overconfidence in new technology, inadequate attention to safety, and slow response to remedy a faulty situation resulted in serious accidents. This case study was prepared by Professor Jennifer Boger, Systems Design Engineering, University of Waterloo.

CUTTING-EDGE TECHNOLOGY

The Therac-25 was a state-of-the-art medical linear accelerator for delivering radiation therapy. It was released to the consumer market in 1983. The

* Professional Engineers Ontario (PEO), *The Use of Computer Software Tools*, 7. Excerpt reprinted with permission.

machine was capable of delivering two types of radiation: accelerated electrons for treating shallow tissue and X-ray photons for deeper tissues. An innovative "turntable" assembly rotated appropriate hardware components depending on whether the operator was positioning the patient for treatment, delivering electron-based therapy, or delivering photon-based therapy. This ingenious mechanism reduced the size and cost of the Therac-25 while enabling it to deliver a range of dosages of radiation to precise targets at different tissue depths.

Between 1985 and 1987, six people who were treated by a Therac-25 were accidentally given doses one hundred times greater than what was intended. This resulted in serious radiation-related injuries and was the direct cause of death of three of the people. The three survivors had to undergo significant post-dosage tissue repair surgeries and live with associated chronic health problems.

How did this tragedy come to pass?

INVESTIGATION

Subsequent investigations in both Canada and the United States revealed a complex combination of events that caused the Therac-25 accidents; no two situations appeared to be exactly the same. Key elements that led to the accidents include these:

Lack of Redundant Safety for System-Critical Features In an effort to save operator time and reduce costs, AECL took advantage of the increasing capabilities of computers and software to control significantly more of the machine than with the Therac-20, the predecessor to the Therac-25. The redesign included the removal of hardware interlocks that prevented incorrect beam/filter combinations. In the Therac-25, mechanical switches were used to determine the position of the hardware (beam filters) on the turntable assembly; however, these were verified solely by the software. The lack of a mechanical or circuit design that physically prevented incorrect operation (a hardware interlock) meant that a software failure could allow high-energy X-ray photons to be delivered without the requisite filter in place—in other words, a radiation overdose. The investigation following the Therac-25 accidents found identical errors in the Therac-20 software, but the Therac-20's hardware interlock would cause a fuse to blow, which prevented accidental overdoses.

Deficient Software Development Practices Large portions of the software that ran the Therac-25 were ported over from previous models, the Therac-6 and Therac-20. As there were no software-related accidents reported with the Therac-6 or Therac-20 and there were no overdoses during the premarket safety tests of the Therac-25, AECL assumed that the software operated correctly. When the accidents did happen, they were difficult to replicate because of the rare combination of factors that were needed for the error to occur. This delay in the identification of the cause was compounded by a lack of software documentation and protocols, making it difficult to understand how the code worked or to identify problematic sections. Finally, the software employed procedures that produced a higher risk of returning incorrect data, such as concurrent access to shared variables.

Flawed Software While the Therac-25 turned out to have several design flaws, the primary deficiencies in the software were the direct cause of the accidents. Poor coding practices and multiple deficits in the code resulted in unintended operations. For example, one of the accidents was caused by a "race condition" where the computer was processing multiple commands simultaneously. One particular error was caused by the operator typing in commands in rapid succession, which resulted in commands that were not executed fully in the intended order. The consequence was the delivery of high-energy X-ray photons without the correct filter placed into the beam's path. This condition appeared only after expert operators had been using the machine for months because their familiarity with the requisite command sequences enabled rapid input; this problem was not something encountered during the safety testing or in the initial investigation when people were typing slowly and carefully.

The failure of the test and investigation to replicate real-world use conditions kept the true source of the error from being identified until much later. In fact, it was the personnel at the East Coast Cancer Center who first deduced what went wrong. After two overdoses in less than a month (the first and second for the Center, which corresponded to the fourth and fifth Therac-25 accidents), the hospital's physicist, Fritz Hager, and the technician who was running the Therac-25 when the accidents occurred spent several days trying to replicate the error before they succeeded. Their evidence was a key piece to pinpointing a flaw in the software that could result in lethal doses of radiation. This proof was the basis of a more thorough investigation by AECL, the U.S. Food and Drug Administration (FDA), and Health Canada.

Poor Interface Design Although the Therac-25 did produce error messages to the operator, these messages did not state the nature of the error in a way the operator could understand. The error message produced when there was an underdose or an overdose was the same: "Malfunction-54." Since "Malfunction-54" and other trivial error messages showed up often during normal operation of the machine, radiation therapy technicians became desensitized. The frequency of error messages, coupled with their cryptic nature, caused operators to be more likely to dismiss them, which they were able to do with a single keystroke before carrying on with the treatment.

Negligence by AECL The first overdose occurred in June 1985 and the sixth in January 1987 across four institutions. AECL was informed of each incident by the institution where it occurred and investigated each on a case-by-case basis. In every case, AECL was unable to replicate the error and therefore unable to identify the cause. Software updates were deployed to fix several bugs early on; however, the defective sections of code that caused the accidents were not found until much later. Communication was handled poorly, with little or no information to the institutions that used the Therac-25. Famously, Yakima Valley Memorial Hospital sent a letter to AECL in January 1986 reporting a possible overdose, to which AECL responded that an overdose was not possible and that it was not aware of any other incidents. By this time, two incidents had been reported and investigated by AECL.

Fritz Hager reported to AECL the error that he and the technician were able to replicate in April 1986. With Hager's guidance, AECL was able to replicate the error; it then filed a confirmed accident report with the FDA, which began a serious investigation. Shortly after the software flaw identified by Hager was fixed, another flaw led to a sixth overdose in January 1987, which caused the FDA and Health Canada to declare the Therac-25 to be defective and require AECL to notify its customers not to use it until a satisfactory solution was in place. Slow response time, lack of appropriate communication to clients, and AECL's reluctance to accept the true nature of the accidents significantly exacerbated difficulties in identifying how and why the malfunctions were occurring. These factors resulted in harm and deaths that may well have been avoided.

Some of the most effective investigations of the causes and possible retrofit solutions of the Therac-25 accidents were not performed by AECL, but rather by the client institutions. Significant efforts by hospital physicists and staff (often outside of work hours) at multiple institutions were the first to replicate and identify the causes of the errors. After a long and costly investigation, there was an extensive redesign of the software and the Therac-25s were retrofitted with hardware interlocks to add a secondary level of protection against accidental overdoses. AECL faced several lawsuits, all of which were settled out of court.

CONCLUSION

The innovative use of new technologies enables us to expand the horizons of what is possible; however, this development must not come at the cost of public safety and well-being. The Therac-25 is infamous as an example of the importance of good software and systems engineering design practices, especially when they are related to life-critical systems. It is difficult to judge the risk of new technologies because we have less information to guide our analysis and are more likely run into new and unexpected situations. It is imperative that technologies are thoroughly tested as separate components as well as integrated systems in as real-world conditions as possible. Even with diligent design and extensive safety testing, accidents can occur. The Therac-25 case highlights the importance of carefully considering all possibilities and of involving the operators in the review of causes of failure. Regardless of the technology used, it is the responsibility of the engineer and his or her employer to anticipate system failures, ensure that extra care is taken to guard against known risks, and investigate possible adverse events quickly and thoroughly.

7.4 USING COMMERCIAL SOFTWARE

Many engineers and geoscientists use large commercial software packages for highly specialized analysis. A PEO guide for using commercial software issues the following warning:

> In many cases, software provides complete design information . . . [and] can produce complete drawings with no operator interaction beyond inputting initial conditions. . . . Professional engineers [and geoscientists] are responsible for all aspects of the design or analysis they incorporate into their work, whether it is done by an . . . intern, a technologist or a computer program. Therefore, practitioners are advised always to use the data obtained from [commercial] software judiciously and only after submitting results to a vigorous checking process. . . . All practitioners must have an acceptable knowledge of and experience in the . . . principles involved in all the work they undertake. . . . In larger organizations, software choice, testing and verification might be undertaken by other qualified people rather than by every practitioner. In these organizations, a practitioner need only assure themselves that such corporate practices exist and are responsibly executed and documented.[10]

Of course, even flawless software can be misused—in fact, users often introduce errors—so professionals must be alert. For example, users may

- use incorrect units for data input,
- apply the program to the wrong problem, unsupported by the program theory (such as using a program intended for planar analysis in a 3-D application),
- set erroneous parameters (such as integration parameters) that result in insufficient computational accuracy,
- not understand the output display, and/or much more. In fact, users are notorious for misunderstanding software written by others.

To use commercial software properly, the first step is obvious: read the documentation. Introductory tutorials provided by the software developer are very useful and should be attended religiously. If questions arise, consult the developer's "help desk." Do not use software if you have doubts or unanswered questions.

In addition, you should always test new software to validate it. Never assume that commercial software "must be right." If a major technical project fails because of software errors, the first question you can expect a lawyer to ask you is this: "What tests did you perform to ensure that the software was operating properly?"

If possible, validation should involve running at least the first three of the following tests, which are discussed roughly in order of increasing effort or complexity. In cases where failure could lead to injury, death, or serious financial or environmental disaster, doing all the validation tests is essential. If the software fails any of the following tests, ask why, and don't go ahead until you have full confidence in the software!

- **Dummy runs:** Run a basic check on the program's computation, using nominal entries such as zeroes or ones, to get a known answer. For example:
  - If zero loads are applied to a structure, the stresses calculated should be zero. (Similar results apply to electrical, thermal, pneumatic, and hydraulic programs.)
  - If a file of identical numbers is input to an averaging program, the calculated mean, median, and mode must equal that number, and the standard deviation must be zero.
  - If a dynamic simulation is re-run with smaller integration parameters (a shorter time-step), the motion should be identical.
  - If an input file for a previous analysis program is fed to a new program (assuming that it is compatible), the programs should give the same output.

  These tests are a necessary (but not a sufficient) condition for validity. In other words, software that fails these simple tests is definitely unreliable, but passing the tests does not guarantee its validity—more advanced analytical or theoretical tests are needed.

- **Approximate analytical checks:** Imagine a simplified configuration of your computer model that can be analyzed mathematically. Apply analytical calculations to the simpler model, find an approximate answer, and compare it with the computer output. For example, a finite-element model of a complex structure can almost always be decomposed and approximated by simple beam and column equations. Take a most optimistic estimate and a least optimistic estimate and apply the analytical equations to each. The computer output should lie between these boundaries. This is a standard method of checking. These tests are fairly quick; the results are approximate but reassuring, although not totally conclusive.
- **Independent theoretical checks:** Make analytical computations using an independent theoretical basis. For example, dynamic simulations use numerical integration, but the integration can be checked by applying the laws of conservation of energy and momentum to the initial conditions and the final answers. Where such tests are possible, they are very convincing.
- **Advanced methods:** Clever and creative analysts can easily develop more advanced validation tests that are unique to the discipline or specialty.
- **Complete duplication:** A full-scale duplication of the computation, using different software, hardware, and input files, is an expensive but convincing validation. Independent employees or consultants should conduct this test, if possible, to avoid systematic errors in the input data. This check is expensive, but it validates almost everything—input data, theory, and computation. If you have any doubts about critical analysis software, you should carry out this independent validation before making major expenditures. It is always cheaper to duplicate a computer calculation at the early stages of a project than to explain the omission to a board of inquiry after the project fails.

In summary, computer software is like any other tool: it must be used properly, and it must be calibrated (or validated). Validation tests are essential before output data are used for critical decisions.

7.5 COMPUTER SECURITY

Professional engineers and geoscientists have an enormous investment in computer hardware and software. In many companies, these are major assets, so professionals must be alert to any threats to this investment. The obvious risks are massive hardware or software failure, data loss, and unauthorized intrusion.

Computer Disaster and Recovery

The professional must provide routine maintenance for equipment, software, and data storage. In addition, it is wise to have a recovery plan for the possibility, however remote, of a complete computer disaster, such as might occur in a fire or flood—the complete destruction of computers and loss of the programs and data. Every professional practice should estimate the cost and impact of a computer disaster on the practice, and how long it would take to recover. For a small professional practice, the first line of protection is to have critical data and programs duplicated on backup disks and stored in a safe, secure location. A plan for recovery, by buying or leasing alternative hardware and software, can easily be developed especially given the recent proliferation of cloud storage and online backup services.

For large operations, backup procedures may be more complex. This topic is too specialized for inclusion here, but several books advertised on the Internet provide further advice on this subject. A simple Internet search for "computer disaster recovery" will provide a wealth of information.

Internet Threats

The Internet is essential to professional engineers and geoscientists for many obvious reasons; however, the Internet poses a security risk. Thoughtless and selfish people, whether hackers, spammers, or vandals, pose increasing levels of threat by degrading email service, destroying or modifying data, or creating denial-of-service (DoS) attacks. A typical DoS attack floods a computer with transmissions, which overwhelms the computer and effectively denies its services to legitimate users. To combat these threats, every professional office must have firewall and antivirus software.

- **Firewall software:** This type of software guards a computer's "gates." That is, it guards your computer's connections to the Internet and blocks or admits data transmissions according to the access rules you have set.
- **Antivirus software:** This software detects, identifies, and removes any viruses that have succeeded in breaching your firewall and entering your computer.

Firewalls and antivirus software protect your computer from a wide range of threats. A full glossary of these threats is available from developers such as Symantec, a provider of Internet security software. Symantec notes that Web-based attacks decreased in 2016 as hackers shifted their focus to email attacks; email malware rates increased to one attack in every 131 emails (compared to one in 220 in 2015). Furthermore, "In 2016, more than 1.1 billion identities were stolen in data breaches, almost double the number stolen in 2015."[11]

In summary, we must protect ourselves, and we must balance the open freedom of the Internet with the potential for abuse. A similar form of abuse occurred in the early days of radio broadcasting. National laws and international treaties now rigidly control radio frequencies, but these treaties did not exist in the 1920s. Early broadcasters simply selected their own frequencies and increased their transmitting power until they drowned out the competition. This action was unfair and unethical and had to be remedied, and it was. We must strive to bring similar order and security to the Internet.

7.6 PREVENTING SOFTWARE PIRACY

Software copying (or software *piracy*) is so easy that, whether through ignorance or intention, the practice is widespread. However, copying is unethical and illegal. The purchase of a computer program does not include the right to duplicate that program (except for a backup copy). There are many good reasons, such as the following, why professional engineers and geoscientists should never use pirated software.

- **Illegality:** The first and most obvious reason is that copying software is illegal. It violates the Copyright Act, which allows copying only for backup purposes. The Act even discourages activities such as reverse engineering. Note that U.S. law permits reverse engineering under their "fair use" rules. Canadian "fair dealing" rules, however, are much stricter. Although the 2012 revisions to the Copyright Act (Bill C-11, the Copyright Modernization Act) extended the limits of fair dealing, reverse engineering is risky, especially if you must disable technological locks (as discussed below) to access the software.
- **Unprofessional conduct:** Obviously, trying to run a professional practice with pirated software would be very unprofessional. In fact, it could be considered professional misconduct and might result in discipline or loss of a professional licence.
- **Breach of contract:** The use of pirated software could result in a breach of any contract in which it is used. For example, a consulting contract could be breached if the client discovers that you are using pirated software.
- **No product support, documentation, updates, or patches:** Product support, documentation, updates, and patches are usually not available for pirated software.

- **Fines and embarrassment if caught:** The Business Software Alliance (BSA) campaigns to combat software piracy around the world. BSA estimates that Canada's economy lost more than $893 million to software theft in 2015. That is BSA's estimated commercial value of unlicensed software in use in Canada, and it represents a "piracy rate" of 24 percent. (The global piracy rate is 39 percent.)[12]

Legal and Ethical Implications

Many Associations condemn software piracy as unprofessional. For example, the Alberta (APEGA) professional guidelines state:

> **2.1 Legal Considerations**
>
> Computer software is covered under the Canadian Copyright Act which provides for a financial penalty as well as a jail sentence for violation. The Copyright Act protects authors' legal rights and privileges to their creative works. It should be noted that a copyright in a work exists as soon as the work is created and there is no requirement to publish the work or to affix any special notice thereto. In addition to copyright considerations, usage of commercial software is also generally governed by contract law under the agreements of the software purchase contract and/or licence.
>
> **2.2 Ethical Considerations**
>
> The Code of Ethics establishes the duty of APEGA members to enhance the dignity and status of the professions. APEGA members shall conduct themselves with fairness and good faith toward other professional members and the public in the area of computer software usage to avoid conduct that would detract from the image of the professions. In consideration of the Code of Ethics, APEGA members must guard against any violations, real or apparent, of the Canadian Copyright Act and contract laws and the resulting legal and ethical consequences.
>
> **2.3 General Principles**
>
> All purchased/licensed computer software is subject to the full provisions of the agreements connected with the acquisition of the software and manuals associated therewith. All APEGA members should be aware of the agreement provisions and abide by the terms of the agreements with particular regard to copying restrictions. The use of copies of computer software or manuals that have been obtained in violation of copyright or trade secrets or in any other fraudulent manner is deemed unprofessional conduct on the part of an APEGA member. In addition to exposure to possible criminal prosecution, violation of copyrights or misappropriation of trade secrets associated with computer software by our members may result in disciplinary action by APEGA.*

* Association of Professional Engineers, Geologists and Geophysicists of Alberta (APEGGA), "Guideline for Copying and Use of Computer Software," Edmonton, AB, November 2005, V1.1, available at www.apegga.org/Members/Publications/guidelines.html (accessed May 29, 2008). Excerpt reprinted with permission of APEGGA.

In view of the importance of copyright and its relevance to computer practice, a brief overview of Canada's intellectual property laws follows.

7.7 COPYRIGHT, PATENTS, DESIGNS, AND TRADEMARKS

The term "intellectual property" includes copyright, patents, industrial designs, "integrated circuit topographies" (or computer circuit designs), and trademarks. All of these forms of intellectual property are valuable, and they may be bought, sold, or licensed like any other property. Intellectual property is different only because the ownership period is limited. When ownership ends, the intellectual property enters the public domain (except for trademarks, which may be extended).

The Canadian Intellectual Property Office (CIPO), an agency of Industry Canada, manages intellectual property in Canada. In particular, CIPO maintains a database that can be searched through the Internet. When intellectual property is registered with CIPO, it is entered in the CIPO database by, for example, book title, patent description, identifying features, or drawings. In the United States, the Patent and Trademark Office (PTO) also maintains a database, searchable by use of the Internet. These databases are open to anyone and are very useful sources of valuable design information. Note that Canadian intellectual property laws are regularly updated, especially when new trade agreements are negotiated with international partners. For example, Bill C-30 passed into law in 2017 to satisfy Canada's obligations under the new Comprehensive Economic and Trade Agreement with the European Union and member states. Bill C-30 includes minor revisions to the Patent Act and the Trade-marks Act.[13]

Importance of Intellectual Property

The basic reasons for regulating intellectual property are to encourage creativity by protecting the rights of creative people and to provide an orderly way to exchange and improve creative ideas. Canadian and international laws protect the rights of people who create intellectual property (for a specified period) so that good inventions and creative works will be disclosed to the public. When the protection ends, the works may be used by anyone. Professionals need a basic knowledge of intellectual property law because

- professional engineers and geoscientists must be able to protect the intellectual property they create (or that is created under their direction);
- everyone must know their rights, respect the rights of others, and avoid infringement; and
- intellectual property is a huge warehouse of ideas, technical knowledge, designs, and inventions that are freely available from CIPO. Anyone can search the CIPO databases for existing patents, trademarks, and designs, and this information is very valuable in research, design, and marketing.

The following paragraphs discuss the basic concepts, and Table 7.1 lists the various forms of intellectual property and how they are protected. For more information, consult the CIPO website at www.ic.gc.ca/eic/site/cipointernet-internetopic.nsf/eng/home, which answers many legal questions.

TABLE 7.1 — Summary of Protection for Intellectual Property

Intellectual Property Laws

Canada's intellectual property laws protect creators by giving them the exclusive right to copy, make, use, lease, or sell their designs or creations in Canada.

Copyright	**Protects:** All original written literature, books, pamphlets, and artistic, dramatic, and musical works, including computer programs, original drawings, paintings, sculptures, and works of art. **How obtained:** Copyright exists immediately, upon creation of the work. Registering the copyright with CIPO improves protection but is optional. **Duration:** The life of the author/creator, plus 50 years. Mechanically or electronically copied works (films, photos, recordings, etc.) are limited to 50 years.
Patents	**Protects:** New, useful, and innovative devices, machines, processes, or compositions of matter (or improvements to existing inventions). A patent protects the way something operates or how it is made. **How obtained:** A CIPO patent must be granted to obtain protection. **Duration:** 20 years, non-renewable.
Industrial Designs	**Protects:** The shape, configuration, pattern, or ornamentation applied to a finished article, made in quantities by hand, tool, or machine. An industrial design protects the appearance or ornamentation. (Note that well-known industrial designs may also qualify as trademarks.) **How obtained:** CIPO registration gives full protection. **Duration:** 10 years, non-renewable.
Integrated Circuit Topographies	**Protects:** The patterns or configurations of components in integrated electronic circuits, including the three-dimensional geometry of the layers of semiconductors, metals, insulating layers, and other materials on a circuit board or sub-layer, which produce a known electronic function. **How obtained:** CIPO registration gives full protection. **Duration:** 10 years, non-renewable.
Trademarks	**Protects:** Logos, symbols, slogans, names, or designs (or any combination of these) used to identify a company's goods or services in the marketplace.

Intellectual Property Laws

	How obtained: CIPO registration gives full protection.
	Duration: 15 years, renewable indefinitely for 15-year periods.
Trade Secrets	**Protection is uncertain:** Manufacturing processes or material compositions may be kept secret, but secrecy contravenes the principle that rights are awarded for full disclosure, so no legal protection exists for trade secrets. If someone independently discovers your secret, the person may patent it and prevent you from using it.

General Rules for Intellectual Property

Each of the five categories of intellectual property mentioned above—copyright, patents, industrial designs, integrated circuit topographies, and trademarks—may be registered with CIPO for positive protection. The owner usually registers the property and, typically, is also the person who created the work. The owner has the right to exclude all others from making, using, or selling the creation for a specified time.

When an employer hires an employee to create intellectual property, the process is slightly different: the employee is named as the creator, but when the property is registered, ownership is assigned to the employer. Employment contracts, signed when an employee is hired, should specify ownership rights. Written agreements prevent misunderstandings and avoid disputes when the work is finished.

Copyright

Under Canada's Copyright Act, the owner of a work has the exclusive "right to copy" the work (or to allow others to copy it). Copying includes any form of duplication.

- **How it is protected:** If someone infringes the copyright by unauthorized copying, the owner may use the law courts to enforce these rights. Creative work is protected for a long time—the life of the author/creator (to the end of the calendar year when the author dies) and 50 years beyond death. However, works that are reproduced mechanically or electronically, such as motion-picture films, videos, photographs, recordings, and music CDs, typically receive a maximum of 50 years from the date of creation. (A few other exceptions exist for specific types of creation.)
- **Obtaining a copyright:** Copyright differs from other forms of intellectual property because the creator (e.g., author, artist, performer, or photographer) has copyright protection immediately and automatically upon creation of the work. Registering the copyright is optional; doing so simply gives more certainty in enforcing the rights. The work may be

marked to identify the copyright owner (even if the work is not registered) using a copyright symbol (a letter "C" inside a circle), the name of the owner, and the date of first publication (for example: © Jane Doe, 2018). When a work has several creators, all must be listed as authors or creators.

- **Illegal copying:** Illegal copying is, of course, the most common form of copyright infringement. Lawsuits to recover damages for copyright infringement are common. A professional person must identify and cite the sources of any (and all) material taken from others. Doing this is particularly important when preparing a professional report. Failure to identify sources can have serious professional and legal penalties, depending on the severity of the infringement.

  In past years, photocopy machines and video recorders were the main source of illegal copying; now, however, the Internet is the key tool for copyright infringement. It is remarkably easy to copy (and thus infringe the copyright of) written, visual, and audio material. Unscrupulous users can make digital copies of software, films, audio, and publications very easily on a flash drive, CD, or DVD. Many computer users are astonished that such easy copying could be illegal, but it is. Copying is not acceptable in school, at work, or in professional practice.
- **Plagiarism:** Claiming credit for work not your own is known as "plagiarism." This is usually both an infringement of copyright and a serious academic offence (in universities and colleges). Always cite your sources! Copying a report and passing it off as one's own is flagrant plagiarism and is subject to penalties. In universities, the penalty for plagiarism may be suspension or expulsion, depending on the severity of the offence. In the business world, the legal penalty for infringement depends on how much the copyright owner lost financially because of the infringement.

In summary, professional people must be alert to the consequences of illegal copying, software piracy, and plagiarism. Unauthorized use of the work of others, or claiming credit for their work, is unethical and may lead to legal problems.

CANADIAN COPYRIGHT LAW: RECENT CHANGES

In November 2012, a "modernized" Copyright Act was enacted. The changes were overdue, and in a few cases, the law is just catching up to current practice. What follows is a brief description of some of the key changes.[14]

- **Digital locks:** A controversial change to the Copyright Act involves "digital locks," also called "technological protection measures" (TPMs). These devices control access to electronic recordings or computer programs and prevent their use. Although a lock may benefit the copyright holder, it could interfere with legitimate access under "fair dealing." For example, a person who purchases a recording in one format may be unable to transfer and play it in another format because of the lock. In addition, the (2012) Copyright Act prohibits people from disabling this lock, helping others to do so, or even making (importing, distributing, selling, etc.) devices that might do so. It is therefore almost impossible to create a legal backup copy of a locked program.

- **Illegal downloading:** Unauthorized downloading of digital recordings is governed by a new policy called a "notice-and-notice" system. Copyright holders must send notifications about alleged infringement to the Internet service providers (ISPs), who must, in turn, forward these notices to the subscribers. The ISP is not required to disclose the subscriber's identity or take further action.
- **Fair dealing:** The new Act expanded the concept of "fair dealing" (permissible uses of copyright material). Under the old Act, copyright material could be reproduced for five reasons: research, private study, news reporting, criticism, and review. Under the revised Act, "fair dealing" permits three additional uses: satire, parody, and education. (In several cases, the law appears to be catching up to a common practice.)
- **Time shifting:** Video "time shifting" (recording television programs for later viewing) is now legally permitted, provided that only one copy is legally made (without circumventing a lock), and it is deleted in a reasonable time.
- **Backup copies:** It is permissible to produce a backup copy of an original or "source copy" in case the source copy is lost or damaged. The copy must be legally made (without circumventing a lock), and it must be destroyed if the person ceases to own the original. This permission was not clearly defined in earlier laws.
- **Moral rights:** Moral rights exist in addition to copyright and permit a creator to exercise some control over the use of the work. For example, a writer has the moral right to be identified as the author of a work (or conversely, to remain anonymous) even after the work is sold to a publisher, broadcaster, or other buyer. In another example, an advertiser may want to use recordings by a famous musician to advertise products that the musician finds demeaning or obnoxious. The musician has the moral right to deny this use. (It may, however, require legal action to enforce this right.) Moral rights remain with the original creator and cannot be assigned to others.

For more information, see the CIPO resource titled *A Guide to Copyright*, which includes details about registering your copyright, including registration forms and fees.[15]

Patents

To receive a patent, an invention must be new, useful, and innovative (or ingenious). Improvements to inventions can also be patented; in fact, most patent applications today are for improvements to existing patents. However, patenting an improvement does not give you the right to use the original invention. A patent protects the way that a device operates (unlike an industrial design, discussed below, which protects the appearance). Some things cannot be patented in Canada, for example, scientific principles, abstract theorems, ideas with no tangible expression, and methods of operating a business.

- **How it is protected:** Under Canada's Patent Act, the owner of a patented invention has the right to make, manufacture, use, or sell the invention for a period of 20 years from the date of the patent application. The patent owner can prevent others from making, using, or selling the invention and may enforce this right in court.
- **Obtaining a patent:** The patent application has a standard format: petition, abstract, specification, claims, and drawings (when needed). The *petition* is merely a covering letter, asking the Patent Office to grant a patent. The four parts attached to the petition become the patent, after the Patent Office approves it. The four parts are as follows:

  1. **Abstract:** The Abstract is a concise summary of the patent, suitable for publishing in the *Canadian Patent Office Record*, the official gazette of the Patent Office.
  2. **Specification:** The specification describes the invention, and usually answers four questions:
     - What problem does the invention solve?
     - What "prior art" exists, and why is it inadequate to solve the problem?
     - How does your invention work? (This is the "Disclosure.")
     - How is your invention new, useful, and ingenious, compared to prior art?
  3. **Claims:** The claims build a fence of words around your invention by defining the features of the invention that you want to be protected as your property. The claims are most important, as they are enforceable clauses.
  4. **Drawings:** Where appropriate, drawings of the invention must be included.

At the start of any design project, designers should search the CIPO database. It is a source of useful ideas. Also, a search may avoid infringing existing rights. When a new design or invention is developed, the professional should register it to protect the inventor's (or the employer's) rights. For a fee, patent agents will assist in patent searches and applications. An invention, when patented, may be marked with the word "Patented" and the patent number issued by the Patent Office to warn against infringers. For more information on patent procedures, consult the CIPO publication *A Guide to Patents*.[16] In addition, *The Canadian Patent Office Record*, published weekly, contains news and information about patents, and important notices for inventors.

Industrial Designs

An original industrial design can be protected through a process similar to patent or copyright protection, but only the aesthetic appearance is protected. Registration of an industrial design protects the shape, configuration, pattern, or ornamentation applied to a finished article, which is typically made in quantities by machine. For example, the decorative pattern on the knives, forks, and spoons of a dinnerware set could be registered as an industrial design.

An industrial design protects the aesthetic (or artistic) appearance of manufactured articles and differs from copyright, which protects original artistic works or written material. For example, an original sculpture is protected by copyright, but mass-produced copies of the sculpture are protected as industrial design.

- **How it is protected:** Under Canada's Industrial Design Act, only the owner of a registered industrial design has the right to make, use, sell, rent (or offer to rent or sell) the design. The protection exists until the later of 10 years from the date of registration or 15 years from the date of filing.[17] It is important to stress that the design must be registered to obtain this protection; designs that are not registered have no legal protection against imitation.
- **Obtaining industrial design protection:** Registering an industrial design is done simply by submitting an application form and at least one drawing or photograph that illustrates the design, plus the appropriate registration fee. Marking the design gives extra protection against copiers. An industrial design is denoted by a capital letter "D" in a circle and the owner's name on the article, the label, or the packaging. If you develop original designs, you should protect your rights by registering them.

Once the design rights have expired, the design enters the public domain. Designers and manufacturers are encouraged to use designs that have entered the public domain. Doing so is often a fast and profitable way to develop attractive new products. For more information, refer to the CIPO resource titled *A Guide to Industrial Designs*.[18]

INDUSTRIAL DESIGNS—APPLE VERSUS SAMSUNG

Industrial design laws commonly protect a product's "shape, configuration, pattern, or ornamentation." Shape and ornamentation are not usually the most important features of a device, especially a complex one. Recent U.S. lawsuits over smartphone designs have had expensive settlements. (Note: In the United States, industrial designs are called "design patents.") The outcome of the U.S. lawsuit outlined below is a good example:

> . . . Industrial designs are like the shy cousins of patents and copyright. Patents and copyright get all the headlines, but industrial design can be a very reliable, useful tool in the intellectual property (IP) toolbox. . . . Industrial design protection expires after 10 years, so it does not extend as long as patents or copyrights, but can provide protection for articles that are not eligible for either copyright or patent protection. . . .
>
> . . . In the famous case of *Apple vs. Samsung,* Apple used seven industrial design registrations to attack Samsung's Galaxy-line of smartphones and tablets. These design patent registrations protected the features of the iPhone and iPad, and one design registration even protected the user interface of the iPhone. In the end, Apple's design registrations were upheld and Samsung was found to have infringed a number of the iPhone and iPad design patents, including the D'305 design for the graphical interface. . . .*

* Neil Kathol and Richard Stobbe, "Protection by Design: Industrial Design Law in Canada," *Field Law*, March 1, 2013, http://www.mondaq.com/canada/x/225796/Patent/Protection+By+Design+Industrial+Design+Law+In+Canada (accessed June 14, 2017). Excerpt reprinted with permission.

The jury initially awarded Apple $1.05 billion in damages for the infringement; however, the judge reduced that amount to $600 million on the basis that damages had been improperly calculated. Both Apple and Samsung petitioned for a new trial to sort out the improperly calculated damages. This expensive design dispute continues.

Integrated Circuit Topographies

Integrated circuits are the basis for almost all modern communications, computers, and similar electronic equipment. Integrated circuit topographies are defined as the geometrical configurations of integrated electronic circuits, including the layers of semiconductors, metals, insulating layers, and other materials on a circuit board or sub-layer. The topography may indeed be three-dimensional. They are a special form of industrial design, they have their own registration process, and they can be extremely valuable. The law protects the geometry of the electronic circuit, but it does not prevent others from designing a different geometrical circuit that performs the same electronic function. (In this case, patent protection may provide broader protection.)

- **How it is protected:** Under Canada's Integrated Circuit Topography Act, only the owner may make, use, or sell the registered topography, and the owner has the right to prevent others from making, using, selling, leasing, or importing the topography, or incorporating it in another integrated circuit. Registration provides legal protection for 10 years from the date of the application.
- **Obtaining design protection:** Integrated circuit topographies can be registered by submitting an application form, fees, a description of the function of the circuit, and a complete set of overlays, drawings, or photographs of the circuit. The registered circuit may be marked (when manufactured) with the alphanumeric title used to identify the topography on the application. For more information, refer to the CIPO resource titled *A Guide to Integrated Circuit Topographies*.[19]

Trademarks

Trademarks are the commonly used logos, slogans, names, symbols, or designs that identify a company's goods or services in the marketplace.

- **How it is protected:** Under Canada's Trademark Act, trademark registration gives the right to use the trademark for 15 years. Unlike other forms of intellectual property, trademarks can be renewed indefinitely—as long as they still serve the purpose of identifying a company's goods or services in the marketplace. Trademark infringement is fairly rare in professional activities, although it occurs often in retail sales. For example, high-priced consumer goods, such as prestige watches and fashion accessories bearing illegal trademarks, are often found in "discount" retail stores. Selling goods with a counterfeit trademark is illegal.

- **Obtaining trademark protection:** Before you apply to register a trademark for a service or product, you should first search the CIPO website to see whether the suggested trademark is already registered. This preliminary search may save time and effort. If your trademark does not conflict with any existing mark, an application form, a fee, and a drawing of the mark (if appropriate) are sufficient to start the examination and approval process. When a trademark is registered, the owner may warn off copiers using ® (the letter "R" in a circle, meaning "Registered"), or the letters MD ("marque déposée"). This symbol warns infringers that the trademark is registered. However, even if a trademark is not registered, it may be marked with ™ (meaning "trademark") or SM ("service mark") or MC ("marque de commerce"). These symbols are not essential to protect your rights, but the Trademark Office recommends them.

A trademark cannot be identical (or deceptively similar) to existing trademarks or to "prohibited marks," which include symbols and logos of the Canadian government, the British Royal Family, the armed forces, provinces, foreign countries, and many well-known international institutions. In addition, trademark applications must satisfy a series of simple rules to ensure that they do not create confusion over the goods or services being offered and do not restrict the public's ability to use common language and geographical names. A summary of these rules and examples of satisfactory and ineligible trademarks are in the CIPO publication titled *A Guide to Trade-marks*.[20]

The following example illustrates the importance of searching the trademark database. The University of Waterloo introduced a Mechatronics Engineering program in 2003. The university contacted Engineers Canada to ensure that the program would satisfy the accreditation process and that the program had the legal right to use the term "engineering." (Engineers Canada is the registered trademark holder of the terms "engineer" and "engineering" as descriptors of services offered.) However, the term "mechatronics"—indicating that the new program combines mechanics, electronics, and systems theory—was not searched until after the program name had been widely advertised. University officials were surprised to learn that a German company had registered the term in Canada as a trademark. (Fortunately, negotiations over the use of the term were agreeably settled.)

Trade Secrets

You can, of course, protect intellectual property simply by keeping it secret. Trade secrets are very effective for some inventions, such as manufacturing processes or material compositions (but they are irrelevant for trademarks, designs, or copyright). In general, you must maintain secrecy by requiring employees to sign employment contracts with confidentiality clauses. Trade secrets have no legal status in patent law, so you must enforce confidentiality using contract law or tort law. For example, if an employee reveals a trade secret, the employer may sue the employee for the loss under the terms of the employment contract. Trade secrets discourage disclosure and are therefore contrary to the purpose of patent law, which gives protection in exchange for full disclosure.

CASE HISTORY 7.3

PATENT INFRINGEMENT: INVERSION IS NOT INVENTION

NOTE: The following case history is adapted from an actual case in which the first author was involved as an expert witness. (The author has simplified events and omitted names.)

BACKGROUND INFORMATION

An inventive construction worker designed a new, innovative winch device for lifting materials on a construction site. The lightweight device was easily installed on a site and could lift tonnes of heavy materials (bricks, siding, windows, and roofing), quickly and safely, to heights of almost a hundred metres. The inventor patented the device and sold the rights to a company owned by engineers Alpha and Beta. Together, Alpha and Beta reworked the design, making it stronger, more robust, and more attractive, but retaining the mechanism's patented function. The company thrived by manufacturing the device named the "Winch-Atomic" and leasing and selling it to construction companies.

Unfortunately, Alpha and Beta did not agree on how the company should operate, and they had several increasingly angry disputes. After a particularly bitter argument, engineer Beta decided to leave the company. Fortunately, when Alpha and Beta formed the company, they had included a clause to allow for an orderly breakup. Under the agreement, engineer Alpha purchased Beta's shares in the company. The patent for the Winch-Atomic belonged to the company, so engineer Alpha obtained the patent rights.

PATENT DISPUTE

A few months after engineer Alpha bought the company, a rival company was started by engineer Beta. The rival company began manufacturing a winch called the "Liftodrome" that also lifted building materials. Engineer Alpha was astonished to learn that the Liftodrome, on inspection, was essentially identical to the Winch-Atomic, except that a key part of the winch was inverted. In other words, key operating parts of the winch were very similar, with only minor changes so that the mechanism worked upside-down. Engineer Alpha complained that Beta's design infringed the Winch-Atomic patent. Engineer Beta ridiculed this claim and insisted that the Liftodrome was new, innovative, and ingenious.

LEGAL RESOLUTION OF THE DISPUTE

Engineers Alpha and Beta could not resolve the dispute, so the matter was turned over to lawyers. Negotiations were fruitless, so a lawsuit was filed based on engineer Alpha's rights under the Winch-Atomic patent. Each side consulted expert witnesses, and the case eventually reached a judge. The key question was whether inverting the mechanism made it a new invention.

It was argued that mechanisms are classified kinematically, depending on the number and types of members and joints, and turning a mechanism upside-down makes no difference to the classification of the mechanism. In fact, it is precisely to avoid such confusion that the topology (the type and degree of interconnection) is used to identify and classify mechanisms. In summary, although the mechanism was inverted, all the components were still performing the same functions. The judge ruled in Alpha's favour, and Beta was required to pay substantial costs and damages for patent infringement.

Federal laws for intellectual property encourage creativity by protecting the rights of creative people and provide an orderly way to exchange creative ideas. Professional engineers and geoscientists must be able to protect the intellectual property that they create and must respect the rights of others. This protection encourages inventors to share ideas. Both CIPO and the U.S. Patent and Trademark Office maintain immense databases of valuable inventions and designs that are freely available to anyone over the Internet.[21]

CASE HISTORY 7.4

PATENT TROLLING: THE DARK SIDE OF PATENTING

BACKGROUND INFORMATION

Patent laws evolved to protect inventors and encourage the exchange of ideas; however, in a curious twist, unscrupulous legal firms are using patent laws to profit at the expense of genuine inventors. These law firms are called "Non-Practising Entities," or NPEs, because they do not invent anything; they simply enforce patent claims—claims that are often trivial, baseless, or erroneous. In common jargon, we call these firms "patent trolls," and there are many of them.

The rapid increase in patent trolls was investigated in a study funded by the U.S. Government Accountability Office (GAO) to determine the effects of NPEs on the U.S. economy. The author of this study calls them "patent monetization entities" or simply "monetizers" because their "primary focus is deriving income from licensing and litigation, as opposed to making products." The study had surprising conclusions:

> The data confirm in a dramatic fashion what many scholars and commentators have suspected: patent monetization entities play a role in a substantial portion of the lawsuits filed today. Based on our sample, lawsuits filed by patent monetizers have increased from 22% of the cases filed five years ago to almost 40% of the cases filed in the most recent year. In addition, of the five parties in the sample who filed the greatest number of lawsuits during the period studied, four were monetizers and only one was an operating company.[22]

This rapid increase in the number of trolls vividly illustrates a serious flaw in the patent system. The flaw originated in the U.S. patent system, which has slightly more flexible rules for what is patentable. It affects Canada, however, because commerce is international, and Canadian companies can file international patents under the Patent Cooperation Treaty (PCT).

SOME ILLUSTRATIVE EXAMPLES

The distortion in the patent system was evident when Nortel Networks, a giant Canadian electronics company, went bankrupt in 2011. Nortel was valued at (only) a billion dollars (US). However, a consortium of companies (including Microsoft and Apple) ultimately bid $4.5 billion (US) for Nortel's patents, at least partly to keep them out of the hands of trolls.

The following excerpt from *Wired* magazine describes a patent-troll case involving Research in Motion (RIM, now BlackBerry) and explains how trolls succeed:

> Perhaps the most famous patent-troll case came in 2006, when an NPE [Non-Practising Entity] charged that Research in Motion's BlackBerry infringed on patents covering wireless email. RIM had asked the Patent Office to re-examine the patents, but before it could reach a decision, the judge had to decide whether to grant an injunction, which could have shut down RIM's entire business. Fearing the worst, RIM settled for [paid] $612.5 million [US]. In a final insult, not long after the case was settled, the Patent Office ruled that many of the disputed patents were indeed invalid. . . .
>
> Trolling may be frowned upon, but it can present an irresistible business model. It costs a few thousand dollars to secure a patent, which can easily bring millions through litigation. That helps explain why trolling has exploded since the turn of the century. In 2011, NPEs brought 5,842 suits, with a direct cost of $29 billion in legal and settlement fees—more than four times the haul in 2005. (And these sums do not include indirect costs to defendants—like the time and energy spent on a court case that could have gone toward building and selling new products and services.) Apparently, many of those claims are baseless—a congressional study found that when defendants fought the trolls, they won 92 percent of the time. But there's no way to know, because the overwhelming majority of patent cases never make it to trial, ending instead in a quick settlement. It is usually more expensive to win a case against a troll than to just settle. In other words, the legal system favors the troll. That has helped make trolling a multibillion-dollar industry, albeit one that doesn't benefit consumers in any way.*

In summary, the patent system works well in theory, but patent trolls divert money and consume energy that would otherwise be spent on productive inventions.

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CONCLUDING COMMENTS

Sadly, "copyright trolls" are now imitating the patent trolls. These trolls send out threatening letters alleging infringement of a copyright that the troll holds, usually on a stock photo or similar widely distributed image, and demand a licence fee. If you receive such a demand, the first step is to collect the facts. *Did* you use the work without authorization? *Does* the complainant own the copyright (or have an exclusive licence)? Only the copyright owner (or an exclusive licensee) can sue you for infringement. An interesting article published by CIPPIC[23] explains the law and suggests several courses of action.

Trolls are like sand in a gearbox: they cause friction and interfere with the operation. Such activities are unethical and should be discouraged; those who exploit this flaw in the law deserve our contempt.

DISCUSSION TOPICS AND ASSIGNMENTS

Note to professors and students: A brief (four-minute) video that shows the stages in the patent process, titled *John Thomson—How to Market an Invention*, is available online from CIPO. CIPO also offers "An Introduction to Intellectual Property," a PowerPoint presentation. Professors may also be interested in a series of (about eight) case studies available to educators, most of which require 90 minutes. For more details, contact CIPO at https://www.ic.gc.ca/eic/site/cipointernet-internetopic.nsf/eng/wr01947.html\\venture.

1. You are a co-op student working in a communications company. You have access to electronic switching source code, and you show it to a fellow student. Later, you suspect that your colleague may have logged on with your password and looked at the software. Although the material is "read only," you believe that he may have copied the code onto a flash drive. Although he is a great friend, you suspect that he may be trying to sell the code or use it for illicit purposes. What should you do?
2. Using the Internet, search and find the Canadian intellectual property listed below, available through CIPO at www.ic.gc.ca/eic/site/cipointernet-internetopic.nsf/eng/Home. Continue your Internet search on the U.S. PTO at https://www.uspto.gov/. (Web addresses were valid as of June 14, 2017.) Are the results identical?
   a. The owner of the trademark for the BlackBerry wireless hand communicator.
   b. The owner of the trademark: "Roll up the rim to win."
   c. The industrial design for the bumper or grill of any recent North American vehicle.
   d. Patented apparatus for reducing noise in a jet engine, issued in the past 10 years.

Additional assignments can be found in Web Appendix E.

NOTES

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Chapter 8

Diversity in the Professional Workplace*

Professional workplaces benefit from a diverse workforce. Engineers and geoscientists with varied backgrounds bring valuable insight and experience to an organization. A supportive and positive work environment helps to maximize employees' contributions to organizational success. Most workplaces have policies and procedures in place to ensure that they are fair and equitable places to work. This chapter discusses the benefits of diversity and the importance of fairness and equity in the professional workplace, beginning with the basis for these rights. It also explores ways to increase the participation of groups that are underrepresented in engineering and geoscience. The chapter closes with case studies illustrating the harmful effects of discrimination in the professional workplace.

Society's laws, practices, and attitudes toward fairness and equity in various professions evolve over time. For example, for women in engineering in Canada, this evolution began in 1912 when Hildegard Scott graduated from the Faculty of Applied Science and Engineering at the University of Toronto in analytical and applied chemistry. Today, innovative programs encourage children (and girls, in particular) to consider STEM (science, technology, engineering, and math) careers. Support is now available to assist immigrants with an engineering or geoscience background to obtain jobs that maximize their education. Although tremendous progress has been made in the last 100 years, there is work still to be done. Human rights legislation is intended to prevent overt discrimination. Canadian society must continue to strive to identify, challenge, and eliminate inherent biases in people and organizations that cause women and minorities to be underrepresented in STEM-related university programs and jobs.

8.1 ACHIEVING DIVERSITY AND EQUITY

The first steps to achieving diversity and equity in the workplace are to recognize the unique situations that underrepresented groups may face within

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an organization and to ensure that effective policies are in place for hiring and promoting employees. Communicating these policies, their meaning, and their purpose to all staff is the key to success. If some issues arouse anxiety or anger in a particular group, it is often because of misconceptions; these can be defused and eliminated through open dialogue and information sessions.

Unfair and unethical behaviour, such as discrimination or harassment based on race, national or ethnic origin, colour, religion, gender, age, mental or physical disability, or sexual orientation, has no place in any profession—or anywhere in a civilized society. In Canada, this type of behaviour is illegal. Some professional engineering and geoscience Acts have included clauses to prevent discrimination within our professions. For example, the *Guideline on Human Rights in Professional Practice*, published by Professional Engineers Ontario (PEO), specifically states that discrimination and harassment are professional misconduct and subject to discipline.[1] Similarly, the Alberta (APEGA) Code of Ethics forbids discrimination and harassment, as explained in the APEGA *Guideline for Human Rights Issues in Professional Practice*.[2] All of these guidelines are available on the Associations' websites.

Nevertheless, unfair practices persist in our professions because they are subtle or systemic, or perhaps because we are unaware of the destructive impact they can have on individuals. These practices and their underlying causes are discussed in this chapter so that readers can recognize and eliminate them.

8.2 DISCRIMINATION AND THE CHARTER OF RIGHTS

Dictionaries define *discrimination* as "the action of discerning, distinguishing things or people from others, and making a difference." In recent years, the term has come to be associated with *segregation*, defined as "the act of distinguishing one group from others, to its detriment." This harmful form of discrimination is illegal under the Canadian Charter of Rights and Freedoms, which protects everyone in Canada, both citizens and non-citizens. The Charter sets out some basic principles to guide us:

- **Section 7** states: "Everyone has the right to life, liberty and security of the person and the right not to be deprived thereof except in accordance with the principles of fundamental justice."[3]
- **Section 15(1)** defines *equality rights*: "Every individual is equal before and under the law and has the right to the equal protection and equal benefit of the law without discrimination and, in particular, without discrimination based on race, national or ethnic origin, colour, religion, sex, age or mental or physical disability."[4]
- **Section 15(2)** also addresses the right to have programs of affirmative action in cases where improvement and more balance in the participation of underrepresented groups are needed. It reads: "Subsection (1) does not preclude any law, program or activity that has as its object the amelioration of conditions of disadvantaged individuals or groups."[5] For example, a Chair (or professorship) for women in engineering was created in 1989 by

the University of New Brunswick with funding from the Natural Sciences and Engineering Research Council (NSERC). In addition, in 1997, NSERC created five regional Chairs for women in science and engineering.[6] The Chairs have the mandate to develop strategies to increase the participation of women at all levels in engineering and science disciplines where the enrolment of women is low.

The Canadian Charter of Rights and Freedoms is important to professionals: all contracts, collective agreements, work protocols, and handbooks must be consistent with provincial human rights legislation and with the Charter. Contracts, including collective agreements, can be rescinded, and statutes and regulations can be nullified if found to be discriminatory. The main difference between the Charter and other federal and provincial human rights legislation is that the Charter applies to all levels of government, including agencies directly controlled by governments. In contrast, provincial human rights legislation applies to organizations under provincial jurisdiction. Within their own jurisdictions, both the Charter and the provincial human rights Acts are examples of *primacy* legislation. In other words, the human rights Acts supersede all other laws of that jurisdiction, unless expressly declared otherwise by an Act of legislature or Parliament.[7]

8.3 ENROLMENT PATTERNS BY GENDER IN UNIVERSITY PROGRAMS

Women are a majority in Canadian university undergraduate programs, yet they remain underrepresented in engineering and geoscience. Engineers Canada collects comprehensive enrolment data for engineering programs, and that data is the source for the following discussion. Professional geoscientists obtain their undergraduate education from a wider variety of programs; their enrolment data are not readily available but are believed to be similar.

- **Undergraduate enrolment:** Figure 8.1 shows the enrolment patterns for both men and women in engineering undergraduate programs between 1991 and 2015. The average proportion of women in engineering undergraduate programs in 1991 was only 15 percent of total enrolment, increasing to 19 percent in 1995 and to 21 percent in 2001. However, the proportion of female undergraduate engineering students peaked in 2001, declined consistently from 2002 to 2007, and then increased again to 20 percent in 2015. It is not yet clear whether this increase in 2015 marks a positive trend, but the author hopes that young women will continue to increase their participation in the years to come.

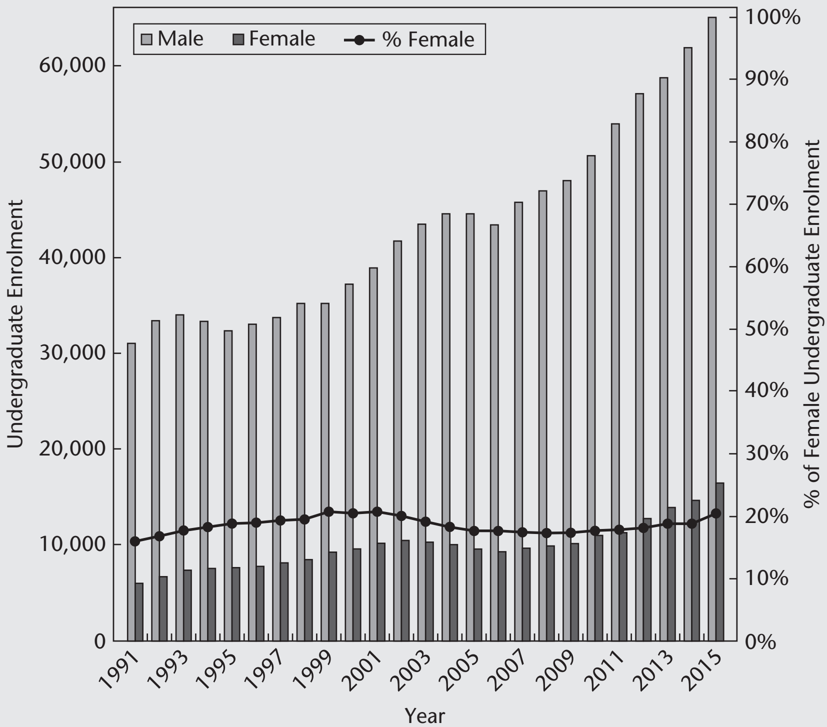
  Women enrol in greater numbers in the fields of biosystems (45 percent), environmental engineering (41 percent), geological engineering (37 percent), and chemical engineering (36 percent), with the lowest enrolments in electrical engineering, mechanical engineering, computer engineering, and software engineering.

In 2015, the province with the highest proportion of women enroled in engineering was Newfoundland and Labrador (26 percent), and the lowest proportion of women was in Prince Edward Island (11 percent).[8]

- **Postgraduate enrolment:** In full-time engineering master's programs, female enrolment was only 10 percent of the total in 1989; by 1995, the figure was 20 percent; by 2001, it was 24 percent; by 2006, it had declined to 22.3 percent; and by 2010, it had further declined to 21.9 percent of total enrolment. In 2015, however, female enrolment in engineering master's programs increased back to 24 percent.[9]

  For doctoral programs, female enrolment was 6 percent in 1989, 13 percent in 1995, 17 percent in 2001, and 18.7 percent in 2006; it reached 22 percent of the total enrolment in 2015. This last gain is a significant one for this degree level that prepares students for potential academic positions, so perhaps we shall see a further increase in the number of female professors in a few years.

FIGURE 8.1 — Undergraduate Engineering Enrolment by Gender, 1991–2015



Source: Engineers Canada, "Canadian Engineers for Tomorrow: Trends in Engineering Enrolment and Degrees Awarded, 2011–2015," 6, https://engineerscanada.ca/reports/canadian-engineers-for-tomorrow (accessed June 29, 2017). Data reproduced with permission of Engineers Canada.

Photo 8.1 — Julie Payette, Canadian astronaut and engineer. *Governor General Payette completed two missions to the International Space Station, was Chief Astronaut for the Canadian Space Agency, and served as Capsule Communicator at NASA's Mission Control Center in Houston, Texas.*

Source: NASA/Getty

- **Faculty members:** Women comprised 2.2 percent of engineering faculty members in 1991 and 7.6 percent in 2001. By 2015, the proportion of female faculty was 14.6 percent. However, a lower proportion of female faculty holding senior positions was reported. Only 10 percent of total faculty members are women at the Professor level, 17 percent at the Associate level, 21 percent at the Assistant level, and 18 percent at the instructor/lecturer level.[10]

In the past few decades, professions such as medicine, dentistry, veterinary medicine, and law have reached female enrolments that surpass the 50 percent mark. The relatively low percentages in engineering suggest that the profession is not yet fully open to women.

8.4 WHAT IS SEXUAL HARASSMENT?

The United Nations defines sexual harassment as follows:

> Unwelcome sexual advances, requests for sexual favours, and other verbal or physical conduct of a sexual nature constitute sexual harassment when any one of the following is true:
>
> - Submission to such conduct is made either explicitly or implicitly a term or condition of a person's employment or academic advancement.

- Submission to or rejection of such conduct by an individual is used as a basis for employment decisions or academic decisions affecting the person.
- Such conduct has the purpose or effect of unreasonably interfering with a person's work or academic performance or creating an intimidating, hostile, or offensive working, learning, or social environment.[11]

Sexual harassment includes behaviour by men to women, by women to men, or between members of the same gender.[12] The three key characteristics of sexual harassment are as follows: (1) the behaviour is unwanted or unwelcome; (2) the behaviour is sexual or related to the sex or gender of the person; and (3) the behaviour occurs in the context of a relationship where one person has more *formal* or *informal* power than another. Examples of a formal power relationship include a work supervisor and an employee; a faculty member and a student; a physician and a patient. An informal power relationship exists where one peer or colleague, while nominally equal in the hierarchy, nevertheless exerts an influence over another.[13]

Photo 8.2 — Hawker Hurricane Fighter Aircraft. *The Hawker Hurricane was a combat fighter manufactured by Canadian Car & Foundry Co. in Thunder Bay (then Fort William). The aircraft was designed in Britain, but produced in Canada under the direction of Elizabeth (Elsie) MacGill, the University of Toronto's first female electrical engineering graduate. She received a master's degree in aeronautical engineering in the United States in 1929 and became chief aeronautical engineer for Canadian Car in 1938. She designed the Maple Leaf Trainer, a small training plane, before assuming responsibility for producing the Hawker Hurricane. Total Canadian Hurricane production was 2,000 aircraft—a significant contribution to the war effort. The photo shows a Hawker Hurricane (YBO) alongside a Spitfire (ZDB). These aircraft were critically important to winning the Battle of Britain in 1940, a victory that prevented the planned Nazi invasion of England.*

Source: Michael Cole/Corbis via Getty Images

An earlier study reported that, although sexual harassment in the engineering workplace is not exclusively a problem for women, women are overwhelmingly the victims. It might also be more difficult for them if only a few women work at a site or in a firm. They may feel isolated and perhaps find little support.[14] Companies vary in policies and procedures for dealing with harassment. Education is at the heart of the solution. To eliminate harassment in the workplace, companies need a fair investigation procedure that ensures accusations are adequately verified, but does not victimize the complainant.[15]

When sexual harassment does occur, providing moral support for complainants can help reduce the stress they feel. Informal investigations may accomplish more than formal ones, which can be confrontational. In some situations, however, a formal complaint is the only possible approach. Organizations should provide some flexibility in their policies.

8.5 THE BENEFITS OF DIVERSITY

Women and minorities can bring new ideas and approaches to the professions. In a 1996 Canadian study, Ann van Beers[16] interviewed 20 female and 20 male engineers in the Vancouver area. She found that some women, when well established in their careers, could develop their own style and approach to problem solving. They used a more contextual approach, had good communication and people skills, and liked the writing part of the work. In her study of science and engineering students at universities in British Columbia, Vickers and colleagues[17] found that a substantially larger proportion of females, compared to males, stated that contributing to society was an important criterion when choosing a career.

Human experience can contribute to good design. Designs developed by homogeneous groups can be one dimensional. The design process is greatly enriched when designers bring a variety of experiences, worldviews, and backgrounds to the table. For example, women may offer a consultative style of working that is in tune with today's management philosophy. Their verbal and interpersonal skills, combined with a solid technical education, become assets, especially for smaller firms whose engineers must interact with suppliers, clients, and regulatory agencies. Similarly, individuals from other underrepresented groups, raised in different cultures, may bring different and innovative solutions to engineering problems. Everyone benefits when diverse and gender-balanced teams design products or solve technological challenges.

8.6 ELIMINATING DISCRIMINATION

As mentioned earlier, discrimination is unlawful. Employers, managers, and employees should be aware of human rights laws and ensure that they are followed. Further assistance can be found on the Internet. In particular, the PEO (Ontario) and the APEGA (Alberta) guidelines (both cited earlier) discuss discrimination from the point of view of the professional engineer or geoscientist, and advise employers and managers on ways to avoid it.

Discrimination against Women

A 2008 survey carried out for PEO's Women in Engineering Advisory Committee (WEAC/PEO), which polled both female and male engineers across Canada, found that "[w]orkplace challenges continue to exist for female engineers. Women feel they face at least some attitudinal barriers from their superiors, and a substantial proportion of men share that view. In particular, women are concerned about opportunities to network and to gain entry to executive levels in their organizations." The study concluded, "The workplace is changing in positive ways for women, but old, lingering beliefs held by even a few can act as barriers to full participation."[18]

In Sweden, in a study of postdoctoral awards, Wenneras and Wold[19] demonstrated that men's performance was overestimated, while women's performance was underestimated. Women needed far more publications than men did to obtain the same postdoctoral fellowship. In another study, male and female applicants had equal qualifications for 20 summer engineering jobs; however, male selectors chose 16 men and 4 women as the best candidates, whereas female selectors chose 11 women and 9 men as the best candidates for the 20 positions.[20] For a discussion on solutions to these potentially discriminatory situations, see the report of the Canadian Committee on Women in Engineering (CCWE).[21]

Discrimination against Minority Groups

Discrimination takes many forms, and may be direct or indirect. Direct discrimination is usually obvious, but indirect discrimination is subtler, and even people who are discriminating may not be aware of the impact of their actions. Indirect discrimination occurs when an employer enforces rules, or perpetuates actions that have a greater effect on one group than another, for no good reason. For example, it is not discriminatory to expect an employee to be adequately experienced; however, requiring every applicant to have 10 years of experience in Canada may discriminate against recent immigrants. Similarly, requiring a valid driver's licence may discriminate against disabled people if driving is not a requirement of the job, and restrictions on an applicant's height, weight, or strength are discriminatory if these criteria are not essential to perform the job.[22] Employers and managers should get advice from the human resources department if a specific job requirement might unfairly affect some groups more severely than others.

Advice to employees is clear: if you undergo (or witness) direct or indirect discrimination, report the incident, following your company's internal policy. If your company does not have a policy for human rights complaints, your provincial Human Rights Commission can receive it. In most provinces, the licensing Association will also investigate allegations of harassment or discrimination involving a professional engineer or geoscientist.

Photo 8.3 — Engineering Students at the University of Waterloo. *Students work with an instructor in the Engineering IDEAs clinic, where they learn hands-on skills, teamwork, and conflict resolution.*

Source: Courtesy of Carole Truemner

8.7 FAIR PRACTICES IN THE WORKPLACE

Realistic objectives for hiring people from underrepresented groups should be based on achieving better than, or at least the level of, the availability of each underrepresented group in the pool of candidates. Creating a committee to identify diversity issues and to design strategies to increase the presence of personnel from underrepresented groups can be highly effective.[23] Some good hiring practices include the following:

- Advertise widely and externally, as well as posting internally.
- Encourage qualified members of underrepresented groups to apply. In other words, find and contact them, as they may be few in number and may not consult the mainstream advertising channels.
- Use unbiased interview techniques. Train hiring staff to recognize inappropriate and illegal questions and the importance of treating all applicants with fairness and respect. One way to test the appropriateness of a question is to consider whether precisely the same question would be asked of every applicant—male, female, or a member of a minority group. If the answer is no, if only a subset of applicants would be asked, then the question should be dropped.

- Obtain input into hiring decisions from a diverse group of supervisors and employees.

Discriminatory practices in hiring are often revealed in workplaces by staff that "look like" management. In recent years, proactive training has helped women with management potential to qualify for promotions. Additionally, training senior management to identify and work on their inherent biases may improve the corporate culture.

Benefits and insights result from hiring women and members of minority groups, especially when they are encouraged to introduce diversity and innovation, and when they feel that their attributes and values are respected.

Employment Equity

Instituting an employment equity program to achieve a fairer societal representation is different from applying affirmative action or quotas. A Saskatchewan government brochure defines employment equity as follows:

> Employment equity is a comprehensive pro-active strategy designed to ensure that all members of society have a fair and equal access to employment opportunities. It is a process for removing barriers that have denied certain groups equal job opportunities. . . . Employment equity programs encourage employers to hire, train, and promote members of these groups.*

Employment equity is not a quota system. The latter refers to hiring from one group until the desired number is reached, whether the candidates are qualified or not. This approach can lead to frustration and anger among groups that feel disadvantaged. Employment equity is fair and leads to a positive outcome.

Fairness in Employee Performance Assessment and Promotions

DiTomaso and Farris[24] conducted a study of employee performance of American scientists and engineers in high-tech companies. The study included Caucasian men, foreign-born men, U.S.-born men from minority groups, and Caucasian women. The study showed significant differences in the way managers rated the performance of men and women, and in the expectations that men and women had of their managers. The study also showed that women rated themselves lower than their managers had done. The article noted that, to avoid unfairness in performance ratings, managers should put more effort into developing objective and measurable criteria for assessments. They must also focus more attention on the type of feedback they provide, communicate the rules clearly, and test whether these rules have been understood.

* Government of Saskatchewan, *Employment Equity (Women in the Workplace)*, brochure (Regina: Women's Secretariat). Used with permission of Queen's Printer for Saskatchewan.

8.8 INTEGRATING IMMIGRANTS INTO THE PROFESSIONS

Professionals should do more than merely obey laws against discrimination—we should actively strive to overcome discrimination. That is the Canadian way. Engineers Canada has taken a positive step to assist internationally educated graduates (IEGs) with a national project to remove barriers to the engineering profession in Canada.[25]

The Importance of Integration

Integration of immigrants is important to Canada's future economic success. The baby boomers (the generation born after the Second World War ended in 1945) are retiring, and the retirement rate will peak in this decade (2010–20), creating vacancies and opportunities for promotion. The financial crisis and recession of 2009 emphasized the need for more resource development and manufacturing in Canada if we are to maintain our standard of living. To help achieve this goal, Engineers Canada took the initiative to improve the way that Canada accepts and validates IEGs.

The Integration Project

In 2003, Engineers Canada started a national project called "From Consideration to Integration" (FC2I) to explore and overcome obstacles faced by IEGs entering the Canadian workforce. The first phase of the three-phase project involved collecting information and consulting with government agencies, provincial and territorial licensing bodies, immigration agencies, universities, and employers. New immigrants must, of course, learn English or French and adapt to Canadian culture, but the most serious obstacles to success for IEGs are the procedures for validating foreign credentials and experience and obtaining a first Canadian job. The first job is critical for an immigrant, because it is the key to getting work experience recognizable to Canadian employers.

The second-phase FC2I report made recommendations to improve the integration of IEGs, without reducing education, experience, or language standards. These 17 recommendations are directed toward federal and provincial governments, licensing bodies, universities, and immigrant settlement groups; they call for streamlining of licensing requirements, adoption of best methods, cross-cultural adaptation, assistance with the transition, and removal of unnecessary obstacles.[26]

In October 2003, APEGBC members approved the development of a new status called "Provisional Membership." This new designation, now approved by five Associations in Canada, recognizes and provides member status to internationally trained engineering and geoscience graduates who have completed the academic, professional, and character requirements for registration as professional engineers or professional geoscientists. Candidates for Provisional Membership are missing only the required one year of experience in a Canadian environment under the direct supervision of a professional engineer or geoscientist.

Roadmap to Engineering in Canada

In 2016, Engineers Canada submitted a report titled *Engineers Canada's Submission to the Government of Canada on Immigration*.[27] This report included 11 recommendations and a description of "Roadmap to Engineering in Canada" (http://newcomers.engineerscanada.ca/). This resource is an online tool to assist newcomers in making a decision about immigration to Canada and to help in this transition. In addition to the Roadmap, immigrant organizations across Canada offer language training, skills upgrading, job support, and many other necessary tools for IEGs, and closer connections with the licensing Associations are developing to disseminate information. Professional development courses help IEGs satisfy licensing requirements. Helping IEGs to understand and follow our human rights legislation when laws differ is, of course, important, but more than that, for Canadian productivity, we should help them get that key first job.

Helping Immigrants in the Workplace

Cross-cultural adaptation is mainly the burden of the immigrant, but professional engineers or geoscientists can also assist by responding positively to IEGs in the workplace. An interesting book, *Managing Cultural Diversity in Technical Professions*, by Lionel Laroche gives much useful advice for human resources managers on cross-cultural training.[28]

Laroche illustrates how minor cultural differences can create serious misunderstandings. For example, in an appendix containing North American idioms, Laroche lists many common sports sayings from football and baseball that are common in daily conversation (although, surprisingly, he overlooked hockey and golf); he points out that these sayings may be meaningless to people who have never played these sports. (The term "home run" may be as meaningless to an immigrant as "Hit them for six!" is to the average Canadian.)

Teamwork and communication are subtly different in some cultures. For example, humour is common in the Canadian workplace and generally makes work more enjoyable; however, an innocent joke, if misinterpreted, may cause serious offence to immigrants who come from cultures where work is not a place for humour. Laroche's book is intended for employers and managers, but it is fascinating reading for anyone who wants to decode the Canadian workplace.

8.9 CONCLUDING COMMENTS

Employers and managers must recognize the benefits and new perspectives that women and minority groups bring to the organization and must not underestimate the performance of these employees. People from diverse backgrounds and perspectives enrich and improve the organization's performance. Every organization must set its own goals, of course, but all should aim to create an environment where the work is challenging, inclusive, comfortable, and productive for all employees.

Women are the majority in the Canadian university student population, yet their underrepresentation in professional engineering and geoscience still poses a challenge. Although some of the references cited in this chapter are one to two decades old, they are still relevant for the second decade of the 21st century. Additional workplace issues and their solutions are discussed in the report *Women in Engineering: More Than Just Numbers*.[29] See also *The Bold and the Brave* for a comprehensive analysis and discussion of solutions.[30]

The rights of minorities and the disabled are clearly specified in the human rights legislation discussed in this chapter. The special problem of integrating new immigrants into the professional workplace is an important challenge, and the proactive initiative by Engineers Canada, discussed above, is worthy of our full support.

As the engineering and geoscience professions continue to integrate diverse populations, many of the obstacles and challenges mentioned in this chapter will eventually disappear. The following case studies, based on real situations, illustrate the challenges that currently exist. The names of individuals and companies are fictitious to protect their privacy.

CASE STUDY 8.1

DISCRIMINATION ON THE BASIS OF GENDER

This case study is based on the "Case of the Mismanaged Ms.," in the *Harvard Business Review*.[31]

STATEMENT OF THE PROBLEM

You are the chief executive officer of a profitable company called the Exeter Corporation. You are contacted by Susan Smith, a highly valued sales manager at Exeter, who has been "passed over" for promotion to director of product development. The promotion was given to Sam Brown on the recommendation of the vice-president of marketing, Peter Young. Smith considers this decision to be discriminatory and is threatening to sue Exeter for unfair practices. She asks you to respond to her concerns within 24 hours. If you do not, you will probably lose a valuable employee, and her lawyer will be exploring the possibility of a settlement through the Human Rights Commission or the courts.

You arrange a meeting with Young and the human resources director. At the meeting, you ask why Brown was selected over Smith. You are told that the difference between the two candidates was marginal. Young's explanation for his recommendation includes both objective and subjective criteria. His first comment is that Brown's experience, seniority, and familiarity with the industrial sector weighed slightly in his favour. Young adds that, through Brown's greater participation in company social events and in the squash ladder, he was better known to all the vice-presidents, who said that Brown "looked like a winner." They could not say the same about Smith because she was less well known.

When prodded by the human resources director, Young suggested an additional list of problems and shortcomings he attributed to Smith:

- "Mark Tannen, vice-president of manufacturing, is thought to be having an affair with Smith, and he is pushing her for promotion."
- "If Smith was promoted, Exeter might be liable to discrimination charges placed by Brown because of Mark Tannen's push for promotion for his honey."
- "The director of product development is a man's position. Human resources—soft, person-to-person stuff—is for women. Factories are for men."
- "Exeter clients prefer to deal with men. They know how to relate to their wives, mothers, and girlfriends, but not to women product development managers."
- "Women are undependable. They get married, get pregnant, want time off, and are less committed to the job."

Young provides no evidence to support these assertions. It is clear, however, that they have influenced his decision to appoint Brown. He believes his decision made good business sense.

After the meeting, you assess the situation. According to the objective data presented, Brown and Smith were both qualified for the position. Smith had shown excellent achievement as a product line manager. The same could be said about Brown. Understandably, choosing between the two would be difficult. Ignoring Young's subjective evaluation of Smith's "shortcomings," the choice was either promoting a woman (Smith) to a higher management level or promoting a man (Brown), who has marginally more experience.

You review your company's existing employment equity policies and current equity situation. Although one-quarter of the employees at Exeter are women, there are no women at the executive level and none on the board of directors. Recently, you and the human resources director issued a policy stating that the company would make great efforts to ensure equity and fairness in the manner in which employees are recruited, trained, and promoted. Although you have no hard evidence, you worry that gender inequity may permeate the organization. Furthermore, if Smith pursues her lawsuit, you wonder if it may encourage other women to come forward with similar experiences. You realize that if Peter Young's comments on Smith's "shortcomings" were repeated in the courts, Exeter would be found guilty of discrimination. Thus, the firm would experience both a financial loss and the loss of an excellent employee.

QUESTIONS

What criteria should have been used to select the new director of product development? Who should have been appointed to the job, based on your criteria: Sam Brown or Susan Smith? Explain your answer.

Since you are the CEO, what should you do in the next 24 hours regarding the potential lawsuit threatened by Smith? What long-term issues do you as CEO face *if you want to ensure employment equity at Exeter, and what steps should you take to put this equity process into place? Does your Association's Code of Ethics address this type of issue? Does it make a difference whether Peter Young, Sam Brown, and Susan Smith are also professional engineers or geoscientists? If your answer is yes, quote the appropriate sections of the Code. If not, should the Code provide guidance for dealing with this case, and what should it say?*

CASE STUDY 8.2

SEXUAL HARASSMENT

STATEMENT OF THE PROBLEM

Michelle Kirkland has been a mechanical engineer in a consulting firm for four years. Recently, she wrote to a senior female engineer to discuss a serious work-related problem and to ask for advice on how to solve it. Below are extracts from her letter:

> In my academic years, I never had any problems being a woman in a male-dominated environment, and therefore very naively entered the workforce with a very positive and healthy attitude toward men in engineering. Today, unfortunately, that is no longer the case. After four years of verbal abuse and three incidents of sexual harassment from my immediate supervisor, I have become cynical about men and I no longer enjoy my work. Most men quite naturally treat women without respect and as second-class citizens, without even being aware of it. The worst part of the situation is that I feel I cannot talk to anyone about this. In our corporation, female managers are practically unheard of, and men seem to stick together like glue. Their attitude is that everything seems to be my fault: "Women are too sensitive" and "Women are less reliable" are the most recent comments that I bluntly received from my manager. I was considering leaving the profession at one point, but meeting other women engineers motivated me to fight back harder and try again. Should I transfer to another department? Should I leave the company? Are there better ones out there? Should I leave the profession and let my daughter solve the problems? I really do not know what to do. Sticking it out means additional stress in an already stressful job, headaches, and more anger. On the other hand, leaving means letting "them" win.

The senior engineer has sufficient personal knowledge of Kirkland and the atmosphere in Kirkland's workplace to believe that these allegations are true.

QUESTIONS

What would you suggest Kirkland do? How does this work atmosphere of verbal abuse and harassment within the company affect the company's effectiveness and profitability? Is this a "professional" environment? Explain and justify your answer. Was the manager's behaviour in violation of your province's Code of Ethics? If so, quote the appropriate sections. What new clauses would you add to the Code to deal with specific issues of harassment?

CASE STUDY 8.3

DISCRIMINATION ON THE BASIS OF RACE

STATEMENT OF THE PROBLEM

Assume that you are a professional engineer or geoscientist working for the Canadian branch of a large, high-precision manufacturing company with a head office located in a foreign country. A huge international technical conference is to be held in your city, including technical seminars and a trade show. Your company wants to present its products and services at the trade show; you are in charge of designing, constructing, and staffing several product displays. The plan includes a reception area and a booth where a receptionist will greet people and direct them to the displays.

On the first day of the trade show, you have everything ready—displays, booths, and literature—and you have arranged with a temporary employment agency to hire a receptionist. The receptionist arrives early, and she appears to be suitable for the job. Before you can explain her duties, however, your boss calls you aside, observes that the receptionist is black, and states, "Company image is critical to the chief executives." He explains that black people are rare in the country where the head office is located, and when the chief executives arrive, they will not expect a black receptionist to welcome them and other visitors to the company's displays. Your boss instructs you: "Express our regrets to the receptionist, pay her for the day, and call the employment agency for another person to fill the job."

QUESTIONS

What action should you take? What laws or Codes of Ethics may be violated if you follow your boss's directions? Does a foreign-based company have the right in Canada to specify the colour of people for jobs? Does anyone?

If you follow your boss's directions, what action would (and should) the receptionist take for being offensively denied an opportunity to work?

Compare your answers with a very similar case: that of *Payne v. OHRC et al.*[32]

DISCUSSION TOPICS AND ASSIGNMENTS

1. You are the senior executive responsible for employing and orienting new engineers and geoscientists in a large consulting firm. What policies should your firm follow for interviewing, hiring, and promoting employees and for resolving internal disputes to ensure fairness and equity?
2. Assume that you are the senior partner in a mid-size professional consulting firm and are in the process of hiring a new professional member. It is likely that the chosen person will stay with the firm for a long and profitable career. The top candidate for hiring has excellent university grades, got three years of relevant experience since graduation, and has applied

for a licence, although it has not yet been awarded. Before you make your final decision, you discuss the candidate's qualifications with other members of your firm. In each of the following cases, discuss the human rights issues and whether the facts should affect the person's hiring:

a. The candidate took a routine medical test and was found to be medically fit, but the physician reported that the candidate has a minor spinal deformity and also was once treated for drug dependency.
b. The candidate is a member of a visible minority, and other members are concerned about whether the candidate will "fit in" with the rest of the consultants.
c. The candidate is a member of a religious group that celebrates different religious holidays than the other members of the firm, who are concerned about sharing the workload.
d. The candidate was charged with welfare fraud as a student, but the charges were dropped.
e. The candidate was convicted of welfare fraud, is presently awaiting trial for drug trafficking, and obtaining a professional licence is, therefore, in doubt.

3. You have heard a rumour that a supervisor is harassing a junior person in your company. The rumour is not definite, but you are the executive responsible for the department in which these two people work. What, if anything, should you do about this situation? Should your actions be the same or different (and in what way) for the following four cases:
   - a female employee allegedly sexually harassed by her male immediate supervisor
   - a male employee allegedly sexually harassed by his female immediate supervisor
   - a visible minority employee allegedly verbally harassed by a white supervisor
   - a white employee allegedly verbally harassed by a visible minority supervisor
4. Sexual harassment, as defined in this chapter, includes "unwelcome sexual advances, requests for sexual favours, and other verbal or physical conduct of a sexual nature." In other words, it means that someone is annoying you by unwelcome actions of a sexual or gender-related nature. Would the following be considered sexual harassment, and if so, what action would be appropriate under the circumstances?

   a. An older, senior female boss makes grossly offensive jokes and remarks about men—their activities and anatomy—during work hours. You must work with her on a close basis over a period of several days during budget preparations, which occur quarterly. You find her conduct unprofessional and working with her unpleasant.
   b. An employee in the machine shop has sexually explicit posters on the full length of a private locker door in a change room. The locker is closed throughout the day but is open at starting time and quitting time

when employees must change into protective clothing to work in an electronics room. You do not use the locker room, and no one has complained, but you find the posters to be pornographic and unprofessional.

Additional assignments can be found in Web Appendix E.

NOTES

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Chapter 9
Principles of Ethics and Justice

Engineers and geoscientists are skilled in solving technical problems; however, many technical problems have ethical consequences. To ensure that solutions are both technically correct and ethically right, you need a basic knowledge of ethics and justice. Although ethics and morals both play a role in guiding professional conduct, they do so in different ways. Morals pertain to the values and beliefs of an individual, while ethics are fundamental principles shared by everyone. Ethics has been described as the science of morals.

In this chapter, we examine four ethical theories that, for centuries, have been important guides for solving ethical problems. These ethical theories do occasionally yield different results, so we must apply them carefully. In addition, solutions that are ethically right in theory may sometimes be unfair in practice; to ensure fairness, we must apply basic principles of justice.

This chapter also discusses professional Codes of Ethics, which are practical guides to professional conduct. The chapter concludes by describing a general strategy for solving ethical problems that readers usually find informative and useful. These ethics and justice concepts are applied to practical case studies in later chapters.

9.1 ETHICS AND PROBLEM SOLVING

Engineers and geoscientists are problem solvers. When faced with a technical problem, we solve it using well-known theorems and laws from mathematics and science. It is reassuring to know that basic theories also exist to solve ethical problems. These ethical theories—developed over the centuries—form the basis of our laws, regulations, and Codes of Ethics. Let us begin this overview by defining our terms.[1]

Ethics is one of the four branches of philosophy (according to one system in common use). Each branch investigates different fundamental questions. The four branches are as follows:

- **Ethics:** The study of right and wrong, good and evil, obligations and rights, justice, and social and political ideals.
- **Logic:** The study of the rules of reasoning. For example, under what conditions can an argument be proved true?

- **Epistemology:** The study of knowledge itself. What is knowledge? Can we know anything? What can we know? What are the sources of knowledge?
- **Metaphysics:** The study of basic ideas such as existence, appearance, reality, and determinism. Metaphysics asks questions about the most abstract and basic categories of thought: thing, person, property, relation, event, space, time, action, possibility/actuality, and appearance versus reality.[2]

Ethics and logic have many practical applications in our lives. Ethics helps us to distinguish right from wrong, an ability that signalled the dawn of civilization. History traces ethical writing back over 3,000 years. In fact, many ethical concepts that we commonly apply today are older than our basic mathematical and scientific disciplines (such as calculus, statics, dynamics, and stress analysis), which originated in the 17th century. Logic is also important to engineers and geoscientists, because it is the basis of mathematical derivation. By contrast, epistemology and metaphysics are highly theoretical and rarely have practical applications.

9.2 FOUR IMPORTANT ETHICAL THEORIES

Many prominent philosophers have devoted their lives to developing ethical theories, and a thorough discussion of their thought would fill a thousand textbooks. We cannot hope to condense this treasury of philosophical thought into a single chapter; however, we can discuss four key ethical theories that apply directly to common ethical problems and are already the basis for many of our customs, laws, and Codes of Ethics.

These four theories are well known. They differ significantly, and none of them is universally superior to the others; even so, it is startling to see how much they are in agreement when applied to certain ethical problems. Each theory carries the name of its main proponent, even though earlier philosophers contributed to formulating the theories, and some modern philosophers have refined the applications. These are the theories:

- Mill's utilitarianism,
- Kant's formalism, or duty ethics,
- Locke's rights ethics, and
- Aristotle's virtue ethics.

Mill's Utilitarianism

John Stuart Mill (1806–1873) was the major proponent of utilitarianism, which states that, in any ethical problem, the best solution produces the maximum benefit for the greatest number of people.[3] This theory is probably the most common justification for ethical decisions in engineering, in geoscience, and, indeed, in modern society. Democratic government itself is a form of utilitarianism, since democracy permits control over government to benefit the maximum number of people (the majority of voters).

The difficulty of applying the utilitarian principle lies in quantitatively calculating the "maximum benefit." Mill proposed that three key factors determine the maximum benefit: (1) the number of people affected, (2) the intensity of the benefit involved, and (3) the duration of the benefit (or, conversely, the severity and duration of the pain avoided). For example, consider automobile seat-belt legislation: all drivers and passengers endure some brief inconvenience when they buckle up, whereas only a few people obtain the benefit (the avoidance of injury or death when they are involved in accidents). We would agree, however, that the intensity and duration of the distress (injury or death) are so severe that, even if they affect relatively few people, they outweigh the brief inconvenience (buckling-up) endured by everyone else.

In evaluating benefits, it is important that we apply certain criteria:

- The benefit to oneself must not have any greater value or importance than the same benefit to anyone else.
- No preference should be given to friends or favoured groups. All benefits should be awarded without regard to race, creed, colour, language, gender, sexual orientation, and so on.
- Benefits must be distributed equally. In other words, when selecting a course of action, an equal distribution of benefits is preferable to an unequal distribution.

In summary, utilitarianism states that the best course of action in an ethical problem is the solution that produces the maximum benefit for the greatest number of people, with the benefit equally divided among those people.

Utilitarianism is very valuable in making ethical decisions. The utilitarian theory is easily understood; it is consistent with the concept of democracy; and in many cases, it is easy to apply. For example, income tax is easily justified by utilitarian theory. A modest hardship (paying tax) is imposed equally on all residents (as a percentage of income). This yields an immense benefit to society, because the tax dollars support hospitals, schools, and essential infrastructure. If we were to eliminate income tax, individuals would have to provide their own private healthcare, schooling, roads, and so forth—a virtually impossible task. We may sometimes disagree with the details, such as tax rates and exemptions, but income tax yields the maximum benefit to the greatest number of people, with the hardship fairly equally distributed.

Kant's Formalism, or Duty Ethics

The theory of duty ethics, or "formalism," is based on the work[4] of Immanuel Kant (1724–1804), who proposed that every individual has a fundamental duty to act in a correct ethical manner. This theory evolved from Kant's belief or observation that each person's conscience imposes an absolute "categorical imperative" (or unconditional command) on that person to follow those courses of action that would be acceptable as universal principles for everyone. For example, everyone has a duty not to tell lies, because if we tolerated lying, then no promises could be trusted, and our society would be unstable. This idea makes sense to most people; almost everyone has this innate sense of duty and believes that rules of conduct should be rules that everyone follows.

Kant believed that the most basic good was "good will," or actively seeking to follow the categorical imperative of one's conscience. This belief is in marked contrast to Mill, who believed that universal happiness was the ultimate good. In Kant's philosophy, happiness is the result of good will: the desire and intention to do one's duty.

Kant emphasized that it was the intention to do one's duty that was significant, not the actual results or consequences. One should always do one's duty, even if the short-term consequences are unpleasant, since this strengthens one's will. For example, even "white" lies should not be tolerated, since they weaken the resolve to follow one's conscience. The formalist theory contends that, in solving an ethical dilemma, one has a duty to follow rules that are generated from the conscience (the categorical imperative) and that if a person strives to develop a good will, happiness will result. Many of the rules that support this universal concept are well known: "Be honest," "Be fair," "Do not hurt others," "Keep your promises," "Obey the law," and so on. Not surprisingly, people would be happier if everyone followed them.

Kant also stated that a consequence of following the categorical imperative would be an increased respect for humanity. Life should always be treated as an end or goal and never as a means of achieving some other goal. Kant's formalism would condemn water or air pollution as unethical, along with any activity that endangered life, regardless of the activity's purpose. In Kantian formalism, everyone (and each engineer or geoscientist, in particular) has an individual duty to prevent harm to human life and to consider the welfare of society to be paramount. As explained later in this chapter, this axiom from Kant is the first rule in almost every Code of Ethics.

In sum, Kant's formalism emphasizes the importance of following universal rules, the importance of humanity, and the significance of the intention of an act or rule rather than the actual outcome in a specific case. The only problem with applying formalism relates to its inflexibility—duties based on the categorical imperative never have exceptions. Fortunately, we can obtain further guidance by considering the other ethical theories.

Locke's Rights Ethics

The rights-based ethical theory comes mainly from the thought and writings of John Locke (1632–1704).[5] Rights-based theory states that every individual has rights, simply by virtue of existing. The right to life and the right to the maximum possible individual liberty and human dignity are fundamental; all other rights flow out of them. Each individual's rights are basic; other people have a duty not to infringe on those rights. This thinking contrasts with Kant's duty-based ethical theory, which contends that duty is fundamental; in the rights-based theory, duties are a consequence of personal rights.

Locke's writings had a powerful impact on British political thought in the 1690s; they also motivated the French and the American revolutions. Basic human rights are embedded in the Canadian Charter of Rights and Freedoms and in the U.S. Constitution. The Charter recognizes that everyone has the following rights:

- fundamental freedom of conscience, religion, thought, belief, opinion, expression, peaceful assembly, and association (section 2);
- democratic rights to vote in an election (or to stand for election) of the House of Commons or of a legislative assembly (section 3);
- mobility rights to enter, remain in, and leave Canada (section 6);
- legal rights to life, liberty, and security of the person and the right not to be deprived of these rights except in accordance with principles of fundamental justice (section 7); and
- equality rights before and under the law and the right to equal benefit and protection of the law (section 15).[6]

We must recognize that everyone has these basic rights and that they must be respected. The Charter does not, however, contain every right that should exist—just the fundamental rights that have been hammered out in Parliament and in the courts of law over the past two centuries. Other rights have evolved from Locke's theory, and they are evident in other legislation. Some rights are still evolving. And, unfortunately, some people claim "rights" as a cloak for selfishness. Examples of these three types follow:

- Locke's theory suggests that everyone has the right to a working environment that is free from sexual harassment or racial discrimination. This right would appear to be common courtesy. Few would challenge it, and it is generally included in provincial labour laws. Similarly, the right to a smoke-free environment is not in the Charter, but many municipal and provincial laws now guarantee it.
- Many people claim rights that are not in the Charter or in other legislation. These rights fall into grey areas, and they may not apply universally. For example, it would seem fair to have a right to private email, the right to protection from loud noise, and the right to freedom from insults on the Internet. These rights support human dignity and individual liberty, and we should respect them where possible (unless it can be proved that denying such rights satisfies a greater good).
- Rights-based ethical theory does have limits. As an example, consider income tax again. Even today, some people challenge the concept of income tax, claiming that it infringes on the individual's right to retain his or her property. Others insist that they have a right to smoke in public buildings, even though laws make such behaviour illegal in most Canadian cities.

Clearly, rights-based arguments cover a spectrum. Some rights are indisputable, and we usually embed them in law; other rights fall into a grey area, suggesting that we should respect them where possible, but they are not absolute.

However, some people claim rights that are really selfishness in disguise. In summary, rights-based ethics has an important place in resolving ethical dilemmas, but the theory is not sufficient to deal with every situation.

Aristotle's Virtue Ethics

Aristotle (384–322 BCE) was one of many early Greek philosophers whose thoughts are still relevant over two millennia later. Aristotle observed that the quality or goodness of an act, object, or person depended on the function or goal concerned. For example, a "good" chair is comfortable, and a "good" knife cuts well.[7]

Similarly, happiness or goodness will result for humans once they allow their specifically human qualities to function fully. Aristotle observed that humans have the power of thought—the one sense that animals do not have. Therefore, he postulated that humans would achieve true happiness by developing qualities of character using thought, reason, deduction, and logic. He called these qualities of character "virtues," and he visualized every virtue as a compromise between two extremes, or vices.

His guide to achieving virtue was to select the "golden mean" between the extremes of excess and deficiency. For example, modesty is the golden mean between the excess of vanity and the deficiency of humility; courage is the golden mean between foolhardiness and cowardice; and generosity is the golden mean between wastefulness and stinginess.

Aristotle's virtue-based philosophy is admirable, and most people have an innate ambition to lead a virtuous, balanced life. Although the concept of virtue is subjective, open to interpretation, and not a universal rule, it still has some obvious applications. In particular, Aristotle's concept of the golden mean is extremely useful in solving ethical problems by considering the extremes and seeking the compromise—the golden mean, or the "happy medium"—between the extremes. This approach is often useful in ethical problems.

9.3 AGREEMENT AND CONTRADICTION IN ETHICAL THEORIES

The four theories described above have survived the test of centuries, and all of them are useful in finding fair solutions to ethical problems. Table 9.1 offers a summary of the theories. Each theory has a wide range of applications, but none is superior in every situation. Philosophers have long been seeking the universal principle at the root of all ethical thought, but a single unifying concept has not yet emerged.

In many applications, all four theories are in complete agreement; sometimes, however, they contradict, and each theory yields its own unique answer to the same problem. We call this contradictory type of ethical problem a "dilemma." A dilemma is an ethical problem that requires a person to choose between two opposing courses of action. (We often use the term "dilemma" for problems with more than two possible outcomes.)

TABLE 9.1 — Summary of Four Key Ethical Theories

	Statement	Conflict
Mill's Utilitarianism	An action is ethically correct if it produces the greatest benefit for the greatest number of people. The duration, intensity, and equality of distribution of the benefits should be considered.	A conflict of interest may arise when evaluating the benefits, or when distributing them equally. Benefits must not favour special groups or personal gain.
Kant's Duty-Based Ethics	Each person has a duty to follow those courses of action that would be acceptable as universal principles for everyone to follow. Human life should be respected, and people should not be used as a means to achieve some other goal.	Conflicts arise when following a universal principle may cause harm. For example, telling a "white" lie is not acceptable, even if telling the truth causes harm.
Locke's Rights-Based Ethics	All individuals are free and equal, and each has a right to life, health, liberty, possessions, and the products of his or her labour.	It is occasionally difficult to determine when one person's rights infringe on another person's rights. Also, people occasionally claim self-serving "rights."
Aristotle's Virtue-Based Ethics	Happiness is achieved by developing virtues, or qualities of character, through deduction and reason. An act is good if it is in accordance with reason. This usually means a course of action that is the golden mean between extremes of excess and deficiency.	The definition of virtue is occasionally vague and difficult to apply in specific cases. However, the concept of seeking a golden mean between two extremes is often useful in ethics.

As an example of agreement between the theories, consider the Golden Rule, "Do unto others as you would have others do unto you." This is a clear statement of Kant's formalism: it imposes a duty on the individual to respect human life as a goal rather than as a means to achieve some other goal. On the other hand, it is also a utilitarian principle, since it brings the maximum good to the maximum number of people. Any inconvenience to the individual is balanced by an equal or greater benefit to the people with whom that person comes into contact. The proponents of rights-based ethics would agree with the Golden Rule but would claim that the duty of the individual to act fairly comes from the rights of others to be treated fairly. Finally, Aristotle would recognize "fairness" as a virtue. The four ethical theories are, therefore, consistent in identifying the Golden Rule as a good maxim for guiding human behaviour, as we would expect.

Similarly, all four ethical theories support the precepts of most religions. Consider the Ten Commandments from the Book of Exodus, which are the ethical basis of Judeo-Christian religions. Each commandment clearly imposes a duty on the individual and at the same time grants rights to others, requires virtuous behaviour, and creates a stable environment that yields the maximum benefit for all. An investigation of the basic precepts of all the great religions would show similar agreement.

9.4 EXAMPLE OF AN ETHICAL DILEMMA

Ethical theories agree remarkably well in solving many ethical problems; however, even when they contradict each other, they may assist in resolving an ethical dilemma. For example, consider the following hypothetical case.

Background Information

Professional engineers Smith and Legault are both senior employees, with more than 10 years of experience. They are part of a 10-person team assigned to develop and test a massive software control system for an electrical power generating plant, which is under construction. They are good friends and occasionally party together after work. Smith drinks heavily and often takes illicit hard drugs. Legault suspects that Smith has an addiction or dependency on alcohol. At times, Smith has wide mood and attitude swings. The project manager cautioned Smith for absenteeism on a few occasions, but took no disciplinary action. Legault occasionally conceals minor errors and "covers" for Smith's absences.

As a friend, Legault is concerned that Smith's erratic behaviour will eventually result in discipline of some sort. Legault is also worried that Smith's alcohol and drug abuse is affecting Smith's work and that the software may be faulty. Legault has repeatedly tried to convince Smith to seek treatment, but Smith denies that any problem exists. Legault hesitates to take any further action because of their close personal friendship.

Questions

Today, the control software failed a preliminary test. Legault has checked the data dump, and it appears that Smith's coding is the likely cause of the failure. The entire team is dismayed. Legault faces a dilemma: Should Legault continue to protect Smith as a friend or should Legault report Smith's drug use and suspected alcohol dependency?

Authors' Analysis

In a real situation, you would have much more information, but a few issues are obvious: Faulty software could cause safety concerns, extra costs, and delays. Even if the software will be fully tested for safety before release, bugs might slip through, and sloppy coding might cause inefficient operation. Let us apply the ethical theories to the dilemma.

- **Duty theory:** As a friend, Legault has a duty to help Smith overcome the dependency but must not act on unproven allegations. The problem statement implies that Legault has done this, but the abuse is entrenched and Smith has refused assistance. Legault also has a duty to colleagues, whose jobs may be jeopardized if the project fails. Furthermore, Legault has a duty to the public to ensure that the software is developed professionally, runs efficiently, and does not contain hidden bugs. In fact (as discussed later), every Code of Ethics states that the public interest should come first. The duty-based theory overwhelmingly indicates that Legault must insist that Smith seek treatment, even if it means reporting the problem to management.
- **Rights theory:** Conversely, the rights-based theory would say that Smith's health is a private matter. Smith has a right to personal privacy, and Legault has no right to investigate Smith's health or to discuss it with anyone.

Obviously, the duty-based and rights-based theories yield simple, clear rules, but those rules contradict each other. We must examine the other theories for further guidance. The utilitarian and virtue-based theories require a subjective judgment, so more information is usually needed before we can apply them. In this case, the degree of danger to others, the seriousness of the abuse or dependency, and Smith's willingness to seek treatment are relevant factors.

- **Utilitarianism:** The utilitarian theory balances the risk of harm to the project and to the public (if Legault does not intervene) against the risk of harm to Smith's career (if Legault exposes the addiction). The estimated intensity of such harm is a factor. If the software fails the final validation test, the project will be delayed, the employer will suffer a loss, the whole team may suffer, and Smith's health problems may become known anyway. Legault's failure to act may simply have delayed the inevitable and made the outcome worse for everyone. The utilitarian theory—even based on such meagre information—would favour intervention, because the greatest good, for the greatest number, would outweigh Smith's potential loss.
- **Virtue:** The virtue-based theory would recognize drug and alcohol dependency as extreme and undesirable. The golden mean between abstinence and addiction is moderate use. The virtue-based theory would condemn Smith's abuse and, therefore, encourage action to alleviate it.

Suggested Decision

Even with the limited information provided, three of the four theories clearly recommend intervention. However, while this may be the end of the ethical discussion, it is not the end of the problem. Knowing the right course of action, finding the courage to implement it, and doing so objectively are equal challenges.

Ideally, the process must be fair and must preserve Smith's dignity and self-respect. Legault might still convince Smith to take sick leave and enter a recovery program, thus salvaging Smith's career and finances. Since a large corporation typically has an Employee Assistance Program (EAP) to help employees with serious personal problems, contacting the EAP would be a good start. Other help may be available. As a last resort, Legault should report Smith to the department manager. The role of Legault as a friend is neither to conceal the problem nor to be a snitch; rather, it is to apply the decision fairly, with a minimum of personal chaos.

In summary, examining a dilemma using the four ethical theories usually gives the right solution. When theories contradict, you must follow the *most* appropriate theory. Doing this requires a value judgment, and is therefore subjective. The good news is that when a decision follows an orderly process, is consistent with a recognized ethical theory, and is fair, the decision maker has a clear conscience. (The next section explores "fairness" in more detail.)

9.5 PRINCIPLES OF JUSTICE

When you face an ethical dilemma and your decision agrees with one or more of the ethical theories above, it is probably right, but is it fair? Curiously, an ethical decision may be unfair even if it agrees with ethical theories. To avoid unfairness, you must seek *justice*. A legal dictionary gives the following definition: "A state of affairs in which conduct or action is both fair and right, given the circumstances."[8]

In other words, to be just, your decision must be both "right" (in agreement with the ethical theories) and "fair." Fairness is hard to identify, although its opposite, unfairness, is usually obvious and helps us understand the concept of justice. For our purposes, we can subdivide justice into the following four basic categories.[9]

1. Procedural Justice—Fairness in Decision Making

According to a well-known saying, "Justice must be done, but it must also be *seen* to be done." The decision-making process itself must be fair and must treat those involved with dignity and respect. For example, consider an unfair process: a supervisor fires an employee for incompetence, based on rumours from coworkers, without discussing the reasons with the employee. Even if the employee deserves to be fired, everyone would see this as an unfair process. In other words, even if the decision was right, the process was unfair.

Fortunately, fair procedures have evolved over the centuries based on two principles usually called "natural justice." The two principles are (1) the right to be heard and (2) the right to be judged by an impartial person. These are "natural" principles because they are fundamental and self-evident. Like axioms in mathematics, they do not need any further proof.

- **The right to be heard:** This principle requires that a person must be informed when the person's rights or property are in jeopardy and must be permitted to defend himself or herself. The legal name for this principle is *habeas corpus*, after the British Act passed in 1679. Habeas corpus entitles people imprisoned without charge to challenge their detention—a vital personal right. It is still a fundamental part of our law, and the Canadian Charter of Rights and Freedoms cites habeas corpus as a precedent.[10]
- **The right to be judged by an impartial person:** This principle requires ethical decisions to be based solely on the merits of the case. Obviously, a judge or decision maker must be unbiased and must have no personal interest or involvement in the case. Otherwise, the judge would have a conflict of interest, and the outcome would be unfair. When a judge (or decision maker) has a conflict of interest, the judge must declare the conflict, step aside, and turn the role over to an impartial judge.

Over the years, courts have defined these two basic axioms of natural justice more specifically. For example, a person charged with a criminal offence now has the right to require the prosecutor to disclose all facts and documents upon which the charge is based. Natural justice requires full disclosure to allow a proper defence.

Similarly, in professional discipline hearings (discussed in Chapter 3), a person who investigates an allegation of misconduct is prohibited from sitting on the Discipline Committee that decides the outcome. Although a person who is already familiar with the case might make a better judge (or a faster decision), that person might already have an opinion. Therefore, we exclude anyone with prior knowledge of the case to avoid any perception of bias that would violate the principles of natural justice.

2. Corrective Justice—Fairness in Rectifying Wrongs

When someone harms a person or damages a person's property, ethical theories agree that the person has the right to rectification, replacement, or repair. (In other words, the person who causes harm or damage has a duty to rectify it.) This is corrective, or retributive, justice. Canada's criminal law, tort law, and professional disciplinary powers are practical applications of corrective justice.

Fairness is difficult to achieve in serious criminal cases involving murder, rape, or bodily harm, where no reparation can relieve the harm done. In these cases, society punishes the offender, usually by imprisonment, which removes the perpetrator from society and deters others from similar behaviour. Questions of fairness in criminal justice are beyond the scope of this book, but discussions of tort law and professional discipline are very relevant for professionals.

- **Tort law:** The word *tort* means "injury or damage," and tort law requires engineers and geoscientists to be responsible for their actions and decisions. (Chapter 6 discusses this aspect of corrective justice.)

- **Professional discipline:** The Associations that license professional engineers and geoscientists protect the public by deterring unlicensed persons from practising and by disciplining licensed professionals. Under the Act, each Association must respond to complaints and must discipline professionals who are guilty of misconduct, which usually includes incompetence, negligence, and breaches of the Code of Ethics. (Chapter 3 discusses this aspect of corrective justice.)

3. Distributive Justice—Fairness in Social Benefits

Distributive justice addresses this question: How should we distribute the benefits and burdens of our society? The ethical theories give slightly different rules: rights, duties, and virtue theories require benefits and burdens to be shared equally, but utilitarianism requires the greatest good for the greatest number. This difference may cause conflict. Moreover, people sometimes apply utilitarianism unfairly. For example, in the days of slavery, utilitarianism was occasionally misused to suggest that imposing severe hardship on a minority (slaves) was balanced by a great benefit to many others (slave-owners and their families). Obviously, such unfair distortion illustrates the dangers of careless application of the ethical theories.

Finally, even if we accept that we should share benefits and burdens equally, what is the fairest interpretation of equality? Consider, for example, the following:

- Canada's income tax system is "graduated"—the tax rate increases with income. In other words, the wealthy pay a higher rate than the poor do. Some advocates recommend a "flat" income tax that requires everyone to pay the same percentage of his or her income. This computation makes the flat tax "more equal." Which approach is fairest?
- Ethics dictates that everyone should be equal before the law. In practice, however, wealthy people can afford to use the courts, poor people can get legal aid from the government, but middle-class people hesitate to use the courts because they must spend their life savings before they get legal aid. Is this equality? Is it fair?

Distributive justice is a major concern for professional engineers and geoscientists. We currently face the environmental problems of pollution, greenhouse gas emissions, climate change, "peak" oil, and sustainable development. Who benefits and who carries the burden in these matters? For example:

- Is it fair for North Americans to use fossil fuels indiscriminately, when the resulting climate change over the next few decades will cause sea levels to rise and flood low-lying countries such as the Netherlands and Bangladesh, thus creating a generation of "environmental" refugees?
- Is it fair for the current generation to consume non-renewable resources inefficiently and thoughtlessly, thus depriving future generations who may need these resources desperately for simple survival?

These environmental problems are modern forms of the "Tragedy of the Commons," discussed in Part 4 of this textbook (Chapters 13 to 15). However, it is important to emphasize that professional ethics alone will not solve these massive distributive justice issues. Democratically elected governments must define the proper balance between development and environmental impact.

4. Political Justice—Fairness in Political Rights

Political justice is concerned with fairness in political rights and duties. For example, how should we divide powers between federal, provincial, and municipal governments? How do we ensure that everyone has an equal vote in elections? This is not an idle question; ethical theories generally support democracy as the best form of government, but with three or more parties, candidates often win elections with less than 50 percent of the votes. Therefore, which is most democratic: our traditional majority rule (also called "first past the post"); proportional representation (which has been proposed and defeated in two provincial referenda); or multi-step elections, in which the less popular candidates are eliminated in "run-off" elections, thus guaranteeing a winner with true majority democratic support?

Political justice is one of the most important areas of justice, and it affects all citizens. Although many Canadians may find constitutional matters boring, we may need political intervention to solve environmental problems. For example, if climate change is a serious threat, should carbon emissions be taxed or rationed? Obviously, political justice is crucial to ensure that everyone is treated fairly.

Some Final Comments on Justice

We seek justice in every ethical decision. Classifying justice into its different types is helpful to gain insight. Applying an ethical theory indiscriminately may result in decisions that are "right," but unfair and unjust. To solve ethical problems, we need the ethical theories (our guides to the right course of action), but the process and the decision must meet the test of fairness. Ethical principles and fairness lead to justice and help us to avoid bad decisions.

9.6 NATURAL JUSTICE AND DISPUTE RESOLUTION

The principles of natural justice discussed above are important when you must resolve disputes or serve on a Complaints Committee or Discipline Committee. To ensure fairness, you must always be guided by natural justice. That means you must do the following:

- **Get all of the information:** Allow each person to state their point of view and to challenge statements made by others. The goal is to ensure that you obtain all the information needed to make the right decision. When possible, ask those concerned to discuss the conflicts directly with one another, rather than interviewing the people separately. Direct, face-to-face

Photos 9.1a and 9.1b — The CN Tower, Toronto. *(Left) The CN Tower, built in 1976, was the world's tallest building and freestanding structure for over 34 years and remains the tallest in the Western Hemisphere and an impressive icon on the Toronto skyline. The tower rises to a height of 553 m (1,815 ft.) and is the centre of telecommunications for Toronto. Antennae on the tower broadcast signals for many Canadian radio, television, and communication companies. The CN Tower is a tribute to Canadian ingenuity. Its construction required innovative techniques. The concrete core and three curved supporting arms were formed using a novel "slip-form" supported by hydraulic jacks, which moved upwards, gradually decreasing in size, to create the tower's elegantly tapered shape. In 1995, the American Society of Civil Engineers (ASCE) declared the CN Tower one of the Seven Wonders of the Modern World. (Right) The design of the CN Tower required extensive analysis and testing. The photo shows a 1:500 aero-static scale model of the CN Tower being tested in the boundary layer wind tunnel at Western University, Canada.*

Sources: (Left) Corel "Toronto" CD #462019; (Right) Courtesy of The Boundary Layer Wind Tunnel Laboratory, University of Western Ontario. © Canada Lands Company (CLC) Limited. Reprinted with permission.

exchanges reduce misunderstandings and inaccuracies. Make certain that you disclose all documents to everyone involved.

- **Act impartially and consistently:** Do not let any personal benefit, conflict, or bias affect the outcome. Avoid any emotional involvement or personality differences (wherever possible). Maintain a positive attitude, and never pre-judge the outcome. In other words, you must act in good faith. When a conflict of interest is unavoidable, you must disclose the conflict. If the conflict of interest is serious, you must step aside and let someone else (usually a superior) resolve the problem.

- **Apply the Code of Ethics or ethical theories:** Most professional disputes can be resolved by using the Code of Ethics, discussed in the next section. In some cases, however, it may be necessary to refer to the basic ethical theories.

9.7 CODES OF ETHICS AS GUIDES TO CONDUCT

To put ethics into practice, clear rules are simpler to apply than philosophical theories. Therefore, over the centuries, society has developed many laws and regulations based on ethical theory and principles of justice, but giving clearer guidance. For example, our criminal and civil laws are effective guides to personal conduct. These laws are surprisingly consistent around the world, in spite of the different political systems, cultural influences, and religious beliefs.

Similarly, each professional Association is empowered to write and enforce a Code of Ethics to guide the professional conduct of engineers and geoscientists. These codes differ, but the principles are consistent. Infringements of the Code can lead to penalties under the Act, as explained in Chapter 3. Each provincial and territorial Association publishes its Code of Ethics on its website (listed in Appendix A—the Codes are also in Web Appendix B).

Overview: Codes of Ethics Clauses

Codes of Ethics usually start with a statement of general principles, followed by a list of the duties to society, employers, clients, colleagues, subordinates, the profession, and oneself. Although some codes express these duties differently, the intent and the results are very similar. The Codes of Ethics usually list the following duties:

- **Duty to society:** A professional engineer or geoscientist must consider his or her duty to the public—or to society in general—as the most important duty. In other words, professionals have a duty to protect the safety, health, and welfare of anyone affected by their work. This goal is accomplished through professional self-regulation. That is, the government delegates its authority to the Associations, which define standards of admission, discipline licensed members, and regulate the profession. This arrangement benefits society, because the Associations ensure that professionals are competent, reliable, up-to-date, and ethical.
- **Duty to employers:** A professional engineer or geoscientist must act fairly and loyally to the employer, must keep the employer's business confidential, and must disclose any conflict of interest.
- **Duty to clients:** A professional engineer or geoscientist in private practice has the same obligations to clients as an employee has to the employer.
- **Duty to colleagues:** A professional engineer or geoscientist must act with courtesy and good will toward colleagues. This simple statement of the Golden Rule agrees with all four ethical theories. Professionals should not permit personal conflicts to interfere with professional relationships. Most

Codes of Ethics state clearly that fellow professionals must be informed whenever their work is reviewed.

- **Duty to employees and subordinates:** A professional engineer or geoscientist must recognize the rights of others, especially if they are employees or subordinates.
- **Duty to the profession:** A professional engineer or geoscientist must maintain the dignity and prestige of the profession and must avoid unprofessional, dishonourable, or disgraceful conduct.
- **Duty to oneself:** Finally, a professional engineer or geoscientist must insist on adequate payment, a satisfactory work environment, and all rights awarded under the Charter of Rights and Freedoms. The professional also has a duty to maintain personal competence in the rapidly changing technical world.

A Model Code of Ethics

Engineers Canada developed the Code of Ethics below in consultation with the provincial and territorial professional engineering licensing Associations. It is therefore a model, or typical, Code of Ethics, but it does not have the legal significance of the codes published by the Associations. For official guidance, you must consult the Code of Ethics for your profession and province or territory. There are 16 provincial and territorial Codes of Ethics when every jurisdiction is included. (Note that a few provinces regulate engineering and geoscience separately.) To read the Code of Ethics for your Association, visit your Association's website, listed in Appendix A, or find it in Web Appendix B. Every Code of Ethics includes the seven duties listed above, but some codes impose additional duties or express duties differently.

Code of Ethics—Engineers Canada

Professional engineers shall conduct themselves in an honourable and ethical manner. Professional engineers shall uphold the values of truth, honesty and trustworthiness and safeguard human life and welfare and the environment. In keeping with these basic tenets, professional engineers shall:

1. Hold paramount the safety, health and welfare of the public and the protection of the environment and promote health and safety within the workplace;
2. Offer services, advise on or undertake engineering assignments only in areas of their competence and practise in a careful and diligent manner;
3. Act as faithful agents of their clients or employers, maintain confidentiality and avoid conflicts of interest;
4. Keep themselves informed in order to maintain their competence, strive to advance the body of knowledge within which they practise and provide opportunities for the professional development of their subordinates;
5. Conduct themselves with equity, fairness, courtesy and good faith towards clients, colleagues and others, give credit where it is due, and accept, as well as give, honest and fair professional criticism;

6. Present clearly to employers and clients the possible consequences if engineering decisions or judgements are overruled or disregarded;
7. Report to their association or other appropriate agencies any illegal or unethical engineering decisions or practices by engineers or others; and
8. Be aware of, and 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 in an objective and truthful manner.
9. Treat equitably and promote the equitable treatment of all clients, colleagues and coworkers, regardless of race, religion, gender, sexual orientation, age, physical or mental ability, marital or family status, and national origin.
10. Uphold and enhance the honour and dignity of the profession.*

Technical Societies and Codes of Ethics

Almost every technical society publishes a Code of Ethics; however, it is important to note that the society codes are *voluntary* guides to conduct. They should not be confused with the Association Codes of Ethics (discussed above), which are enforceable under provincial or territorial Acts in Canada. The licensing Associations have the legal authority to enforce their Codes of Ethics to regulate professional conduct (as explained in Chapter 3).

In contrast, an infraction of the Code of Ethics of a technical society may lead to reprimand or expulsion from the society, but even these minor penalties are extremely rare. Several society codes are in Web Appendix C, and the code for the National Society of Professional Engineers (NSPE) is in Web Appendix D. Although the NSPE code is similar to the provincial codes, and endorsed by many engineering societies, it is a voluntary code.

Geoethics

Geoethics is an emerging branch of ethics that is concerned with the interaction of the physical world and human activity. Geoethics deals with the ethical, social, and cultural implications of geoscience knowledge, education, research, and practice, providing a point of intersection for geosciences, sociology, philosophy, and economy. Geoethics represents an opportunity for geoscientists to become more conscious of their social role and responsibilities in conducting their activity.[11]

9.8 A STRATEGY FOR SOLVING COMPLEX ETHICAL PROBLEMS

The Codes of Ethics are useful guides for professional practice. Most ethical decisions are simple, and we solve them using common sense. However, some ethical problems can be more challenging, perhaps because logic suggests one

* Engineers Canada, "Code of Ethics," National Guideline on the Code of Ethics, March 2016, Ottawa, https://engineerscanada.ca/publications/national-guideline-on-the-code-of-ethics (accessed June 20, 2017).

decision, but intuition (or emotions) suggests another. A strategy for solving these ethical dilemmas is useful. Even if you never use this formal strategy, it is reassuring to know it exists.

Engineers and geoscientists have an advantage in resolving ethical dilemmas, since problem solving is part of their professional education. The design process taught in most programs provides the framework for an ethical problem-solving strategy.

The Design Process

New designs do not spring fully developed into the mind of the designer. Design begins with a vaguely perceived need and ends with a plan to satisfy the need. Creation requires a series of steps, including inspiration and deduction, in the right order and at the right time. The steps in the design process are typically as follows:

1. Recognize that a problem or need exists and gather information about it.
2. Define clearly the problem to be solved and any constraints that limit the solution.
3. Generate or propose alternative solutions or methods to achieve the goal (*synthesis*).
4. Evaluate the benefits and costs of alternative solutions (*analysis*).
5. Choose the optimum design (or re-define the problem and repeat the process).
6. Implement the best solution.

When faced with a problem or need, many people want to "jump in" and solve it immediately; however, the early steps are critical; action without thought is usually unproductive.

Applying the Design Process to Ethical Problems

The design process is a methodical problem-solving technique. It easily becomes a strategy for solving ethical problems, as well.

RECOGNIZE THE PROBLEM AND GATHER INFORMATION

Ethical problems are usually vague and difficult to recognize, especially in the early stages when remedial action is simpler. Sadly, some professionals may not realize their duties under the Code of Ethics until something tragic occurs. When suspicious activities occur, or allegations arise, we must investigate them impartially in keeping with natural justice. We start by asking the questions that all news reporters ask: "*Who, What, Where, When, Why, How*?" For example:

- *Who* is involved? (Identify the individuals involved, and their motivations.)
- *What* type of harm or damage has occurred (or may potentially occur)?
- *Where, when, why*, and *how* has harm occurred (or may potentially occur)?

To give an example, a manufacturing process, once thought to be harmless, may be a cause of cancer or toxicity in the workplace. This concern raises an ethical (and perhaps a legal) problem, because workers cannot be placed at risk in this way. However, more information is essential. A supervisor must meet with the people in the workplace and document any incidents that might support this allegation. Information about the manufacturing process and the toxic agent must be gathered and verified to confirm this suspicion. If the information shows a clear and present danger, then you must act immediately to protect those at risk (as discussed in Chapter 6). If there is no urgent danger, however, wait until you collect all relevant information, because the proper course of action may be very different from what was initially expected.

DEFINE THE ETHICAL PROBLEM

The next step is to define the ethical root of the problem. You must ask yourself: What exactly is wrong? What is unfair about the situation? Do any actions contravene the law, the Association's Code of Ethics, or any other laws or regulations? Often, what first appeared to be an ethical problem was really a rumour, a misunderstanding, or a disagreement over technical facts. When you know all the facts, action may be unnecessary or obvious, and you can skip directly to the implementation step. In some cases, however, you have a problem with no clearly correct answer. Your next job is to generate possible solutions.

GENERATE ALTERNATIVE SOLUTIONS (SYNTHESIS)

This phase of problem solving requires creative thought and is usually difficult. Many alternatives may exist, and you must try to consider them all to find the optimum solution. The creative methods used in design problems (such as brainstorming) apply equally to ethical problems. Try to avoid an ethical dilemma with only two equally undesirable courses of action. Creative thinking usually yields a better (third) option.

EVALUATE ALTERNATIVE SOLUTIONS (ANALYSIS)

Alternative courses of action must be analyzed and compared. Of course, your solution (or decision) must satisfy the law and the Code of Ethics. If the laws and the Code do not apply to the case, then you would look to the ethical theories. Finally, in your evaluation, you would ask whether the solution has any unfair side effects. The analysis should answer the following questions:

- **Legality:** Does the solution satisfy the law and the Association's Code of Ethics?
- **Utilitarian ethics:** What benefits result from this solution, and for whom? What hardships are involved? Are the benefits and hardships equally distributed?
- **Duty-based ethics:** Can you apply this solution to everyone equally? Can the solution be published and withstand the scrutiny of your colleagues and the public?

- **Rights-based ethics:** Does this solution respect the rights of all participants (or "stakeholders")? Does anyone suffer harm?
- **Virtue-based ethics:** Does the solution develop or support virtues? Is the solution a golden mean between unacceptable extremes? In particular, does the solution maintain the ideals of the profession?
- **Fairness:** Is the decision fair to all? Does it impose any unfair conditions or unexpected side effects on those concerned?

DECISION MAKING AND OPTIMIZATION

During the analysis, one course of action usually appears to be best; however, before making a final decision, ask yourself if you can improve or "optimize" this decision. In addition, check again that the solution is fair. If the best solution is also fair, then you can defend your decision fully. You have an optimum solution.

In difficult cases, however, *no* course of action may be clearly superior. When this happens, you must trace back through the process from the beginning, and answer the following questions:

- Have I gathered all the necessary information?
- Have I defined the problem clearly?
- Have I sought advice from the people concerned?
- Have I overlooked an alternative or compromise solution?
- Have I evaluated the consequences of each alternative fully?
- Is a personal benefit or conflict of interest affecting my judgment?

These questions usually help you break through to a solution. (In the rare cases of a deadlock, see below for further advice.)

IMPLEMENT THE SOLUTION

Implementing the decision is the final step. Although the appropriate action will vary from case to case, it is usually advisable to act quickly and decisively, especially if health, safety, or someone's reputation is at stake.

Some Final Comments on This Strategy

This strategy may seem too formal, but try it a few times. After applying it rigorously to a few practical problems, readers find that they recognize ethical patterns and can select appropriate solutions quickly and intuitively.

Some additional advice may help.

RESOLVING DEADLOCKS In particularly difficult cases, the process may still result in a dilemma, with no optimum course of action. If so, you should select the course of action that does not yield a benefit to you, the decision maker. In a closely balanced decision, you must avoid any personal benefit, as it will appear to be the result of bias. If no personal benefit is involved, then you must select and follow the ethical theory that you consider most appropriate. Doing so involves making a personal value judgment, but you will have a clear conscience since you made the decision carefully, logically, and ethically.

UTILITARIAN BIAS This strategy aims for solutions that satisfy all four ethical theories (or at least most of them); therefore, this strategy is itself a form of utilitarianism. The authors offer this observation without apology. Engineers and geoscientists are familiar with utilitarianism; it is at the root of most applied science. And, when utilitarianism is balanced by the other theories and the principles of justice, it is a powerful tool for good decisions.

ETHICS, MORALITY, AND RELIGION Readers will note that this textbook rarely uses the term "morality," even though *morality* and *ethics* mean virtually the same thing. The term "ethics" is preferred for consistency. Similarly, religion is an important aspect of ethics and morality. Many of the ethical theories have their roots in religious teaching, and when applied to ethical problems, religious precepts usually agree with the ethical theories. For many Canadians, religion is the most important guide. In keeping with the Canadian Charter of Rights and Freedoms, however, professional decisions must be independent of any specific religion.

OTHER METHODS OF APPLIED ETHICS Several other formal methods exist for ethical problem solving, but none is universally recognized. Methods for "applied ethics," originally called "moral casuistry," go back over three centuries. Casuistry began in the 17th century and was a "sincere effort to apply rigorous standards of critical argument to the questions of moral conduct."[12] This older method is very different from the problem-solving technique discussed here. In fact, the term "casuistry" is now a very disparaging label for arguments that are poorly formed or hypocritical.

DEONTOLOGY AND TELEOLOGY These terms are in many older textbooks, but are seldom heard in English speech today. *Deontological ethics* (or simply *deontology*) is derived from Greek roots that mean literally "science of duty." Deontology refers to duty-based ethical systems, such as that proposed by Kant. Since *déontologie* means "ethics" in French, a Code of Ethics is therefore a "*Code de Déontologie*" in Quebec. Conversely, *teleological ethics* (or simply *teleology*), derived from Greek roots that mean "science of ends" (where *ends* means "consequences"), refers to ethical systems such as Mill's utilitarianism, which focus on the consequences of a person's actions. The modern synonym for teleology is *consequentialism*.

CONCLUDING COMMENTS ON ETHICS AND JUSTICE Many people have an intuitive sense of ethics; they apply their Code of Ethics easily, and they have an innate ability to generate ethical and fair solutions. For the rest of us, the methodical strategy explained in this chapter may help to develop this ability. The strategy proposed in this chapter is merely one more tool—a tool, however, that engineers and geoscientists may find useful for solving ethical problems. The strategy is useful in personal ethical problems (also called "micro-ethical" problems) or in larger societal, environmental, or humanitarian ethical problems (also called "macro-ethical" problems).[13]

In ethics, as in any discipline, practice makes perfect. That is, testing your problem-solving ability will improve it. The next three chapters illustrate applications of ethics and justice, using case studies from professional employment, management, and consulting.

CASE STUDY 9.1

THE TROLLEY PROBLEM: A WELL-KNOWN ETHICAL DILEMMA

STATEMENT OF THE PROBLEM

The "trolley problem," first stated more than 50 years ago, proposes a ghastly scenario in which you observe a train (or trolley) hurtling along a track toward a group of (typically five) workers. The train is certain to kill the workers, and they are unaware of the danger. The problem then splits into two cases:

- **Case A:** In Case A, you are fortunately next to a railway track switch that will divert the train onto a siding if you act quickly. Sadly, however, there is another worker on the siding who will certainly be killed if you do so.
- **Case B:** In Case B, you are observing the train from a footbridge over the track, and there is a very heavy man beside you on the bridge. If you push the heavy man onto the tracks, his mass will stop the train (or slow it sufficiently), and the workers on the track will easily escape. The heavy man is already leaning over the railing, and you could easily push him. Of course, he will not survive. (The question apparently presumes that your weight is too light to stop the train by jumping onto the track yourself.)

QUESTIONS

In both of these cases, you would sacrifice the life of one person but save the lives of five others. Which action is ethically correct, according to the theories discussed in this chapter? In Case A, should you switch the train onto the siding and save the lives of five strangers, even though it will certainly kill the lone worker on the siding? In Case B, should you save the five workers by pushing the heavy man onto the tracks? (This "mind test" assumes that these people are all strangers to you and overlooks the fact that police would likely charge you with manslaughter in either case, even if you saved lives.)

AUTHORS' ANALYSIS

This dilemma pits Mill's utilitarianism against Kant's formalism. Mill would certainly approve of exchanging one life for five, as the greatest good for the greatest number, and would intervene in both cases. Conversely, Kant would object to taking any life and would let the train continue in both cases. (Locke's rights-based theory and Aristotle's virtue-based ethics are not directly relevant in this example.)

However, although the two cases appear to be ethically identical, if you are a typical reader, you will switch the train to the siding in Case A but refuse to push the heavy man in Case B.

This result may seem curious, but researchers have replicated this ethical "mind test" many times and tabulated the responses. In every test, the results are similar. In Case A, 90 percent of the people surveyed believe it is ethically correct to switch the train onto the siding to save five lives at the cost of one; however, in Case B, 90 percent believe it is wrong to push the heavy man onto the track to achieve the same goal.

Although both cases appear to involve the same ethical trade-off, they are slightly different. In Case A, harm is unintentional (if the worker on the siding can miraculously avoid being hit by the train, everyone survives); however, in Case B, the harm is intentional, because the heavy man must collide with the train to stop it. People intuitively reject harming the heavy man intentionally.

Moreover, the cases differ in fairness. The worker on the siding accepted a job that has the inherent risk of being hit by a train and should be alert to the possibility. The heavy man is presumably a passerby, with no expectation of danger. A war analogy of the trolley problem explains this subtle difference by observing that the death of the worker on the track is unintentional "collateral damage," whereas pushing the heavy man is "deliberately killing a civilian."[14]

In recent decades, philosophers have proposed many dilemmas similar to the trolley problem (they are easily found; simply search for "ethical dilemmas" on the Internet). The dilemmas usually describe horrifying situations in which readers must choose between two equally harrowing alternatives. However, engineers and geoscientists know that probability enters into every activity, so predictions, whether ethical or technical, are never certain. Therefore, when you face a dilemma with two equally bad alternatives, never accept their inevitability without striving to find a third option where everyone escapes injury.

A modern version of the trolley problem can be found in the development of autonomous vehicles, which are expected to become commonplace in the next decade or two. Software engineers program the computer controllers on these driverless cars so that they avoid obstacles, other cars, and pedestrians; however, the situation may arise that "the safety of one person may be protected only at the cost of the safety of another person." The U.S. National Highway Traffic Safety Administration has issued guidelines to developers of autonomous vehicles, including the requirement that "ethical judgments and decisions are made consciously and intentionally."[15]

A HISTORIC EXAMPLE: CHURCHILL AND THE V-1 BOMB

Although the trolley problem may seem unrealistic, many equivalent ethical situations occurred during the Second World War (1939–1945), forcing similar life-or-death choices. For example, Churchill faced a comparable dilemma in the last year of the war, when Hitler attacked Britain with unmanned flying bombs.

The city of London was the target for the V-1 pulse-jet bomb and, later, the V-2 ballistic missile. The first V-1 bomb struck London on June 13, 1944, and began a terrifying new phase in the war. The pulse-jet engine made a distinctive buzzing noise, and Londoners soon called them "buzz-bombs." The V-1 had enough fuel to fly across the English Channel carrying about 850 kg (1870 lbs.) of explosives. A primitive autopilot guided it, and a simple distance-measuring device shut off the engine when the V-1 was (approximately) over London. The bomb would then crash and explode, demolishing everything in the vicinity. The Nazis launched more than 9,000 of these bombs in the last year of the war. Although many malfunctioned and some were shot down, they caused devastation, and killed or seriously injured tens of thousands of people.

In early attacks, however, the bombs fell slightly south of central London. British Military Intelligence (MI5) suggested a plan to Prime Minister Churchill: If they could convince the Nazis that the V-1 bombs were falling *north* of London, then the Nazis would move their aim southward. Although damage to south London might be more severe, it had fewer vital targets and, over time, the bombs might fall in the countryside.

Churchill's war cabinet did not completely agree. A minister who represented south London understandably objected to this utilitarian proposal that, in effect, substituted victims in his area for those in central London. At Churchill's insistence, the cabinet approved the proposal, and a secret program of disinformation proceeded. MI5 used double agents to send out false information about the bomb impacts; the Nazis "corrected" their aim, and the bomb impacts moved away from central London.[16]

Most readers would agree that Churchill was right to use this utilitarian method of reducing casualties, even though the families of those who died might disagree.

DISCUSSION TOPICS AND ASSIGNMENTS

1. Codes of Ethics typically forbid statements that maliciously injure the reputation or business of another professional; however, is a prohibition against malicious statements an infringement on the right to free speech? For example, if a colleague makes a serious error in judgment, or even a serious mathematical error, pointing it out in good faith would be beneficial. How do you define the boundary between statements that are justified criticism and those that are clearly malicious?

2. Some Codes of Ethics include duties that do not appear in other codes. Examine the Code of Ethics for your Association. Does it require professionals to
   - advertise in a dignified, professional manner?
   - report infractions of the Code of Ethics to the registrar of the Association?
   - set fees based on the difficulty of the work and the degree of responsibility?
   - refuse to pay commissions or reduce fees to obtain professional work?
   - obey the law of the land?

   For each of the above clauses, consider the following: Is this duty specified in your Code of Ethics? Is the clause essential in a guide for professional conduct? Why (or why not)?

Additional assignments are in Web Appendix E. Additional ethics case studies involving employment, management, and consulting are presented in the next three chapters. An additional 25 cases (with answers) are provided in Web Appendix F.

NOTES

[1] This chapter is based on hundreds of sources. The main work supporting each of the four ethical theories is cited below. Copies (or reproductions) of these works are available from publishers or on the Internet.

[2] J.T. Stevenson, "Philosophy," *The Canadian Encyclopedia* (Toronto: Historical Foundation of Canada, 2014), http://www.thecanadianencyclopedia.ca/en/article/philosophy/ (accessed June 20, 2017).

[3] J.S. Mill, *Utilitarianism,* published by Parker, Son and Bourn, London, 1863, reproduced in *Utilitarianism, On Liberty* and *Considerations on Representative Government* (ed. H.B. Acton), published by J.M. Dent & Sons Ltd., London, 1988; also available in full at books.google.ca (accessed March 12, 2012).

[4] Immanuel Kant, *The Metaphysic of Ethics*, 1797, translated from German by J.W. Semple, published by Thomas Clark, Edinburgh, 1836, available in full at books.google.ca (accessed March 12, 2012).

[5] John Locke, *Two Treatises of Government*, 1690, reproduced by C. Baldwin, printer, London, 1824, available in full at books.google.ca (accessed March 12, 2012).

[6] Government of Canada, The Canadian Charter of Rights and Freedoms, Part I of the Constitution Act, 1982, being Schedule B to the Canada Act 1982 (UK), http://laws-lois.justice.gc.ca/eng/Const/page-15.html (accessed June 20, 2017).

[7] Aristotle, *Ethica Nichomachea*, c. 322, ethics lectures transcribed by Aristotle's son, Nichomachus. The work, or reviews of it, are widely available; for example, see *Masterpieces of World Philosophy,* ed. F.N. Magill (New York: HarperCollins, 1991).

[8] L. Duhaime, "Justice," *Legal Dictionary*, http://www.duhaime.org/LegalDictionary/J/Justice.aspx (accessed June 20, 2017).

[9] L. Solum, "Legal Theory Lexicon 018: Justice," posted on *Legal Theory Lexicon*, lsolum.typepad.com/legal_theory_lexicon/2004/01/legal_theory_le_2.html (accessed June 20, 2017).

[10] Canadian Charter of Rights and Freedoms, section 10.

[11] International Association for Promoting Geoethics, *Definition of Geoethics*, www.geoethics.org/geoethics (accessed July 14, 2017).

[12] John Haldane, "Applied Ethics," in *The Blackwell Companion to Philosophy,* ed. Nicholas Bunnin and E.P. Tsui-James (Oxford: Blackwell, 2003), 494–98.

[13] Joseph R. Herkert, "Microethics, Macroethics, and Professional Engineering Societies," *Emerging Technologies and Ethical Issues in Engineering: Papers from a Workshop* (Washington, DC: National Academies Press, 2003), 107–14, www.nap.edu/catalog/11083.html (accessed June 20, 2017).

[14] David Edmonds, "Matters of Life and Death," *Prospect Magazine*, October 7, 2010, https://www.prospectmagazine.co.uk/magazine/ethics-trolley-problem (accessed June 20, 2017).

[15] [U.S.] National Highway Traffic Safety Administration, "Federal Automated Vehicles Policy: Accelerating the Next Revolution in Roadway Safety," September 2016, 26, https://www.transportation.gov/AV/federal-automated-vehicles-policy-september-2016.

[16] Edmonds, "Matters of Life and Death."

Chapter 10

Ethics Concepts and Cases: Employment

Most engineers and geoscientists are professional employees. In this chapter, we discuss practice and ethics issues that often arise in professional employment, such as working conditions, disputes, and conflicts of interest. We also examine how the Code of Ethics applies to these issues, the professional response to unethical managers, the limits of an employer's authority, and whistle-blowing. Seven practical case studies illustrate workplace issues and ethical dilemmas. The chapter closes with the *Challenger* space shuttle disaster: an avoidable tragedy in which technical advice was overruled.

10.1 COMMON ETHICAL ISSUES AND DILEMMAS

Your Association's Code of Ethics is a useful professional guide (as explained in Chapter 9). Codes differ slightly, but they ask professionals to uphold the same basic values: competence, ethical conduct, responsibility and accountability for actions, and a commitment to the public interest. The provincial and territorial Codes of Ethics are not mere slogans; failure to maintain these values can lead to disciplinary action.

Engineers Canada lists 12 common ethical situations that arise in the professional workplace in which the Code of Ethics gives good guidance.* These issues fall into 10 categories, as noted below:

- **Overruling technical decisions:** Managers must respect technical expertise, and professionals must reply effectively if technical advice is overruled (see below).
- **Avoiding employment disputes:** Employment disputes must not interfere with professional judgment (see below).
- **Duty to report:** Professionals are required to report unethical or illegal activities (also called "whistle-blowing"—see below and Chapter 13).

* Engineers Canada, "Appendix B—Body of Knowledge," in *National Guideline on the Professional Practice Examination* (Ottawa: Engineers Canada, 2013), https://engineerscanada.ca/publications/national-guideline-on-the-professional-practice-examination (accessed June 20, 2017).

- **Conflict of interest:** These conflicts are tempting and sometimes subtle; they are also serious breaches of the Code of Ethics (as explained below).
- **Professional respect:** Professionals must collaborate for success; offensive, unethical, or rude behaviour can destroy cooperation and sabotage projects.
- **Incompetence:** Professionals must practise within their competence; practising in new areas without adequate training can be disastrous (see Chapter 3).
- **Negligence:** Timeliness in writing reports or responding to requests and acting as a faithful agent for the employer or client are essential. Negligence is a breach of the Code of Ethics and subject to discipline (see below and Chapter 3).
- **Minimal compliance:** Safety or sustainability may be at risk if a professional (or an employer) insists on marginal technical standards (see Chapter 6).
- **Plagiarism:** Computers make plagiarism (copyright theft) easy and tempting, but plagiarism is unethical and illegal (see Chapters 7 and 11).
- **Discrimination:** Fairness and equity for women and minorities is an essential, basic rule in the professional workplace (see Chapter 8).

10.2 CONFLICTS IN TECHNICAL AND MANAGEMENT AUTHORITY

Professional employment is a contract. The employee agrees to use his or her professional ability to achieve the employer's goals, and the employer agrees to pay fair compensation.

The need for employer authority is obvious; lack of direction could lead to chaos and bankruptcy. The employer must have *management* authority to direct the company's resources, whereas the professional must have *technical* authority to apply engineering or geoscientific knowledge and skills. In a well-run organization, professionals understand the distinction between management and technical authority, show mutual respect, and cooperate to achieve the employer's goals.

What would you do, however, if your employer overruled you or asked you to perform activities that are illegal or unethical? These problems are not common but do occur. Consider four situations that involve overruling technical advice, breaches of Canadian law or the Code of Ethics, and violations of a professional's conscience.

Overruling Technical Advice

Occasionally an employer or client overrules the technical recommendation of a professional engineer or geoscientist. For example:

- **Outdated equipment purchase:** The operations manager in an oil exploration company insists on purchasing expensive electronic equipment for oil and gas exploration, even though the geoscientist knows that the equipment is outdated and advises the manager against buying it. The manager wants to buy it because of favourable exchange rates. If the manager overrules the geoscientist and purchases the expensive equipment, it will sit idle. Senior management and company shareholders will want to know why. They will presume that the geoscientist requested the purchase and showed poor judgment. This perception might affect his or her career prospects. The purchase is the manager's error, so what can the geoscientist do?

Many ethical guides specifically mention this type of case, because it is a relatively common problem.[1] If an employer or client overrules your advice as a professional, the proper action is to

- explain your advice to the employer or client in writing and also clearly explain the consequences of ignoring your advice; and
- get a response in writing to ensure that the employer or client fully understands your advice and the consequences of ignoring it.

This latter action is particularly important when the employer or client is not a technical professional. The employer or client now has full responsibility for the decision and any consequences. You have satisfied your responsibilities, unless the decision involves illegal or unethical activities (discussed next).

Illegal Activities

On rare occasions, an employer may ask a professional engineer or geoscientist to engage in an activity that is clearly contrary to criminal, civil, or business law or contrary to a regulation made under the authority of an Act (such as an environmental regulation). Often, pressure on management to generate profits converts into pressure on the professional to "cut corners." For example:

- **Geoscience:** Although borehole results at a new mining site are disappointing, the chief executive officer (CEO) of the mining company privately asks the senior geologist to write an optimistic news release concerning the tests so that share prices will not drop. The CEO argues that a new share issue is underway: the new funds will permit further exploration, and discoveries will justify the (unprofessional and illegal) news release.
- **Engineering:** An engineer and his employer meet with a municipal government committee to discuss tenders for construction of a new town hall. After the meeting, the clerk returns the preliminary plans; however, the clerk inadvertently includes the preliminary plans of a rival consultant. In the few minutes available, the employer instructs the engineer to photocopy the rival's plans. Copying the plans is unethical and an infraction of the Copyright Act. In addition, if the engineer were caught in the act of copying plans, the clerk or the rival company could claim that the tender process was violated, and legal or disciplinary action might follow.

In situations like this, the necessary action is clear: the professional must advise the employer that the action is illegal and refuse to comply with the request. Employers do not have the authority to direct an employee to break the law.

Activities Contrary to the Code of Ethics

An employer may ask a professional engineer or geoscientist to perform an action that, while not clearly a criminal act, is a breach of the Code of Ethics of the Association. For example:

- **Honesty:** Using the ISO standard for gear design, a machine design engineer calculates that a gear train has a factor of safety of 1.82 against fatigue failure. The employer, who is not a technical person, asks the engineer to "round off" the factor so that the gear train meets the client's specifications, which require a factor of safety of 2.0. This is technically wrong, because rounding to two figures gives 1.8 (not 2.0). Therefore, the fatigue life is inadequate, although this fact may not become evident for many years. The designer must refuse because the employer's request contravenes the Code of Ethics, which requires competence and integrity (or honesty, depending on the Code). The request might also be attempted fraud, which is illegal.
- **Integrity:** Assume you are a professional geoscientist working for a resource company that has recently been taken over by a larger corporation. Their two explorations and analysis units will be combined, so some employees must be laid off. A manager asks you to review and comment secretly on a colleague and provides copies of the colleague's reports and expense accounts. The manager plans to use your comments to justify firing the colleague, who is competing for the manager's position. The manager's final comment is "I have been fighting with this jerk for years!" This request is clearly contrary to the Code of Ethics. Every Code requires professionals to treat colleagues with courtesy, with fairness, and in good faith. Most Codes of Ethics specifically forbid secret reviews of colleagues. Secret reviews are contrary to the concept of natural justice.

In these cases, the professional should decline to act on the employer's request. An employer cannot direct a professional to violate the Code of Ethics. The employer may be unaware that the Code of Ethics has legal significance under the professional engineering and/or geoscience Act. You should simply inform the employer of this fact. An employer, manager, or client who is also a professional is equally bound to follow the Code of Ethics (and other professions have similar Codes of Ethics).

Activities Contrary to the Conscience of the Professional

An employer may ask a professional to perform an activity that, while legal and not a violation of the Code of Ethics, nevertheless contravenes his or her conscience.

Conscientious objection has a long and honourable history in Canada, and objections to slavery, nuclear weapons, and unjust wars are well known. Conscientious objection is *not* common in the professions, because professionals simply avoid working in industries that operate against their personal ethics or standards. The following are examples of such industries:

- **Addictive products:** Industries that produce potentially addictive products, such as distilleries, breweries, wineries, and tobacco processors
- **Gambling:** Industries that ostensibly entertain but encourage behaviour that may result in serious financial loss, such as casinos, slot machines, and lotteries
- **Armament:** Industries that manufacture landmines, weapons, ammunition, or explosives
- **Reckless pollution:** Industries that recklessly or needlessly pollute or create harmful byproducts

Each individual must decide whether an industry benefits society enough to justify working for it. Government prohibitions of alcohol and gambling in the early 1900s were unsuccessful. Therefore, Canada has chosen (along with most Western countries) to balance the ethical equation by controlling and taxing these industries more stringently, and by alleviating the misery of pollution or addiction by regulations, welfare, and social programs. Nevertheless, many professionals face a dilemma when asked to work in such industries. For example:

- **Ethics and gambling:** A software engineer is hired to develop banking software, but during a slow period, the employer asks the engineer to develop computer graphics for slot machines in a gambling casino. Slot machines are legal (in casinos and licensed restaurants, depending on the province), but many people consider them to be deceptive and unethical. Slot machines do not reveal the true odds of winning. Casinos themselves are designed with a deliberately distracting atmosphere. The maze-like, windowless, noisy surroundings deter gamblers from realizing the time of day, the weather, or even the way out. In addition, many gamblers become addicted to betting and lose everything: their families are affected; their standard of living drops; and some require counselling or social assistance. The software engineer does not want to put his or her creative effort into promoting gambling, so what should he or she do? In this case, laws and Codes of Ethics do not give much guidance. The ethical strategy in the previous chapter might yield a compromise solution—the software engineer could simply request a move to another project unrelated to gambling. However, if no alternative is available, the engineer may face a serious ethical dilemma: ignore his or her conscience, or find other employment.

Ethical problems sometimes have unfair outcomes. Obeying your conscience and refusing to follow the employer's directive may result in disciplinary action or dismissal. You should never make a major ethical decision impulsively, without considering the risk of dismissal and unemployment. Although Canadian law has remedies for wrongful dismissal (discussed in Chapter 11), the law moves very slowly.

10.3 PROFESSIONAL EMPLOYEE GUIDELINES

Professional employees sometimes need help with common job problems, such as working conditions, salaries, benefits, hours of work, and hiring or firing. Because the licensing Associations do not control working conditions, they usually cannot help (although most Associations provide valuable salary surveys and help individuals with job searches). Provincial labour laws regulate some working conditions, as explained in law textbooks,[2] but labour laws usually set minimum values that rarely apply to professional employees. The technical societies (discussed in Chapter 18) give excellent technical advice but rarely assist with employment problems.

The Canadian Society of Professional Engineers (CSPE) was set up in 1983 to advocate for engineers across Canada. CSPE is intended to be a national federation of advocacy groups, but at present (2018), Ontario has the only provincial branch—the Ontario Society of Professional Engineers (OSPE). OSPE was established in April 2000 to assist Ontario engineers.[3] In addition, an American advocacy group, the National Society of Professional Engineers (NSPE), established in 1934, provides advice that may help Canadian engineers and geoscientists.

In 1973, NSPE published a set of guidelines for professional employees and employers. The crisis that prompted creation of the guidelines was the U.S. government's cutbacks on aerospace expenditures in the late 1960s, including cancellation of the proposed supersonic transport aircraft (SST). Many engineers and scientists were suddenly and unexpectedly unemployed and suffered severe financial hardship in the following years. In 2006, NSPE published a fourth revised edition of the set of guidelines, still useful for both employees and employers.[4]

The purpose of the NSPE guidelines is to establish a professional workplace based on "ethical practices, co-operation, mutual respect, and fair treatment." The guidelines contain more than 60 detailed clauses, divided into four sections: "Recruitment," "Employment," "Professional Development," and "Termination." Although the NSPE guidelines do not have any legal authority in the United States or in Canada, they give valuable advice for all professional employees. The guidelines are available online from NSPE and are reproduced in Web Appendix D (on the textbook website).

10.4 PROFESSIONAL EMPLOYEES AND LABOUR UNIONS

Professional engineers and geoscientists have a right to negotiate pay scales, hours of work, and other conditions of employment. Ideally, the professional employee should have a personal contract specifying salary, hours of work, overtime requirements, benefits (e.g., sick leave, vacations, pensions, and professional insurance), regular review of performance and working conditions, promotion or raises based on merit, terms for permanent employment after a probationary period (or alternatively, terms for contract renewal), and so forth.

In many workplaces, however, an employer refuses to negotiate these basic conditions. The engineer is then faced with the choice to accept the employer's unilateral conditions of employment, resign, or take part in "collective action" (group negotiation or unionization) against the employer. Professional employees have a duty not only to the employer but also to themselves and to the profession as a whole: they must not accept unprofessional working conditions or inadequate pay.

Labour legislation in both Canada and the United States determined long ago that professional employees have the right to take collective action and even to form or join unions. Every province has a Labour Board and a Labour Relations Act that can provide guidance and assist employees who are contemplating collective action. Of course, professionals who are also company managers cannot join unions, and it would be illogical for them to do so, but other professional employees may take such action.

However, forming a union involves confrontation, generates bureaucracy, and takes time and effort. Therefore, unionization should be a last resort. Professional employees should first try to negotiate personal (or group) employment contracts, because contracts are simpler and, with effective advice and negotiation, are as legally binding as union contracts.

Professional employees who are unable to negotiate personal or group employment contracts may need to unionize. In this case, they should form a collective group composed entirely of professionals, if possible. Professional employees should not join an existing staff or labour union, because they usually will be a minority in the union and may be obliged to support labour action that is not in their interests.

In summary, when professional employees resort to collective action, they do so reluctantly. Unionization is ethical, but the need to unionize usually indicates that the employer failed to set fair policies and negotiating procedures.

10.5 UNETHICAL MANAGERS AND WHISTLE-BLOWING

A professional employee who finds evidence of illegal or criminal activities in the workplace, such as fraud, theft, misrepresentation, or destructive environmental practices, has a duty to remedy the situation. The proper action depends on the case; usually the professional would report the facts to his or her employer (or supervisor) for action.

If the illegal activity is a hazard to the public, then urgent action is essential—any delay might be interpreted as condoning the illegal activity. For example, if an audit of toxic materials reveals that negligent storage practices are permitting poisonous liquids to seep into the environment, the professional has a duty to inform the employer immediately, and the employer has a duty to remedy the hazard and notify regulatory agencies and others who may be affected.

However, what do you do if the employer ignores a hazardous problem? When this happens, a dilemma is created: your duty to the employer conflicts with your duty to the public welfare. The public welfare must take precedence, according to the Code of Ethics (and Canadian environmental law), so the professional employee typically has three possible courses of action: correct the problem, blow the whistle, or resign in protest.

- **Correct the problem:** The employee should first try to correct the problem and change company policy. This course of action is usually the most effective; most employers and supervisors are honest and act quickly when a hazard exists. However, some supervisors resist improvement and change. If the supervisor disputes the situation or refuses to act, the professional has a duty under the Code of Ethics to "go over the supervisor's head" to senior management.
- **Blow the whistle:** If it is impossible to correct the problem, the professional employee should alert external regulatory agencies that the company is acting dishonestly. This is "whistle-blowing," and it is an unpleasant and unfriendly act. Companies usually find reasons to dismiss whistle-blowers. However, in those rare situations where a professional employee has informed employers and senior management of a clear and serious hazard to the public, but they have refused or neglected to correct it, then whistle-blowing may be the only option. Whistle-blowing should be the last option, after all other routes have been tried. (Chapter 13 discusses whistle-blowing and its associated problems.)
- **Resign in protest:** The employee could resign in protest. This course of action may be necessary in a serious case, where remaining with the company might imply collusion in the illegal activities. The professional employee should always consult a lawyer before resigning. There may be grounds for considering a forced resignation as wrongful dismissal. (Chapter 11 discusses wrongful dismissal.)

10.6 CONFLICT OF INTEREST—AN OVERVIEW

Professional people, whether employees, managers, or consultants, must avoid conflicts of interest, as defined below. Conflicts of interest are contrary to every Code of Ethics, are sometimes criminal, and often result in disciplinary action.

Definition of Conflict of Interest

A conflict of interest occurs whenever a professional receives any benefit or has any relationship that interferes with the duty owed to the client or employer.

Every Code of Ethics requires disclosure of a conflict of interest. Secret payments, or "secret commissions," are unethical and illegal. However, conflicts are not always about money. A conflict of interest could arise over a benefit, such as hockey tickets, free trips, or sexual favours. The benefit might be indirect, such as secretly assisting a close friend, or something intangible, such as an opportunity to meet a celebrity.

Common Conflicts of Interest

In their book, *The Responsible Public Servant*,[5] Kernaghan and Langford define seven common categories of conflict of interest, as listed below in terms relevant to engineers and geoscientists.

- **Accepting secret commissions:** Accepting a secret payment or a significant gift from anyone with whom you have a business relationship creates a conflict of interest. The conflict exists, even if no obvious benefit is given in return. A common, shameful example is accepting a bribe for ignoring shoddy work or substandard materials.
- **Misusing an employer's facilities:** Using an employer's computers, telephones, or supplies for private activities is theft and needs no further explanation.
- **Secret employment, or "moonlighting":** If you create a private business that is secret from your employer (even if you try to run it in your spare time), you have a conflict of interest. The conflict is severe if your secret business competes with your employer for clients or uses your employer's facilities or clients list. An employer pays a professional for knowledge, skill, and initiative, and it is unfair to divert these, secretly, to your personal gain.
- **Self-serving decisions:** Using your position within an organization to hire relatives, or to divert business to a favoured company, is a conflict of interest, sometimes called "self-dealing" or "abuse of privilege."
- **Influence peddling:** Using your position to support a special group, cause, or political party is also a conflict of interest. This is a self-serving decision, as above, even though the benefit to you is less tangible.
- **Abusing confidential information:** Professionals have a duty to keep the employer's information confidential. Acting on confidential information for personal gain is an abuse of privilege, a clear conflict of interest, and often illegal.
- **Arranging future employment:** As a professional, you are free to resign and join a new company or start your own practice; however, if the new company competes with your former employer, you may have a conflict of interest. Does the information that you obtained on the job belong to your former employer, or is it your professional experience? The interpretation depends on the facts of the case. If you take any of your former employer's trade secrets or confidential information to the new company, you have a serious conflict of interest, and the former employer may be able to sue you and your new employer. In addition, if your employment contract had a non-competition clause, you may have breached that contract. Before you accept a new job, clarify these points, because lawsuits are expensive even if you win.

Three Categories of Conflict of Interest

Conflicts of interest typically fall into three categories.

- **Clear (or actual) conflicts:** In this case, the conflict clearly compromises the professional's service to the client or employer. For example, a professional employee is responsible for measuring the quantity and quality of concrete delivered to a runway construction site. The professional has a secret agreement with the owner of the concrete company: the professional ignores the fact that some concrete contains cheap pit-run gravel, rather than crushed stone (as required by the contract). In return, the concrete company secretly supplies a few loads of concrete to build a dock at the professional's summer cottage. This conflict of interest is a form of theft.
- **Potential (or latent) conflicts:** In this case, the professional does not have a conflict of interest at present, but a reasonable person would predict a conflict to exist in future. In other words, the potential for conflict exists, and a probable event could trigger it. For example, a professional engineer or geoscientist intends to run for mayor of a small town. A childhood friend, who operates the gravel company that spreads sand on the town streets in winter, offers to contribute $25,000 to the election campaign. The friend wishes to remain anonymous. (Assume that municipal donors may remain anonymous in this province, and no tax receipts are given.) The professional accepts the money. Until the election, no conflict of interest exists. However, if the professional is elected, the situation changes, because one of the mayor's duties is negotiating the annual winter contract for spreading sand on town streets. Therefore, a potential conflict of interest exists: the professional, if elected, must negotiate a sand-spreading contract with a friend who made a large secret payment to the professional's campaign. Obviously, secrecy is the problem; the donation must be public. The mayor must declare a conflict of interest and step away from the negotiations. The voters can judge whether the conflict is serious and can ensure that the mayor does not favour supporters.
- **Perceived conflicts:** In this case, the professional does not have a conflict of interest, but observers believe (or might believe) that a conflict exists. For example, a professional engineer or geoscientist requires an administrative assistant and asks the human relations department to advertise the job opening, interview candidates, check references, and hire the best candidate. By coincidence, however, the new administrative assistant has the same last name as the professional. Colleagues may believe that the assistant is a relative. To avoid this perceived conflict of interest, it is usually sufficient to explain publicly that no family relationship exists.

Avoiding Conflicts of Interest

You can avoid conflicts very simply by refusing to accept gifts or bribes, refusing to misuse your authority for personal gain, and refusing to favour specific people. When a conflict arises accidentally or unavoidably, full disclosure will eliminate it. Secrecy is the problem; when you disclose a conflict of interest, people can see that no benefit or favouritism is involved. For example:

- **Family relationships:** Professional people, working for the same company, meet on the job and marry one another. This is common. However, family relationships inside and outside an organization can create potential conflicts of interest, so they must be disclosed to a superior who can verify that no favouritism exists.

In summary, as a professional, you are in a position of authority and responsibility, and you must resist the temptation to give or receive favoured treatment. Never ask for or accept a secret commission. Always disclose a conflict of interest.

10.7 INTRODUCTION TO CASE STUDIES

Each of the ethics cases below (and in the following chapters) describes a practical problem and asks for a decision supported by the Code of Ethics and/or basic concepts of ethics and justice. Try to solve each case before you read the suggested solution.

Notes on Case Studies

- **Code of Ethics:** The Code of Ethics is a good guide for professional decisions, as shown in the first six cases below (Case Studies 10.1 to 10.6). In rare instances, a decision may satisfy the Code of Ethics and Canadian law but still violate the individual's conscience. Case Study 10.7 illustrates such a situation. The strategy discussed in Chapter 9 may then be useful. Try the strategy; it is a logical method of attack for ethical problems and becomes intuitive with practice.
- **Limitations:** Case studies are artificial, because readers have only a summary of the facts and cannot speak to the participants. Even so, case studies help to develop decision-making skills. In real cases, you must seek information assertively; natural justice requires that all viewpoints be heard.
- **Similarity to real cases:** These ethics cases are based on real events, or reports of real events, but names and details have been altered for anonymity. Any similarity to real people in current situations is entirely coincidental.

CASE STUDY 10.1

JOB OFFERS AND THE CODE OF ETHICS

STATEMENT OF THE PROBLEM

Assume that you are a professional engineer or professional geoscientist, employed for several years by Alpha Company, a major corporation. Consider the following three scenarios concerning a better paying job at Beta Company, a rival corporation:

- **Random meeting:** You meet a friend from Beta Company by chance at a social gathering. The friend tells you that Beta is hiring new employees, describes the job opportunities, and offers to introduce you. Under Beta's recruitment policy, the colleague will receive a bonus if you are hired.
- **Targeted contact:** You are preparing a bid on a major project for Alpha Company. Your friend at Beta Company, who is bidding on the same project, tells you of an attractive job opportunity at Beta. Your friend says that you would receive a very good salary plus a bonus from Beta if you bring a few documents, such as Alpha's cost estimates and design details for the project.
- **Downsizing:** You spent the past year preparing Alpha Company's project bid, but the rival, Beta Company, won the project. Your boss tells you that your department may be "downsized" and you might soon be unemployed. Beta's Human Resources director calls you and offers you a job—working on the same project but for Beta Company.

QUESTIONS

Does the Code of Ethics allow you to take job materials from Alpha to Beta in any of these three cases? Are any of your friends breaking the Code of Ethics by making these job offers? Which, if any, of these offers could you ethically accept?

AUTHORS' SUGGESTED SOLUTION

You would seriously violate your Association's Code of Ethics if you secretly take documentation or proprietary materials from Alpha Company to Beta Company, in any of these three cases. For example, the Alberta Code of Ethics requires professionals to "conduct themselves with integrity, honesty, fairness and objectivity in their professional activities."[6] Ontario expects a professional to act "as a faithful agent or trustee and shall regard as confidential . . . the business affairs, technical methods or processes of an employer."[7] Other Codes have different wording, but agree in principle; however, these cases differ in other ways.

- **Random meeting:** This is not really a job offer but a request to apply. Beta Company's recruitment bonus creates a conflict of interest for your friend (so your friend may be biased). However, your friend disclosed this conflict of interest to you, so it does not contravene the Code. You could ethically apply.

- **Targeted contact:** This offer is clearly unacceptable ethically; your friend's request to "bring a few documents" is industrial espionage. Engaging in this is unethical (for you and your "friend") under every Code of Ethics and possibly illegal. This job offer could end in disciplinary action.
- **Downsizing:** This offer is ethically acceptable under the circumstances, unless your employment contract with Alpha has a non-competition clause. You should, however, disclose the offer to Alpha. If asked, you must assure Alpha that you will not give confidential or proprietary information to Beta.

CASE STUDY 10.2

OVERRULING BY A SENIOR PROFESSIONAL

STATEMENT OF THE PROBLEM

Assume that you are a licensed professional geoscientist with six years' experience, employed by a large consulting firm. You are working on a major project in northern Canada to divert water away from a mineral-rich deposit and then to mine the deposit. Your responsibility is to design and to estimate costs for an earth dam almost 60 m long and 8 m high. Your report will be part of a final project proposal that the client must approve before construction will go ahead.

Over the last six months, you have conducted a thorough drilling program, and you are confident that you have consistent soil properties. Your initial concept for the dam required much iteration, using several computer analysis programs, to get the optimum dam configuration. You believe that your design gives maximum strength and reliability at minimum cost. You write a final report to submit to your supervisor.

Your supervisor is a senior geoscientist with 25 years' experience and is a principal in the consulting firm. He reads your report closely and returns it the next day, saying that you are being too conservative. Before sending the report to the client, your supervisor wants you to make the side slopes of the dam steeper and reduce the amount of fill material needed. His experience tells him that you could reduce costs by at least 15 percent. He is surprised that the computer analysis does not agree.

You take your supervisor's advice as constructive criticism and re-check your assumptions, calculations, input data, and units thoroughly. You validate the computer program again with data from a previously built dam, and you get close agreement. You are confident that your cost estimates are accurate, and you cannot reduce them by more than a few percent without jeopardizing strength and reliability. Your supervisor is unhappy with this result. In lengthy discussions, you realize that he bases his opinion on a "gut feeling" but offers no alternative analysis. The supervisor is clearly worried that the client will cancel the project if cost estimates are too high.

As the deadline approaches, he instructs you to revise all costs in your report to reduce the dam project cost by 15 percent. He argues that the report is only an estimate, and when the client awards the construction contract, the "overruns" and "add-ons" will generate enough money to build the dam properly.

QUESTIONS

Your supervisor is your boss, so how should you respond to his instruction to reduce costs in your report by 15 percent? Can he direct you to change your estimates, or can you refuse? If you refuse to change the estimates and the client cancels the dam construction project, how would this incident affect your future career?

AUTHORS' SUGGESTED SOLUTION

If a thorough and independent check convinces you that your analysis report is correct, then you must not change it to suit your supervisor. Every Code of Ethics requires professionals to act honestly and in good faith. Ontario specifically defines "signing or sealing" a final report that is not actually "prepared or checked by the practitioner" as professional misconduct.[8] It is wrong to put your seal and signature on a report that you think is incorrect.

Of course, your supervisor has the prerogative to overrule you and change the report, but if he does so, then he must put his seal and signature on it. His proposal to submit a low estimate but find the necessary funds through contract overruns and add-ons is dishonest, unprofessional, and an infraction of the Code of Ethics. If discovered, it could lead to disciplinary action.

Diligent professionals occasionally differ, so this disagreement over the report should not affect your career; however, your supervisor's unethical proposals might encourage you to look for a better job.

CASE STUDY 10.3

SUPERVISION OF TECHNICAL STAFF

STATEMENT OF THE PROBLEM

Engineer Gamma is a competent professional engineer, specializing in manufacturing plant layout. She supervises a staff of 10 technologists and is always very busy. Her employer has contracts from a major automotive manufacturer to supply and install a new production line, and deadlines are tight. The employer minimizes salary expenses by using many technologists to prepare the engineering work and hiring one engineer to review, sign, and seal their output. The employer knows that the Act allows non-engineers to do this work if it is under an engineer's supervision.

Gamma's boss unexpectedly asks her to evaluate and report on an additional "small job"—a plant enlargement for a new client. Gamma initially declines the task, as she is extremely busy. Her employer, however, persists, and Gamma does not want her boss to think she cannot cope with stress. Gamma finally agrees to write a brief report and assigns technologist Delta to read the proposal and suggest a response.

Technologist Delta is experienced in material handling and has designed several complex conveyor systems; however, he is not familiar with some of the machine tools to be installed in the enlarged plant. He tries to get advice from engineer Gamma, but Gamma is always busy with other projects. Technologist Delta prepares a draft report, leaving gaps for missing information, and emails it to Gamma, asking for advice.

Unfortunately, Gamma misinterprets the email and, in her haste, believes she has a final report. Her secretary formats the report and prints it on high-quality paper. Gamma signs, seals, and sends it to the client by courier without reading it.

QUESTIONS

What clauses of the Code of Ethics has engineer Gamma violated? What disciplinary actions could she expect? What should she have done to avoid this bad outcome? Should the employer bear some responsibility for overloading Gamma with tasks?

AUTHORS' SUGGESTED SOLUTION

This case involves two issues: negligence and an apparently unfair workload. Gamma is clearly guilty of negligence; she neglected to communicate with her technologist properly, and she signed and sealed a report that she had not personally prepared or checked. This is professional misconduct under every Code of Ethics. A professional seal on a document is not a formality—it is a mark of quality. The seal assures the client that the report was carefully and competently prepared, and the client can follow its advice with confidence.

If Gamma retrieves the report from the client immediately and apologizes, the only damage may be to her reputation. If, however, the client complains to the Association, a disciplinary hearing would likely find Gamma guilty of negligence; a "busy schedule" is not a defence.

The second issue is the employer's role in Gamma's apparently excessive workload. The employer may be exploitative by hiring only one engineer to supervise a full department of technologists, each preparing documents that the engineer must review, sign, and seal. The Code of Ethics does not address workload directly, but the Code does require competence, and when workload affects competence, the situation becomes unprofessional.

It is ironic that, if the client suffers a loss by relying on Gamma's faulty report, a lawsuit would likely find Gamma's employer financially liable for the loss. Therefore, the heavy workload may be a false savings if the employer is later faced with lawsuits for incompetent or incomplete work.

Gamma is apparently overworked; however, as a professional, she must take the initiative to prevent exploitation. If her workload degrades the quality of her work, she has a duty to uphold the Code of Ethics clause that requires competence. In future, she must decline excessive work assignments, request her employer re-prioritize her assignments, or insist that the employer hire more help.

Most Associations provide some sort of confidential guidance to licensed professionals when employment problems interfere with professional competence. In Ontario, OSPE was established to assist in these issues, as explained earlier in this chapter; the NSPE guidelines (mentioned above) may also help.

CASE STUDY 10.4

PART-TIME EMPLOYMENT (MOONLIGHTING)

STATEMENT OF THE PROBLEM

Philip Forte is a licensed electrical engineer who has worked for Federal Electronic Design for 10 years. Unfortunately, the company has not had many large contracts, and Forte's salary is very low. For the past six years, his pay raises have rarely exceeded cost-of-living increases. As a result, he must take on extra work in his spare time.

Forte secretly brings work to his office in the evening, where he uses the circuit design and analysis software on his employer's computers. He is careful to pay for any materials, office supplies, or photocopying out of his own pocket, and he argues that the computers would be sitting idle in the evening anyway, so his employer is suffering no loss. In fact, Forte contends that his evening work is benefiting his employer, since it enables Forte to keep working for Federal Electronic Design in spite of his low salary.

QUESTIONS

Is it ethical for Forte to carry on his part-time employment in this manner? Is it legal, according to licensing regulations? Discuss Forte's argument that his evening work may benefit the employer, since it permits Forte to accept a low salary.

AUTHORS' SUGGESTED SOLUTION

Forte has a clear conflict of interest, which is contrary to every Code of Ethics. Many professionals "moonlight" (that is, work part time on evenings and weekends), but when an employee works for more than one employer, all employers must be fully informed of the situation (to verify that the employee is not unfairly competing with an employer, or diverting an employer's resources). Forte is not acting ethically in this situation, since he did not inform his employer of his part-time employment. Secrecy is the problem.

Legally, Forte may also be at risk. If Forte is offering services to the public when he moonlights, then in a few provinces (such as Ontario), he must obtain a Certificate of Authorization (also called a "Permit to Practise") and may need liability insurance. Failure to do so (in those provinces) is professional misconduct.

Although Forte's evening work may indirectly benefit the employer, it does not "uphold the principle of adequate compensation"[9] that appears in some Codes of Ethics. This compensation clause is good advice but is virtually impossible to enforce; some Codes state merely that members "shall uphold and enhance the honour, dignity, and reputation of their professions."[10] A decent salary is implied.

CASE STUDY 10.5

MISLEADING TECHNICAL DATA IN ADVERTISING

STATEMENT OF THE PROBLEM

Audrey Adams is a licensed mechanical engineer with five years' experience in designing, building, and testing small boats. She works for a Canadian manufacturer of fibreglass pleasure boats. The company recently promoted her to assistant engineering manager.

Adams's boss, the engineering manager, asks her to calculate hull capacity (buoyancy) for the company's bestselling 6 m boat model, using the latest edition of the Transport Canada construction standards for small vessels. She quickly confirms that previous calculations for maximum safe load and maximum number of persons are still valid. While writing her report, however, she notices that photos in the advertising brochure for the boat show six people on a boat with five seats and rated for only five people. The brochure correctly states (in fine print) that the boat carries "a maximum of five adults," but the photos show six adults. She goes to the warehouse and checks the capacity label riveted to each boat; each label says a maximum of five adults.

By chance, Adams meets the sales manager in the warehouse; she tells him that the photos in the sales brochures are misleading and possibly hazardous; they should be replaced immediately. The sales manager rejects her suggestion emphatically. He explains that the brochure photos are taken from videos, which are part of a million-dollar television advertising campaign scheduled to start next month. All videos show six people on each boat because "You can't have a party with five people." He claims it is too late to make changes, telling Adams to keep quiet, or she will hurt buyers' confidence and reduce sales commissions and profits. He concludes dismissively, "The boats were floating okay when we took the pictures. Your interference with my sales campaign, over a trivial matter, undermines the whole company."

QUESTIONS

Is Adams needlessly interfering in this advertising campaign? Although the boat in the brochure is overloaded, it does float with six people on board. Advertising is not her responsibility. The capacity labels on the boats are correct, so does she have an ethical obligation to require changes to the photos? If so, should she confront the sales manager again, more forcefully? What should she say?

AUTHORS' SUGGESTED SOLUTION

Every Code of Ethics states that public safety is paramount (or most important). In this case, the Transport Canada hull capacity calculation guarantees a consistent safety rating. Advertising must conform to this rating. Advertising photos that show an overloaded boat convey a false idea of the boat capacity and are a potential hazard. (They might also be false advertising.) Adams has an ethical duty to eliminate this hazard.

However, it would be inappropriate for Adams to confront the sales manager again. She should immediately contact her boss, the engineering manager, explain the problem, and share the photos. The sales and engineering managers should then negotiate changes to the advertising campaign to satisfy both safety and promotional goals. If the managers are unable to agree, the engineering manager's technical authority should overrule the misleading advertising plan, and, if necessary, the company's chief operating officer should settle any dispute.

Boats occasionally sink. If a fatality or serious injury occurs, lawsuits often follow. During the pretrial "discovery" process, lawyers are entitled to examine all relevant literature, drawings, documents, websites, and videos to ensure that the design was safe. In this case, if an overloaded boat should sink, resulting in loss or damage, lawyers would scrutinize the brochures and hull capacity data. The brochure photos of overloaded boats would be evidence of a cavalier attitude toward safety. They would also imply that Adams (and her boss) are either incompetent or agreed to misrepresent the boat capacity. In future, sales plans should have input from the engineering department.

CASE STUDY 10.6

ALTERED PLANS AND PUBLIC SAFETY

STATEMENT OF THE PROBLEM

Assume that you are a licensed civil (structural) engineer employed by a large retail company. You work directly for the company architect, who designs the new retail stores and renovates existing stores. As an architect, your boss concentrates on creating stores that are eye-catching, colourful, and attractive to the customer—concepts that will achieve maximum sales. Your job is to ensure that the architect's concepts are safe by inserting structural details, preparing structural drawings, obtaining building permits, and supervising construction. Large construction projects are tendered out for contract. However, the company also employs a three-person crew for small jobs. The crew manager was originally a frame carpenter and was later certified as a technologist but is neither an architect nor an engineer.

In the last seven years, you successfully supervised the design of two large new stores and their construction by contractors. You also planned about 20 small projects built by the company crew. Recently, however, you discovered that the crew manager has sometimes been deviating from your plans on the small jobs. In technical discussions, he always agreed to follow your instructions, but you now realize that he has often altered your plans—for example, by substituting different structural steel shapes, changing joint connection designs, changing column locations, and using salvaged structural steel instead of the specified I-beam sections. You are genuinely uncertain of the extent of his changes and the factors of safety in the "as-built" structures.

You confront the crew manager, somewhat angrily. He responds that he was simply "using cost-saving measures" and that "the changes didn't affect strength." Moreover, he insists that he has "25 years of experience in project management" and that he has had "very few problems in the past." You report these facts to your boss, the architect, who says, "I am simply too busy with project deadlines to worry about personnel problems." She instructs you to "sort it out yourself." You realize that you are partly to blame for this problem because you were responsible for "supervising," which includes ensuring that your plans were followed. The crew manager is a company employee; you trusted him more than an external contractor, you failed to inspect these small projects adequately, and you did not prepare as-built drawings.

QUESTIONS

Can you accept the crew manager's assurance that "the changes didn't affect strength," or do you need to do more? If so, what would you do? If you do nothing, what risks are you taking?

AUTHORS' SUGGESTED SOLUTION

Under every Code of Ethics, the professional's primary responsibility is to ensure the safety of the public. The crew manager's assertion that "the changes did not affect strength" is not adequate, since he is not qualified to make that judgment. Sadly, you were the only professional with the qualifications, knowledge, and responsibility to monitor this work, and you did not supervise it well enough. You must correct this oversight. If you do nothing and any structural components collapse, your inadequate supervision will be obvious and disciplinary action could follow.

Clearly, the factors of safety in the final designs are unknown, so you must calculate them. Regardless of the pressure of deadlines or the costs involved, you must convince your boss, the architect, that this problem needs priority.

Under the Code of Ethics for architects, she has an obligation to respect your expertise in structural strength decisions.

In this case, the ethical analysis is easy: the Code of Ethics requires every professional to put public safety ahead of personal gain or inconvenience. The main decision is how to do it. In order to guarantee safety, you must review all of the 20 projects as quickly as possible to determine the actual factors of safety in the as-built structures. Revised calculations and "as-built" drawings should be filed with the original design calculations. If the as-built strength is marginal or inadequate, immediate structural repairs are essential. In the future, you must monitor these small projects more closely. The crew leader exceeded his authority and failed to notify you of key changes to your designs. This lapse justifies firing him, but instead, you would insist that he help with the as-built drawings, since he knows where the unauthorized changes were made.

Two incidents involving errors in structural projects are very relevant:

- **Hyatt Regency Hotel:** In 1981, in Kansas City, Missouri, two concrete walkways spanning the lobby of the Hyatt Regency Hotel collapsed, killing 114 people and injuring more than 200 others. This structural failure was the deadliest in North America since the collapse of the Quebec Bridge in 1907 (discussed in Chapter 1). The cause of the Hyatt Regency collapse was traced to a minor change in the design of the fittings supporting the upper walkway. Both walkways were to be hung from steel rods roughly 18 m long. However, such rod lengths are difficult to transport, so the fabricator suggested that two shorter (9 m) steel rods replace the longer (18 m) rod. The shorter rods were bolted to the fitting that supports the upper walkway. This change seemed minor; however, it doubled the load on the fitting—a point that would have been obvious if anyone had drawn a free-body diagram of the fitting. The design engineer did not recall making the change, but his engineer's seal appeared on the revised drawings. The collapse was a tragedy for the victims. It was also costly for the insurance companies and for the engineers who lost their licences and were forced into bankruptcy.[11]
- **LeMessurier and the Citicorp Tower:** William LeMessurier was hired as a structural consultant to the Citicorp Tower in New York City, a 59-storey building with a structural steel frame. After the building was completed, LeMessurier re-checked his strength calculations and realized that, when winds blew from a certain direction, the forces on the bolted joints were much greater than he had earlier calculated. LeMessurier chose to face his error directly. Wind tunnel tests confirmed his fears, and he revealed his concerns to the building designers and to the client, Citicorp. Citicorp agreed to immediate action, and repairs were made in record time before the building risked being demolished by a hurricane. Surprisingly, even though the repairs cost millions of dollars, LeMessurier was shielded from most of the financial loss and was highly praised for his prompt, ethical actions. (Note: This important case is discussed in detail in Chapter 12.)

CASE STUDY 10.7

PERSONAL JOB SEARCH DILEMMA

This case illustrates an ethical dilemma in which the Code of Ethics is neutral, but the strategy discussed in Chapter 9 may help to make a decision.

STATEMENT OF THE PROBLEM

Ralph X is a licensed computer engineer with four years' digital control experience. He was laid off when his employer declared bankruptcy. He applied for several jobs but has received no offers. He responds to a job advertised at a nearby tobacco company and arranges an interview.

The job interviewer explains that the tobacco company manufactures cigarettes using newly built high-speed automated machinery. In fact, Ralph's first assignment would be to optimize the digital control software to obtain maximum productivity from the new machinery. Ralph asks about alternative jobs, such as research work that is unrelated to manufacturing or promoting cigarettes, but the company has no other vacancies. The interviewer offers Ralph the job at an attractive salary.

Ethically and emotionally, Ralph does not want to work for a tobacco company. Ralph's father was a heavy smoker who died of lung cancer about 10 years earlier, when Ralph was a teenager. Ralph attributes his father's death, at least in part, to smoking. Cigarettes have been proven to be addictive and harmful. Also, how could he face his mother? She suffered after his father's death, and she would be dismayed to see Ralph working for a tobacco company.

Financially, Ralph has enough money to survive for another few months, but he wants to repay a loan from his mother and still has a student debt. He is unmarried, rents an apartment, and has no children.

QUESTIONS

Should Ralph just flip a coin to decide whether to accept the engineering job offer at the cigarette factory? If not, how should he make this decision?

AUTHORS' SUGGESTED SOLUTION

This case was selected to illustrate the most difficult type of ethical dilemma—those that fall outside the Code of Ethics. This case concerns ethics and conscience, but tobacco production is legal, and the Code of Ethics gives us no clear guidance. However, the ethical theories and the problem-solving strategy discussed in Chapter 9 may give insight.

- **Recognize the problem and gather information:** Ralph recognizes that he faces an ethical dilemma: he needs a job, but his conscience rebels against manufacturing cigarettes. He has already gathered relevant information from the job interview, and he has examined his financial situation.
- **Define the problem:** This dilemma has several aspects: Accepting the job means a good salary and work in his field but also a daily reminder

of a tragic period in his life. Rejecting the offer means more uncertainty, applying for jobs and attending interviews, struggling to pay bills and loans, but also the possibility of a job that he would find fulfilling.

- **Generate alternative solutions:** Ralph should not make a final decision without considering all the alternatives.
  - Ralph could reject the job offer and look more aggressively for a better job. If necessary, he could get a line of credit.
  - Ralph could reject the offer but accept a part-time job to avoid borrowing more money. The part-time job might interfere with his job search.
  - Ralph could accept the offer and try to ignore his conscience.
  - Ralph could accept the offer, keep looking for a better job, and quit as soon as possible. (Note: This option is dishonest and ethically unacceptable.)
- **Evaluate the alternatives:** Evaluate the four alternatives above, using the ethical theories discussed in Chapter 9.
  - **Mill's utilitarianism** tells Ralph to balance the benefit of a secure job (and his ethical distaste for the job) against the benefit of a better job (and the uncertainty and financial struggle that goes with it). Duration and intensity of the benefits are important; an engineering job typically lasts from three to five years and may set the tone for the rest of a career. Each reader would balance these factors differently, but most would likely conclude that three to five years in a distasteful job is too high a price for security.
  - **Kant** reminds Ralph that human beings should always be treated as an end or as a goal, and never as a means of achieving some other goal. In accepting, Ralph would sacrifice his self-respect for security. A job that requires him to deny his true conscience would be demoralizing and is unlikely to lead to a productive career.
  - **Locke's rights-based ethics** would likely contribute little to resolving Ralph's dilemma. Cigarettes are harmful but not illegal, so the company has the right to manufacture them. Unfortunately, no one has a right to a good job, although it may be an admirable concept.
  - **Aristotle's concept of seeking virtue** is very relevant, since there is little virtue in manufacturing a harmful product.
- **Decision making:** Given the above analysis, the authors conclude that most theories show that Ralph should reject the job offer and continue to look, aggressively, for a better job. Some uncertainty is involved, but the risk is worth it.
- **Fairness check:** We must make a final check for fairness. This case does not appear to have any unfair side effects, but the situation could be different. For example, if Ralph's mother were losing her home because of an unpaid mortgage, it would likely be unfair for Ralph to reject the job offer and delay repaying his debt to her.

DISCUSSION OF THE DECISION-MAKING STRATEGY

This case illustrates an ethical dilemma that is not covered by laws or Codes of Ethics. Some readers might prefer to seek religious guidance in such cases. The ethical theories are consistent with most religions and span cultural differences.

In closing, what conclusion would you reach? You may weigh the utilitarian benefits differently, or you may be able to suggest more alternatives. In questions of conscience, there is no right answer; however, a decision made in haste, or strictly for personal gain, is almost certainly wrong. The authors respect other decisions based on gathering information, considering alternatives, and weighing the ethical nature of the alternatives.

CASE HISTORY 10.1

THE CHALLENGER *SPACE SHUTTLE DISASTER*

The *Challenger* space shuttle explosion in 1986 is an infamous engineering tragedy. Millions of people were watching the televised launch when *Challenger* exploded, resulting in the loss of seven lives, immense costs, and severe problems for the American space program.

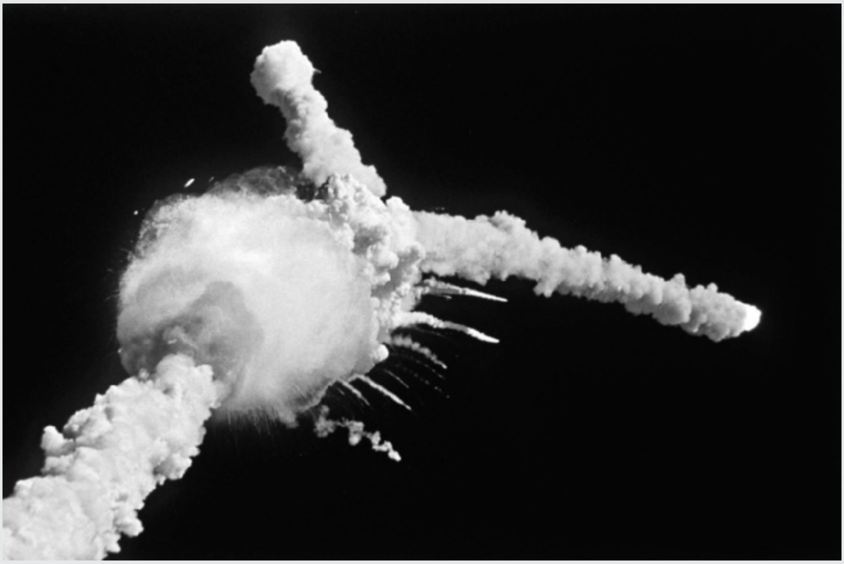

Photo 10.1 — The *Challenger* Space Shuttle Explosion. *The Challenger space shuttle mission, unofficially called the "Teacher in Space Project," was launched on January 28, 1986. At 73 seconds after launch, a series of structural failures caused a fuel tank to explode. The shuttle and its crew of seven were lost, in the most widely televised engineering failure in history. The subsequent inquiry revealed that managers overruled engineers who tried to delay the launch for safety reasons.*

Source: © AP/Bruce Weaver/CP Images

INTRODUCTION

On January 28, 1986, the U.S. National Aeronautics and Space Administration (NASA) launched the space shuttle *Challenger* at Cape Canaveral, Florida. The launch had been delayed by bad weather, and the weather overnight had been exceptionally cold (for Florida). At 11:38 a.m., the rockets were finally ignited.

At first, the shuttle rose according to the flight plan; however, at 59 seconds into the flight, a plume of flame was evident near the booster rockets. By 64 seconds, the flame had burned a hole in the booster; at 72 seconds, the booster's strut detached from the external tank. At 73 seconds into the flight, the booster struck *Challenger*'s right wing and then struck the fuel tank. The tank exploded. The shuttle was at an altitude of 14.6 km (9 miles) and travelling at about Mach 2 when the explosion occurred. The explosion may have killed the crew members; the crew module separated from the rocket during the explosion and was in free fall for 2 minutes 45 seconds. It hit the ocean at a speed of about 320 km/h. There were no survivors. Fragments of the shuttle continued to rain down on the rescue team for about an hour after the explosion.[12]

The *Challenger* explosion caused the first deaths of American astronauts during a mission (although there had been three deaths in a ground test for the first Apollo mission and three Soviet deaths when parachutes failed to deploy at the end of the first Soyuz mission). The *Challenger* disaster was a serious setback for the U.S. space program.

INVESTIGATION

American President Ronald Reagan convened a commission to investigate the *Challenger* explosion. The investigation involved more than 6,000 people and, in a 256-page report published in June 1986, the commission traced the *Challenger* explosion to failure of a rubber O-ring seal between sections of a rocket booster.[13] Hot gas from the rocket motor escaped past the O-ring (and past a secondary O-ring intended to double the factor of safety). The leak generated a lateral thrust that eventually broke a supporting strut. The strut failure permitted the booster rocket to swivel, puncturing the central hydrogen fuel tank and causing the hydrogen fuel to explode.

The investigators also learned that engineers had tried to delay the launch because they were uncertain how the O-ring seals would perform in such cold weather. The investigation then focused on NASA's management style; the commission concluded that the *Challenger* launch decision was flawed.

THE O-RING PROBLEM

When rockets fire, they create enormous stress in the rocket casing. The joint between the rocket sections distorts, and the gap between the sections widens under this stress. The O-rings keep the joint sealed, preventing the hot gas from escaping. The O-rings are compressed in a groove but must be resilient enough to "spring back" to fill the gap and keep the joint sealed as it widens due to joint stress. The temperature is important, because low temperatures increase the hardness of the O-rings and decrease resilience.

Roger Boisjoly was the Morton-Thiokol engineer most familiar with the O-ring design. He had conducted temperature tests on O-rings, and as early as July 31, 1985, he had recommended in writing that the problem of O-ring erosion (burned by hot gas) be studied. Furthermore, he had warned that failure to "solve the problem with the field joint" could result in loss of a shuttle, probably on the launch pad.[14] He was authorized to set up an O-ring team, and in October 1985 he sought advice from 130 vendors and other seal experts. However, no help was forthcoming from these sources.[15]

THE EVENING TELECONFERENCE—BOISJOLY IS OVERRULED

The evening before the launch, weather forecasters predicted that the launch site temperature would drop to 20°F (–6°C) overnight. NASA engineering managers, worried about the effect of this unusually low temperature on the rocket boosters, held a late-night teleconference involving 34 people. Engineers and managers from Morton-Thiokol (the manufacturers of the rocket boosters) explained their concerns to the NASA managers at the launch site. This critical evening conference is described in a definitive book, *The Challenger Launch Decision*, written a decade after the tragedy.[16]

The teleconference focused on the O-ring seals in the rocket. Boisjoly stated that no previous shuttle had launched at temperatures below 53°F (12°C) and that the rocket boosters recovered from that flight showed extensive damage to the primary O-ring, indicating that the O-ring failed to seal properly. Fortunately, the joint has two O-rings, and the secondary O-ring contained the hot gas. Oddly, Boisjoly's data also included anomalous results from a launch where the primary O-ring failed at a higher temperature of 73°F (23°C).

The engineering managers at Morton-Thiokol then advised NASA's launch staff that, since the low temperature could cause failure of both O-rings, they recommended delaying the launch until the ambient temperature reached at least 53°F (12°C).

At NASA, Lawrence Mulloy, an engineering manager at the next level (of a four-level launch approval protocol), questioned the recommendation to delay the launch. Mulloy pointed out the discrepancy in the data presented by Boisjoly from the previous boosters. One O-ring failed during a fairly low-temperature launch (53°F), but another failed during a fairly high-temperature launch (73°F). This problem might indicate that temperature is not the key factor in the joint failure. The Morton-Thiokol group asked for a brief delay so that they could discuss the question among themselves.

In the closed discussion with Morton-Thiokol engineers and managers, Boisjoly and the other engineers remained convinced that, in spite of the apparent discrepancy in the data, the cold temperature would seriously affect the O-ring performance. However, they could not explain the discrepancy. Their knowledge of O-ring performance at low temperatures was obviously inadequate. At this point, Morton-Thiokol's vice-president, Joe Kilminster, intervened to prepare the formal recommendation to NASA. After some prodding, the four Morton-Thiokol engineering managers agreed to reverse their initial recommendation and approve the launch, effectively overruling Boisjoly. The teleconference with NASA resumed; Kilminster announced the change in opinion and recommended that the shuttle launch go ahead. The shuttle launched the next morning at 11:38 and exploded 73 seconds later.

DISCUSSION OF THE ETHICS

In the aftermath of the explosion, there was plenty of blame to go around. Boisjoly was appointed to the investigation team and was initially involved in redesigning the seal. He provided information freely to the President's commission, which led to severe friction with his colleagues and superiors. Eventually, he began to feel isolated. He drifted out of contact with his colleagues—especially the NASA management—and finally resigned. In 1987, he filed lawsuits against Morton-Thiokol and NASA for personal damages.

Boisjoly was seen as an ethical whistle-blower—his recommendation to delay the launch had been overruled. One unanswered question is whether he could have done more to obtain cold-temperature O-ring data and present a more convincing case for launch delay at the crucial late-evening teleconference. Boisjoly insists that he made the proper ethical choices during his engineering career, often at the risk of his job. In 1988, he received the American Association for the Advancement of Science (AAAS) award for Scientific Freedom and Responsibility for his efforts to act ethically in the events leading to the *Challenger* shuttle disaster.[17]

The key decision to overrule the recommendations of the engineers, made by Kilminster on the eve of the launch, was clearly an ethical and management error. The engineering managers were under intense pressure to meet schedules driven by political and financial priorities, with a space shuttle that was still experimental, and not a tested, proven vehicle. The pressure changed the basic management philosophy from "launch only when engineers can prove it is safe to do so," to "launch unless engineers can prove it is unsafe to do so." It took years for NASA to redesign and recertify the rocket boosters and to get the space shuttle flying again.

THE *COLUMBIA* DISASTER

On February 1, 2003, a second shuttle disaster happened: the *Columbia* broke up on re-entry from orbit. This disaster took place at a very high altitude, and observers on the ground saw the debris as several bright meteors streaking across the sky. Seven crew members died. An accident investigation board was convened. After intensive investigations, the board issued its final report on August 26, 2003.[18]

In simple terms, this second disaster happened because a piece of insulating foam broke away from the fuel tanks and struck the wing of the shuttle. The damage went unnoticed during flight, but the heat of re-entry was able to penetrate the left wing, weakening the internal structure. The shuttle disintegrated, and the pieces that did not burn at high altitude fell to the ground in a swath 1,000 km (600 miles) long. The disaster was a pointed reminder that the space shuttle is not a tested airliner, but a vehicle still under development.

The U.S. shuttle program was again put "on hold" to review safety philosophy. In July 2005, shuttle launches resumed with *Discovery*. Unfortunately, foam insulation again struck the shuttle during launch. The shuttle's Canadarm, however, had been equipped with a 15 m (49 ft.) Canadian-made Orbiter Boom, permitting astronauts to inspect the heat shield on the underside of the shuttle. Minor damage was found, so repairs were made during a spacewalk. Although *Discovery* returned safely, NASA shut down the shuttle program for another year to redesign the insulation and eliminate foam strikes. The shuttles went back into space in 2006 and completed their allotted missions. The U.S. shuttle fleet retired from service in 2011; three decommissioned shuttles, *Atlantis*, *Discovery*, and *Endeavour*, are on display in science centres. The Russian *Soyuz* rocket now provides logistics support to the International Space Station (ISS).

DISCUSSION TOPICS AND ASSIGNMENTS

1. A professional employee (engineer or geoscientist) is assigned to purchase computer hardware and software for a new design office to house 10 designers, engineers, and geoscientists. The professional calls for tenders and competitive tests for the software but purchases the hardware from a local supplier, without competition. The hardware price is high but not outrageous. The employer does not know that the supplier is the professional's cousin. Does the professional have a conflict of interest? If so, is it an actual, potential, or perceived conflict? What does your provincial Code of Ethics say about conflicts of interest? Does this conflict expose the professional to any penalty?
2. Would any of the following tasks be unacceptable according to your conscience? That is, if the employer asked you to participate in designing the following equipment or machinery, which (if any) would you refuse on ethical grounds? Explain your reasons, briefly.

    - Bottling equipment for the beer and liquor industry
    - Medical equipment to make abortions safer and more convenient
    - Pill-making machines for the birth control or pharmaceutical industries
    - Security locks for the prison system
    - Equipment or electronics for nuclear power plants
    - Roulette wheels for casinos
    - Rifles or handguns for the Canadian Armed Forces
    - Rifles and handguns for hunters and private use
    - Printing equipment for lottery tickets

3. You are working as a professional (engineer or geoscientist) in a small consulting company that gives its professional employees considerable latitude in scheduling tasks, meeting deadlines, and reporting expenses. The company president contacts you and states that senior management has recognized your professional attitude and attention to high standards. The president also expresses concern about the lax attitudes of your colleagues, who seem to be abusing the freedom extended to them. Discuss, explain, and justify whether it would it be ethical for the president to offer, and for you to accept any of the following:
   - a secret assignment to monitor the behaviour of your colleagues and your immediate superior and report back to the president
   - a promotion to technical vice-president to replace your immediate superior on the basis that the current technical vice-president is not competent as a manager and should be replaced

Additional assignments and case studies are in provided Web Appendixes E and F.

NOTES

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[14] R.M. Boisjoly, interoffice memo to R.K. Lund, vice-president, Engineering, Wasatch Division, Morton Thiokol, July 31, 1985, in *The Challenger Launch Decision by* Diane Vaughan (Chicago, IL: University of Chicago Press, 1996), 447. Also in *Roger Boisjoly—The Challenger Disaster*, Online Ethics Center for Engineering & Science, www.onlineethics.org/cms/7123.aspx (accessed June 20, 2017).
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[16] Diane Vaughan, *The Challenger Launch Decision* (Chicago, IL: University of Chicago Press, 1996).
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Chapter 11
Ethics Concepts and Cases: Management

According to statistics, most professional engineers and scientists become technical managers during their careers. Promotion to management means more salary and authority, but it also means more responsibility—when problems arise, the manager must solve them. As a role model, the manager must show decisive, ethical leadership. This chapter discusses some of the ethical issues faced by managers, particularly when hiring professionals, reviewing their work, and, where necessary, dismissing them. Six case studies illustrate practical ethical problems. The chapter ends with a brief case history of the collapse of the Vancouver Second Narrows Bridge, which shows that negligent professional practice can lead to tragedy.

11.1 CREATING A PROFESSIONAL WORKPLACE

As a manager, you want to lead a competent, motivated staff in working on creative projects. You are responsible for hiring, firing, planning, scheduling, budgets, fair pay, and good working conditions, as well as setting priorities, solving problems, and building morale. In return, your staff must work toward achieving the company's goals, maintain and improve their competence, and support your decisions. To assemble a competent technical team, proper licensing is an essential first step.

Professionals Must Be Licensed

As explained in Chapter 2, every province and territory restricts the practices of engineering and geoscience to licensed professionals. Confusion sometimes arises because Canadian law differs from U.S. law—unlicensed professionals are allowed to practise in the United States, providing they do not use professional titles. The law is stricter in Canada. An unlicensed person cannot use a professional title, cannot practise engineering or geoscience, and, of course, cannot approve or seal engineering or geoscience documents in Canada. Doing any of these things is an offence punishable under the Act. Managers must rectify such situations by tactfully encouraging each unlicensed "professional" employee to obtain a licence; otherwise, a licensed professional must monitor the employee's technical decisions.

Professional Titles Must Be Accurate

Many companies have positions with the word "engineer" or "geoscientist" in the title, such as "Project Engineer" or "Chief Geoscientist." These titles imply that the person is a licensed professional; if that is not true, the manager must insist on accurate titles. An unlicensed person cannot use a professional title, even if the person performs tasks that do not require a licence. Assigning a new job title is usually simple; managers must insist, tactfully, on accuracy.

A manager who permits an unlicensed employee to practise engineering or geoscience, or permits an employee to use a misleading engineering or geoscience title, might be "contributing to illegal practice," which is contrary to the Act.

11.2 HIRING AND DISMISSAL

The manager usually hires and dismisses technical staff and should therefore be familiar with provincial regulations for hiring and dismissal. Some key points follow.

Employment Contracts and Policies

The best method for employing professional engineers is through clear-cut employment contracts that specify duties, contract duration (either fixed length or indefinite), remuneration, pay raises, vacation entitlements, statutory holidays, and so forth. Some contracts even include definitions of just cause (reasons) for termination, along with terms and amounts of severance pay.

A large company, however, may have too many professional employees to negotiate personal contracts. In this case, the company management should establish and publish employment policies. The professional should receive a letter of appointment that refers to these policies. Of course, policies must be fair, and the employer must negotiate and administer them fairly. Otherwise, employees may be demoralized and/or resort to labour action, such as unionization. The NSPE *Guidelines to Employment for Professional Engineers* (discussed in Chapter 10 and reproduced in Web Appendix D) describe topics that should be included in professional employment policies.

Terminating Employment for Just Cause

A manager is responsible for terminating or discharging employees when their services are no longer required. Termination procedures must adhere to the employment contract or company policies. In addition, employees may be discharged for *just cause*, which is defined as a "fundamental breach of the employment contract, justifying termination."[1]

Issues that would allow an employer to terminate an employee, without notice or severance pay, are as follows:

1. Serious misconduct;
2. Habitual neglect of duty;
3. Serious incompetence, not just management dissatisfaction with performance;
4. Conduct incompatible with his or her duties, or prejudicial to the company's business;
5. Wilful disobedience to a lawful and reasonable order of a superior, in a matter of substance;
6. Theft, fraud, or dishonesty;
7. Continual insolence and insubordination;
8. Excessive absenteeism, despite corrective counselling;
9. Permanent illness; and
10. Inadequate job performance over an extended period because of drug or alcohol abuse, and failure to accept or respond to the company's attempt to rehabilitate.

If one of these elements of misconduct exists and is ascertained (discovered) even after the employee has been discharged, the company can rely on that misconduct and not pay the employee any severance allowance.*

Wrongful Dismissal

An arbitrary dismissal may be *wrongful*, if the reason is not just cause, as defined above. Wrongful dismissal cases sometimes end up in the courts, so both the employee and the manager may need legal advice. In a comprehensive article on wrongful dismissal, lawyer Howard Levitt described six situations that could be considered wrongful dismissal, even if technically the employee was not dismissed:

- Forced resignation;
- Demotion;
- A downward change in reporting function;
- A unilateral change in responsibilities;
- A forced transfer; and
- Serious misconduct of the employer toward the employee.[2]

In summary, managers must be alert when supervising others. Knowledge of the law (or access to legal advice) is very useful—but get advice *before* making hard decisions.

11.3 REVIEWING WORK AND EVALUATING COMPETENCE

The law requires professionals, whether they are employees or managers, to practise only within their limits of competence. Professional employees should

* Howard A. Levitt, "The Law of Dismissal in Canada," as quoted in *CSPEAKER* [Canadian Society of Professional Engineers (CSPE)] (September 1981): 1–4. Reprinted with permission of Howard A. Levitt.

not undertake—and managers should not assign—work that is not within the individual's competence.

Reviewing Work for Accuracy

Engineers and geoscientists never base key decisions on a single, unchecked calculation. Important analyses or calculations are always double-checked for errors. Professionals expect this routine review, because errors could be extremely costly. For example, structural design, aerospace, and nuclear industries have standard procedures for double-checking all calculations and the decisions resulting from them.

This routine check greatly increases the accuracy of the work, improves confidence and safety, and lowers the risk of failure and liability. The person who performed the original calculations is always informed prior to the review, given the opportunity to clarify any doubtful points, and shown the results.

Reviewing Work to Assess Performance

It is common practice for the manager to evaluate the performance of all employees annually. The manager must discuss the annual review with each employee, and the employee should be given an opportunity to challenge or explain an unsatisfactory assessment and to include these comments with the manager's evaluation. Additional performance reviews may be necessary if performance is unsatisfactory.

However, a manager should never ask a professional to review secretly the work of another professional. This courtesy is required by most Codes of Ethics and should apply to any professional employee. A secret review is like a trial in absentia, something contrary to natural justice. Professional work is based on specialized knowledge, and the person who checks it must be able to understand the opinions and conclusions expressed. A careless review could inadvertently damage someone's professional reputation, a valuable asset created through years of study and experience.

In summary, professionals should expect frequent reviews of their work for accuracy and an annual review for performance; however, secret reviews of one employee's work by another employee contravene the Code of Ethics. This rule does not apply, of course, when the professional resigns, and the manager reassigns duties. Obviously, a new employee must review the departing employee's work for continuity.

Maintaining Competence

All licensing Acts specifically require professional engineers and geoscientists to maintain competence, as explained in Chapter 17, but managers have a duty to encourage and assist the professional. The employee must show initiative, but the manager must support it.

For example, when a company takes on a new project or installs new software, professional employees must upgrade their skills and knowledge. The manager should arrange orientation, courses, or workshops to assist employees to learn the new skills. Doing so is a win–win arrangement for employee and employer.

When a professional fails to keep skills up-to-date, drifts into incompetence, and refuses to exert the effort to become more effective, the manager must make a difficult decision. An incompetent professional should not be practising; in fact, every licensing Act cites incompetence as a basis for removing a licence. Dismissal may be necessary, but the task of the manager, as in any problem-solving exercise, is to gather information, generate alternatives, examine those alternatives, and seek the optimum course of action. The outcome will depend on the facts of the individual case, but the manager must deal with the professional employee fairly and ethically.

11.4 CONFLICT OF INTEREST IN MANAGEMENT

Chapter 10 gives a detailed overview of conflict of interest and lists seven common forms of conflict (or "abuse of privilege"). Managers must set an example by avoiding conflicts of interest and should establish clear policies for employees.

- **Policy on unsolicited gifts:** Some companies have a strict policy that employees cannot accept any gifts or benefits (meals, entertainment, or travel) from clients, suppliers, or colleagues. This is simple, easily understood, and easily applied. Other companies set a limit for the value of a gift, such as $50, but this limit is subjective—the value may be unknown. Accepting even a small gift may be construed as a conflict of interest.
- **Disclosing conflicts of interest:** All employees must disclose conflicts of interest; requiring this should be a company policy. Every Code of Ethics cites failing to disclose a serious conflict of interest as unprofessional conduct (or has equivalent wording about integrity or honesty).

11.5 DISCRIMINATION IN PROFESSIONAL EMPLOYMENT

The manager plays a key role in hiring professionals, evaluating their performance, promoting them, and (when necessary) dismissing them. In Canada, the Charter of Rights and Freedoms prohibits discrimination. Hiring must be based on merit, promotion must be based on performance, and dismissal must be for just cause (or follow contract terms).

Although discrimination is not common in Canada, certain groups, such as women, Aboriginal peoples, and people with disabilities, are still underrepresented in engineering and geoscience. The problem is especially obvious where women are concerned—they are a slight majority in the general population, but definitely a minority in our professions.

These groups have a legal right to fairness. They do not expect preferential treatment, but artificial obstacles should not be put before them. (Chapter 8, "Diversity in the Professional Workplace," studies discrimination in detail.)

CASE STUDY 11.1

HIRING AN UNLICENSED PROFESSIONAL

STATEMENT OF THE PROBLEM

Assume that you are the technical manager of a large oil and gas consulting firm. As part of your job, you hire and dismiss department staff, including geoscientists, engineers, computer technicians, and clerical workers. Six months ago, you hired Jorge Xavier, who recently moved from another province. During the employment interview, he said he was licensed, and your letter of appointment stipulated that he must be "licensed as a professional geoscientist, or eligible for licensing, and experienced in well-logging." After Xavier started work, you had a sign placed on his door and had business cards printed for him, both of which bore the "P.Geo." designation after his name.

You are startled to receive a complaint from a client who claims that Xavier is not a licensed professional. The client is furious that you and your company would send unqualified people to work on her project. You contact the provincial Association, which confirms that Xavier does not hold a licence. Now, *you* are furious.

QUESTIONS

Who is responsible for this problem? Can you fire Xavier for just cause? Would it make any difference if

- *Xavier is licensed in another province, but neglected to apply for a licence in your province?*
- *Xavier is licensed in another province and has applied for a licence in your province, but the provincial Association is still processing the licence?*
- *Xavier has never been licensed in any province?*

AUTHORS' SUGGESTED SOLUTION

This case involves a breach of a professional Act. A professional licence is valid only for the province in which it was issued, but a licence can easily be obtained in the new location. When you move to a different province or territory, you merely submit a licence application to the Association in that jurisdiction. The process is routine, and a new licence is usually issued without additional licensing conditions.

There is little doubt that Xavier is guilty of practising professional geoscience without a licence. He used the business cards that clearly say "P.Geo." without protest or correction, and he is not licensed in the province in which he is working. Consequently, he is committing an infraction of the Act. If you allow Xavier to continue to practise, you will be guilty of assisting illegal practice—a breach of the Code of Ethics.

It is critical that you determine what work Xavier performed during his first months with the firm. If Xavier had a probationary position and was supervised by another geoscientist (which is the usual case), then the risk to the client or to the public may be small. Damages may be limited to embarrassment and over-billing of fees.

If, however, Xavier has been making independent decisions on well-logging work, then your firm would be liable for any problems that arise from those decisions. You must review the work that Xavier has done and discuss this liability problem with the company lawyer. You may also have some liability as manager, since you are responsible for verifying the qualifications of those who work for you.

As to whether you should dismiss Xavier, and the grounds for that dismissal, it depends on which situation applies:

- If Xavier failed to apply for a licence after six months of employment (even if he has a valid licence from another province), then this negligence is a serious misconduct, which is just cause for dismissal.
- If Xavier has applied for a licence but the application is still being processed, and if he has a valid licence from another province, then he has probably complied with your requirements. He should have informed you of the delay, but dismissal would probably be unfair.
- If Xavier has never been licensed in another province, and if he has been unwilling (or unable) to obtain a licence in your province, then he is dishonest (or unqualified). Either case would be just cause for dismissal.

Xavier contravened the Act when he used the “P.Geo.” title without a valid licence. Therefore, he may also be subject to a charge under the Act even if he has a licence from another province. The provincial Association would decide whether to charge him in the provincial court.

As manager, you have some responsibility for any liability that the firm suffers. You stated the requirement for a licence clearly, but you did not follow up to verify that Xavier had a valid licence. A company that offers professional services to the public has a duty to verify that all licences are up-to-date.

CASE STUDY 11.2

CONCEALING A CONFLICT OF INTEREST

STATEMENT OF THE PROBLEM

Assume that you are an engineering manager in a large automotive parts manufacturing company. You also serve as a member of a standards committee for automotive equipment. The committee consists of 10 people: 3 industry representatives (including you), 3 government representatives, and 3 engineering professors. The chair is a staff member from a technical society.

During the meeting, Mr. X, an industry representative, proposes a change to the standard for an automotive component. The change would improve the quality slightly, but it requires special manufacturing equipment. Your company manufactures this component, and you realize that if the change were adopted, your company would benefit greatly. Your company has a patented process for making the component, and it could easily be adapted for this change. However, competing companies would suffer, since they would have to develop new technology or license yours.

You believe that Mr. X's company would have the same advantage, since his company has a different patented process that yields the same result. You are uncertain whether you should mention this to the committee. You did not propose this change, but it would improve the automotive component slightly, and your company would benefit immensely.

QUESTIONS

Is this a conflict of interest? Do you have an ethical obligation to inform the committee that your company will benefit from this change? Do you have an obligation to point out that Mr. X (who proposed the change) may also benefit?

AUTHORS' SUGGESTED SOLUTION

You have a clear conflict of interest, which you must disclose to the committee. The Code of Ethics requires a professional to place the welfare of society above narrow personal interest. The main function of a standards committee is to serve the public welfare, not the financial interests of its members. After you disclose your conflict of interest, it might be acceptable for you to answer questions and express your opinion of the change; however, you definitely should not participate in the formal vote on changing the standard.

Mr. X (who proposed the change) has a similar obligation to disclose that he has a conflict of interest. Your disclosure would likely encourage him to do so. If not, his silence might be an unethical attempt to benefit from this conflict of interest. You should not accuse him of this without more evidence, but you could ask if any other members of the committee have a similar conflict of interest.

Conflicts of interest are common on standards committees for the simple reason that the best-informed people are those involved in the design and manufacture of the components concerned. However, conflicts of interest must be disclosed; it is unethical to tolerate abuse of such positions of trust.

CASE STUDY 11.3

CHALLENGING CLIENT AUTHORITY

STATEMENT OF THE PROBLEM

Assume that you are the engineering manager for Acme Mechanical, which designs, fabricates, and assembles machinery. During a slow period, Acme bids on, and wins, a subcontract to manufacture and install three large gearboxes designed by Delta Leisure, a company that usually designs and builds carnival rides. The gearboxes will drive ski lifts in a new winter recreation complex under construction in the Canadian Rockies. The lift towers are already in place, awaiting the cables and drive-gear. Your subcontract is to manufacture and install the gears, shafts, housings, and a braking mechanism on each gearbox; Delta will install a driving motor on each lift, string the cables, and install passenger gondolas.

Your engineers review Delta's detail and assembly drawings and notice several apparent errors. The shaft and gear sizes on Delta's drawings seem too small for the high torque ratings of the gearboxes, and the drawings do not cite either the ISO or AGMA codes for gear strength. In addition, the braking systems do not appear to have enough brake capacity as required by the Canadian Standards Association (CSA) standards for ski lifts and conveyors. Drawings show that each ski lift has a brake on the motor shaft, but they do not show any "rollback" brakes. These rollback brakes are not part of your contract, but they affect ski lift safety.

You call the chief engineer at Delta to arrange a meeting to discuss the design but he says, rather rudely, that he is too busy to double-check drawings. He has confidence in his designers and tells you to "get on with the job." He points out that you are not the designer; the rollback brakes are not your responsibility, and you should not be reviewing his work.

QUESTIONS

Is your check of Delta's design an unethical review (as discussed earlier in this chapter)? The rollback brakes are not in your subcontract, but they affect safety. Are you justified in asking about them? Delta's chief engineer told you to "get on with the job." Does this mean that you have been overruled (as discussed in Chapter 10)? If you still want to investigate the apparent design errors, how would you approach the chief engineer at Delta? What alternatives do you have if he does not respond?

AUTHORS' SUGGESTED SOLUTION

A free exchange of information is essential for successful collaboration. Your design review is clearly to protect the public (and indirectly, the client, Delta), so it is not a secret review and does not violate the Code of Ethics.

As every Code of Ethics states, public safety is most important. Therefore, Delta must not overrule Acme by instructing work to proceed without responding to safety concerns. Ski lifts usually have a service brake on the shaft between the motor and the gearbox to stop movement. If the gearbox fails, however, the service brake is ineffective, and the ski lift will roll backwards unless anti-rollback brakes are applied.

In other words, the weight of skiers can make the ski lift run in reverse, pick up speed, and throw skiers off, causing injury or death. (Runaway rollback cases occur somewhere in North America, almost every winter.)

To prevent rollback, ski lift standards require redundant (extra) braking systems. They are not in Acme's subcontract, but they directly affect ski lift safety. If a gearbox fails, and the rollback brakes do not work when needed, Acme might be liable (at least partly) for the damage, so Acme is justified in asking for details.

In the Delta design, shaft and gear sizes are questionable, and braking does not appear to be sufficiently redundant. This is the perfect combination for a runaway rollback scenario, so engineers have valid concerns. You must not "get on with the job" if you believe you are building unsafe machinery.

You must follow up your telephone call to Delta with a letter or email explaining your concerns about strength and safety in more detail. In spite of his initial curtness, the chief engineer at Delta should welcome your advice, check the drawings, correct any errors (or explain any misunderstandings), and thank you for avoiding an unsafe design.

In the unlikely event that Delta refuses to investigate these safety problems, you would discuss the contract with your senior management and legal advisers. Such a negative attitude for safety implies that the contract might be risky. Acme might be better off breaching (declining) the contract. Since the problem involves the Code of Ethics, in most provinces you could also call your Association for confidential advice on how to proceed.

The first author of this book was aware of an actual case involving similar principles (although all other details differ). In that case, "Acme" was overruled and built machinery following "Delta's" drawings. The machines failed during the first year in service. Millions of dollars were lost in damages and lawsuits. "Delta" later closed its office in Canada.

In addition, several well-known cases illustrate that secrecy over dangerous design faults can lead to tragedy. In these cases, challenging authority (or whistle-blowing) would have saved lives. For example:

- **Ford Pinto:** The Ford Pinto, built in the 1970s, was prone to gas-tank rupture when the vehicle was hit from behind. A design modification to prevent the rupture (and the fire that often ensued) would have cost only about US$11 per vehicle. An engineer resigned from Ford in protest and disclosed the faulty design.[3]
- **DC-10 cargo door latch:** Convair had a subcontract for the design of the cargo door on the DC-10 passenger airplane. The door latch failed during a cabin pressurization test, and a senior engineer wrote a memo to the management at Convair, itemizing the dangers in the design. Convair managers kept the information confidential, even though a cargo door blew out in flight over Windsor in 1972. The information was revealed only after a DC-10 crash at Orly Field in Paris killed 346 people in 1974.[4]

In serious cases such as these, the duty to public safety must take priority over the duty to an employer, client, or colleague.

CASE STUDY 11.4

DISCLOSING PRELIMINARY MINING DATA

STATEMENT OF THE PROBLEM

Assume that you are a professional geoscientist responsible for all the ore assays in a mine. You report directly to the mine's chief executive officer (CEO), who is an accountant by training. You are presently evaluating ore assays for a newly opened part of the mine. These show much lower ore content than expected. The CEO is very disappointed at the news. You reassure him that the results are preliminary and that complete results will be available in a week or so. The CEO had hoped to give good news to shareholders at a meeting to be held in the next few days. The CEO tells you to keep the results confidential and not to report or discuss them—not even with the company's employees—until after the shareholders' meeting.

QUESTIONS

Does the CEO have the right to overrule the professional geoscientist over the release of this information? Should the geoscientist release "preliminary data"? Is it ethical to hide this information from the shareholders, who are the owners of the company?

AUTHORS' SUGGESTED SOLUTION

This question is important, as it illustrates the difference between *management* authority and *technical* authority. It also illustrates corporate management structure.

The shareholders are indeed the owners of the corporation, but they do not run it. The shareholders elect a board of directors. In turn, the board appoints the officers of the company—the president, CEO, treasurer, and so on—and these people are responsible for the company's day-to-day operations. They have management authority; employees, including the geoscientist, take direction from these company officers.

In the mining, oil, and gas industries, geological data are extremely sensitive information and can be the basis for important financial decisions. Unauthorized disclosures can lead to abusive stock market tactics. Most boards authorize only the CEO to issue public statements.

In addition, all public disclosures from mineral companies must follow the strict guidelines set out by the Canadian Securities Administrators (CSA). The CSA guidelines were introduced after the Bre-X mining fraud (discussed in Chapter 2). Every geoscientist involved in preparing mineral studies should be familiar with the CSA guidelines, which regulate all public statements relating to mineral projects, whether oral or written (including news releases, prospectuses, and annual reports). All disclosures must be based on a technical report prepared by a "qualified person" (as defined in the document and in Chapter 2), and the report must adhere to a set format.[5] In summary, the CEO has the management authority to decide when to release a geological report, but the geoscientist, as a "qualified person," has the technical authority and responsibility to ensure that the report is accurate, complete, and following the CSA format.

CASE STUDY 11.5

MANAGEMENT ACCOUNTABILITY*

STATEMENT OF THE PROBLEM

Edward Eager, P.Eng., is a licensed chemical engineer in a well-known specialty chemicals company. The company makes cosmetics at several plants in Canada and also refines raw pharmaceutical materials for processing in the United States. U.S. plants compete with Canadian plants for North American production mandates.

Eager started out five years ago in a junior production position, reporting to the production supervisor Cam Complacent, P.Eng. When Eager started at the Canadian plant, it was highly successful. Over the five years of his employment, however, the plant has become steadily less competitive relative to other firms and its sister plants in the United States. When Complacent retired recently, Eager was promoted to fill his job.

Eager passed his Professional Practice Exam while working at the company, and he is aware of the importance of professional ethics in engineering. Over the past five years, he has noticed several unusual practices and events in the plant and the office. For example, supplies often run out before forecast, inventory is invariably balanced by assuming losses, and there are frequent shortages in customer shipments. In the human resources area, he has noticed a tendency to "horseplay" on the graveyard shift, as well as instances of (what he considers) racial and sexual harassment. Also, procedures for recording the hours that employees work are casual, and overtime is high.

These discrepancies disturbed him, and Eager had approached his boss, Cam Complacent, about them several times. Each time, Complacent dismissed Eager's concerns and said being "easy" on these subjects helped keep morale and productivity up. Although Eager was personally convinced that some employees were cheating their employer by taking products home and misrepresenting their hours of work, as a junior employee he decided to take his manager's advice to keep quiet.

* Case Study 11.5 is adapted from James G. Ridler, P.Eng., "Accountability: At the Core of Professional Engineering," *Engineering Dimensions* 18, no. 1 (January–February 1997): 40–41. Used with permission of PEO.

Shortly after he replaced Complacent as supervisor, however, Eager learned early one Monday morning that there had been a major theft at the plant on the weekend. A truck had pulled up to the warehouse without being challenged, loaded up, and disappeared. Fortunately, the police soon caught the two thieves, who turned out to be employees, one of them a relative of a senior employee. Indeed, the police soon found that a network of employees was involved. They now want to interview Eager about further investigations.

Meanwhile, Eager has just received a fax from the company's vice-president for North American manufacturing, who wants to investigate why the Toronto plant's costs have been so high and why productivity has been so low relative to the company's other plants. The fax concludes: "Understand major theft has occurred. Will be in Toronto tomorrow to review your situation." The future of Eager and his plant looks grim.

QUESTIONS

Should Eager be held accountable for the employees' actions? Is Eager subject to dismissal or disciplinary action by his employer? Is Eager subject to any disciplinary action by his licensing Association? Does his predecessor (Cam Complacent) have any responsibility in this case? What could Eager have done to avoid this situation?

AUTHORS' SUGGESTED SOLUTION

As a middle manager and a professional engineer, Eager is accountable to his superiors and to his profession, because he allowed a dishonest environment to flourish. Although he was not involved in the theft, he may be subject to demotion or dismissal for habitual neglect of duty, which is just cause (as discussed earlier in this chapter).

In addition, if the employer complains to the provincial Association, it is plausible that he could be reprimanded for negligence. As a professional engineer, Eager had a duty under the provincial Code of Ethics to act with devotion to high ideals of personal honour and professional integrity. He also had a duty to expose, before the proper tribunals, unprofessional or unethical conduct. His predecessor is partly responsible for this situation, and there are mitigating circumstances in this case (e.g., Eager's relative inexperience and his employer's lack of an ethics program). However, Eager will bear most or all of the blame. He has learned that accountability is important and that there are no "small" ethical problems.

In hindsight, Eager now knows that ignoring the problems at his plant was wrong. He should have explained to his supervisor, Cam Complacent, that, as professional engineers, they had a duty to manage the employer's factory properly. He should have insisted that, together, they discuss the subject with senior management. Eager should have put his concerns in writing. As a last resort, Eager should have spoken directly to senior management or obtained confidential advice from the provincial Association.

CASE STUDY 11.6

CONDONING PLAGIARISM

STATEMENT OF THE PROBLEM

Oliver T. is an engineering student in the last week of his co-op summer work term at a large manufacturing company. Oliver has enjoyed the job, worked hard, learned much, and been well paid. He is on very good personal terms with his boss, who is a licensed professional engineer. The boss will likely give Oliver an excellent work evaluation, and a job offer may appear if Oliver gets good marks in his final term.

However, Oliver must write a work report describing a professional project he undertook during his work term. The report is due when he returns to university next week. A professor marks the report according to university standards and records the grade. Oliver's graduation may be delayed if the report is late or unsatisfactory. (Work reports are routine requirements in professional programs at most Canadian universities.)

Oliver had several interesting jobs that were suitable report topics, but he was "too busy" to write anything down. He is beginning to worry—he has no plausible excuse for failing to write a report.

Oliver mentions his problem to his boss. Surprisingly, the boss suggests that Oliver could save a lot of time by simply submitting an older work report as his own. The boss has a file cabinet containing copies of work reports written by former work-term students. Most of the reports are also stored on computer hard drives and DVDs.

QUESTIONS

Since his boss suggested it and obviously approves, should Oliver "recycle" a work report written by a former student and submit it as his own? If he does so, what penalties (if any) does he face? Is Oliver's boss guilty of any unethical action?

AUTHORS' SUGGESTED SOLUTION

A person who submits a report written by someone else is committing copyright theft—that is, plagiarism. Every Code of Ethics or ethical theory condemns plagiarism as unethical, either directly or indirectly. (In common parlance, this case is an ethical "no-brainer.") Obviously, Oliver should resist the temptation to submit a plagiarized work report, get busy, and use the remaining week to write his report.

We all share the duty to prevent plagiarism, yet plagiarism has increased dramatically in the past decade. Plagiarism is dishonest and illegal; it undermines the educational process and cheapens university degrees. It is particularly harmful in co-operative (work/study) programs. Co-op employment is not just a job. Co-op integrates work experience with academic study, and the work report tests this integration.

The power of the Internet makes plagiarism tempting, and some websites have even turned plagiarism into a business. A recent survey showed over 250 Internet "paper mills" engaged in reproducing essays, term papers, and reports. Of course, the Internet also provides tools for detecting plagiarism. Universities have these tools and apply severe penalties to those found guilty.

The consequences for plagiarism are strict and are typically as follows:

- **Academic penalties:** Plagiarism is a serious academic offence; it usually results in suspension for a first offence and expulsion for a second offence. Both suspensions and expulsions are usually shown on grade transcripts. A suspension or expulsion will delay graduation far more than a late report.
- **Future recommendations:** Obviously, professors and co-op employers hesitate to recommend students for job openings or for graduate admission when the students have been suspended or expelled for plagiarism. Character references, needed to obtain a professional licence, may also be hard to get.

The fact that the boss offered to help Oliver to commit plagiarism would not lessen the penalties for Oliver; in fact, the boss has breached the Code of Ethics, so the Association might (and should) discipline the boss. In addition, the university could (and should) alert the boss's employer to this collusion. Finally, this is a breach of the co-op contract, so the university might not allow the employer to hire co-op students in future.

- **How to avoid plagiarism:** If your work includes any material (including sentences, photos, drawings, or figures) from any other source, cite the complete source—it is easy to do. Failure to cite sources is plagiarism. In particular, any material cut and pasted from websites must have a proper reference that cites the URL and the date. Authors are guilty of plagiarism if they submit reports containing Internet material that is not fully cited.
- **How to detect plagiarism:** Written material plagiarized from the Internet is easy to detect. A simple search on any search engine, using a phrase from the plagiarized report, will detect the source quickly. In addition, several websites provide plagiarism detection to professors for a nominal fee. A well-known service is *Turnitin*®, which boasts that over a million university professors use its facilities.[6] Many universities are also developing in-house plagiarism detection by scanning submitted reports to create a database for searching. Even one passage in a report is proof of plagiarism if the source is not cited.
- **Where to learn more:** Several excellent guides to avoid plagiarism can be found by a simple Internet search using "plagiarism" as the search term.

CASE HISTORY 11.1

THE VANCOUVER SECOND NARROWS BRIDGE COLLAPSE

The snowy tops of the mountains on the north shore of Vancouver's Burrard Inlet make an attractive background for the graceful arches of the Second Narrows Bridge (now re-named the "Ironworkers Memorial Second Narrows Crossing"). The beauty of the panorama belies the fact that the bridge was the scene of a terrible tragedy during its construction. On June 17, 1958, two spans of the Second Narrows Bridge collapsed while under construction. The falling steel killed 18 workers; in addition, a diver searching for bodies drowned a few days later. The catastrophe remains the worst industrial accident in British Columbia history. Author Eric Jamieson describes the tragedy in an award-winning book[7] that should be read by every structural engineer. This gripping story alerts us to a recurring danger: engineers rarely analyze temporary supports and scaffolds as thoroughly as the permanent structure.

BACKGROUND INFORMATION

The traffic congestion on the Lions Gate Bridge, which links Vancouver via Stanley Park to the north shore, stimulated public demand for an additional route across Burrard Inlet. The B.C. government of Premier W.A.C. Bennett considered several bridge proposals, including a causeway (first proposed in 1911). They chose to span Burrard Inlet with a cantilever bridge parallel to an aging lift bridge about 8 km east of the Lions Gate Bridge. The designer (engineer of record) was the firm of Swan, Wooster and Partners, Consulting Engineers; the contractors for the substructure (piles and concrete piers) were Peter Kiewit Sons Co. Ltd. and Raymond International Co. Ltd; and the contractor for fabricating and erecting the steel superstructure was the Dominion Bridge Company.[8]

The bridge is a cantilever design, with a basic structure similar to the Quebec Bridge. Four short bridge spans extend from the north shore and then a longer "anchor" span flares into a large, curved centre arch. The centre arch soars over the maritime traffic in Burrard Inlet to the "anchor" span on the south shore. The centre span is 335 m (1,100 ft.) between supports, somewhat shorter than the Quebec Bridge, the world's longest unsupported cantilever span, at 549 m.

Construction on the Second Narrows Bridge began in 1957, and the piles and concrete piers were completed ahead of schedule. The piers are numbered from 1 to 17. (The centre span is actually nearer to the south end, between piers 15 and 16.) Dominion Bridge then erected the steel superstructure on the piers, starting on the north shore; the first four short (simply supported) spans were erected without incident. Span 5, between piers 14 and 15, required two

Photo 11.1 — Vancouver Second Narrows Bridge Collapse. *Eighteen people were killed when failure of temporary construction supports caused two Vancouver Second Narrows Bridge spans to collapse on June 17, 1958. The bridge was rebuilt and opened in 1960, and later renamed the Ironworkers Memorial Second Narrows Crossing.*

Source: Vancouver Public Library Special Collections, 39999

temporary towers (called "falsework bents") to prop up the steel structure until it reached pier 15, when it would be self-supporting.

DESCRIPTION OF THE COLLAPSE

On June 17, the small Dominion Bridge diesel locomotive moved south on the overhanging portion of span 5, past pier 14, pulling a travelling crane and two small railway flatcars loaded with steel for installation. Before the crane could begin lifting the steel into place, the temporary tower supporting the south end of span 5 collapsed, plunging the steel, locomotive, cars, and 79 workers into Burrard Inlet, about 60 m below. As span 5 fell, it pulled pier 14 out of alignment, and the adjacent span 4 also fell. The falling steel crushed many workers, and several more were pinned underwater and drowned. The total number killed included 14 ironworkers, 3 engineers, and a painter. A few days later, a diver drowned in the tangle of steel while searching for bodies. Most of the workers who survived were injured; about 20 were seriously injured. People streamed down to the site to help, and boaters saved a few lives. The hospitals responded quickly, but the morgue filled to capacity. Within hours, the B.C. government moved to create a royal commission to determine the cause of the disaster.

THE ROYAL COMMISSION

The B.C. Attorney General appointed Chief Justice Sherwood Lett to lead the royal commission. Lett, in turn, appointed several internationally eminent engineers to sit on the commission and hired others to examine various aspects of the bridge design and collapse. Lawyers represented the consulting engineers, contractors, workers unions, the Workers Compensation Board (WCB), and even the government (the B.C. Toll Highways and Bridges Authority). The commission examined a wide range of possible causes, from earthquake to sabotage, but examination of the design calculations indicated that failure of the temporary support under span 5 most likely triggered the disaster. Inspection of the wreckage confirmed this hypothesis.

The calculations for the base of the temporary tower contained two simple numerical errors made by the “Assistant Field Engineer,” a junior design engineer. In addition, his boss, the “Field Engineer,” evidently missed the errors when he checked the calculations. The wreckage showed that the I-beams in the grillage (or base) supporting the tower had buckled laterally, indicating that the beam webs were too thin for the load.

Dominion Bridge had not submitted design calculations for the supports to the engineer of record (Swan, Wooster) because the temporary towers were not part of the permanent bridge structure. The calculation errors therefore went unnoticed until the collapse. In previous contracts, there had been no requirement to submit these calculations; however, as the commission testimony progressed, it emerged that the contract did indeed contain a clause requiring Dominion Bridge to do so.

In its final report, the royal commission found the negligence of the Dominion Bridge Company responsible for the collapse. The report cited three basic oversights: (1) failing to design the temporary support properly; (2) failing to submit the design calculations to the engineer of record, as specified in the contract; and (3) leaving the design of the base support for the temporary tower to an inexperienced engineer and failing to check the engineer’s design adequately.

Although several other factors may have contributed to the collapse, the numerical errors were damning. Neither the assistant field engineer nor the field engineer could defend their calculations; they worked on-site during the steel erection, and both died in the collapse.

COMPLETION OF THE BRIDGE

After the royal commission rendered its verdict, most of the workers who survived the collapse went back to work to dismantle the wreckage and complete the bridge. The new construction followed the original design, although the temporary supports were more robust and built more accurately. Strength calculations and steel properties were checked more closely, and design calculations were now submitted to the engineer of record.

Before the bridge was finished, however, a long and bitter labour strike occurred. Several almost unbelievably bad legal decisions delayed the construction for months (as Jamieson explains fully in his book). The bridge finally opened for use on August 25, 1960, over four years after construction began. A recent online video documents the bridge collapse, with an animated sequence illustrating the mode of failure.[9] The video features songs that commemorate the tragedy.[10]

However, although the collapse taught a hard lesson, not everyone was paying attention. Almost three decades later, in April 1988, the roof of a Save-on-Foods supermarket collapsed in Vancouver. The subsequent inquiry discovered similar basic errors in the design: mistakes in the load calculation led to the lateral buckling of a deep beam. Fortunately, no lives were lost, and the collapse provoked changes to B.C.'s licensing procedures for structural engineers.

The message is clear: engineers and geoscientists must be constantly alert to avoid errors in strength calculations, especially when inexperienced professionals work on critical components.

DISCUSSION TOPICS AND ASSIGNMENTS

1. Assume that you are a project manager, and one of your key responsibilities is to make cost and time estimates for a project. Your calculations result in very high estimates—so high that you fear the project may be cancelled. Older colleagues on your team tell you: "Many earlier projects would have been cancelled if the true costs had been known this early in the game." Moreover, they argue that no one can ever be really sure of what something is going to cost: "After all, these are only estimates!" You know from experience that several earlier projects exceeded the cost estimates, but funds were found, and the projects were successful.

   The older colleagues urge you to reduce your estimates so that the project will not be cancelled. You have put a lot of careful work into your estimates and believe your figures are as correct as any estimate of the future can ever be. Therefore, if you reduce the estimates, you know you will be lying. Furthermore, you know your own reputation in the company will be damaged if it becomes apparent that you shaved your estimates. If your project is cancelled, however, some of the people in your project team may be laid off. You are caught in a dilemma, and as a manager, you must decide one way or the other. Explain how you would try to solve this ethical dilemma. What additional information would you need? Assume that you have this information (and state it), then write a summary of your decision and your reasons for it.

2. Assume that you are a licensed professional in a fairly large engineering and geoscience consulting company. You have recently been promoted to manager and transferred to manage a branch in a western city. The branch is swamped with work, and you rely heavily on an older assistant, who has been with the company for about three decades. You notice that the assistant has the sign "Associate Geoscientist" on his door and the same title on his business cards. You check the personnel files and realize that the assistant has extensive personal experience and is an incredibly valuable employee but obtained his expertise in the field and has neither a licence as a geoscientist nor certification as a technologist or technician. Is the "Associate Geoscientist" contravening the professional geoscience Act in your province or territory? If so, what (if anything) would you do about it, as manager?
3. Renée Langlois is a professional geoscientist who has recently been appointed president of a large dredging company. She is approached by senior executives of three competing dredging companies and asked to cooperate in bidding on federal government dredging contracts. If she submits high bids on the next three contracts, the other companies will submit high bids on the fourth contract and she will be assured of getting it. This proposal sounds good to Langlois, since she will be able to plan more effectively if she is assured of receiving the fourth contract. What word or phrase best describes this arrangement? Is it ethical for Langlois to agree? If not, what action should she take? If she agrees to this suggestion, does she run any greater risk than the other executives, assuming that only Langlois is a licensed professional?

Additional assignments and case studies are provided in Web Appendixes E and F.

NOTES

[1] Brian M. Samuels and Doug R. Sanders, *Practical Law of Architecture, Engineering, and Geoscience*, Canadian ed. (Toronto: Pearson Prentice Hall, 2007), 238.
[2] Howard A. Levitt, *The Law of Dismissal in Canada* (Aurora, ON: Canada Law Book, 2003).
[3] Charles E. Harris, Michael S. Pritchard, and Michael J. Rabins, *Engineering Ethics: Concepts and Cases* (Boston, MA: Thomson Wadsworth, 2005), 142.
[4] Ibid.
[5] Canadian Securities Administrators (CSA), *National Instrument 43-101: Standards of Disclosure for Mineral Projects*. Document NI-43-101 can be found on several securities websites, such as those in British Columbia, www.bcsc.bc.ca; Ontario, www.osc.gov.on.ca; Quebec, https://lautorite.qc.ca; or Alberta, www.albertasecurities.com (accessed June 20, 2017).
[6] *Turnitin* (plagiarism prevention) website at www.turnitin.com (accessed June 20, 2017).
[7] Eric Jamieson, *Tragedy at Second Narrows* (Madeira Park, BC: Harbour Publishing, 2008).

[8] Sherwood Lett, Commissioner, *Report of the British Columbia Royal Commission, Second Narrows Bridge Enquiry, 1958*, vol. 1 (Victoria, BC: Queens Printer, 1958).
[9] Intrinsic Pictures, *19 Scarlet Roses*, © 2004. This 28-minute video contains photos, workers' stories, and an animated sequence of the collapse of the Ironworkers Memorial Second Narrows Crossing, Vancouver, June 17, 1958, www.youtube.com/watch?v=NHPchkZ2RMI (accessed June 20, 2017).
[10] Stompin' Tom Connors, "The Bridge Came Tumbling Down," words and music by Stompin' Tom Connors, 1971 (published by Crown Vetch Music [SOCAN], administered by Morning Music, Ltd.).

Chapter 12

Ethics Concepts and Cases: Consulting

Professional engineers and geoscientists in consulting, or "private practice" as it is often called, offer their services to the public and often have an ownership share in the consulting company (typically as shareholders, as partners, or as the sole proprietor). Consultants must cope with the responsibilities and stress of a private enterprise, as well as the typical technical and ethical problems of a professional job. In addition, an important group of "freelance" contract consultants (employees on short-term contracts, as discussed in Chapter 5) face similar issues. In this chapter, we discuss the consultant's relationship with clients, the ethical aspects of advertising, the competition for contracts, reviewing another professional's work, and several other aspects of private practice. Six case studies illustrate ethical pitfalls, and a case history recounts how an engineering consultant overcame an immense ethical challenge.

12.1 THE CLIENT–CONSULTANT RELATIONSHIP

A consulting engineer or geoscientist is usually hired by a client to monitor a project such as the design of a building or the development of an ore deposit. The client needs the consultant's advice to confirm that a contractor's work is properly performed. This creates a three-way relationship between

- **the client** (or owner, who may or may not have any technical knowledge),
- **the contractor** (designer, builder, or developer, skilled in the activity, but who may or may not be a licensed professional), and
- **the consultant** (professional engineer or geoscientist, whose role is to guide and protect the interests of the owner by giving technical advice and helping the project to move along quickly, safely, honestly, and fairly).

The client–consultant relationship may take many forms, depending on the knowledge, skill, and personalities of those involved. The result is a wide range of client–consultant relationships. D.G. Johnson describes three typical relationships along this range:

- **The "independent" model:** The client explains the problem and then delegates decision-making power to the consultant, who takes charge of the problem and makes decisions for the client. The consultant does not guide the client, but acts in place of the client, keeping the client's interests in mind, in a paternalistic but independent way. This end of the client–consultant spectrum is generally unacceptable, since it robs the client of the ability to make choices.
- **The "balanced" model:** The consultant interacts with the client, by providing advice and evaluating the risks and benefits of various alternatives, but the client makes the choice of the action to follow. This relationship is similar to an ideal patient–physician relationship, where the professional has the expertise to solve the client's problem, but must inform the client of the benefits and risks, before proceeding with treatment. In a balanced relationship, the client and consultant treat each other as equals. The consultant provides professional expertise, but the client retains power to make the key decisions. The balanced relationship is the approximate mid-point of the spectrum, and is generally the optimum client–consultant relationship.
- **The "agent" model:** The consultant is simply an agent or "order-taker" for the client, and contacts the client for instructions before acting. This is the other end of the client–consultant spectrum, and it is also generally unacceptable, since the client does not make full use of the professional's knowledge. This relationship is usually demeaning to the consultant.[1]

At the start of a project, the consultant and the client should agree on a working relationship, probably near the middle of the spectrum described above. Information then flows both ways between client and consultant, both are aware of key areas of the work, and well-informed decisions are made in a timely manner.

12.2 ADVERTISING FOR NEW PROJECTS

Consultants need to advertise. This thorny issue plagues all the professions; advertising is important to attract clients and to ensure that they obtain accurate information about your professional qualifications and experience. Unfortunately, mediocre, self-serving advertising dominates all our communications media, from newspapers to the Internet, and it is demeaning to promote professional services as if they were soap, soup, or chewing gum. Every province and territory therefore restricts advertising of professional services to ensure honesty, fairness, and respect.

General rules are in the Act or the regulations, and more detailed advice is in the Code of Ethics or in professional practice guidelines. Advertising a professional's availability, experience, and areas of expertise is fair, acceptable, and expected. "Calling card," or "business card," advertising in the back pages of most technical publications is very professional.

In Alberta, the APEGA *Guideline for Advertising of Professional Services* requires that all advertisements, proposals, presentations, and solicitations for professional engagement must follow these general principles (which are good advice in every profession):

- Advertising shall be clear, factual, and without exaggeration.
- Advertising shall be in good taste and not diminish the dignity, professional image or stature of the professions.
- Advertising shall not be critical of, or claim superiority over, others.
- Advertising shall comply with all applicable laws.
- A professional service shall not be advertised, unless that service is provided under the direct personal supervision of a Member who is available to the extent necessary to provide competent direction of the work.
- Advertising shall not make any reference to fees or charges for services.*

The Alberta guideline gives specific advice on every conceivable advertising and publication format, from business cards to vehicle signs, including radio, television, Internet, and email.

The Quebec (OIQ) Code of Ethics gives similar guidance for advertising but permits fee information, providing that a professional "who, in his[/her] advertising, mentions fees or prices shall do so in a manner that can be understood by the public."[2]

Ontario regulations permit advertising that is professional and dignified, that is factual and does not exaggerate, and that does not directly or indirectly criticize another licensed engineer or the employer of another licensed engineer. The regulation expressly forbids the use of the engineer's seal or the Association's seal in advertising.[3] Licensed professionals may use the Association's name and logo on business cards and letterhead (to signify that they are licensed), but a professional seal cannot be used. The seal has a legal significance (as explained in Chapter 4) that is incompatible with advertising.

Of course, professionals should avoid the common advertising tricks observed daily in the mass media. For example, advertising that uses any of the following is unprofessional and unacceptable:

- photos showing a project in which the professional has little or no involvement, implying undeserved authority, experience, achievement, or credit
- statements that claim an unjustified share of credit for a joint project
- negative advertising that belittles a colleague, product, or service
- exaggerated advertising, implying unjustified performance or achievement

In summary, although the rules vary slightly across Canada, advertising is acceptable if it is factual, truthful, and communicating accurate information about qualifications, experience, location, or availability in a dignified manner.

* APEGA, *Guideline for Advertising of Professional Services*, V2.1, May 2013, 1–2, available at https://www.apega.ca/assets/PDFs/advertising.pdf (accessed June 21, 2017). Excerpt reprinted with permission.

12.3 COMPETITIVE BIDDING FOR NEW PROJECTS

A detailed procedure for selecting a consultant—often called Qualifications-Based Selection (QBS)—was explained in Chapter 5. The procedure involves several stages and separates the process of selecting the best-qualified professional (or firm) from the process of negotiating the fees. This approach prevents many problems that commonly arise when clients select consultants on a competitive basis by lowest bid. As mentioned, a form of the QBS selection process is endorsed by the Federation of Canadian Municipalities and the National Research Council.[4]

It must be emphasized that seeking professional services by lowest bid is legal and ethical; in fact, fair competition is beneficial. Ingenuity thrives on healthy competition. However, there is a danger in competitive bidding, as illustrated in some of the tragedies discussed in this textbook. When professionals are short-changed on fees, they are tempted to substitute less-skilled personnel or skimp on time spent on crucial tasks. Harried professionals may make simple errors that go undiscovered until something fails. Short changing on fees is a false savings.

In addition, some competitive activities in obtaining contracts are unfair and unethical. For example, an agreement to pay a kickback, gift, or commission, either openly or secretly, is an unfair and unethical (and likely illegal) method of obtaining contracts. Many codes describe "supplanting" a colleague as unethical, where supplanting means intervening in the professional relationship of a colleague and, through inducements or persuasion, convincing the client to fire the professional and hire the intruder.

12.4 PROFESSIONAL COMPETENCE

Professional competence, gained through education or experience, is a valuable asset. The client is paying for that competence. If a project should fail because a professional accepted an assignment that was clearly beyond his or her ability and experience, then the professional could be judged incompetent and be subject to disciplinary action.

You do not have to be an expert in every phase of a proposed project before accepting it; however, you must be confident that you can become competent, through study or research, in reasonable time. Otherwise, you must hire a knowledgeable colleague or consultant, without delaying the project.

The Act in every province or territory allows the licensed professional to assess his or her own competence to carry out a technical task (with very few exceptions, such as structural design or acting as a "qualified person" in mineral disclosures, where additional certification, qualification, or licensing is required). Therefore, you must know your level of competence and perform within it. You must also continually expand your knowledge and experience to maintain your competence (as discussed in Chapter 17). Above all, you must be realistic about your abilities—a difficult task at the best of times. However, no one knows the limits of your knowledge better than you do yourself.

In summary, when you present your qualifications to a client, you must avoid exaggeration by cataloguing the experience, education, training, and so forth that have prepared you for the task and by estimating, frankly, what knowledge you can acquire in a reasonable time. If you later realize that the project demands expertise, labour, equipment, or skill that is beyond your ability to provide, then you must immediately seek assistance—typically by hiring the necessary help. The essential principle is that you must not place the client's project at risk by your lack of competence, as that could lead to a complaint of professional misconduct.

12.5 CONFIDENTIALITY

Under the Code of Ethics, professionals are obliged to keep the client's affairs confidential, and a client will often ask a consultant to sign a confidentiality agreement. Since professionals intend to maintain confidentiality anyway, they willingly sign these agreements. Confidentiality can, however, create ethical problems for consultants. Consider the following two cases.

- **Trade secrets:** If a new client is a competitor of a former client, the professional may have a conflict of interest. A consultant must not accept a contract that requires disclosure of a previous client's affairs, be they technical, business, or personal. This prohibition applies especially to proprietary information or trade secrets. The professional must honour the confidentiality agreement with the former client or risk legal reprisal. Even if the new client does not ask or expect the professional to disclose proprietary information, the appearance of a conflict of interest remains. The only sure way to eliminate the conflict is to disclose the facts and ask the former client to confirm that no conflict exists.
- **Environmental or safety hazards:** Another problem with confidentiality agreements arises in environmental projects. Where danger to the public is involved, the Code of Ethics (and environmental regulations) may require the consultant to reveal confidential information. Consider a case where a consultant advises a client to remedy an environmental or safety hazard. What happens if the client refuses to do so? If the consultant has signed a confidentiality agreement and later "blows the whistle" to the authorities, this could be a breach of contract. Clearly, the consultant is facing a serious ethical dilemma: breach the contract or obey the law. The Alberta *Guideline for Environmental Practice* anticipates this situation and suggests:

  > Professionals must conduct their work in a manner such that the confidentiality can be maintained to the maximum degree possible. In doing so, however, the professional must recognize that in some instances there may be regulatory requirements to release or report information relating to environmental effects.[5]

  A suitable compromise in such cases is to include a clause in the confidentiality agreement stating that, if the client should fail to act on certain hazards within a specified time, the consultant shall fulfill any reporting requirements specified by law after notifying the client. Of course, environmental consultants should get legal advice on the proper wording of such agreements.

12.6 CONFLICT OF INTEREST

As noted earlier, a conflict of interest arises when the professional has any interest that interferes with the service owed to the client. For example, a serious conflict of interest arises if a consultant recommends that a client purchase goods or services from a company that pays a secret commission to the consultant. This conflict of interest is contrary to the Code of Ethics.

Conflicts can be much simpler than this. For example, a consultant may be tempted to suggest a technical change that simply reduces the consultant's workload. Unless there is a similar reduction in fee, the consultant has a conflict of interest. Whenever a conflict (or potential conflict) of interest arises, the consultant must disclose it to the client, who can assess the severity of the conflict. If the client agrees that the conflict is insignificant, then work proceeds, but the client is now making a fully informed choice.

Conversely, if a client follows advice allegedly based on technical factors but later learns that the consultant benefited personally (and secretly) from the decision, then the client could (and should) lodge a complaint for professional misconduct.

12.7 REVIEWING THE WORK OF ANOTHER PROFESSIONAL

Reviewing another professional's work is a sensitive issue for consultants. As a courtesy, a professional must inform another professional before reviewing his or her work. The purpose is to ensure full communication; it is not necessary to seek the person's permission for the review.

This rule is simple professional courtesy; a consultant should usually refuse to review the work of another professional, secretly. However, the rule has some exceptions. When public safety is involved, a review may occur without informing the professional. Similarly, informing is not required when a lawyer requests the review, and the review will remain confidential under solicitor–client privilege. Proprietary matters, such as trade secrets, also take precedence and allow for reviews without informing the professional. Therefore, it is not an absolute rule, but it is a common and expected courtesy.

Note that *practice reviews* are not secret reviews. Some Associations conduct practice reviews to ensure that continuing competence programs are effective (as explained in Chapter 17). Each year, a small, random sample of members undergoes a practice review. Practice reviews are confidential and occur with the full knowledge and cooperation of the professional.

12.8 OWNERSHIP OF DESIGN CALCULATIONS

A client may ask a professional to submit the calculations that support a recommendation. Requiring this amounts to a review of the professional's work, but, obviously, it has the full knowledge of the professional. The client has an ethical right to review these calculations and to make a copy for permanent record. If the calculations are output from a commercial software program, it is not possible to provide the program itself, of course, but all input and output data should be available. However, the professional should charge for the time needed to prepare the calculations in a format understandable to the client.

Occasionally, the computation techniques, or the data on which the computation is based, are proprietary, so the professional may not wish to divulge them. To avoid this situation, consultants should negotiate the conditions for reviewing the calculations beforehand so that the extent of disclosure is understood in advance. If proprietary data are given to the client, there must be a clear understanding that the data will be kept confidential, with safeguards and remedies in case of failure to do so.

12.9 NEGLIGENCE AND CIVIL LIABILITY

The professional in private practice must avoid the two main sources of liability: breach of contract and negligence. These are usually inadvertent and unfortunate, because they can lead to massive personal financial loss. Some protection against loss is available for these risks.

- **A breach of contract** is a failure to complete the obligations in a contract. By incorporating a practice, the individual gets some protection against personal financial loss due to lawsuits resulting from breach of contract. After incorporation, the company becomes the contracting party and the assets of the company are separate from the individual's.
- **Negligence** is a failure to exercise due care in the performance of professional duties. Liability insurance protects the individual against massive personal financial loss due to lawsuits resulting from negligence.

However, incorporation and liability insurance will not protect the individual from disciplinary action for negligence, incompetence, or professional misconduct (as discussed in Chapter 3). In the event of a charge under the Act, the individual must respond to the Discipline Committee.

12.10 CODES OF ETHICS FOR CONSULTANTS

Consulting engineers and geoscientists must be licensed in Canada and are governed by the same Code of Ethics as employee engineers and geoscientists. However, advocacy groups have been created by consulting firms to work on behalf of members. These groups publish guidelines, specifications, and fee schedules to assist consulting practice. Some groups publish a voluntary Code of Ethics that applies to their members. The codes are similar to the Codes of Ethics of the licensing Associations but lack the enforcement provisions of the provincial and territorial Acts, of course. A few clauses apply specifically to private practice, as mentioned below.

- **Association of Consulting Engineering Companies (ACEC):** This advocacy body works on behalf of Canadian engineering companies and engineers in private practice. Although it is not a licensing body, ACEC emphasizes on its website that engineering is a regulated profession in Canada and states that "every individual employed by our members is required by law to act with fidelity to the public interest."[6] ACEC comprises 12 independent member organizations, which represent all of Canada. Each member organization is incorporated in its own province or territory, and is linked to the ACEC website (cited above). When consulting engineering companies join their local member organization, they automatically become ACEC members. ACEC is a member of the Fédération Internationale des Ingénieurs-Conseils (FIDIC).
- **International Federation of Consulting Engineers (FIDIC):** This is an international advocacy group for consultants. FIDIC publishes a voluntary Code of Ethics that guides the conduct of its members, who are mainly firms of consulting engineers.[7] The FIDIC code is similar to the ACEC code and to the Association Codes, and requests members to fulfill their duties with responsibility, competence, integrity, impartiality, and fairness, and to avoid corruption. The FIDIC code encourages sustainable development (discussed in Chapter 15) and Qualifications-Based Selection (QBS), discussed in Chapter 5. The FIDIC Code of Ethics is reproduced in Web Appendix C.

12.11 ETHICS IN FOREIGN CONSULTING

A consultant engaged on a project in a foreign country must obey that country's laws. But what if the laws are much harsher and the working conditions are much poorer than the standards we would expect in Canada? Which laws and working conditions should apply? Few Codes of Ethics deal with this situation.

New Brunswick's Code of Ethics[8] is unique in having a clause that advises professionals to "observe the rules of professional conduct that apply in the country in which they practise and, if there are no such rules, observe those established by this Code of Ethics." This is very good advice and, if followed, will lead to harmonious relationships and positive outcomes. However, it is conceivable that, in an extreme case, this rule could lead the professional into a moral dilemma.

Consider, for example, an engineer or geoscientist who is working in a developing country wracked by civil war, where no local professional rules apply. The country is likely to have extremely low wage scales and a local militia or police force that demands extortion to permit the company to operate. Both of these activities—exploiting the poor by low wages and paying the extortion—would be contrary to any Canadian Code of Ethics. It is impossible for a single consulting firm to impose Canadian standards on an entirely lawless state, so following the New Brunswick code implies leaving the country. However, abandoning developing countries will not advance them either to the higher standard of living or the more civilized ethics that we enjoy in Canada. Another solution must be found.

In a case such as this, Aristotle's concept of the golden mean (discussed in Chapter 9) may be useful. The golden mean seeks some intermediate level of virtue between the extremes of excess and deficiency. In this case, the extremes are accepting the anarchic or self-serving practices in a lawless country or seeking to impose impossibly high Canadian standards and eventually abandoning the country to its fate.

The text by Harris, Pritchard, and Rabins contains an informative chapter on this problem and suggests nine factors (or "culture-transcending" norms) that should guide your actions.[9] Harris et al. suggest that fairness can be determined easily for each of these factors by applying the well-known Golden Rule: if a foreign corporation were involved in a project in Canada, how much should the corporation adjust to our practices and traditions? (This situation is not difficult for most Canadians to imagine.) The nine factors are as follows:

- **Avoid exploitation:** In Canadian and international law, a contract must be entered into freely and must provide some benefit to both parties. Exploitation occurs when one party sets all the terms of the contract and the other party receives inadequate benefit. This form of exploitation is unethical and violates all of the ethical theories described earlier.
- **Avoid paternalism:** Paternalism is the process of controlling the behaviour of citizens and making personal decisions for their best interests without their involvement. For example, suppose that a large corporation decides to pay all workers by bank transfers when the workers are used to cash payments, and many do not have access to banks. Such payments may be more secure, may help to track income tax, and may be convenient for the company, but if the process is contrary to the country's tradition, it may be paternalistic and unfair to workers who cannot obtain their pay.
- **Avoid bribery:** Bribery is a very common problem in international consulting. Bribes or "secret commissions" are illegal under Canadian law, and every Code of Ethics forbids them, either directly or indirectly. Bribery distorts the fair trade of goods and services and corrupts the reputation of all involved. The process of giving "gifts" is common in many countries, so some discretion may be necessary to avoid giving offence. This activity should be investigated before undertaking a contract in a foreign country. In recent years, the term "grease money" has entered the Canadian vocabulary, and it is only subtly different from a bribe or extortion. To clarify: A *gift* is freely given, to enhance the personal relationship, with no expectation of benefit; however, a *bribe* is given in expectation of favourable treatment,

grease money is intended to "open doors" so that favourable treatment will arrive more quickly, and *extortion* is a demand from a person in authority for a payment before providing an action that should be given freely.

- **Respect human rights:** Human rights are guaranteed in Canada under the Charter of Rights and Freedoms,[10] and similar rights apply to almost all societies under the United Nations' Universal Declaration of Human Rights,[11] which is older than our Charter. Even in a wealthy country such as Canada, not all citizens enjoy all the rights, and our goal must be to extend these rights. We cannot, however, improve the rights in a foreign country if we abandon it, so some compromise may occasionally be needed. Each situation must be analyzed to determine when accepting an infringement on rights will improve the country's social conditions, so that human rights will improve in future. Clearly, there are some limits that cannot be crossed. The UN Declaration specifically forbids slavery and torture, and such behaviour cannot be condoned in any civilized society.
- **Respect cultural norms and laws:** Consultants in foreign countries must recognize the laws and customs of these countries. Doing so is simple courtesy. However, some practices conflict with Canadian customs. For example, many countries forbid alcohol and forbid women to drive vehicles. Canadians must respect these laws when working in those countries, even if they are contrary to Canadian laws.
- **Promote the country's welfare:** As mentioned above, any contract requires both parties to benefit. The public welfare should also benefit; that is, consultants should not collaborate in any activity that would be harmful to the public or would be a criminal activity in that country or ours. In particular, consultants should not agree to conceal the adverse effects of their activities on the public.
- **Protect health and safety:** Professional consultants must seek to protect the public from harm, whether in Canada or elsewhere. This effort is particularly important when the employees' work environment does not meet Canadian Occupational Health and Safety standards. A consultant must decide whether the employer is adequately protecting the health and safety of employees. If the situation is unacceptable, and your continued involvement will not lead to improvement, then it is more ethical for you to abandon the project than to damage the health of citizens and leave them even more vulnerable.
- **Protect the environment:** Of course, in foreign countries as in Canada, all professionals must protect the environment. The problem is complex and involves more than simply improving efficiency, because research indicates that our climate is changing, as discussed in the next three chapters.
- **Promote the society's legitimate institutions:** Professional consultants in underdeveloped countries should support the laws, customs, and institutions that will guide the country to stability and financial well-being. In general, this means supporting (providing they are operating honestly) the elected government, the health system, the established police

and justice system, and the banks and other financial institutions that are essential to the free trade of goods and labour, all of which can improve the life of the average person.

In summary, a Canadian professional may face many ethical problems when working in a foreign country (particularly an underdeveloped country). The professional must seek the intermediate level of virtue between the extremes of excess and deficiency and should not accept extremely anarchic, self-serving practices or, conversely, try to impose impossibly high Canadian standards. When you evaluate the nine factors listed above, the result must satisfy the contract, benefit the country as a whole, and yet agree as closely as possible with Canadian Codes of Ethics. Each situation requires an individual analysis.

CASE STUDY 12.1

PUBLIC SERVICE OR CONFLICT OF INTEREST?

STATEMENT OF THE PROBLEM

Edward Beck is a consulting engineer in a small town. He also sits on the town council as an elected councillor, a part-time job that he considers a form of public service. For the past year, Beck has been working for a developer to draw up plans for a new residential subdivision in the town. The plans include a street layout, water supply, and sewage facilities. The developer needs approval from town council to continue. The town council discusses the subdivision at a regular meeting. The developer's submission to town council includes Beck's drawings and specifications. During the discussion, Beck does not publicly state his relationship with the developer, nor does he conceal it. His signature and seal are on some of the plans submitted to council. When the town council comes to the vote, Beck votes to approve the subdivision. Everyone knows that he is the only engineer in town who does this type of work, and Beck is certain that they would prefer to see local people hired for this project.

QUESTIONS

Must Beck state publicly that he has a personal interest in the town council vote? Has Beck acted unethically by voting to approve this project? Does a public-spirited local professional like Beck deserve a few privileges in town decisions?

AUTHORS' SUGGESTED SOLUTION

This situation sometimes occurs in small towns with few professionals. Professional engineers and geoscientists certainly should not be disqualified from projects because they are serving the public as members of a town council.

However, conflicts of interest must always be avoided or disclosed. The town council must judge a proposal on its merits, without favouritism, bias, or special privileges. It is not a credible excuse that "everyone knows" that Beck has a business relationship with the developer. Beck will surely benefit if council approves the proposal, so the Code of Ethics requires full disclosure of this conflict of interest. He should have made a clear, unequivocal statement of his involvement in the project and his relationship with the developer, then withdrawn from the debate and abstained from the vote. By participating in the formal vote without declaring his conflict of interest, Beck acted unethically and contravened the Code of Ethics. More importantly, he exposed himself to possible disciplinary action by the Association for unprofessional conduct.

CASE STUDY 12.2

CONSULTING IN A FOREIGN COUNTRY

STATEMENT OF THE PROBLEM*

The government of Pradonia, South America, wanted to build a 400 km highway across its mountainous coastal range to give its citizens easier access to the country's interior. The Pradonian government hired a Canadian company, ABC International Inc., to design the highway and later hired another Canadian company, XYZ Overseas Inc., as the contractor to build the highway. In addition, Pradonia hired ABC to oversee the construction work by XYZ since, as the designers, ABC was familiar with the project.

Professional Engineer Epsilon was hired by ABC International and sent to Pradonia with the title of Senior ABC Engineer. Although relatively new to the project, Epsilon had more than 25 years of experience. Epsilon's job was to ensure that XYZ Overseas fulfilled its construction contract with the Pradonian government. As Senior ABC Engineer, Epsilon was in charge of approving all expenditures, including materials and labour, paid to the contractor (XYZ). Epsilon's signature on a payroll meant that the interests of the Pradonian government were met.

Almost immediately, Epsilon began to experience doubts about the project. The highway design involved cutting deep channels—some of them more than 100 m deep—through mountains with cliffs rising sharply on both sides of the road. Epsilon was concerned about the instability of the mountains and worried whether enough geological borings had been taken to identify potential slide areas. Epsilon's fears were confirmed, unfortunately, when several landslides and other construction accidents occurred, killing some workers. XYZ Overseas asked Epsilon to add [a large sum] to the payroll to cover the substantial costs for slide removals.

* Professional Engineers Ontario (PEO), *Professional Practice Exam, Part A—Ethics*, April 2006. Excerpt adapted and reprinted with permission.

Epsilon viewed the request as "padding" and, therefore, not justified by anything in the contract. At first, Epsilon's position was supported by ABC International; however, with mounting pressure from XYZ Overseas, ABC International ordered Epsilon to approve the slide-removal costs, conceal them from the client as "labour," and add them to the payroll. Epsilon refused to do so, insisting that they were not in the agreement and adding them would violate the Pradonian government's interests, which ABC International was responsible to protect. Epsilon was then relieved of the resident engineer's responsibility and was subsequently fired by ABC International.

QUESTIONS

Discuss Epsilon's actions. Should Epsilon's primary loyalty lie with ABC International or with the Pradonian government? Was ABC justified in firing Epsilon for disobeying the order to pay for debris removal? According to your Association's Code of Ethics, was Epsilon justified in refusing to "pad" the budget for slide-removal costs? What recourse can Epsilon pursue in view of his dismissal?

AUTHORS' SUGGESTED SOLUTION

This case involves a typical client–contractor–consultant relationship. The client is the Pradonian government; the contractor is XYZ Overseas, hired to build the highway, and the consultant is ABC International, hired by Pradonia to "oversee" the highway construction. Epsilon's assignment (as an employee of consultant ABC) is to act for the client (Pradonia) to make sure that XYZ builds the highway properly. The fact that Epsilon's employer (ABC) also designed the highway should not influence Epsilon's judgment in bringing flaws to light.

This question outlines at least four typical ethical issues: workplace safety, possible design flaws, controversial payments, and Epsilon's dismissal. We can investigate these issues using the Code of Ethics (and the nine factors discussed above in Section 12.11 on foreign consulting).

- **Protecting health and safety:** The most critical events were the landslides, which caused several deaths. Mountainous terrain is dangerous, and workplace safety is the responsibility of the contractor (XYZ). Epsilon's job is to ensure that XYZ fulfills the contract, and this would include safety. If XYZ was not operating safely, then Epsilon had an obligation to report unsafe conditions to the Pradonian government. Under Canadian Occupational Health and Safety (OHS) laws, every worker is entitled to a safe and healthy work environment, and the employer has a duty to provide it (as explained in Chapter 6). The Code of Ethics encourages Canadian professionals to follow similar standards in a foreign country.

  In addition, while the question mentions landslides, accidents, and deaths, it does not describe any remedial action. In Canada, unsafe practices can lead to charges under OHS laws. Workplace fatalities are investigated, and work stops until safety is restored. Even if OHS legislation does not exist in Pradonia, the contractor (XYZ) had a duty to remedy safety problems, and Epsilon had a duty to insist on this action.

- **Design flaws:** The question hints that the highway design may be flawed. Epsilon had doubts about the design because the geological borings appeared to be inadequate to identify potential slide areas. If Epsilon had the authority under the contract to review the design, he should have done so, even though his employer (ABC) was also the designer of the highway. Obviously, a design review may create a conflict of interest for ABC (and Epsilon), but the client, Pradonia, should not suffer because of it.
- **Improper payments:** The payments are a minor issue compared to the workplace deaths; however, if XYZ asked Epsilon to add the landslide clearing costs to the payroll to conceal them from the Pradonian government, then these hidden costs are indeed illegal "padding." Approving the payments would be contrary to the contract and to the Code of Ethics.
- **Unfair dismissal:** To judge whether the dismissal was unfair, it is important to determine precisely why ABC fired Epsilon. If ABC fired Epsilon for being too vigilant in defending the client, then it was a wrongful dismissal. Although ABC was Epsilon's direct employer, Epsilon's primary duty was to the client (the Pradonian government). The disputed payments for the landslide costs were not in the contract, and ABC's instructions to pay XYZ were contrary to Epsilon's judgment. An employer cannot direct an employee to perform an act that is illegal or clearly contrary to the Code of Ethics. ABC is a Canadian company, so Epsilon could contact a lawyer to discuss a wrongful dismissal suit against ABC in Canada (even though the job was in Pradonia).

In summary, the real tragedy lies in the workplace deaths. If safety had been a higher priority, perhaps they would not have occurred. The purpose of professional ethics is to prevent harm and loss, but after damage occurs, the only remedy is in the law courts. (Note: This problem is very brief; many assumptions were needed. Different assumptions might lead to other conclusions.)

CASE STUDY 12.3

THE HAZARDS OF INSIDER TRADING

STATEMENT OF THE PROBLEM

Assume that you are a licensed geological consultant (P.Geo.) specializing in petroleum exploration and development. You are hired by Alpha Petro Resources to evaluate the economic potential of two properties that Alpha Petro wants to acquire from a competitor, Beta Holdings. You prepare a preliminary report for Alpha Petro, titled *Overview and Recommendation to Drill*. Your report concludes that the properties have very good potential. You show the report to your brother who, unknown to you, immediately buys some shares in Beta Holdings. A few months later, you summarize your analysis in a second report, titled *Petroleum Reserves Assessment*, showing that the property owned by Beta Holdings has even greater value than initially believed. You send this report to your client, Alpha Petro. At the same time, you establish a numbered company that quietly purchases a sizable minority stake in Beta Holdings. A few days later, you meet with your client (Alpha Petro) to review your report. You enthusiastically recommend Beta as an excellent investment. You do not inform Alpha of your share purchase. Within a few weeks, Alpha Petro purchases the properties from Beta Holdings; you sell your Beta shares and receive a large financial windfall. You compliment yourself for having an astute business sense.

QUESTIONS

Was it ethical and legal for you to discuss the value and potential sale of the Beta Holdings property with your brother? Was it ethical and legal for you to purchase shares in Beta Holdings while evaluating the property for a purchaser? Are you subject to any penalty or censure for either of these activities?

AUTHORS' SUGGESTED SOLUTION

Acting on confidential information for personal gain is an abuse of privilege (as explained in Chapter 10). Both the release of information to your brother and your self-serving purchase of shares are unethical conflicts of interest that contravene the Code of Ethics of every Association and deservedly expose you to severe disciplinary action.

In addition, you are subject to prosecution under the provincial Securities Act, which typically states that no person in a "special relationship" with a company issuing shares may buy or sell these shares if the person has "knowledge of a material fact . . . that has not been generally disclosed."[12] In other words, a consultant who acts on confidential technical knowledge to buy shares is involved in "insider trading," and it is illegal. The provincial Securities Commission monitors share purchases by insiders, so the Commission would likely prosecute you and your brother under the Securities Act. Your conviction would lead to further disciplinary action under the engineering or geoscience licensing Act. It is likely that you would be fined and your licence would be revoked.

CASE STUDY 12.4

WHEN TO ACCEPT CONTINGENCY FEES

STATEMENT OF THE PROBLEM

As a professional in private practice, you are considering whether to offer your services on a contingency basis—an arrangement whereby you would receive a percentage of the outcome. Two clients wish to retain you.

- **Client A** wants to retain you to act as an expert witness in a lawsuit against a third party. The lawsuit, if successful, should result in a very large settlement.
- **Client B** has shown an interest in retaining you to reduce the energy used by a manufacturing process. You believe that Client B would be more positive if you base your fee on a percentage of the energy saved. After an initial study of the problem, you believe that the energy savings could be immense.

QUESTIONS

Is it ethical to offer your services on a contingency basis to either of these clients with the understanding that you would receive a percentage of the legal settlement (Client A) or a percentage of the value of the energy savings (Client B)?

AUTHORS' SUGGESTED SOLUTION

These two cases appear to be similar but are distinctly different.

- **Client A:** An expert witness may express opinions, whereas a non-expert witness must confine his or her testimony to known facts. Therefore, a professional testifying as an expert witness must be absolutely impartial. If, however, you receive a percentage of the potential settlement from Client A, you have a conflict of interest and your testimony would be questionable. Therefore, it is unethical to accept this case on a contingency basis. You should bill Client A for your time and expenses so that your reimbursement is independent of the outcome of the case.
- **Client B:** The case of Client B is different, because there is no need for impartiality. In fact, your bias toward reducing energy consumption could be very beneficial to the client. Of course, you have a duty under most Codes of Ethics to charge an adequate fee. From your study, you evidently believe that this fee will be adequate. Therefore, the proposal to use a contingency fee is ethical. A word of warning, however: You must measure the energy savings accurately and impartially, and you must not degrade the client's product or facilities. Therefore, although a contingency fee is ethical in this case, it has some risks. The more common billing methods (described in Chapter 5) are usually simpler.

CASE STUDY 12.5

UNAUTHORIZED CHANGES TO SEALED DRAWINGS

STATEMENT OF THE PROBLEM

Professional engineer Gamma is a consultant in private practice. A contractor hires Gamma to design and analyze the scaffolding and forms needed for a reinforced concrete bridge. The scaffolding must sustain about 1,400 tonnes of concrete while the concrete cures. The construction contract requires the structural engineer of record (SER)—the senior engineer who designed the bridge—to approve the scaffold design.

Engineer Gamma prepares the drawings electronically and seals the model file by scanning a professional seal and signature. Gamma then transmits the model file (drawings and certification) to the contractor for approval by the SER.

The contractor later hires engineer Gamma to inspect the completed scaffold structure prior to pouring the concrete. Gamma is surprised to see that the design has been changed. The scanned seal was not secure, and the contractor made several major revisions to the design before submitting the drawings to the SER. The contractor explains that an unexpected obstacle prevented the scaffold from being built as originally designed.

Without further calculations, Gamma cannot say whether the modified design is safe, and a strength check might take a few days as Gamma is busy on another assignment. The contractor is also under a tight schedule; concrete will start arriving in 48 hours. Gamma knows that the delay will be costly to the contractor and feels an obligation because of their previously excellent professional relationship. The contractor suggests that perhaps the strength check is unnecessary, since the SER approved the drawings.

QUESTIONS

Was it acceptable for the contractor to change the design without Gamma's permission? Was it proper for Gamma to transmit the model file with an insecure seal? Does SER approval exempt Gamma from further responsibility? If not, what should Gamma do?

AUTHORS' SUGGESTED SOLUTION

This case involves several ethical issues. Improper use of a professional seal is a serious offence. The contractor acted illegally by changing Gamma's design before submitting it to the SER for approval and could be charged under the Act.

The contractor's suggestion to skip the strength check is unacceptable. Although the SER is the final authority, the SER relies on other registered professionals to take responsibility for components. The SER reviews the components for obvious flaws and incorporates their effects into the design. The SER would not duplicate or update Gamma's analysis, so the strength of the modified scaffold is unknown, and pouring the concrete could be dangerous to workers and the public.

Under the Code of Ethics, safety must take priority, so Gamma must notify the contractor immediately, in writing, that the contractor must not pour the concrete until Gamma can re-check the scaffold design for safety. Gamma should complete the strength analysis as quickly as possible, but the contractor must not pour the concrete until the scaffold is shown to be safe, even if the 48-hour deadline is missed.

Although the contractor is basically at fault, Gamma's reputation may also suffer if inadequate security of the scanned seal is deemed to be negligence. Gamma should have exercised tighter control over the model file and seal. Newer design software permits professionals to electronically store, transmit, and sign electronic documents, securely. The software involves encryption and requires an annual subscription fee.[13]

Temporary structures occasionally collapse because they were not properly analyzed, as the collapse of the temporary supports for the Vancouver Second Narrows Bridge illustrates. (Read the case history in Chapter 11.)

CASE STUDY 12.6

FEE REDUCTION FOR SIMILAR WORK

STATEMENT OF THE PROBLEM

Susan Johnson is a professional engineer in private practice. She is hired by Client A to design a small, explosion-proof building for storing flammable paints, chemicals, and explosives. The work is carried out in her design office, and copies of the plans are provided to her client. After construction, Client B sees the building and contacts Johnson. Client B needs a similar building, but suggests that Johnson should reduce her fee substantially, since the design is finished and only minor changes are required.

QUESTIONS

Would it be ethical for Johnson to reduce her fee as suggested? Would it be good business practice?

AUTHORS' SUGGESTED SOLUTION

First, Johnson would check the contract with Client A to confirm who owns the copyright for the drawings. A professional in private practice typically retains the copyright unless the contract explicitly transfers ownership to the client. Reuse of the design or drawings for a new structure, even by the original client, needs the professional's permission; unauthorized use is an infringement of the copyright. This requirement differs for salaried professionals who prepare plans because employees typically sign an agreement that assigns copyright to the employer.

Second, establishing fair and reasonable fees depends on five factors:

- level of knowledge and qualifications required
- difficulty and scope of the assignment
- responsibility that the engineer must assume
- urgency (Will overtime or extra help be required?)
- time required (number of people-hours)

Of these five factors, only the last two (urgency and time required) are likely to be reduced because of the earlier project. If Client A were requesting a second building of the same design, then it might be appropriate to pass on some of the savings in time. However, Client B hopes to benefit from receiving a tested design that is likely to be more dependable and easier to construct. The level of knowledge, the qualifications, and, most important, the responsibility that the engineer must assume are unchanged. In summary, it would be poor business practice, and unfair to Johnson and to Client A, to reduce the fee for Client B.

CASE HISTORY 12.1

LEMESSURIER AND THE CITICORP TOWER

This case shows an exceptional engineer resolving a serious ethical dilemma. It therefore differs from most case histories in this text in which negligent or incompetent decisions led to disaster.

William LeMessurier faced an ethical dilemma when he discovered a flaw in his design. He pondered several alternatives, including concealing the flaw, but realized that the most ethical route was to face the problem squarely. To do so, he had to solve several technical, logistical, and financial problems.

INTRODUCTION

Structural engineer William LeMessurier was hired as a consultant to advise the designers of the 59-storey Citicorp Tower in New York City. The design was severely constrained by the building site, because a church occupied one corner of the lot. It was agreed that the Citicorp Tower could occupy the space above the church but must not touch the ground on the church's corner of the site. To satisfy the constraint, four massive pillars were constructed, each rising 35 m (114 ft.) from the ground. These four pillars support the building in the middle of each of the four walls, instead of the corners, and thus avoid the church. The building rises 59 storeys above the pillars, with a crown structure that peaks at 279 m (914 ft.).

LeMessurier created a simple, innovative design for supporting the corners: a steel frame with six sets of structural steel braces running diagonally upward from the columns at the middle of the walls to the corners, with each brace welded to the floor-beams of nine stories. The diagonal braces support the corners and give the finished building a distinctive appearance. In addition, the building was the first major skyscraper to incorporate an active damper to reduce sway during high winds. This was a 363 tonne (400 ton) concrete block on the top of the building. Sensors control the dampers by measuring the building's lateral acceleration and, using hydraulic pressure, drive the massive block to counteract the sway. In this way, the dampers cancel some of the structural stress.

Photo 12.1 — Citicorp Tower. *William LeMessurier designed the 59-storey Citicorp Tower in New York City. Because of lot restrictions, four massive pillars support the building, as shown in the photo. In May 1978, a few months after the building's completion, LeMessurier learned that a design fault could cause the building to collapse under certain severe wind conditions. The gripping story of his successful efforts to strengthen the building before the start of the storm season is a tale of professional ethics at its best.*

Source: © REUTERS/Peter Morgan

LeMessurier's analysis of the loads and design of the main supporting structure were essential to guarantee the strength of the building. His analysis was given to the design engineers, who determined the structural details. The design engineers were not required to inform LeMessurier of all the subsequent design details, provided that the structural strength appropriately exceeded the predicted loads. The building was completed in 1977.

FIRST PROBLEM: RECOGNIZING AND RESOLVING THE ETHICAL DILEMMA

In May 1978, a few months after the building's completion, LeMessurier learned that the design engineers had used less expensive bolted joints in the construction, instead of the welded joints he had recommended. This was not a serious change, provided the bolted joints were as strong as the welded joints. But in June 1978, motivated by a question from a graduate student studying the Citicorp Tower design, LeMessurier reviewed the design to prepare a lecture explaining the analysis. He came to a shocking realization: when strong winds blew from a "quartering" direction (at a 45-degree angle to the wall), the stresses in the structural members and the forces on the bolted joints would be significantly greater than he had earlier calculated. This quartering load condition had not been part of the New York building code when he calculated the stresses during the design phase, and the design engineers had not considered it either. Although the diagonal braces would withstand quartering loads, the bolted joints specified by the design engineers likely would not.

LeMessurier now suspected that the finished building was under-strength and might pose a serious hazard. He faced an ethical dilemma. By revealing the design flaw, he would be risking almost certain humiliation and financial ruin. Yet by concealing his knowledge, he would be placing tenants and neighbours of the building at risk of disaster. According to one source, LeMessurier "contemplated, ever so briefly, destroying his notes or even killing himself."[14] LeMessurier evaluated the alternatives and decided that the ethical choice was clearly to investigate the design flaw, remedy it if necessary, and accept the consequences, however cruel they might be.

SECOND PROBLEM: DETERMINING THE HAZARD AND THE BEST TECHNICAL REMEDY

LeMessurier consulted Alan Davenport, an award-winning Canadian civil engineer. (Among his many achievements and commissions, Davenport carried out the wind-tunnel tests for the CN Tower.) Davenport had run earlier wind-tunnel tests for the Citicorp Tower; he ran the tests again using winds at an angle to the wall surfaces. Davenport's results reinforced LeMessurier's concerns. A severe storm could cause one of the mid-level joints to fail; if this happened, the entire structure would come cascading down. Statistically, such a storm could be expected to occur about every 16 years. Moreover, although the active damper would reduce the loads and stresses, the damper required electric power, which might be disrupted during a severe storm.

The best technical solution was fairly clear—the joints could be reinforced by heavy steel strapping, which would be welded across the joints from the inside. But who would pay for such repairs, and how could they be completed without panicking the tenants and neighbours of the huge building? Moreover, time was of the essence: the design flaw became clear to LeMessurier in July 1978; the hurricane season typically reaches New York in September.

THIRD PROBLEM: CORRECTING THE PROBLEM WITHOUT INCITING PANIC

LeMessurier acted on the last day of July 1978. His initial contacts were through the lawyers for the company that had hired him as a consultant and that company's insurance company. Many meetings followed, and Leslie Robertson, also a prominent structural engineer, was retained to review LeMessurier's calculations and conclusions. (Ironically, Robertson was the structural designer for the twin towers of the World Trade Center, which collapsed minutes after the terrorist attacks of September 11, 2001.)

Citicorp, the tenants of the building, were informed next, and their response was critical. Fortunately, Citicorp realized the value of LeMessurier's advice, and although questions of cost and inconvenience arose, the gravity of the problem took precedence for everyone concerned. Citicorp authorized repairs to start almost immediately. At the same time, weather experts were hired to monitor and predict wind conditions, and New York City officials were contacted to work out an evacuation plan for the area around the Citicorp Tower. A press release was issued. Worries were diminished somewhat by explaining that the repairs were intended to cope with higher winds. This explanation was partially true, since slightly higher winds were predicted for the autumn of 1978.

Robertson became a key figure in designing and supervising the repairs. The welding was done at night to minimize the inconvenience and allay the concerns of the tenants. Standby generators were installed to ensure that the electrical supply to the active damper could not be interrupted by a storm. Plywood shelters concealed the work areas while repairs were made.

Repairs to the Citicorp Tower had not been completed by September 1978 when the weather office observed Hurricane Ella moving toward New York. Fortunately, the hurricane moved back out to sea without incident. By October, the repairs were complete. The building's strength now significantly exceeds the original design objectives. It is believed that the tower will be able to withstand a windstorm that, statistically, can be expected to occur only once every seven hundred years! It is now one of the safest structures in the world.[15]

FINAL PROBLEM: PAYING THE BILL

Citicorp willingly paid for the repairs but informed LeMessurier that it expected to be reimbursed. After negotiation, LeMessurier's liability insurance company agreed to pay US$2 million. Citicorp eventually agreed to accept that amount as the settlement and to exonerate LeMessurier. Citicorp did not reveal the total costs, but a rough estimate would be at least double the insurance coverage.

LeMessurier fully expected his liability insurance premiums to rise steeply; after all, his design error had resulted in a large claim and a great deal of anguish. However, the insurance company agreed that LeMessurier had acted promptly and ethically; if he hadn't done so and if the building had collapsed, the company would have been liable for a much greater amount in death and injury claims. In fact, perhaps not surprisingly, LeMessurier's liability insurance premiums were reduced.[16]

CONCLUSION

Obviously, LeMessurier could have ignored any responsibility for this problem. Initially, he had no firm knowledge that the structure was deficient, and with good luck (no serious windstorms), the building might have survived indefinitely. However, as an ethical engineer, he had a clear perspective: if you have a licence from the state to hold yourself out as a professional, you have a corresponding responsibility. If your structure poses a risk to the lives of others, you must do something about it.

DISCUSSION TOPICS AND ASSIGNMENTS

1. Assume that you and a colleague are starting a consulting engineering partnership. Your partner suggests that the business cards and stationery should include
   - a stylish logo;
   - your engineering seal, reduced in size to fit; and
   - the slogan "The best in the business!"

   Which (if any) of these advertising components would be acceptable under the advertising rules in your provincial or territorial Code of Ethics (and/or professional practice guidelines)? Cite a reference for each answer.
2. You have been hired as a machine design consultant to a soap manufacturer to suggest methods of speeding up a liquid detergent production line. In the course of your work, you inadvertently gain access to confidential company documents and discover that the company is adding minute quantities of a known carcinogen to the detergent without listing it as an ingredient. You know this substance has been banned. This confidential information is totally irrelevant to the job you were hired to perform, and you have discovered it entirely by chance. You have a duty to the client to maintain confidentiality, but do you have a duty to the public to act on this information? Does it matter that the information is unrelated to your work and was discovered accidentally? What action would you take? Explain your answer, citing your Act or your Code of Ethics, or by referring to the basic ethical theories.
3. Assume that you are a consultant to a large Canadian manufacturing corporation, hired to assist the chief engineer to establish a branch plant in a developing country. Your task is to supervise the installation and commissioning of the manufacturing equipment. Local people, with little or no education, will operate the equipment.

   As soon as you arrive on the site and familiarize yourself with the plan, which is well under way, you realize that the manufacturing line to be installed was removed from service in Canada because it created toxic waste. The waste can be disposed of only by special incineration equipment that was too expensive to install in Canada, which was one of the reasons the line was removed. The manufacturing line would not be permitted in Canada, but the developing country does not have environmental laws that would prevent its installation and operation.

   You have some ethical concerns about this project and discuss them with the chief engineer. He is sympathetic but points out that the manufacturing line ran in Canada for more than 10 years before pollution laws stopped it, and no illnesses or deaths were attributed to it. Moreover, the local people will be much better off when the line is running, giving employment and producing products for domestic use or export.

   What guidance does your provincial Code of Ethics provide for this problem? (Obtain the Code from your Association's website in Appendix A, or as reproduced in Web Appendix B.) Does the Code apply to activities conducted in a foreign country? What alternative courses of action are open to you? Which course is best from the ethical standpoint?

Additional assignments are provided in Web Appendix E. Additional case studies are presented in Web Appendix F. Sample Professional Practice Examination questions are provided in Chapter 16.

NOTES

[1] M.D. Bayles, *Professional Ethics*, 2nd ed. (Belmont, CA: Wadsworth, 1989), as quoted in D.G. Johnson, "Engineering Ethics," in *The New Engineer's Guide to Career Growth and Professional Awareness,* ed. I.J. Gabelman (Piscataway, NJ: IEEE, 1996), 173.

[2] Ordre des Ingénieurs du Québec (OIQ), *Code of Ethics*, section 5.01.07, www.oiq.qc.ca/Documents/DAJ/Lois/TheCodeofEthicsofEngineers.pdf (accessed June 21, 2017).

[3] Ontario Regulation 941, section 75, made under the Professional Engineers Act, R.S.O. 1990, c. P.28, https://www.ontario.ca/laws/regulation/900941 (accessed June 21, 2017).

[4] "Selecting a Professional Consultant," *InfraGuide—National Guide to Sustainable Municipal Infrastructure* (Ottawa: Federation of Canadian Municipalities and National Research Council, 2006), http://www.fcm.ca/Documents/reports/Infraguide/Selecting_a_Professional_Consultant_EN.pdf (accessed June 21, 2017).

[5] APEGA, *Guideline for Environmental Practice*, V1.0, February 2004, 14, https://www.apega.ca/assets/PDFs/environment.pdf (accessed June 21, 2017).

[6] Association of Consulting Engineering Companies (ACEC)—Canada, "About ACEC," Ottawa, www.acec.ca/about_acec/about_acec.html (accessed June 21, 2017).

[7] International Federation of Consulting Engineers (FIDIC), *Code of Ethics*, Geneva, Switzerland, http://fidic.org/about-fidic/fidic-policies/fidic-code-ethics (accessed June 21, 2017).

[8] APEGNB, "Code of Ethics," *By-Laws under the Engineering and Geoscience Professions Act* (Fredericton, NB: APEGNB, 2017), section 2, http://www.apegnb.com/site/media/APEGNB/APEGNB_Bylaws.pdf (accessed June 21, 2017).

[9] Charles E. Harris, Michael S. Pritchard, and Michael J. Rabins, "International Engineering Professionalism," chap. 10 in *Engineering Ethics: Concepts and Cases* (Boston, MA: Thomson Wadsworth, 2005).

[10] Government of Canada, Canadian Charter of Rights and Freedoms, Part I of the Constitution Act, 1982, being Schedule B to the Canada Act 1982 (UK), http://laws-lois.justice.gc.ca/eng/const/page-15.html (accessed June 21, 2017).

[11] United Nations, Universal Declaration of Human Rights, Office of the High Commissioner for Human Rights, Geneva, Switzerland, https://www.un.org/ruleoflaw/blog/document/universal-declaration-of-human-rights/ (accessed June 21, 2017).

[12] Alberta, Securities Act, R.S.A. 2000, c. S-4, https://www.canlii.org/en/ab/laws/stat/rsa-2000-c-s-4/latest/rsa-2000-c-s-4.html (accessed June 21, 2017).

[13] Charles Tremblay, "Digital Signatures Made Simple," [APEGBC] *Innovation*, (September/October 2011): 19, http://www.digitalityworks.com/Newsstand/IssueDetails.aspx?ID=16 (accessed July 6, 2017).

[14] J.R. Chiles, *Inviting Disaster: Lessons from the Edge of Technology* (New York: HarperCollins, 2002), 196.

[15] Gerard Voland, *Engineering by Design* (Reading, MA: Addison-Wesley, 1999), 398.

[16] Caroline Whitbeck, *Ethics in Engineering Practice and Research* (Cambridge, UK: Cambridge University Press, 1998), 146.

Chapter 13
Environmental Ethics

Our environment is a public resource, and protecting it is everyone's duty; however, professional engineers and geoscientists have a special responsibility because their actions can often cause great harm. As professionals, we must avoid unsafe, unethical, or illegal environmental practices, even if clients or employers request them. Sometimes assertive action is needed—a professional engineer or geoscientist may be forced to report unethical practices to the appropriate authorities.

This chapter discusses the professional's duty to protect the environment, lists some of the laws regulating environmental hazards, and discusses the environmental guidelines published by Engineers Canada, by several provincial Associations, by the Ceres organization, and by ISO (International Organization for Standardization) in the ISO 14001 standard.

Although reporting (or "whistle-blowing") is rare, this chapter discusses when it might be justified and how it should be done. The chapter concludes with a history of the 1982 Lodgepole blowout—a well-known Alberta case of sour gas (hydrogen sulphide) emission. The next chapter (Chapter 14) reinforces the importance of ethical treatment of the environment by describing several environmental threats and disasters.

13.1 THE DUTY TO SOCIETY

Engineers and geoscientists are bound by our Code of Ethics to protect the public welfare, which includes our environment. In general, we do a good job. Perfection is not attainable, however, so some risk always exists. The judge in a tort liability case once remarked: "Engineers are expected to be possessed of reasonably competent skill in the exercise of their particular calling, but not infallible, nor is perfection expected, and the most that can be required of them is an exercise of reasonable care and prudence in the light of scientific knowledge at the time, of which they should be aware."[1]

The duty to society therefore does not require perfection, but it does require reasonable care, so we may ask, "What is reasonable?" In environmental terms, reasonable care, prudence, and scientific knowledge mean the following:

KNOWLEDGE OF ENVIRONMENTAL LAW Professional engineers and geoscientists should seek advice before taking any action that might contravene an environmental law, regulation, or bylaw. Compliance with environmental law is essential. General environmental laws are listed later in this chapter.

ADEQUATE TECHNICAL KNOWLEDGE Before releasing any substance into the environment, professional engineers and geoscientists must have an adequate knowledge of the effects of the release, even when the substances are not toxic. This information is too voluminous for inclusion here, but it is easily obtained through the Internet, as explained later in this chapter.

THOROUGH ANALYSIS In any new process, and in large or dangerous projects such as a chemical plant or nuclear facility, a "cradle to grave" systems approach is needed to ensure that hazards are controlled. The designers must foresee the problems of handling, storing, and disposing of hazardous substances. They must also consider the decommissioning and disposing of the plant itself, even though this may be 50 years in the future. Designers must foresee how plant operations might go astray, as well. Sophisticated failure analyses such as failure modes and effects analysis (FMEA), event tree analysis, and fault tree analysis are useful for estimating operating hazards. The designers must try to find every conceivable mode of failure, evaluate the probability that it will occur, and devise a remedy.

INSISTENCE ON HIGH ETHICAL STANDARDS Obviously, high ethical standards are essential, and this textbook is devoted to encouraging these standards. Engineers and geoscientists must follow their Codes of Ethics (see Chapter 9) as well as the environmental guidelines discussed in this chapter.

13.2 THE DUTY TO THE EMPLOYER (AND ITS LIMITS)

If you are an employee, you have an obligation to your employer. In rare cases, however, an employer may instruct an employee to carry out acts that are contrary to the welfare of society. For example:

- An engineer may be asked to design a factory cooling system that takes in water from a nearby stream and dispels polluted waste water into the city sewer system, without the knowledge of city authorities.
- A geoscientist may be asked to falsify ore records for a mine to suggest that lower-than-actual quantities of toxic chemicals are being disposed of in the tailings.

Fortunately, the situations suggested by these examples do not arise often. As a professional, you must refuse to carry out such unethical activities. Unfortunately, your employer may ask you to defend or explain your refusal. The following advice is adapted from a previous chapter:

ILLEGAL ACTIONS Any activity that contravenes an environmental law or regulation is illegal. No employer has the authority to direct an employee to break the law. A professional engineer or geoscientist must refuse to perform any activity that is clearly illegal and must take action if other employees are observed in illegal activities. By participating in (or merely by ignoring) illegal acts, the professional employee becomes liable for the penalties prescribed by the law; in addition, he or she may face disciplinary action by the provincial Association.

ACTIONS CONTRARY TO THE CODE OF ETHICS OR ENVIRONMENTAL GUIDELINES A professional engineer or geoscientist must refuse to carry out any activity that, while not clearly illegal, is a breach of the Association's Code of Ethics or is a breach of the environmental guidelines developed by the Association. In some situations, the employer may simply be unaware of the legal significance of the Code of Ethics and may need to be informed. If the employer is an engineer or geoscientist, he or she has a similar obligation to obey the Code of Ethics. The employee has a legal basis for insisting on ethical behaviour—an employer cannot direct a professional engineer or geoscientist to take an action that would result in a loss of licence.

ACTIONS CONTRARY TO THE CONSCIENCE OF THE EMPLOYEE An employee may be asked to perform an act that, while not illegal and while not clearly a violation of the Code of Ethics or the environmental guidelines, nevertheless contravenes the employee's conscience or personal moral code. For difficult situations such as these, the decision-making procedure described earlier (in Chapter 9) may be useful.

Ethical problems sometimes have unfair personal consequences. Obeying your conscience and refusing to follow the employer's directive may result in disciplinary action or dismissal. In other words, you may be fired, or pay raises or promotions may be delayed. You must consider the possibility of dismissal, the consequences of unemployment, and the remedies for wrongful dismissal (as discussed in Chapter 11). Decisions such as these must be made carefully but ethically.

13.3 CANADIAN ENVIRONMENTAL LAW

If your actions affect the environment, your first responsibility is to know the law and to follow it. The federal, provincial, and territorial governments (and many municipalities) have environmental laws and regulations that may limit or regulate your activities. Fortunately, these laws are now very easy to find on the Internet. Canadian law is usually defined in two parts: the Act and the regulations. The Act usually states the principles and purpose of the law, but the regulations usually give the details for interpreting or applying the law.

- **Federal, provincial, and territorial laws:** These laws are available from the government websites listed below.
- **International summary:** A comprehensive summary of environmental law, including equivalent American and Mexican law, is published by the

Photo 13.1 — Oil Well Fire. *Firefighters shield themselves from the heat of a fire as they train their hoses on a drill rig at CFB Suffield in southern Alberta, near Medicine Hat, on June 30, 2000. The drill rig hit an unexpected pocket of high-pressure natural gas, which blew the rig out of the hole. The gas flare then ignited. Crews worked around the clock to extinguish it. Blowouts are uncontrolled, wasteful, and dangerous and can damage or destroy the drill rig. If the oil or gas in the well ignites, as it did in this case, the fire will be an extremely hazardous flare that may take days or weeks to extinguish; the negative effects on the environment can be significant.*

Source: © Medicine Hat News/Mike Bednar/CP Images

North American Commission for Environmental Cooperation (CEC). It is also available on the Internet.[2]

- **Provincial summaries:** Summary publications are available in most provinces to explain the myriad of provincial environmental laws. One example is the *Handbook of Environmental Compliance in Ontario*.[3] Many textbooks are available, and law firms that specialize in environmental law may distribute summaries of law topics.[4]
- **Local laws:** Your municipal government may have specific laws that apply only locally. Contact your city hall or regional government for information.

A sample of the most relevant Canadian environmental laws is listed below, along with a Web address (valid as of June 2017) for the legislation or for the department that administers the legislation.

Federal Government Acts

The Environment and Climate Change Canada website (www.ec.gc.ca) monitors the environment (wind, water, climate change, ozone layer, and so forth). It also explains the Canadian Environmental Protection Act and offers links to the Canadian Environmental Assessment Agency and to federal environmental laws. (Laws are also accessible from the Department of Justice website: laws-lois.justice.gc.ca/eng/acts/.) The key Acts are as follows:

- **Canadian Environmental Protection Act 1999:** This is the main federal law regulating the environment. It is aimed mainly at preventing pollution as the best way to protect the public. Its 12 sections deal with an extensive range of topics, such as public participation, information gathering, codes of practice, pollution prevention, controlling toxic substances, biotechnology, waste management, and enforcement. The Act, administered by Environment and Climate Change Canada, provides enforcement officers with powers similar to those awarded to police under the Criminal Code.
- **Fisheries Act:** This Act also protects the environment and forbids activities that might degrade any fish habitat. The Act provides severe penalties to prevent people from dumping toxic materials into water that contains fish. Fisheries and Oceans Canada administers the law. However, the sections most relevant to this chapter—those that concern the placing of deleterious substances in "water frequented by fish"—are administered jointly with Environment and Climate Change Canada.
- **Canadian Environmental Assessment Act, 2012:** The goal of this Act is to encourage sustainable development. The Act applies to projects for which the Government of Canada has decision-making authority, be it as proponent, land manager, source of funding, or regulator. All projects must receive an environmental assessment before they can proceed. The Environmental Protection Section of Environment and Climate Change Canada administers the Act.
- **Environmental Enforcement Act:** The goal of this Act is to strengthen the enforcement of nine federal environmental Acts. The Act standardizes fines through the Environmental Violations Administrative Monetary Penalties Act and offers a set of sentencing principles and enforcement tools to enforcement officers. The implementation of this Act has occurred in stages, between December 2010 and July 2017.

Provincial and Territorial Acts

Every province and territory has environmental laws and regulations. Table 13.1 lists the Web address of each provincial and territorial environment department and the key laws or Acts administered by the department. The regulations are usually available on the same websites as the Acts. (If necessary, click on "Legislation" or search the website.) In addition, the websites usually contain guidelines, advisory notices, information on climate change, and information explaining the legislation.

TABLE 13.1 — Summary of Provincial and Territorial Environmental Departments and Legislation

Alberta
aep.alberta.ca
Environmental Protection and Enhancement Act
Water Act
Climate Change and Emissions Management Act

British Columbia
www2.gov.bc.ca/gov/content/environment
For Acts and Regulations: www.leg.bc.ca/parliamentary-business/bills-and-legislation
Environmental Management Act
Water Sustainability Act
Water Protection Act

Manitoba
www.gov.mb.ca/sd/
For Acts and Regulations:
www.gov.mb.ca/sd/envprograms/index.html
The Environment Act
The Water Protection Act
The Waste Reduction and Prevention Act

New Brunswick
www.gov.nb.ca
For Acts and Regulations:
www2.gnb.ca/content/gnb/en/departments/attorney_general/acts_regulations.html
Clean Air Act
Clean Environment Act
Clean Water Act

Newfoundland and Labrador
http://www.mae.gov.nl.ca/
Environmental Protection Act
Water Resources Act

Nunavut
http://www.gov.nu.ca/justice/
Environmental Protection Act
Environmental Rights Act
Nunavut Wildlife Act
Pesticide Act

Ontario
https://www.ontario.ca/page/ministry-environment-and-climate-change
https://www.ontario.ca/laws
Clean Water Act, 2006
Environmental Protection Act
Environmental Bill of Rights
Environmental Assessment Act
Ontario Water Resources Act

Prince Edward Island
www.gov.pe.ca/jps/index.php3
For Acts and Regulations:
www.canlii.org/en/pe
Environmental Protection Act
Natural Areas Protection Act
Pesticides Control Act

Quebec
www.mddelcc.gouv.qc.ca/index_en.asp
For Acts and Regulations:
www3.publicationsduquebec.gouv.qc.ca/loisreglements.en.html
Environment Quality Act
Sustainable Development Act
Civil Code of Quebec (Code civil du Québec)

Saskatchewan
www.environment.gov.sk.ca
The Environmental Assessment Act
The Environmental Management and Protection Act, 2010
The Fisheries Act (Saskatchewan)

Northwest Territories
www.enr.gov.nt.ca
Environmental Protection Act
Environmental Rights Act
Pesticide Act
Waste Reduction and Recovery Act

Nova Scotia
http://www.novascotia.ca/nse/
Environment Act
Environmental Goals and Sustainable Prosperity Act
Water Resources Protection Act

Yukon
www.env.gov.yk.ca/
For Acts and Regulations:
www.canlii.org/en/yk
Environment Act
Waters Act
Solid Waste Regulations
Air Emissions Regulations

All websites are valid as of June 21, 2017.

13.4 ENVIRONMENTAL GUIDELINES FOR ENGINEERS AND GEOSCIENTISTS

Although the care of our environment is everyone's responsibility, professional engineers and geoscientists must assume a key role because their decisions often have a great impact on the environment. Environmental guidelines are published by several Associations and by Engineers Canada. Professional Engineers Ontario (PEO) has modified the definition of professional engineering activities to include the safeguarding of the environment, in addition to life, health, property, economic interests, and the public welfare. This brings protection of the environment within the legal responsibilities of professional engineers in Ontario.[5]

Historical Development

The Association of Professional Engineers and Geoscientists of Alberta (APEGA) developed the *Guideline for Environmental Practice* in 1994, revising it in 2004.[6]

The Association of Professional Engineers and Geoscientists of British Columbia (APEGBC) developed their *Guidelines for Sustainability* in 1995, updating them in 2016.[7] The APEGBC guidelines have many clauses that are similar to the APEGA guideline, but they emphasize the importance of sustainability—a philosophy that links a viable economy to protection of the environment and to social well-being. These APEGBC guidelines are advisory and are intended to help members maintain a state in which these features flourish indefinitely. The APEGBC guidelines on sustainability specifically do not create any legal duty or obligation by any member to any person.

In 2016, the Qualifications Board, a standing committee of Engineers Canada, prepared a *National Guideline on Sustainable Development and Environmental Stewardship for Professional Engineers*,[8] based on the 2004 APEGA guideline and incorporating additional material from the APEGBC guidelines. Many provincial Associations have endorsed the *National Guideline*.

These guidelines are complementary to the Code of Ethics. They commit professional engineers and geoscientists to protecting the environment and safeguarding the public's well-being. The original documents contain a wealth of explanatory information.

Guideline Summary

Professional members:

1. Should maintain and continuously improve awareness and understanding of environmental stewardship, sustainabxility principles, and issues related to their field of practice.

2. Should use expertise of others to adequately address environmental and sustainability issues and enhance understanding and improve practices.
3. Should incorporate global, regional, and local societal values applicable to their work.
4. Should establish mutually agreed sustainability indicators and criteria for environmental stewardship at the earliest possible stage in projects, and evaluate these periodically against performance targets.
5. Should assess the costs and benefits of environmental protection, eco-system components, and sustainability in evaluating the economic viability of the work.
6. Should integrate environmental stewardship and sustainability planning into the life-cycle planning and management of activities that impact the environment, and should implement efficient, sustainable solutions.
7. Should seek and disseminate innovations that achieve a balance between environmental, social and economic factors while contributing to healthy surroundings in the built and natural environment.
8. Should become engaged in a leadership role in the ongoing discussion of sustainability and environmental stewardship and solicit input from stakeholders and accredited experts in an open and transparent manner.
9. Should assure that projects comply with regulatory and legal requirements by the application of best available, economically viable technologies and procedures.
10. Should implement risk mitigation measures in time to minimize environmental degradation where there are threats of serious or irreversible damage but a lack of scientific certainty.*

Implementing Environmental Guidelines

Legally, the above guidelines appear to be voluntary guidance; in Alberta, however, the mandatory wording ("shall") in precepts 2, 3, and 8 appears to make these three clauses more forceful and therefore possibly enforceable under the APEGA Code of Ethics. These clauses put a special onus on the professional to

- find and comply with the appropriate regulations for the professional's discipline,
- apply professional and responsible judgment,
- call for specialist guidance when it is needed, and
- disclose information when necessary to protect public safety.

* Engineers Canada, *National Guideline on Sustainable Development and Environmental Stewardship for Professional Engineers*, September 2016, https://engineerscanada.ca/publications/national-guideline-on-sustainable-development-and-environmental-stewardship #-the-ten-guidelines (accessed July 13, 2017). Reprinted with permission.

13.5 ENVIRONMENTAL GUIDELINES FOR CORPORATIONS

The Ceres Principles

In addition to the above guidelines, which apply to individuals, a notable set of environmental principles has evolved for corporations. These principles were developed in 1989 by the Coalition for Environmentally Responsible Economies (Ceres), an American coalition of institutions—mainly environmental, public interest, and community groups, as well as investors, advisers, and analysts.

The Ceres environmental principles were developed in the wake of the *Exxon Valdez* oil spill, an environmental disaster that polluted the Alaskan shoreline in March 1989. The *Exxon Valdez* ran aground in a bay on the Alaskan coast. The accident was attributed to navigational errors; also, it is possible that the captain was drunk. The resulting 41,000 m^3 oil spill (10.8 million US gallons) killed wildlife and coated over 2,000 km (1,300 miles) of shoreline. It was one of the worst environmental disasters in North American history[9] (although it was exceeded many times over by the BP Deepwater Horizon oil spill in April 2010—the largest accidental oil spill in history).

In the autumn of 1989, Ceres published the Valdez Principles (later renamed the "Ceres Principles"), a 10-point code of corporate environmental conduct. Ceres asks industrial corporations to support the Ceres Principles by adopting them as a corporate Code of Environmental Ethics. The 10 principles, reproduced in Web Appendix C, with permission of Ceres, include protection of the biosphere, sustainable use of natural resources, reduction and disposal of wastes, energy conservation, environmental risk reduction, safe products and services, environmental restoration, need to inform the public, management commitment to environmental issues, and regular audits and reports.

The Ceres Principles have been successfully expanded into a guide for incorporating sustainability into every aspect of the 21st-century corporation. "The Ceres Roadmap for Sustainability" is a progress report that measures how well corporations are meeting an arduous set of goals for sustainability.[10]

Registration under ISO 14001

Of course, when corporations are serious about demonstrating their commitment to responsible interaction with the environment, the most visible route to follow is registration under the ISO 14000 series of Environmental Management System Standards, established in 1996—in particular, ISO 14001 (discussed in Chapter 6 in this textbook). ISO 14001 registration requires a commitment from senior management, a review of all of the applicable environmental laws, an audit of the environmental impact of the corporation's operations, development of environmental policies, establishment of measurement techniques and methods for recording the measurements, preparation of a procedures manual to define who does what, training of employees, full communication within the corporation, and regular audits to ensure that the system is working and achieving its goals. Obviously, registration indicates that the corporation has made a serious commitment to act responsibly in environmental matters. Moreover, since the ISO 14001 standard is recognized internationally, registration should be an aid in international trade.

13.6 THE DUTY TO REPORT—WHISTLE-BLOWING

An engineer or geoscientist who observes unsafe, unethical, or illegal practices must take action. Each case is different, of course. Although no procedure works every time, a direct, personal contact will resolve most problems. Some general rules apply.

- **First**, you must decide whether the situation is dangerous to human life, because a much more aggressive approach is necessary in this case. Many cases involve infractions of the Code of Ethics, but serious cases may also be offences under the Criminal Code.
- **Second**, you must decide whether the problem is caused by the situation or by the individual, and what the simplest remedial action would be. Obviously, some personal judgment is required at this stage, and the problem-solving technique described earlier (in Chapter 9) may be useful.
- **Third**, a direct, but informal personal conversation with the closest person involved (presumably a colleague or your boss) in which you propose your solution (and not just restate the problem) usually yields the best results. If this approach is ineffective, then you would speak to someone further up the chain of authority. (For example, speak to your boss's boss.)
- **Finally**, if you can see no resolution in sight, it would be appropriate to consult your Association for further guidance.

For example, a concern about unethical billing practices is not usually urgent and can usually be resolved informally. A situation where workers' lives are at risk is clearly urgent and might be referred immediately to the authorities (including the police) if a delay in acting might cause injury or death. Failure to take immediate action to protect human life is professional misconduct.

Provincial Associations have often served as mediators to help professionals who believe that clients, colleagues, employers, or employees are involved in unsafe, unethical, or illegal practices. The Association can play a useful role by helping define the ethical issues involved, advising the professional, communicating the concerns to the client or employer in an unbiased way, and generally mediating as informally as possible.

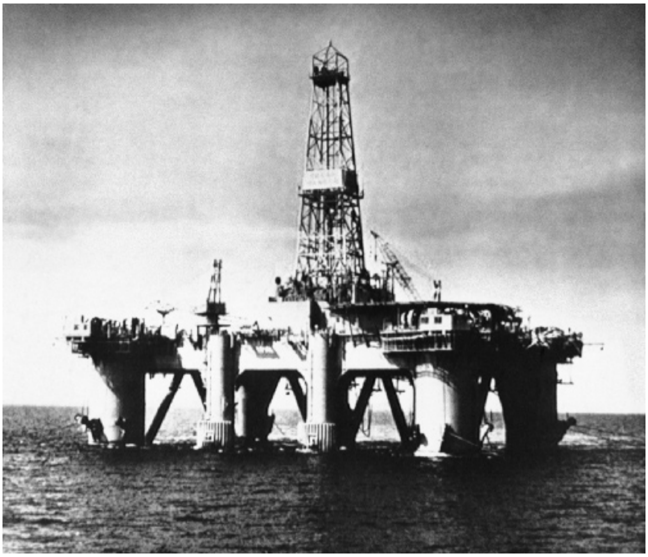

Photo 13.2 — The Ocean Ranger Floating Oil Rig. *The sinking of the Ocean Ranger in the North Atlantic on February 15, 1982, was the worst offshore drilling accident in North American history and Canada's worst maritime tragedy since the Second World War. When it was built, the Ocean Ranger was the world's largest self-propelled "semi-submersible" drilling rig. It was designed by Ocean Drilling and Exploration Company, Inc. (ODECO) to weather winds of 190 km/h (100 knots) and 34 m (110 ft.) waves and was often called "indestructible." Nevertheless, it sank in a heavy storm. All 84 crew members drowned, including 69 Canadians. Both the United States and Canada convened inquiries into the tragedy. The primary cause for the sinking was traced to a storm wave that smashed a portal (window) in the ballast control room. The ballast control keeps the rig stable by pumping water in or out of ballast tanks to balance the rig. However, the flood of seawater through the portal short-circuited the control panels, and valves began to open erratically, allowing seawater into the supporting pontoons. As the supporting pontoons filled with water, the Ocean Ranger began to list (tilt), and after several hours, it eventually capsized. Two inquiries were held, and a more complex scenario emerged. The Ocean Ranger had several design flaws, the control room operators were totally untrained, and their inexperienced actions made the pontoons even more unstable, causing the rig to eventually capsize. Safety equipment and safety training were inadequate.*
The full story is told in several books. An incisive and comprehensive summary is found in Susan Dodd's The Ocean Ranger: Remaking the Promise of Oil *(Fernwood Publishing, 2012). Several memorials, novels, songs, and films commemorate the tragedy, including a provincial government website at www.heritage.nf.ca/articles/politics/ocean-ranger-disaster-response.php. An excellent documentary film,* The Ocean Ranger Disaster, *produced by CineNova Productions Inc. (2002), is available on the Internet at www.imdb.com/title/tt0368096 (accessed June 21, 2017).*

Source: © AP Photo

PEO defines the procedure for reporting in *A Professional Engineer's Duty to Report—Responsible Disclosure of Conditions Affecting Public Safety*. An excerpt from their publication follows:

The Reporting Process

Engineers are encouraged to raise their concerns internally with their employers or clients in an open and forthright manner before reporting the situation to PEO. Although there may be situations where this is not possible, engineers should first attempt to resolve problems themselves.

1. If resolution as above is not possible, engineers may report situations in writing or by telephone to the Office of the Registrar of PEO. In reporting the situation to PEO, engineers must be prepared to identify themselves and be prepared to stand openly behind their judgements if it becomes necessary.
2. The Office of the Registrar will expect the reporting party to provide the following information:
   a. The name of the engineer who is reporting the situation;
   b. The name(s) of the engineer's client/employer to whom the situation has been reported;
   c. A clear, detailed statement of the engineer's concerns, supported by evidence and the probable consequences if remedial action is not taken.
3. The Office of the Registrar will treat all information, including the reporting engineer's name, as confidential to the fullest extent possible.
4. The Office of the Registrar will confirm the factual nature of the situation and, where the reporting engineer has already contacted the client/employer, obtain an explanation of the situation from the client/employer's point of view.
5. If the Office of the Registrar has reason to believe that a situation that may endanger the safety or welfare of the public does exist, the Office of the Registrar will take one or more of the following actions:
   a. Report the situation to the appropriate municipal, provincial and/or federal authorities;
   b. Where necessary, review the situation with one or more independent engineers, to obtain advice as to the potential danger to public safety or welfare and the remedial action to be taken;
   c. Request the client/employer to take steps necessary to avoid danger to the public safety or welfare;
   d. Take such other action as deemed appropriate under the circumstances;
   e. Follow up on the action taken by all parties to confirm that the problem has been resolved.
6. Wherever possible, the Office of the Registrar shall maintain accurate records of all communications with the reporting engineer, any authorities involved and the client/employer.

In Summary: The Office of the Registrar will cooperate with any engineer who reports a situation that the engineer believes may endanger the safety or welfare of the public. Wherever possible, the confidentiality of reporting engineers and the

> information they disclose will be maintained. In all dealings with the engineer's client/employer and the public, the Office of the Registrar will emphasize the engineer's duty to report under the Act and Regulations, and will provide the reporting engineer with an endorsement of the performance of his/her duty, provided that the Registrar has determined that the engineer has acted properly and in good faith.*

The above PEO policy is orderly and impartial. It clearly places public welfare first. However, not all Associations have implemented a similar policy.

13.7 THE ETHICAL DILEMMA OF WHISTLE-BLOWING

Whistle-blowing always involves an ethical dilemma. Every Code of Ethics requires engineers and geoscientists to consider their duty to society as paramount. However, every code also stipulates duties to clients, employers, colleagues, and employees. At what point does the duty to society override these other duties? For example, the Code forbids disclosing confidential information, but conversely, the Code requires disclosure of any situation that may endanger the health or safety of the public. Obviously, these duties may conflict. Whistle-blowing is a controversial act, so we must define the term clearly. Connie Mucklestone provides a good definition in her article "The Engineer as Public Defender":

> Whistleblowers are people (usually employees) who believe an organization is engaged in unsafe, unethical or illegal practices and go public with their charge, having tried with no success to have the situation corrected through internal channels.[11]

True whistle-blowing is rare because, as the above quote emphasizes, a true whistle-blower must be concerned about "unsafe, unethical or illegal practices," and such valid complaints can usually be resolved simply by communicating the facts to the people in charge. Personal complaints or disputes are not a proper basis for whistle-blowing. A whistle-blower is different from a troublemaker in two important ways: (1) the motive of the person involved and (2) the methods used to protect the public. The following quote illustrates these points:

> Engineers must act out of a sense of duty, with full knowledge of the effect of their actions, and accept responsibility for their judgement. For this reason, any process which involves "leaking" information anonymously is discouraged. There is a basic difference between "leaking" information and "responsible disclosure." The former is essentially furtive, and selfish, with an apparent objective of revenge or embarrassment; the latter is open, personal, conducted with the interest of the public in mind and obviously requires that *engineers put their names on the action and sometimes their jobs on the line*.** (emphasis added)

* Professional Engineers Ontario (PEO), *A Professional Engineer's Duty to Report: Responsible Disclosure of Conditions Affecting Public Safety*, brochure (Toronto: PEO, January 2010), 3–5, available at http://www.peo.on.ca/index.php/ci_id/16158/la_id/1.htm (accessed June 21, 2017). Excerpt reprinted with permission of PEO.

** Ibid, p. 2. Excerpt reprinted with permission of PEO.

The whistle-blower must be aware that the process may involve public exposure and scrutiny and may place his or her career in jeopardy. Obviously, whistle-blowing should not be done casually, unknowingly, or wantonly. The provincial Association should be contacted, and its reporting process should be followed.

In summary, before using the reporting process described earlier, an engineer or geoscientist should consider the following three points:

- **Informal resolution:** It is extremely important to try to resolve problems informally and internally, in an open and professional manner. In most cases, clear communication is all that is required. A professional must be certain that an informal internal solution cannot be obtained before whistle-blowing and must assume the responsibility and consequences of any harm that results from a frivolous accusation.
- **Confidentiality:** Professionals must always report unethical cases to the appropriate regulating body and not to the news media. The goal is to remedy a problem, not to embarrass individuals.
- **Retaliation:** When an employee reports an unethical, illegal, or unsafe act to public authorities, the employer may retaliate by firing the employee. Professional engineers and geoscientists should know that reporting (when justified) is not a basis for dismissal (as explained in Chapter 11). A wrongfully dismissed employee can sue to recover lost wages and costs.

13.8 A DISSENTING VIEW OF THE DUTY TO SOCIETY

The first clause of every Code of Ethics says that professionals must consider their duty to society to be paramount. This obligation seems clear and unequivocal. However, one well-known expert on engineering ethics, Samuel Florman, spoke against this clause as a general guide, because it does not have a precise meaning. His comments are quoted, in part, below:

> If this appeal to conscience were to be followed literally, chaos would ensue. Ties of loyalty and discipline would dissolve, and organizations would shatter. Blowing the whistle on one's supervisors would become the norm, instead of a last and desperate resort. It is unthinkable that each engineer determine to his or her own satisfaction what criteria of safety, for example, should be observed in each problem he or she encounters. Any product can be made safer at greater cost, but absolute freedom from risk is an illusion. Thus, acceptable standards must be specifically established by code, by regulation, or by law, or where these do not exist, by management decision based upon standards of legal liability. Public-safety policies are determined by legislators, bureaucrats, judges, and juries, in response to facts presented by expert

> advisers. Many of our legal procedures seem disagreeable, particularly when lives are valued in dollars, but since an approximation of the public will does appear to prevail, I cannot think of a better way to proceed. . . .
>
> The regulations need not all be legislated, but they must be formally codified. If we are now discovering that there are tens of thousands of potentially dangerous substances in our midst, then they must be tested, the often-confusing results debated, and decisions made by democratically designated authorities—decisions that will be challenged and revised again and again. . . .
>
> This is an excruciatingly laborious business, but it cannot be avoided by appealing to the good instincts of engineers. If the multitude of new regulations and clumsy bureaucracies has made life difficult for corporate executives, the solution is not in promising to be good and eliminating the controls, but rather in consolidating the controls themselves and making them rational. The world's technological problems cannot even be formulated, much less solved, in terms of ethical rhetoric: especially in engineering, good intentions are a poor substitute for good sense, talent, and hard work.*

Florman's comments are thought-provoking and refreshing. A professional person should not have to be a martyr, or sacrifice his or her career, to protect the public welfare. The public (as represented by the government) must assist by providing the regulation and controls upon which a professional can depend when making a difficult decision. Florman's recommendation for developing standards and regulations based on solid research deserves support—such standards are essential to the practising professional. Instead of discarding the public safety clause in the Code of Ethics as Florman suggests, however, it might be better to provide more mediation between whistle-blowers and their employers (as some provincial Associations are now doing) and to provide protection against retaliation for professionals who, after exhausting all other routes of action, report unethical practices.

In addition, note that Florman is referring to the United States, where licensing laws are much less restrictive than Canadian laws. As explained in Chapter 2, Canadian laws require a licence to practise, whereas U.S. laws permit anyone to practise engineering or geoscience; a U.S. licence is required only to use the title of Professional Engineer or Professional Geoscientist. Canadian Codes of Ethics apply to all practitioners and are enforceable, whereas U.S. law is not fully enforceable—unlicensed practitioners may practise as long as they do not call themselves "Professional Engineers" or "Professional Geoscientists."

* Samuel C. Florman, "Moral Blueprints," *Harper's Magazine*. Copyright ©1978 by Harper's Magazine. All rights reserved. Reproduced from the October issue by special permission.

CASE HISTORY 13.1

THE LODGEPOLE BLOWOUT

INTRODUCTION

Residents of the Drayton Valley area of Alberta will long remember the autumn of 1982. At 2:30 p.m. on October 17, the Amoco Lodgepole oil well, being drilled near Drayton Valley, encountered sour gas (gas laden with hydrogen sulphide) and blew out of control. Over the next two months, while specialists fought to regain control of the well, residents living within a 20 to 30 km (12 to 19 mile) radius were twice exposed to the rotten egg smell of hydrogen sulphide (H_2S) and the threat of H_2S poisoning. The first H_2S exposure period lasted 16 days; the second lasted 12 days. During attempts to cap the blowout, two employees were overcome by H_2S and died, and the well was twice engulfed in flames. About 28 people were voluntarily relocated to avoid the H_2S, and several homes were ordered evacuated during especially heavy H_2S concentrations on October 29 and from November 17 to 24. Even people living far from the well were subjected to noxious and unpleasant odours, depending on the prevailing winds.

The well was not capped successfully until December 23. In January 1983, a Lodgepole Blowout Inquiry Panel was convened to investigate the causes of the blowout, the actions taken to prevent it and to regain control, and the hazard to human health and the impact on the environment, and to recommend what should be done to avoid future blowouts at wells in Alberta. The Panel issued a comprehensive report in December 1984.[12]

EVENTS LEADING UP TO THE BLOWOUT

The Amoco Lodgepole oil well, known officially as Amoco Dome Brazeau River 13-12-48-2, is located about 140 km (90 miles) west of Edmonton (about 40 km/25 miles west of Drayton Valley). The well was named after the nearby hamlet of Lodgepole, which is situated about halfway between the well and Drayton Valley. The Amoco Canada Petroleum Company obtained a licence to drill the Lodgepole oil well from the Alberta Energy Resources Conservation Board (also known for several years as the Alberta Energy and Utilities Board). The well was “spudded” (started) in August 1982. Drilling proceeded to a depth of about 3,000 m (10,000 ft.) without problems. An intermediate casing was then installed, and the drilling crew began coring operations to examine the strata prior to drilling into the oil-bearing formation. Two cores were obtained without apparent problems. On October 16, the crew was obtaining a third core when they realized that fluid was entering the well from the oil-and gas-bearing formation.

The drill crew stopped the coring operations to deal with this problem, which is known as a “kick,” because reservoir fluids enter the wellbore and force the drilling mud out of the well. For the next 16 hours, the crew fought to regain control of the well, but eventually the drill pipe "hydraulicked" up the hole and the kelly hose was severed, at which point the well was out of control. The intense pressure caused a continuous, uncontrolled flow of mud and sour gas into the atmosphere. The exact flow rate is unknown; however, during the Inquiry it was estimated at 1.4 million m^3 of gas per day. Later tests indicated that the flow could have been even greater.[13]

EMERGENCY MEASURES

Amoco immediately implemented its Major Well-Site Incident Response Plan, and key Amoco personnel were notified of the blowout. People and equipment were dispatched to the site, including safety personnel, paramedics, ambulances, helicopters, and firefighting equipment (including breathing apparatus). Hydrogen sulphide monitoring equipment was ordered for both on-site and off-site monitoring. The company immediately hired specialists to cap the well, and special equipment to do so was ordered.

Over the next two months, several plans for capping the well were tried without success. On November 1, 1982, a failed attempt resulted in a fire that engulfed the well. A new control plan was developed, and on November 16, the fire was extinguished with explosives prior to implementing the plan. Two days later, while attempting to execute the plan, an accident occurred, resulting in the deaths of two employees who were overcome by H_2S. On November 25, the well was again on fire. It was later determined that this fire probably resulted from an undetected underground muskeg fire that had been smouldering for some time. Amoco decided to try to cap the well while it was still ablaze; however, the well specialists declined to attempt this procedure, which had seldom succeeded with other blowouts. On December 1, new well-capping specialists were hired, and by December 23, they had installed a blowout preventer (BOP) over the stub of the intermediate casing. Lines were then connected to flare off the gas and pump mud into the well. Over the next five days, 96 m^3 of mud were pumped into the well, the pressure was stabilized, and the crisis was brought to an end.

WHAT WENT WRONG AT THE LODGEPOLE WELL?

The blowout occurred because Amoco personnel were unable to control the hydrostatic pressure in the well. This is a critically important and delicate balancing procedure. The control strategy—usually called the "well control plan"—sets out the basic principles and procedures that must be followed to ensure that a well will not blow out during drilling, completion, or production operations.

The well control plan is rarely a single document. Rather, it is the sum total of all drilling program documents, special instruction bulletins—including those posted at the site—company procedure manuals, and other books, manuals, and written and verbal instructions that guide drilling procedures. To help you understand the importance of the control plan and how it applies to the critical balancing of hydrostatic pressure in the well, the following explanatory note is reproduced from the Inquiry report, with permission:

> The drilling fluid (mud) system has a dominant position in the general well control plan for any well. The plan requires that the hydrostatic pressure in the wellbore be greater than the formation pressure. Hydrostatic pressure depends on the height of the column of drilling mud and the density of the mud. A reduction in either or both of these will reduce the pressure that results from the column or head of drilling mud. If the hydrostatic pressure is too low, a state of underbalance exists and fluids from the formation, such as gas, may flow into the wellbore. Unless this flow is properly controlled, a blowout will result. On the other hand, if the hydrostatic pressure is too great and a state of excessive overbalance exists, the drilling mud may flow into the formation. This is referred to as "lost circulation" and will result in a loss of hydrostatic pressure which can also lead to a blowout. . . .
>
> . . . In developing a drilling program, an operator must therefore consider formation pressures encountered at other wells in the general vicinity of the well being planned for and select a drilling mud density which will ensure a modest overbalance. To ensure that neither a state of underbalance nor of excessive overbalance develops as the well is drilled, close attention must be given to:
>
> a. mud density,
> b. any contamination of the drilling mud that will change its effective density, such as by drill cuttings (increase) or by air introduced during tripping (decrease),
> c. maintaining a full mud column,
> d. the rate of lowering the drill pipe,
> e. the rate of hoisting the drill pipe, and
> f. pumping rate and pressure.
>
> Should the hydrostatic pressure from the mud column prove to be insufficient, and as a consequence, formation fluids such as gas enter the wellbore, a kick condition would exist. Procedures have been developed such that those fluids may be controlled within the wellbore using the BOP [blowout preventer] system mounted on the well casing. The gas is flared at the surface and control operations are continued until the flow is progressively restricted and stopped. If the kick has occurred and efforts to control and contain the in-flowing formation fluids have failed, an uncontrolled flow or blowout results and re-establishing control may be both technically difficult and dangerous.
>
> The general well control plan must include the procedures to be used to circulate out the kick, and it must also ensure that proper equipment will be available should a kick occur. This includes the BOP system but additionally, casing and drill pipe design and selection are important components of the plan.
>
> In order to carry out the general well control plan, the detailed drilling plan must provide for the integrity of the drilling fluid system throughout the drilling operation regardless of the circumstances encountered. The operator should have on site, at critical times, experts in geology and mud properties. The operator must also ensure

> that the drilling and well equipment, particularly the BOP, is functioning properly. Finally, for the general well control plan to be implemented effectively, on-site supervisors and the drilling crew must be properly trained, regularly briefed, and always prepared to act promptly in carrying out prescribed kick control procedures.*

EVALUATING AMOCO'S ACTIONS

Amoco assisted the Inquiry Panel by providing complete documentation on its drilling plan, drilling mud program, rig, and well equipment, and on the qualifications of the well-site crew and supervisors. It also provided a detailed chronology of events leading to the blowout and expert witnesses to explain the events surrounding the blowout. An especially important point was the density of the drilling mud used. As explained above, well drilling is a "balancing act." Obtaining the optimum mud density is a key part of the act: it requires knowledge of the formation pressures and careful monitoring of the hydrostatic pressure. The Inquiry report continues as follows:

> . . . In developing its drilling plan, Amoco reviewed information concerning formation pressures encountered at a large number of other wells in nearby areas. These indicated that the pressures in the formation of interest at the [Lodgepole] well would ordinarily be around 33 000 to 35 000 kPa. In isolated cases, pressures as low as 22 430 kPa and as high as 46 540 kPa had been reported. Amoco decided to design the drilling mud density to meet a pressure of 33 600 kPa with provision for increasing the density if higher pressure was encountered.
>
> Amoco also indicated that its normal practice was to design mud density to provide a mud column overbalance of some 1500 kPa above the expected formation pressures. . . .
>
> Calculations by the Panel indicate that, at the predicted Nisku reef depth of 3035 m, the planned mud density of 1150 kg/m^3 would result in an overbalance of some 630 kPa relative to the expected pressure of 33 600 kPa. . . .
>
> The planned pressure overbalance of 630 kPa plus or minus the effects of operations such as pumping or pulling out of the hole, was less than the 1500 kPa normally used by Amoco. . . .
>
> . . . In summary, the Panel concludes that the planned mud density for the [Lodgepole] well was on the low side and therefore extra care should have been specified during the critical period of drilling into the Nisku zone. Although substantial seepage losses were reported and these might have been interpreted by on-site personnel as an indication that the mud was on the heavy side, an analysis of the situation indicates that the reported losses were likely due to errors. This is an indication that the drilling practices . . . were less than satisfactory.**

* *Lodgepole Blowout Inquiry: Phase 1—Decision Report*, Report to the Lieutenant Governor in Council with Respect to an Inquiry Held into the Blowout of the Well: Amoco Dome Brazeau River 13-12-48-12 (Calgary, AB: Energy Resources Conservation Board, December 1984).

** Ibid.

ASSIGNING RESPONSIBILITY

Although the Lodgepole Inquiry Panel concluded that "no single element in the chain of events was the sole cause of the blowout," the Panel's examination of the events led it to conclude that the initial kick occurred mainly because "drilling practices during the taking of cores were deficient." When combined with the marginally adequate mud density being used, this deficiency permitted the entry of reservoir fluids into the wellbore.[14]

Amoco expected the Lodgepole well to find "sweet" oil, but the company's control plan definitely recognized and accounted for the possibility of encountering sour gas. The Panel accepted this testimony and did not believe that "the expectation of sweet oil played a direct role in the cause of the blowout. However, it may have influenced planning for the well and may have led to less caution in the drilling operations than might have been the case if the well was being drilled specifically for sour gas."[15]

The Panel also concluded that in all likelihood the kick was not controlled because the drilling crew did not immediately recognize the problem and therefore did not immediately apply and maintain standard kick-control procedures. With regard to contributing factors, the Panel noted that several pieces of vital equipment did not function properly and that supplies of mixed drilling mud were not adequate during the kick-control operations. As the Panel wrote in its report:

> The unexpected entry of reservoir fluids into the wellbore was probably due to a combination of Amoco not adhering to sound drilling practices and only marginally adequate mud density. If the degasser had operated effectively, the initial kick might have been circulated out of the system, and subsequent kicks would likely have been avoided. Even with the failure of the degasser, control might have been maintained if there had been sufficient and properly weighted mud on hand to pump into the well. Additionally, if the casing pressure instruments had been operational from the outset, the crew might have recognized the kick at an earlier stage and implemented standard kick-control procedures when fluid influx was still relatively small. If the decision had been made to use hydrogen sulphide (H_2S)-resistant pipe for the full drill string, the pipe might not have parted and the succession of kicks might still have been successfully circulated out. And finally, if the travelling block hook latch had not failed, it may have been possible to retain control of the well by "top kill" methods.*

The Panel was satisfied that Amoco applied reasonable judgment in selecting the type of drilling rig, the degasser, and the type of drill pipe, even though, in retrospect, other choices might have been better. However, the Panel concluded that Amoco's actions were deficient with respect to

* *Lodgepole Blowout Inquiry: Phase 1—Decision Report*, Report to the Lieutenant Governor in Council with Respect to an Inquiry Held into the Blowout of the Well: Amoco Dome Brazeau River 13-12-48-12 (Calgary, AB: Energy Resources Conservation Board, December 1984).

a) drilling practices during coring operations (cores No. 2 and 3),
b) implementation of standard kick-control procedures,
c) ensuring adequate mixed drilling mud was available at all times, and
d) maintaining equipment in satisfactory operating condition (casing pressure instruments).

> It appears to the Panel that the fundamental problem was that Amoco did not apply the necessary degree of caution while carrying out operations in the critical zone. Amoco did not appear to be sufficiently aware of the potential for problems that could occur when coring into the Porous zone and thus the need to be fully prepared in the event of a fluid influx. Consequently, when a kick developed, there were delays in responding to it. Then, when equipment problems occurred and supplies of mixed mud were inadequate, Amoco was forced into further delays of precious time in implementing kick-control actions.*

In the second phase of the Inquiry, the Panel made a series of recommendations for reducing the possibility of future blowouts.[16]

LODGEPOLE BLOWOUT: CONCLUSION

Oil drilling is a demanding, uncertain, and dangerous job. The Lodgepole blowout, which resulted in two tragic deaths and millions of dollars in financial losses, illustrates this point. There are other losses that are harder to put a price on, such as the threat of H_2S poisoning, the disruption of life, and the inconvenience caused to almost all the residents within a 30 km (19 mile) radius of the well. It is also difficult to evaluate the magnitude of loss suffered by Amoco and its technical staff as a result of the negative publicity resulting from the blowout. Safe, standard procedures on drill sites are essential to avoid these dangers.

DISCUSSION TOPICS AND ASSIGNMENTS

1. Assume that you have graduated from university and have been working for five years as a plant design and maintenance engineer for a pulp and paper company in northern Canada. The company is a wholly owned subsidiary of a large multinational conglomerate. When you received your P.Eng. licence, you were promoted to chief plant engineer. You work directly for the plant manager, François Bédard, who reports to the head office, which is not in Canada. The company employs about 150 people—most of the adult population of the nearby village—either directly as employees or indirectly as woodcutters.

* *Lodgepole Blowout Inquiry: Phase 1—Decision Report*, Report to the Lieutenant Governor in Council with Respect to an Inquiry Held into the Blowout of the Well: Amoco Dome Brazeau River 13-12-48-12 (Calgary, AB: Energy Resources Conservation Board, December 1984).

In the course of your work, you have become aware that the plant effluent contains a very high concentration of a mercury compound that could be dangerous. In fact, since the plant has been discharging this material for 25 years, water in the nearby river downstream from the plant is unfit for drinking or swimming. You suspect that a curious new illness in an Aboriginal village about 40 km (25 miles) downstream is really Minamata disease, the classic symptoms of which are spasticity, loss of coordination, and, eventually, death. You also suspect that the fish in the river have been contaminated with the mercury and have spread the contamination to all the downstream lakes.

Remedying these problems would involve drastic changes to the plant that would cost at least $10 million. So far, you have told no one of your suspicions except Bédard, with whom you have discussed the problem at length. Bédard, who is not an engineer, has confided that the head office considers the plant only marginally profitable and that an expenditure of this magnitude is simply not possible. He has also told you that the head office would close the plant, causing massive unemployment in the area and probably forcing the workers to abandon their homes to seek work elsewhere. What should you do?

2. Approximately 50,000 people are killed every year in car accidents in North America, yet people apparently consider driving a car to be worth the risk. Fewer than 10 people have been killed in North America in nuclear reactor accidents, yet many people are afraid of nuclear power. Many people die every year while producing food (even farming is dangerous), and many thousands of miners were killed in the 20th century (coal mining is especially dangerous). Clearly, there is a discrepancy between the average person's perception of danger and the true probability of death (as shown by statistics). Yet when it comes to public support of major engineering and geoscience projects, perceptions often have a strong impact on the public. Using the information resources available to you, complete the following assignments:
   a. Examine the risks associated with the various energy sources (solar, wind, wave, geothermal, fission, fusion, and so on), and develop a fair method for comparing the risks and benefits of each. In other words, find the statistics for the probability of injury or death per unit of energy produced. Compare this with automobile travel on the basis of risk per unit of energy consumed.
   b. Using the concepts provided in this chapter and in Chapter 6 on hazards, state in one or two pages an ethical guideline for deciding when construction of a dangerous facility (such as a nuclear power plant) or production of a dangerous chemical (such as a pesticide) is morally justified. Include financial, technical, and political arguments in your answer, as well as ethical concepts.

3. We North Americans consume more energy and resources per capita than any other people on Earth. By making even small lifestyle changes, we could reduce our consumption significantly; yet as a society, we resist doing so for reasons that are unclear. The following is a brief list of simple ways that we could reduce our consumption of resources. Can you add to this list? How would you go about convincing the general public to "do the right thing" in each of the following cases?
   a. Although many cities have Blue Box recycling programs, some residents insist on discarding bottles, cans, and plastics with garbage. The recyclable materials are dumped in landfills, which exceed their capacities more quickly. The value of the recyclable materials is lost, and costly new landfill sites must be found.
   b. In many homes, the cellar drainage sump (which should be connected to the municipal storm drain system) is connected to the municipal sewage system pipe, which is usually closer. The sump typically collects rainwater from the house's perimeter drain, so this connection permits rainwater to flow into the sewage treatment plant, which must process the otherwise clean rainwater along with the sewage. After a heavy rain, the sewage plant may not be able to cope with the flow. The overflow, which is now polluted with sewage, is usually released into a stream or lake, fouling the environment.
   c. Some car owners who change their own oil do not take the old oil to a gas station for recycling. Instead, they simply dump the used oil into a storm drain or septic sewer. Yet even a small amount of oil can seriously harm the environment—most obviously, by killing aquatic life. The oil may even enter the municipal drinking water system.
   d. Many trailers and recreational vehicles have self-contained toilets that must be emptied regularly. Some people pollute the environment by dumping the toilet contents in parks, fields, or storm sewer systems, rather than into septic systems that would carry it to sewage treatment plants.

Additional assignments can be found in Web Appendix E.

NOTES

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[3] John-David Phyper and Brett Ibbotson, *The Handbook of Environmental Compliance in Ontario* (Toronto: McGraw-Hill Ryerson, 2003).

[4] *Environmental Law in Canada*, 2014, a basic 24-page summary of environmental law in Canada, available from Blake, Cassels & Graydon LLP, http://www.blakesfiles.com/Guides/Blakes_Environmental_Law_in_Canada.pdf (accessed June 21, 2017).

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[6] Association of Professional Engineers and Geoscientists of Alberta (APEGA), *Guideline for Environmental Practice*, V1.0, Edmonton, February 2004, https://www.apega.ca/assets/PDFs/environment.pdf (accessed June 21, 2017).

[7] Association of Professional Engineers and Geoscientists of British Columbia (APEGBC), *Professional Practice Guidelines—Sustainability*, V1.1, April 2016, https://apeg.bc.ca/APEGBC/media/APEGBC/Sustainability%20and%20Climate%20Change/APEGBC-Sustainability-Guidelines.pdf (accessed June 21, 2017).

[8] Engineers Canada, Qualifications Board, *National Guideline on Sustainable Development and Environmental Stewardship for Professional Engineers*, September 2016, https://engineerscanada.ca/publications/national-guideline-on-sustainable-development-and-environmental-stewardship#-the-ten-guidelines (accessed July 13, 2017).

[9] "Exxon Valdez Oil Spill," Valdez, Alaska, http://www.valdezalaska.org/discover-valdez-history/valdez-history-exxon-valdez-oil-spill (accessed June 21, 2017).

[10] "The Ceres Roadmap for Sustainability," Ceres, https://www.ceres.org/roadmap (accessed July 13, 2017).

[11] Connie Mucklestone, "The Engineer as Public Defender" [PEO] *Engineering Dimensions* 11, no. 2 (March–April 1990): 29.

[12] *Lodgepole Blowout Inquiry: Phase 1—Decision Report*, Report to the Lieutenant Governor in Council with Respect to an Inquiry Held into the Blowout of the Well: Amoco Dome Brazeau River 13-12-48-12 (Calgary, AB: Energy Resources Conservation Board, December 1984).

[13] Ibid., 7–17.

[14] Ibid., 1–1.

[15] Ibid., 5–30.

[16] *Lodgepole Blowout Inquiry: Phase 2 Report—Sour Gas Well Blowouts in Alberta; Their Causes, and Actions Required to Minimize Their Future Occurrence (bound as Appendix 5 of Lodgepole Blowout Inquiry: Phase 1—Decision Report)* (Calgary, AB: Energy Resources Conservation Board, April 1984).

Chapter 14
Environmental Threats and Disasters

We take pride in Canada's environment, but we must be alert: our water, land, sea, and air are at constant risk from pollution, negligence, and abuse. This chapter discusses these disturbing vulnerabilities and threats to our environment. As discussed in Chapter 13, Professional Engineers and Geoscientists have certain legal and ethical responsibilities to protect our natural environment.

The chapter has three general themes. The first theme is the wide range of environmental hazards. The second theme is the "tragedy of the commons," which explains the selfish motivation behind many environmental problems and suggests ways to counter it. The chapter closes with case histories on toxic pollution, nuclear safety, and geohazards, including the 2011 Fukushima disaster. Sadly, these environmental disasters resulted from negligence or complacency and were preventable.

14.1 CANADA'S ENVIRONMENTAL HEALTH

Engineering, geoscience, and technology have been of immense benefit to Canada and to civilization. Medicine gives us health, the humanities give us pleasure, and technology gives us time and resources to enjoy them both. However, industrialization brings problems: our lifestyle requires high resource consumption, high energy usage, and high emissions. Environment and Climate Change Canada administers about a dozen Acts of Parliament to

- monitor air and water quality and emissions of greenhouse gases,
- control the level of toxic substances in commercial products,
- forecast meteorological patterns and report weather conditions,
- research and protect the habitat of migratory birds and species at risk, and
- regulate international trade in hazardous waste, hazardous recyclable materials, and endangered species.

The following paragraphs give a glimpse of our environment and the role and problems Environment and Climate Change Canada is facing in fulfilling its mission.

The National Pollutant Release Inventory (NPRI)

Canada discharges millions of tonnes of pollutants every year through industrial activity. Under the Canadian Environmental Protection Act (CEPA, 1999), these emissions must be reported. More than 7,000 "reporting facilities"—factories, processing plants, generating plants, oil and gas operations, and similar industrial facilities as well as commercial and institutional facilities that emit pollutants—must report the release, disposal, or recycling of these substances to Environment and Climate Change Canada. Canadians can obtain this information through the *National Pollutant Release Inventory* (NPRI), established in 1992 to monitor facilities that release or recycle pollutants.[1]

The NPRI website currently lists more than 300 pollutants in six categories, as outlined below:

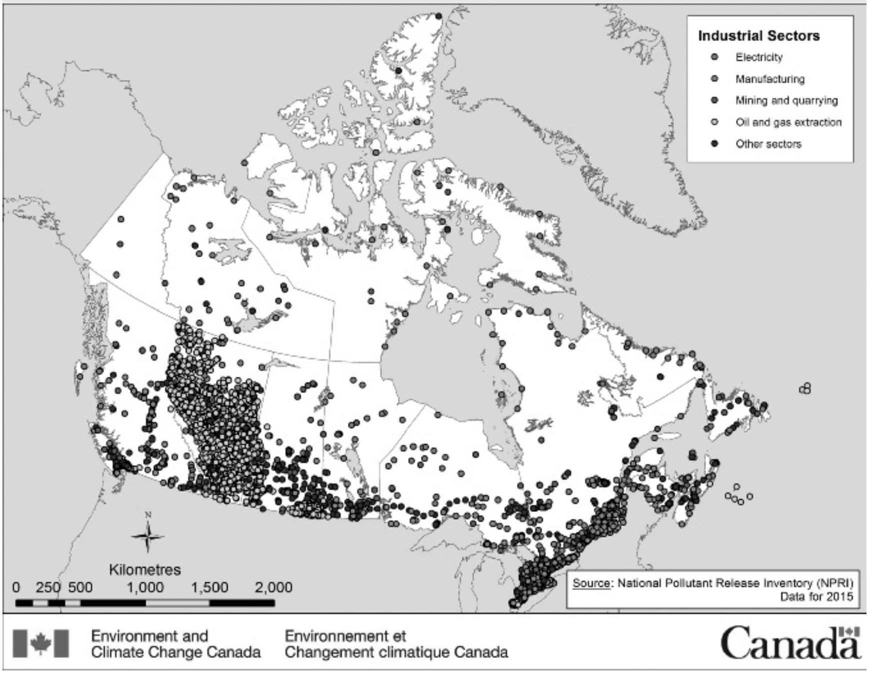
- **1A. Core:** about 195 substances from acetaldehyde to zinc compounds
- **1B. Alternate Threshold:** 17 substances, including bisphenol A, isoprene, arsenic, cadmium, chromium, lead, selenium, and mercury compounds
- **2. Polycyclic Aromatic Hydrocarbons:** 30 organic compounds, from acenaphthene to quinoline
- **3. Dioxins, Furans, and Hexachlorobenzene**
- **4. Criteria Air Contaminants (CACs):** carbon monoxide, nitrogen oxides, sulphur dioxide, particulate matter, Volatile Organic Compounds (VOCs)
- **5. Speciated VOCs**

Reporting is required when quantities of compounds meet specified criteria, which differs for each class of compound. NPRI compiles this information and provides it to the public to track pollution in Canada. The purpose is clear:

> The NPRI is Canada's legislated, publicly accessible inventory of pollutant releases (to air, water and land), disposals and transfers for recycling. It is a key resource for:
>
> - identifying pollution prevention priorities;
> - supporting the assessment and risk management of chemicals, and air quality modelling;
> - helping develop targeted regulations for reducing releases of toxic substances and air pollutants;
> - encouraging actions to reduce the release of pollutants into the environment; and
> - improving public understanding.[2]

The facilities that report pollutant releases to NPRI are easily found using the NPRI website, by using a series of data products, including an NPRI Facility Online Data Search, NPRI datasets (in CSV format, Excel, or MS Access). NPRI facility locations can also be visualized by using NPRI map layers through Google Earth™. It is therefore easy to find reporting facilities located in your community.[3] For example, Figure 14.1 plots the location of each industrial facility that reported to NPRI in 2015.

Figure 14.1 — Industrial Facilities Reporting Pollution Releases, 2015



*This map shows NPRI reporting faciltiies for 2015 (7,284 facilities), excluding those that did not meet the reporting criteria (1,327 facilities).

This map shows the locations of about 7,280 industrial facilities that reported to the National Pollutant Release Inventory (NPRI) in 2015. The NPRI data are available free through the NPRI website for analysis, research, comparisons, or general interest.

Source: 2015 NPRI Reviewed Facility Data Release, https://www.ec.gc.ca/inrpnpri/default.asp?lang=En&n=D55C89B3-1, Environment and Climate Change Canada, 2016. Reproduced with the permission of the Minister of Public Works and Government Services Canada, 2017.

In addition, Environment and Climate Change Canada publishes a wealth of information on almost every aspect of Canada's environmental health on the Internet, including the following:

- **Air and climate indicators:** "National Greenhouse Gas Emissions," "Ambient Levels of Air Pollutants," and "National Air Pollutant Emissions"
- **Water indicators:** "Freshwater Quality in Canadian Rivers," "Water Availability in Canada," and "Restoring the Great Lakes Areas of Concern"
- **Nature indicators:** "Protected Areas," "Ecological Integrity of National Parks," and "Status of Major Fish Stocks" (Regrettably, some indicators are out-of-date.)

NPRI and similar pollutant registers worldwide were created after a major industrial accident near Bhopal, India, in December 1984. The methyl isocyanate gas leak from a Union Carbide pesticide plant killed thousands of people in neighbouring communities. The public realized that they needed to know what industrial threats existed in their communities. (Case History 14.1 describes the Bhopal tragedy.)

Commission for Environmental Cooperation (CEC)

The NPRI data on the release of pollutants into the environment is also provided to the Commission for Environmental Cooperation (CEC), an agency set up by the governments of Canada, Mexico, and the United States as part of the North American Free Trade Agreement (NAFTA). In 1993, the three countries also signed the North American Agreement on Environmental Cooperation (NAAEC) that established "a framework, including a Commission, to facilitate effective cooperation on the conservation, protection and enhancement of the environment in their territories."[4]

The Commission has written many significant reports on environmental matters, available on its website, including these:

- **Environmental Hazards of Transborder Battery Recycling** (lead acid battery exports and lead recycling)
- **Sustainable Freight Transportation** (reducing greenhouse gas emissions from freight transport)
- **Green Building in North America** (sustainable building practices)
- **Electricity and the Environment** (benign but affordable electricity)

The Commission also has an environmental enforcement process, allowing members of the public to "assert" (complain) when a member country is failing to enforce its environmental law effectively. The list of complaints stretches back to the establishment of the CEC, so most of them are settled. Canada appears in about 30 of the 90 complaints. Here is a sample of previous and current complaints:

- **Alberta tailings ponds II** (alleges tailings ponds from oil sands "contain . . . substances . . . deleterious to fish" and "these substances migrate to groundwater.")
- **B.C. salmon farms** (alleged failure to enforce the Fisheries Act exposes wild salmon to "amplified levels of parasites such as sea lice, viral and bacterial diseases, toxic chemicals and concentrated waste.")
- **Protection of polar bears** (alleged failure to enforce the "Species at Risk Act" by failing to list the polar bear . . . as a threatened or endangered species.)
- **St. Lawrence River wind farms** (alleged failure to enforce environmental laws for migratory birds and endangered species by allowing wind farms in sensitive areas.)[5]

14.2 GREENHOUSE GAS EMISSIONS

Scientists have observed that the global mean surface air temperature is rising and warn that this "global warming" is dangerous, as even a slight warming of the entire planet could cause severe climatic changes. Evidence points toward the *greenhouse effect* as the cause of this warming. This effect results from emissions of carbon dioxide (CO_2), methane (CH_4), nitrogen dioxide (NO_2), ozone (O_3), and the chlorofluorocarbons ($CFCl_3$ and CF_2Cl_2, called "CFCs").

Chlorofluorocarbons were mass-produced in the 1940s, when wartime factories were retooled to manufacture household refrigerators. Production of CFCs increased rapidly because they are superb refrigerant gases (commonly called "freons"). More recently, we learned that freons are much more potent greenhouse gases than CO_2. One molecule of CFC has the same greenhouse effect as 10,000 molecules of CO_2. A more detailed mathematical analysis of these problems is found in the excellent text *Environmental Science: The Natural Environment and Human Impact*.[6]

Since the end of the 19th century, the amount of CO_2 in the atmosphere has increased significantly. Carbon dioxide is a vital factor in Earth's heat balance because it traps heat in the atmosphere. If there were less than an optimal amount of CO_2 in the atmosphere, heat would radiate too rapidly and the surface of Earth would be coated with ice. Conversely, if the amount of CO_2 were to double, Earth's average temperature would increase dramatically. How quickly the amount of atmospheric CO_2 could double depends on the rate at which we burn fossil fuel. Initial estimates ranged from 88 to 220 years,[7] but after publication of the Intergovernmental Panel on Climate Change (IPCC) report in 2014, these time estimates were reduced, as Chapter 15 discusses in detail. Researchers now predict serious climate changes over the next century, including global temperature rises, sea level rises, decreases in the levels of inland lakes, and climate variations. We may also see weather extremes: droughts, heavy precipitation, heat waves, melting of ice cover and glaciers, intense storms, hurricanes, and tropical cyclones.[8] Chlorofluorocarbons play a sinister role in environmental degradation. They are greenhouse gases, and they are the primary cause of ozone layer depletion. Ozone in the stratosphere helps screen out damaging ultraviolet rays (although ozone at ground level is a pollutant and irritant). CFCs combine with ozone to create gaps in the stratospheric ozone layer, thus permitting ultraviolet rays to reach Earth's surface where they harm plants and increase skin cancer rates. Scientists from the British Antarctic Survey first observed this in 1985. Measurements showed ozone depletion increasing in severity,[9] but significant recovery has occurred since controls on CFCs took effect.

An international agreement (known as the "Montreal Protocol") was successfully negotiated, and all major industrial countries passed laws to phase out the use of CFCs. These controls appear to be effective in protecting the stratospheric ozone; they also lessen the greenhouse effect. Regrettably, a criminal black market in illicit CFCs has sprung up, mainly for servicing out-of-date refrigeration plants.[10]

As professionals, we must insist on upgrading any process that emits needless carbon dioxide or other greenhouse gases. In particular, refrigeration lines containing CFCs—a refrigerant used in cooling systems for decades—should never be voided into the atmosphere. Criminal trade in CFCs should be reported to the police.

14.3 ENERGY CONSERVATION AND NUCLEAR POWER

During the 1970s, two oil shortages caused long lineups at gasoline stations. By the 1980s, there was an oil glut. Gasoline became cheaper, and we lost interest in energy conservation. However, another energy crisis looms in this century. Although coal reserves may last for centuries,[11] the easily accessible oil and natural gas reserves are nearing maximum productivity. Professor C.J. Campbell predicts the total global oil and gas production peak (often called the "Hubbert Peak") will occur around 2021. This estimate includes recent shale gas developments. After the peak passes, the supply of easily accessible energy will drop, but global energy demand will continue to increase and prices will rise, leading to another oil crisis.[12] Chapter 15 discusses "peak oil" in detail.

Alternative energy sources (solar, wind, wave, geothermal) have not added much to the global energy supply, as of yet. It seems that nuclear fission (and nuclear fusion, should it ever be developed) will be essential if we are to maintain our present standard of living and extend it to the citizens of developing nations.[13]

From 1980 to 1989, nuclear energy use ranged from 2.5 to 5.0 percent.[14] However, by 2017, the World Nuclear Association (WNA) reported that 448 commercial nuclear reactors were operable in 30 countries (with 60 reactors under construction). Thirteen countries rely on nuclear energy for 25 percent or more of their electricity. For example, France obtains over 70 percent of its electricity from nuclear power; the United Kingdom and the United States obtain about 20 percent; and Canada obtains 15 percent.[15] Japan obtained about 29 percent of its power from nuclear energy in 2010, but after the Fukushima tsunami (discussed below), Japan temporarily closed all its 50 nuclear plants. Nevertheless, in July 2012, the spectre of "very severe power shortages" and the cost of alternative electricity forced the government to reopen two nuclear generators; by July 2017, five reactors were running and another 24 of Japan's operable 42 reactors were in the process of restart approvals. Nuclear advocates sound aggressively self-serving in their predictions, but in spite of the Fukushima tragedy, the world will likely need nuclear energy.[16]

Atomic Energy of Canada Ltd. (AECL), the designer of the CANDU nuclear reactor, contends that the CANDU is safer and more reliable than the Americans' light-water reactors, since it is fuelled by natural uranium and moderated by heavy water (although heavy water adds to the cost). AECL and other Canadian industries began developing the CANDU reactor in the 1950s. The reactors use natural uranium for fuel, but require heavy water (deuterium oxide) as a moderator and coolant. The uranium does not have to be enriched, reducing reactor cost and "downtime" for refuelling.[17]

Nuclear energy has the great advantage of using fuel that is compact and plentiful. Even so, public concerns over operating safety and the disposal of radioactive waste are slowing plans to construct new nuclear generating plants. As this chapter examines below, nuclear meltdowns devastate surrounding cities and towns. The risk is remote, but the consequences are extremely grave.

Another serious worry connected with nuclear power concerns the long-term disposal of highly radioactive waste. It is necessary to isolate nuclear waste for thousands of years because of the extremely long half-lives of some elements, such as plutonium. At present, the plan is to store waste in stable geological underground layers from which water has been absent for millions of years. As with most matters related to nuclear energy, waste disposal is the subject of bitter debate. One issue has to do with the level of certainty regarding the future. Supporters of nuclear energy admit that there can be no absolute guarantee that humans will not be exposed to the waste for thousands of years into the future; however, they add that the risk of future exposure is small. Opponents of nuclear energy insist on a guaranteed method for keeping nuclear waste permanently isolated. Since a guarantee is impossible, they declare that this is an adequate reason to phase nuclear energy out of existence.

Clearly, nuclear plants must be designed and managed carefully, professionally, and ethically and that this must be transparent to the general public. Nuclear plant designers and operators must recognize the public's anxiety and must demonstrate the safety of the CANDU reactor (and improve it even further).

Coal-fired power does not seem to be a reasonable alternative to nuclear energy because of the associated problems of air pollution. In the aftermath of the Three Mile Island and Chernobyl disasters, coal power was compared with nuclear power to ascertain which is more dangerous. One writer asserts that their dangers are similar, even if we accept the high estimate of 39,000 cancer deaths (or future deaths) from Chernobyl. He estimates that the death toll from the use of coal in the former U.S.S.R. is between 5,000 and 50,000 people per year. Many of these deaths result from the mining and transporting of coal, which requires 100 times as much material handling as uranium (with an equivalent energy output). In the United States, 100 or more coal miners die every year, and nearly 600 of the 1,900 deaths in railway accidents each year are the result of transporting coal. The big killer, however, is air pollution, although it is impossible to say with certainty whether coal burning is the cause of a specific, given death. Even so, it has been estimated that 50,000 people in the United States die every year as a result of air pollution, mostly resulting from the burning of coal. Extrapolating these data, assuming similar populations and similar pollution conditions, we can achieve a rough estimate of 5,000 to 50,000 deaths from burning coal in the former U.S.S.R.[18]

The debate over safety of our energy sources will not be resolved in this text; however, the issue emphasizes the importance of practising professional ethics, conserving energy, increasing efficiency, and avoiding waste. Ethical action is essential.

14.4 WASTE DISPOSAL

The most common environmental degradation is the indiscriminate disposal of wastes—be they solid, liquid, or gaseous—as byproducts of manufacturing, processing, or construction. Controlling waste disposal is usually within the authority of an engineer or geoscientist (or should be). As professionals, we must strive to minimize the harm.

In the early part of the 20th century, the insidious effects of heavy metals, dioxin, asbestos, pesticides, and other toxic substances were not well known. People believed that the environment was a vast sink that could accept any amount of waste without becoming contaminated. Waste was simply tipped into dumps, rivers, lakes, and oceans, as quickly and cheaply as possible, with little regard for the environment.

We now realize that in many parts of Canada, ill-considered methods of industrial and domestic waste disposal are creating a crisis. Large cities are transporting waste hundreds of kilometres for disposal, and small towns are beginning to realize that the local dump is a source of disease, a fire hazard, and a danger to groundwater. Dumps are gradually being replaced by closely monitored landfills, which accept only low-hazard solid waste and cover it every day with a layer of soil to reduce odour and pest problems. Some landfills are lined with plastic to prevent waste fluids from entering the groundwater or to at least reduce this problem.

These "sanitary landfills" are a great improvement over town dumps, but they are not the ideal solution to waste disposal. Incineration has one advantage: the volume of waste is reduced, so only the ash needs to be buried. However, the gases and particulate emissions released by the incinerators are still objectionable. Moreover, if chlorine-based organic compounds are burned, trace amounts of toxic chemicals may be dispersed.

The best way to solve waste disposal problems is to prevent them by efficient use of resources and by reusing or recycling waste materials. For example, waste automobile tires are now being used as fuel to heat cement kilns; in this process, even the ash is consumed since it becomes part of the product.[19] Composting, pyrolysis, and density-based separation of organic and non-organic materials are also successful. Although serious research is needed, recycling waste materials could be a financial opportunity.

Every province now has environmental protection laws and recycling programs to reduce solid waste. However, some wastes—especially toxic, flammable, explosive, radioactive, or hazardously reactive chemicals—are still being dumped illegally because of the shortage of proper incineration facilities and high-hazard disposal areas. Hazardous liquid waste is a serious health threat if it leaks into the water table, something that has happened many times. The names "Love Canal" and "Minamata" are now synonymous with the unethical disposal of industrial waste and with the human tragedy that followed. (Case histories follow, later in this chapter.) In the United States alone, 32,000 hazardous waste disposal sites were identified by 1991; very few of them have been cleaned up.[20] Any solution to this problem will require both technical ability and political awareness.

14.5 AIR POLLUTION

Air pollution has many components, but the best known are sulphur oxides and nitrogen oxides. Sulphur oxides (such as SO_2) result from burning fossil fuels such as coal and petroleum and from other industrial activities. SO_2 is a foul-smelling gas that reacts with oxygen in the atmosphere to form SO_3, which then combines immediately with water to yield sulphuric acid in the form of droplets. The highest SO_2 values have been reported in the northeastern United States and in Europe, where high-sulphur fossil fuels are burned in large quantities. In most large cities, SO_2 emissions have been reduced recently as a result of the shift from high-sulphur coal to low-sulphur natural gas.

Sulphur oxides are detrimental to plant life. They also corrode metals, discolour fabrics, and degrade building materials. Severe damage to plant life can be observed many miles downwind from certain smelting operations. It seems that a combination of sulphur oxides and air particles is especially damaging to human health, partly because of the action of small particles in conveying sulphuric acid into the lungs. SO_2 is a serious lung irritant, and dramatic episodes such as the "London smogs" have been attributed to the combination of SO_2 and particulates. The London smog of 1952 established the link between atmospheric pollution in smog and increased mortality.[21] The worst smog in Canada occurred in southern Ontario in 1962 and lasted five days. It is believed to have been London smog, and it was named the "Grey Cup smog" because it caused the 1962 Grey Cup football game to be postponed due to poor visibility.[22]

Even in the absence of sulphur, the burning of fossil fuels causes serious air pollution in urban areas. Exhaust gases typically contain unburned hydrocarbons (HC), carbon monoxide (CO), nitrogen oxides (NOx), and "normal" combustion products such as SO_2 and water (H_2O). In the atmosphere, many of these products react chemically to produce new contaminants. Because these processes are stimulated by sunlight, the resulting products are referred to as "photochemical oxidants." Two of the principal photochemical oxidants are ozone (a lung irritant) and peroxyacetyl nitrate (PAN, a lung and eye irritant). Ozone is constantly being created in the atmosphere by natural processes, but not to a degree great enough to constitute a pollution hazard.

Nitrogen oxides are also a problem in air pollution. There are several known oxides of nitrogen, but the important ones from the standpoint of air pollution are nitric oxide (NO) and nitrogen dioxide (NO_2). The term NOx is commonly used to refer to nitrogen oxides collectively. NOx is a product of almost any combustion process that uses air, since nitrogen is the chief component of air. To a great degree, the formation of NOx is the result of high combustion temperatures, principally from motor vehicles, which, in industrialized urban areas, account for 50 to 60 percent of atmospheric NOx. The Los Angeles type of photochemical smog is caused mainly by NO emissions from cars. It occurs on warm, sunny days when traffic is heavy and reaches a peak in the early afternoon. It therefore differs from the London smog, which forms on cold winter nights as a result of SO_2 produced by coal combustion.[23]

The nitrogen oxides participate actively in photochemical reactions with hydrocarbons, thus helping produce photochemical smog. NO_2 plays a double role in air pollution: it is a component in the formation of photochemical smog, and it is toxic in its own right. NO is much less toxic than NO_2, but NO is readily converted into NO_2 in the atmosphere: by reacting with oxygen in the presence of water, it becomes nitric acid, which is extremely toxic to any growing organism. The adverse effects of air pollution on humans and animals include serious lung disorders, reduced oxygen in the blood, eye and skin irritation, and damage to internal organs.[24] Damage to painted surfaces, cars, and buildings is mainly the result of acid rain, the topic of the following section.

Most provinces and the federal government have Clean Air Acts that specify emission standards and ambient air-quality standards. Air pollution control is mainly a provincial responsibility, although the federal government regulates trains, ships, and gasoline.[25] Professional engineers and geoscientists must follow government regulations—reducing harmful emissions should always be a primary objective.

14.6 ACID RAIN

The problem of acid rain captured Canadians' attention in the 1980s. Both sulphur oxides and nitrogen oxides are implicated, because they form sulphuric and nitric acids in the atmosphere and cause rainfall to become more acidic than it otherwise would be. Neutral water ideally has a pH of 7.0, but "normal" rainfall in remote areas that are unpolluted has a pH of about 5.6 because of small amounts of acid of natural origin.[26] Rain is typically called "acid rain" when the pH falls below 5.0. In many areas of Canada and the northeastern United States, the rain has a pH value as low as 4.0.

When acid rain falls, it harms mainly fish, trees, farms, buildings, and cars. Aquatic life begins to be affected when the pH falls below 5.0, and most fish are killed when a pH of 4.5 is reached. The result is hundreds of lakes in northeastern North America (and in Scandinavia) that are devoid of fish and thousands of other lakes that are threatened.[27] Lesions on plants caused by simulated acid rain have been observed when the pH drops lower than 3.4, although subtle effects may be occurring at higher pH levels. Humans may also be harmed, because the acidity leaches magnesium, aluminum, and heavy metals out of the soil and concentrates them in drinking water. Fish are especially susceptible to dissolved aluminum, and this may be a risk to humans as well. Acid rain does severe damage to limestone buildings and monuments, since it dissolves the key chemicals in limestone.[28]

Acid rain is an international problem. The heavier flow of pollutants is believed to be from the United States into Canada, because of the greater industrial activity south of the border. Smelter operations around Sudbury (Ontario) were major sources of the sulphur dioxide that causes acid rain; however, the situation is improving. Lakes in the Sudbury/Killarney region are showing signs of chemical and biological recovery. The most effective way to reduce acid rain is to reduce acid emissions, although adding lime to neutralize the acid can reverse low pH levels in lakes. Reducing emissions is costly, but an early study shows that, in addition to a cleaner environment, the economic benefits are about equal to the cost of the controls.[29]

14.7 WATER POLLUTION

Some rivers are less polluted now than they were in the 19th century, when there was a serious pollution crisis. In the mid-19th century, 20,000 people in London, England, died of cholera. As Donald Carr says, "in the Western world this was the greatest pollution disaster of history."[30] Typhoid and cholera epidemics from water contaminated by sewage were widespread. Water pollution has at least six possible sources:

- disease-causing bacteria;
- organic waste decaying in the water, reducing the dissolved oxygen content;
- fertilizers that stimulate plant growth and also depress oxygen levels;
- toxic materials, such as heavy metals and chlorinated hydrocarbons (DDT, PCB);
- acidification, as mentioned earlier; and
- waste heat, which can also reduce dissolved oxygen levels.[31]

Cholera and typhoid are practically unknown in Canada today as a result of sewage treatment and the use of chlorine to kill bacteria in drinking water. Nevertheless, we must be vigilant in monitoring water quality. The pollution caused by lawn fertilizer in summer and highway salt in winter is said to come from "non-point" sources (that is, from everywhere) instead of from "point" sources, such as sewage treatment plants, power plants, and factories, which can be more easily monitored.

Agriculture also creates dangerous pollution when the runoff from dairy or pig operations is too close to the intake of municipal water systems. Such a problem occurred in Walkerton, Ontario, in May 2000. Contaminants, mainly *E. coli* bacteria from a local pig farm, leaked into the Walkerton water supply system through one of the town's water wells. Before the cause was discovered and remedied, seven people died and more than 2,300 became ill. The Walkerton Commission of Inquiry report states that the Walkerton Public

Utilities Commission staff lacked the training and expertise needed to run the water system safely and engaged in unprofessional (and improper) operating practices.[32]

Although laws to control pollution exist at all levels of government, many of our beaches must be closed to swimmers because of high bacteria and fecal content in the water. This is a scandal for a country that has the largest endowment of fresh water in the world. We must enforce the principle that "the polluter pays." As a professional (and as a citizen), you have a duty to follow environmental laws.

14.8 EXPONENTIAL POPULATION GROWTH

We usually view population growth as an achievement, not as a problem. Moreover, individual engineers or geoscientists are rarely able to affect population growth. However, we must discuss it, because consumption of resources and environmental degradation are proportional to population, and world population is growing quickly.

In 1800, there were about 1 billion people on the planet. After the Industrial Revolution, new machines, medicines, and nutrition improvements caused life expectancy to rise and infant mortality to fall. As a result, the world's population passed 2 billion in 1930, 3 billion in 1960, 4 billion in 1975, 5 billion in 1987, 5.6 billion in 1994,[33] and 6.5 billion in 2005; in 2011, it was at 6.9 billion.[34] A simple graph of these numbers indicates that the world's population is growing exponentially. Engineers and geoscientists know that exponential growth cannot be sustained by finite resources—even resources as vast as our planet's. Moreover, expectations of citizens in developing countries are increasing sharply. Satellite television shows everyone the conspicuous consumption of the developed world, and the world's poor rightly want a share. The consumption of resources will reach disastrous proportions within the lifetime of most readers. Wildlife and plant populations do not increase in size indefinitely. Eventually they encounter environmental resistance that limits the population.[35]

Every species in a given habitat has an equilibrium point for its population. For example, food shortages (such as dwindling prey) limit the population of wild animals. Less food leads to increased mortality—especially infant mortality—until the birth rate, the death rate, and the food supply are in equilibrium. Human population is different—we devise ways to raise the equilibrium point. However, we have limits; resources are finite. The UN population projections show world population exceeding 11 billion in 2100.[36] This is, however, a median projection in a wide range of scenarios. If we look at the extremes (the 5 and 95 percentiles), the UN data show that in the year 2300, world population could range from 2.5 billion to 36 billion.[37]

Most population growth will occur in developing countries that do not have financial resources, stable governments, or infrastructure. The result could be anarchy, disease, and war. Many people will try to escape these conditions, so Canada may face the ethical dilemma of sharing our prosperity with billions of refugees, or refusing to admit them in fear that the surging tide may lower our quality of life.

Most demographers call for a reduction in population growth to cope with the problem. A few "Cornucopians," however, insist that innovation, free enterprise, and international trade will permit us to adapt to population growth. The Cornucopian philosophy is that there are no limits to human ingenuity and therefore no limits to growth. In the long run, a larger population should yield greater wealth for society. Many people might find the Cornucopian theory to be reassuring, but most demographers find Thomas Malthus (1766–1834) to be more convincing. Malthus noted that (in 18th-century England) population grew exponentially, while food supply grew linearly. His recommendations could (at best) be called draconian (or even hardhearted), because he endorsed war, starvation, abortion, and birth control as checks on overpopulation.

Of course, the optimum lies somewhere between these two extremes. As a paper in the UN population report explains poetically, "According to this model, mankind plunges into the future like a diver, holding his breath for a long time before rising back to the surface."[38] That is, peak population will oscillate around an equilibrium point. This scenario is familiar to engineers and geoscientists who have studied basic dynamics; however, while this simple harmonic motion is familiar, it masks the hardship that will be visited on individuals as thousands (perhaps millions) learn that the oscillating availability of food, water, shelter, air quality, and so forth condemns them to death. It is clear we must strive for a "softer landing" to avert these crises.

In 1968, Garrett Hardin, a U.S. philosopher, published a paper on a syndrome (observed 140 years earlier) called "the tragedy of the commons" (discussed below). Hardin applied this idea to overpopulation and observed that it is impossible to divide finite resources among an indefinitely large number of people. Although our society is based on the ethical precept that everyone has certain inalienable rights, Hardin came to the contradictory conclusion that the only way to preserve this freedom is the draconian regulation of procreation (as in China). Several U.S. groups, most notably Population Connection, presently advocate similar solutions to the population problem.[39]

Engineers and geoscientists cannot control overpopulation or even affect it significantly. What we can do is ensure that we are not contributing to the inefficient use of resources or creating threats to the environment as illustrated by the "tragedy of the commons." In the long term, ethical actions are always in our own self-interest.

14.9 THE TRAGEDY OF THE COMMONS

The tragedy of the commons often arises in environmental discussions. William Forster Lloyd, a political economist at Oxford University, first described the degradation of common pastures in England in 1832. Lloyd observed that the cattle that grazed on these "commons" were smaller and stunted when compared to cattle on privately owned pastures. The private pastures were obviously better kept and healthier environments for the cattle. His conclusions were republished in Hardin's paper in 1968.[40]

The concept can be explained as follows. Imagine a pasture open to all local cattle owners. Each owner, quite naturally, wants to increase his or her herd and thus tries to graze as many cattle as possible on the commons. Each animal added to the herd yields a significant benefit to the owner, but slightly reduces the food available to other animals. This process of increasing herd size may be sustainable for many years, especially if the commons is very large. Eventually, however, adding more animals will reduce the quality of the commons below an acceptable level. Yet, even at this point, there is no way to stop the process. As Hardin says:

> [T]herein is the tragedy. Each man is locked into a system that compels him to increase his herd without limit—in a world that is limited. Ruin is the destination toward which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons. Freedom in a commons brings ruin to all.[41]

Hardin applied this concept as a motivating force for population limitation. However, the tragedy of the commons also applies to other environmental effects. For example, the inconsiderate citizen who dumps garbage along the roadway, or the negligent corporation that spills waste (especially toxic or radioactive waste) or emits heat, noise, or noxious or toxic fumes into the air, is like the cattle owner who adds one more animal to the commons. These selfish acts degrade the environment.

Whether we classify these acts as vandalism or simply as human nature, they are the philosophy of utilitarianism in reverse. Utilitarianism supports a small sacrifice by the general population to aid the public good. In the tragedy of the commons, a selfish individual imposes degradation upon society to reap a small personal benefit. Moreover, without intervention, human nature makes the outcome inevitable. As Hardin puts it:

> [T]he rational man finds that his share of the cost of the wastes he discharges into the commons is less than the cost of purifying his wastes before releasing them. Since this is true for everyone, we are locked into a system of "fouling our own nest," so long as we behave only as independent, rational, free enterprisers.[42]

By enacting thoughtful laws, regulations, and taxes, we can avoid the tragedy of the commons. The true owners—the public—must police the environment, and degradation must be linked to the cause. In other words, the polluter must pay. This monitoring creates the feedback loop that we need to protect the environment. Monitoring might not be an easy task, but as Case History 14.1 (below) shows, ignoring pollution is far more expensive than monitoring and regulating it.

CASE HISTORY 14.1

TOXIC POLLUTION: LOVE CANAL, MINAMATA, BHOPAL, SUDBURY

The improper disposal of toxic waste is professional misconduct, whether it occurs deliberately or through incompetence. The following four instances of toxic pollution are so well known that their names—Love Canal, Minamata, Bhopal, and Sudbury—are now synonymous with environmental degradation or disaster.

LOVE CANAL, NEW YORK—DIOXIN

Love Canal is in Niagara Falls, in New York State, and is named after one of the early residents of the area. The canal was excavated for boats and barges, but it was never completed, so it was more of a ditch than a canal. Between 1942 and 1953, the Olin Corporation and the Hooker Chemical Corporation saw it as a convenient hole for burying waste chemicals. Over 18,000 tons of chemical wastes (including dioxins) were dumped and buried, and eventually the "canal" was again a flat plot of land.

In 1953, the Hooker Chemical Company sold the land to the Niagara Falls Board of Education for the nominal sum of one dollar. The conditions of the sale are not completely clear, but it appears that the Board needed the land to meet a growing school population boom and allegedly insisted on the location, threatening expropriation. Hooker Chemical apparently attempted to warn the Board about the contamination by drilling test boreholes to show the Board the chemical contamination and including a clause in the deed that mentions the buried chemicals. In subsequent years, when the Board moved to sell parts of the land for real estate development, Hooker Chemical representatives publicly opposed such use because of the buried chemicals.[43]

In spite of this, the land eventually became a residential area, and homes, playgrounds, and a school were built on it. In 1976, after several seasons of heavy rain, people began to notice a terrible stench of chemicals. Homes reeked, children complained of chemical burns, and pets died or became sick. Yet these problems were minor when compared with the miscarriages, birth defects, and cases of cancer that occurred in the Love Canal area, more and more frequently, as the years passed. Residents soon demanded some action on the basis that these problems were far too frequent.

In 1978, a government study of the area exposed some remarkable—and frightening—statistics. More than 80 different chemicals had been detected, some of which were carcinogenic. The chemical pollution in the air was 250 to 5,000 times established safe levels. There was an unusually high (almost 30 percent) rate of miscarriage. Of 17 pregnant women in the Love Canal area in 1978, only 2 gave birth to normal children.

New York State authorities recognized the serious health threat posed by the buried chemicals, moved a few hundred families out of the area, closed the school, and surrounded it with barbed wire. The area over the buried chemicals became a ghost town, with derelict houses, empty streets, and "No Trespassing" signs. Neighbouring residents who lived only a small distance from the chemicals were concerned about their health, but faced a dilemma: they wanted to move, but since "Love Canal" was now a synonym for hazardous waste, their homes were worthless. In 1980, residents' demands forced the government to carry out further testing. The tests showed high levels of genetic damage among the neighbouring residents. The area was declared a disaster area by the U.S. president, and 710 families were relocated. Many of the abandoned homes were demolished, and the chemical wastes were excavated for treatment and proper disposal. The total cost of the cleanup was estimated at US$250 million.[44]

The Love Canal tragedy revealed questionable ethics, although it is disputed whether the true fault lies with the Hooker Chemical Corporation, which buried much of the chemical waste, or with a careless or naive Board of Education. The agreement to transfer the land contained a clause that protected Hooker against future claims for liability and should have alerted the Board to the pollution. However, it is alleged that, after the extent of the disaster became public, chemical industry spokespeople ridiculed the residents as hypochondriacs.[45] This toxic secret brought tragedy to many families who risked their life savings in worthless homes, whose children were born deformed, and who even now may live in fear of contracting cancer.

Love Canal heightened awareness of the need for ethical conduct and environmental regulations. In the years after Love Canal, the U.S. Environmental Protection Agency (EPA) discovered thousands of hazardous waste sites contaminated with chemicals that prevent the groundwater from meeting drinking water standards.[46]

The resulting furor over Love Canal led to stricter laws and more severe penalties for improper disposal of waste. Unfortunately, public awareness of the danger of the dumping was too slow in coming. Lois Gibbs, the resident who drew public attention to the environmental disaster at Love Canal, stated: "As a society, we begin with this toxic thing and say: 'How much can we put in the environment before somebody is harmed?' This risk-assessment approach means there is a subset of our society that will always be sacrificed."[47] Dioxin was being released into the environment at Love Canal for years, and when women discovered that dioxin caused birth defects in their children, it still took 13 years for scientists to verify the facts.

MINAMATA BAY, JAPAN—MERCURY POISONING

Since 1953, thousands of residents of the Minamata Bay area of Japan have fallen ill because of organic mercury poisoning. Mercury (also called "quicksilver") is the liquid metal often used in thermometers and barometers.

Whether as a pure liquid or in compound form, mercury can cause serious renal and neurological dysfunction. Mild cases often mimic amyotrophic lateral sclerosis (ALS, also called "Lou Gehrig's disease"). The symptoms of severe poisoning include clumsiness, stumbling, severe mental or behavioural problems, and loss of speech, taste, and hearing.

The Chisso Company, a nitrogen fertilizer company in Minamata, the main city on Minamata Bay, first began producing acetaldehyde in 1932. Mercury was required as a catalyst in this process and was also used for chemicals the company would produce later, such as vinyl chloride. The mercury was used in liquid form, and during the production process, a portion of it was lost—washed into Minamata Bay with the wastewater. In the bay, microbes acted on the mercury and converted it into an organic (methyl or carbon-based) mercury compound. Shellfish absorbed the organic mercury, and since mammals do not excrete mercury, it becomes more concentrated as it moves up the food chain. When concentrations are sufficiently large, the toxic effect becomes apparent. The first humans affected were fishers and their families, who had a diet rich in fish, including shellfish. Physicians and health officials in the Minamata area recognized the seriousness of the problem around 1956, although cases were later traced back to 1953, about 20 years after mercury first began washing into the bay.[48]

The medical director of the hospital associated with the Chisso Company became sufficiently concerned about the problem in 1956 that he began a series of tests on cats. Since family cats ate fish, they were the first to exhibit this curious behaviour. He identified the manufacturing plant effluent as the cause of the problem. However, when he reported these results to his superiors at Chisso, they ordered him to stop his tests and forbade him from passing on his findings to the local health authorities.[49]

It was not until 1959 that medical authorities requested help from the Kumamoto medical school and an investigation began. By 1962, they were certain that organic mercury was causing the problem and that the source of the mercury was the Chisso effluent. Initially, estimates were that about 2,900 people had contracted *Minamata disease*, as the debilitating neurological syndrome is now called. The government indicted Chisso, but it took years for the various cases to work their way through the legal system. The first decision occurred in 1970, and the government awarded some compensation. However, in 1995, the Japanese government reached a political settlement with about 11,000 unrecognized sufferers that called for lump-sum payments, and in 2007, 5,000 more people applied for official recognition as sufferers of Minamata disease. In 2010, a settlement was reached to compensate the remaining victims.[50]

The ethical issues in this case are clear. The Chisso Company's actions—stopping the medical tests, suppressing knowledge of the problem, and continuing to permit mercury to be dumped in Minamata Bay—were unethical and inexcusable. Even though the damaging effects of mercury were poorly understood in 1932, the company knowingly inflicted personal tragedy on thousands of unwitting people in later years.

An outbreak of Minamata disease occurred in Grassy Narrows, Ontario, in 1970. Members of two Ojibwa bands living near the Wabigoon River began to show the debilitating symptoms of mercury poisoning, and the source of the pollution was traced to the Reed Paper Company in Dryden, just upstream from the Ojibwa reserves. The provincial government ordered Reed to reduce mercury usage, and the pollution was gradually eliminated. Although compensation was eventually paid to the two bands, the economic and social effects were devastating.[51]

BHOPAL, INDIA—METHYL ISOCYANATE

In the early morning hours of December 3, 1984, a poisonous cloud of methyl isocyanate gas escaped from the Union Carbide plant in Bhopal, India. It killed thousands of people up to 6 km (4 miles) away, many while they were asleep in their beds. This was probably the worst industrial accident in history, and its social and economic impacts on Bhopal were devastating. It is estimated that between 3,000 and 12,000 people died in this catastrophe. Around 30,000 more suffered permanent injuries; 20,000, temporary injuries; and 150,000, minor injuries. And even these horrific numbers are disputed by victims' rights organizations, which say that the real numbers were even higher.[52]

The Union Carbide plant was established in 1969 as a mixing factory for pesticides. Methyl isocyanate, which is used in large quantities in the production process, is highly volatile as well as highly toxic. Methyl isocyanate reacts vigorously with many common substances and must be maintained at very low temperatures to prevent uncontrolled reactions. The precise cause of the disaster is not known, but most explanations state that an employee closed a valve on a piping system so that a filter connected to the pipe could be washed. A metal disc should have been inserted to make certain that the valve could not leak, but this was not done. During the washing process, water leaked past the closed valve, entering piping that was connected to the methyl isocyanate holding tank. The water reacted with the methyl isocyanate, generating intense heat. The pressure in the tank increased dramatically and pushed past pressure relief valves into the atmosphere. Safety measures were either inadequate or did not work. Over the next 90 minutes, about 40 tonnes of methyl isocyanate and other reaction products were released into the atmosphere. Since the vapour is heavier than air, it filled low-lying areas, crept into houses through windows and doors, and asphyxiated thousands of people while they slept.

Union Carbide India Limited (UCIL) operated the plant, but the plant was mainly owned (50.9 percent) by Union Carbide Corporation, a U.S. company. Union Carbide disputes the above explanation for the disaster. Based on a forensic study conducted by a consulting engineer, Union Carbide concluded that the gas emission was sabotage. They believe that an unknown plant employee deliberately added water to a storage tank, apparently intending to ruin the methyl isocyanate.[53]

An inquiry was held after the disaster. The construction, operation, and maintenance of the Bhopal plant were examined, as well as management

Photo 14.1 — Union Carbide Factory, Bhopal. *A methyl isocyanate gas leak from a Union Carbide pesticide plant in Bhopal, India, killed thousands of people in neighbouring communities. The Union Carbide factory (in the background) looms over relatives and friends carrying a victim's body to cremation.*

Source: © AP/CP Images

decisions that permitted such a potentially dangerous plant to operate in such an unsafe manner, in an urban area, with no suitable emergency plan. The Indian government charged the company management with negligence, brought murder charges against its chief executive, and demanded US$3.3 billion to settle victims' claims. Then, in 1989, the Indian Supreme

Court announced a settlement of all claims for US$470 million, conditional on the dropping of criminal charges.[54] Shortly after the settlement was announced, a new Indian government disallowed the claim and sought to reinstate the criminal charges.[55] In 2010, eight ex-employees (including the former UCIL chair) were convicted of causing death by negligence.[56]

SUDBURY, ONTARIO—SULPHUR DIOXIDE

Canada is the world's second-largest producer of nickel, and the mines around Sudbury, Ontario, are the main source of this metal. Nickel was first discovered in the area in 1856, but it was not until the Canadian Pacific Railway reached Sudbury in 1883 that anyone realized the full extent of the ore body.[57] The nickel is in the form of sulphide ore, which cannot be converted directly into metallic form. It must first be smelted—that is, burned to remove the sulphur and convert the ore to nickel oxide, which can then be reduced to pure nickel. In the early 1900s, the first conversion step was typically done in huge, open "roasts," where layers of timber were interspersed with layers of ore. The roasts burned around the clock and emitted a toxic cloud of sulphur dioxide.[58] A century ago, when the Sudbury area was sparsely populated, the ecological impact of this process could be ignored. Few people realized that the sulphur dioxide, when dissolved in rainwater, created acid. However, in 1928, the federal government became aware of the problem and banned the use of open roasts.[59] Enclosed smelting is still permitted.

The problem was partly solved by erecting taller smokestacks, which spread the pollutants over a wider area, reducing their concentration. The largest superstack, built at Sudbury's Copper Cliff mine in 1972, is 380 m (1,247 ft.) high.

The environmental effects of acid rain on the Sudbury region were severe. In the area around the smelters, trees were stunted, lakes were devoid of fish, and only the hardiest bird species could survive. However, in 1978, the Regional Municipality of Sudbury began an ambitious program to restore barren land. By experiment, it was discovered that, in most locations, a combination of fertilizer, agricultural lime (to neutralize acidity), and a seed mixture of grass and legumes generates a healthy grass cover. Two years after grass begins growing, crews return to plant trees and shrubs. Over the years, they have planted 15 different tree species, with trees more than 3 m high after a few years. Although soil acidity is still very high, levels of heavy metals have been reduced. Insect, bird, and small mammal populations have increased. Successful tree growth has averaged 70 percent across all species. By 2012, after 34 years of reclamation, more than 9 million trees and shrubs had been planted, and about 10,000 hectares had been limed, fertilized, and/or seeded.[60] As a result of its efforts to remedy environmental damage, Sudbury has become one of the most closely studied ecological areas in the world.

DISCUSSION OF TOXIC POLLUTION CASES

These environmental disasters were not of equal magnitude, nor were they equally unethical. Thousands of deaths and injuries were directly linked to Bhopal—the world's worst environmental disaster—and to Minamata.

Hundreds of illnesses, miscarriages, and cancer cases were related to Love Canal. As for the Sudbury sulphur dioxide emissions, no such human tragedies have been directly attributed to them, although some pollution is evident in the lakes and vegetation downwind of the smelters.

CASE HISTORY 14.2

NUCLEAR SAFETY: THREE MILE ISLAND AND CHERNOBYL

Nuclear-generated electrical power is always an environmental concern, although earlier American and British studies showed that power generation by coal is 250 times more hazardous than nuclear power and that generation by oil is 180 times more hazardous. Only natural gas poses fewer hazards than nuclear power to workers and the general population.[61] A few serious radiation releases occurred in the early experimental days of Canadian and American nuclear development, and a few deaths in North America have been attributed to power reactor accidents. However, the American reactor accident at Three Mile Island in 1979, the later accident at Chernobyl in Ukraine (then part of the Soviet Union) in 1986, and the Fukushima disaster in 2011 (see Case History 14.3, below) all involved partial or complete meltdown of the nuclear reactor cores and were much more serious. The public was horrified to learn that meltdowns—the most unthinkable nuclear accident—could really occur.

THREE MILE ISLAND

Three Mile Island is located on the Susquehanna River in southern Pennsylvania. Construction on its two-unit nuclear power plant began in the late 1960s, and the second unit (unit TMI-2) was completed, tested, and brought online in December 1978. The two units were designed to produce a maximum of 880 megawatts of electrical power. The TMI-2 unit experienced many minor problems during its commissioning and early operation. It had been operating for only three months when it became the source of North America's worst nuclear accident.[62]

THE ACCIDENT AND ITS CAUSES

The problem began shortly after 4 a.m. on March 28, 1979, and recovery efforts lasted for a month. The initial cause of the accident was a blocked feedwater line, which caused pumps to stop. Operator errors and other minor malfunctions then magnified the problem. James Carter, the U.S. president at the time (and a nuclear engineer), commissioned an Inquiry into the accident. The Inquiry report describes the first few minutes of the accident as follows:

> In the parlance of the electric power industry, a "trip" means a piece of machinery stops operating. A series of feedwater system pumps supplying water to TMI-2's steam generators tripped on the morning of March 28, 1979. The nuclear plant

was operating at 97 percent power at the time. The first pump trip occurred at 36 seconds after 4:00 a.m. When the pumps stopped, the flow of water to the steam generators stopped. With no feedwater being added, there soon would be no steam, so the plant's safety system automatically shut down the steam turbine and the electric generator it powered. The incident at Three Mile Island was 2 seconds old. . . .

When the feedwater flow stopped, the temperature of the reactor coolant increased. The rapidly heating water expanded. The pressurizer level (the level of the water inside the pressurizer tank) rose and the steam in the top of the tank compressed. Pressure inside the pressurizer built to 2,255 pounds per square inch, 100 psi more than normal. Then a valve atop the pressurizer, called a pilot-operated relief valve, or PORV, opened—as it was designed to do—and steam and water began flowing out of the reactor coolant system through a drain pipe to a tank on the floor of the containment building. Pressure continued to rise, however, and 8 seconds after the first pump tripped, TMI-2's reactor—as it was designed to do—scrammed: its control rods automatically dropped down into the reactor core to halt its nuclear fission.

Less than a second later, the heat generated by fission was essentially zero, but as in any nuclear reactor, the decaying radioactive materials continued to heat the reactor's coolant water. This heat was a small fraction—just 6 percent—of that released during fission, but it was still substantial and had to be removed to keep the core from overheating. When the pumps that normally supply the steam generator with water shut down, three emergency feedwater pumps automatically started. Fourteen seconds into the accident, an operator in TMI-2's control room noted the emergency feed pumps were running. He did not notice two lights indicating a closed valve on each of the two emergency feedwater lines—no water could reach the steam generators. A yellow maintenance tag covered one light. No one knows why the second light was missed.

With the reactor scrammed and the PORV [relief valve] open, pressure in the reactor coolant system fell. Up to this point, the reactor system was responding normally to a turbine trip. The PORV should have closed 13 seconds into the accident, when pressure dropped to 2,205 psi. It did not. A light on the control room panel indicated that the electric power that opened the PORV had gone off, leading the operators to assume the valve had shut. But the PORV was stuck open, and would remain open for 2 hours and 22 minutes, draining needed coolant water—a LOCA [loss of coolant accident] was in progress. In the first 100 minutes of the accident, some 32,000 gallons—over one-third of the entire capacity of the reactor coolant system—would escape through the PORV and out the reactor's let-down system. Had the valve closed as it was designed to do, or if the control room operators had realized that the valve was stuck open and closed a backup valve to stem the flow of coolant water, or if they had simply left on the plant's high pressure injection pumps, the accident at Three Mile Island would have remained little more than a minor inconvenience. . . .[63]

The combination of the initial blockage in the feedwater lines, the overlooked lights (warning that the valves were closed from the emergency feedwater pumps), and the relief valve that was stuck open created a confusing combination of effects that would cause incorrect actions, expose the reactor core, and release radioactive water. Before the incident ended, the reactor was destroyed and millions of people were in fear for their health and safety.

In the days and weeks after the initial incident, the nuclear plant owners, the news media, and politicians—from the mayor to the U.S. president—were involved in a debate over the need for evacuation and what information should be released to local residents. Control was not fully regained for another month. The plant went into a cold shutdown on April 27, 1979. The full report of the incident (on the Internet) is a chilling story of confusion and fear.[64]

THE RESULTING DAMAGE AND AFTERMATH

During the accident, the loss of coolant caused the reactor core to be exposed. The extreme heat melted about one-third of the core, rendering the reactor useless—a billion-dollar loss. The site cleanup likely cost another billion dollars. A small amount of radioactive material was released from the reactor into the environment, raising the fear of radiation-induced health effects, principally cancer, in the neighbourhood of the reactor. Over the next 18 years, the state government would trace the health of 30,000 people who had been living within five miles of Three Mile Island at the time of the accident. Fortunately, no unusual trends were found, and in 1997, the registry was discontinued.[65]

CHERNOBYL

The Chernobyl nuclear power plant is located about 100 km (62 miles) north of Kiev, the capital of Ukraine. In 1986 the plant comprised four reactors constructed between 1977 and 1983. At full capacity, the plant generated 4,000 megawatts of electricity. The Chernobyl reactors were a Soviet design, designated by the acronym RBMK, which is a pressurized water reactor design that uses ordinary water as a coolant and graphite as a moderator. This type of Soviet reactor was intended for plutonium generation (for weapons) as well as electrical power production. No other power reactor design uses this combination of graphite and water.[66]

At 1:23 a.m. on April 26, 1986, the No. 4 nuclear reactor in Chernobyl exploded, releasing huge, sinister clouds of radioactive plutonium, cesium, and uranium dioxide into the atmosphere. It was the worst nuclear accident in history involving a nuclear generating plant. Ukraine was then part of the U.S.S.R., but regrettably, the Soviet authorities were slow to issue a warning or to release any details about the accident. In fact, two days later, Swedish experts, who had noticed the nuclear fallout over Scandinavian countries, released the first information about the accident.

THE ACCIDENT AND ITS CAUSES

The reactor explosion had three basic causes: poor reactor design, inadequately trained reactor personnel, and unsafe operating procedures that permitted tests to be carried out at a low and unstable power. The reactor design flaws included an inadequate containment shell, poorly designed graphite control rods, and a feature called a "positive void coefficient," which refers to the tendency for voids (or steam pockets) to form in the cooling water. Although graphite is the main moderator, the cooling water also has a moderating effect. However, when steam pockets in the water get too large, then the moderating effect of the water begins to fluctuate, and the reactor may experience rapid and uncontrollable power surges.

The RBMK reactors were known to have a positive void coefficient, so other control features were in place to prevent the instability from occurring; however, the reactor's inexperienced operators overrode these features. By the time the problem was recognized, the heat had deformed the channels and the control rods could not be reinserted. The World Nuclear Association (WNA) website describes the Chernobyl accident as follows:

> On 25 April [1986], prior to a routine shut-down, the reactor crew at Chernobyl-4 began preparing for a test to determine how long turbines would spin and supply power following a loss of main electrical power supply. Similar tests had already been carried out at Chernobyl and other plants, despite the fact that these reactors were known to be very unstable at low power settings.
>
> A series of operator actions, including the disabling of automatic shutdown mechanisms, preceded the attempted test early on 26 April. As the flow of coolant water diminished, power output increased. When the operator moved to shut down the reactor from its unstable condition arising from previous errors, a peculiarity of the design [the positive void coefficient] caused a dramatic power surge.
>
> The fuel elements ruptured and the resultant explosive force of steam lifted off the cover plate of the reactor, releasing fission products to the atmosphere. A second explosion threw out fragments of burning fuel and graphite from the core and allowed air to rush in, causing the graphite moderator to burst into flames.
>
> There is some dispute among experts about the character of this second explosion. The graphite—there was over 1200 tonnes of it—burned for nine days, causing the main release of radioactivity into the environment. A total of about 14 EBq (10^{18} Bq) of radioactivity was released, half of it being biologically-inert noble gases. . . . Some 5000 tonnes of boron, dolomite, sand, clay and lead were dropped on to the burning core by helicopter in an effort to extinguish the blaze and limit the release of radioactive particles.*

* World Nuclear Association, *Chernobyl Accident*, Information Papers, March 2001 (updated November 2016), http://www.world-nuclear.org/information-library/safety-and-security/safety-of-plants/chernobyl-accident.aspx (accessed June 22, 2017). Excerpt reprinted with permission.

Photo 14.2 — Chernobyl Nuclear Power Plant. *Two images, one taken in 1982 and the other on March 31, 2011 (bottom), show before-and-after views of the same corner in the now abandoned city of Prypiat near the Chernobyl nuclear power plant, where the world's worst civil nuclear accident took place.*

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THE RESULTING DAMAGE, INJURIES, AND DEATHS

The WNA states that "30 people were killed, and there have since been up to ten deaths from thyroid cancer due to the accident." However, these numbers are challenged and do not reveal the truly massive disruption of life that took place. A full list of damage and disruption was included in a 1988 UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation) report. It describes

- hundreds of direct injuries and deaths,
- evacuation of several cities, involving hundreds of thousands of people,
- extensive radiation monitoring,
- repeated decontamination of buildings and destruction of some buildings,
- creation of a prohibited area within a 5 km radius around Chernobyl,
- creation of a restricted movement area within a 30 km radius around Chernobyl,
- destruction of poisoned food and movement of thousands of cattle, and
- millions of protective medical treatments, radiation tests, and so on.[67]

AFTERMATH

Unit 4 at Chernobyl was enclosed in concrete shortly after the accident to permit the other three reactors to continue operating. Much money was spent on improving the safety of the reactors, but in view of the desperate need for electricity, they were kept running. Unit 2 was shut down after a turbine hall fire in 1991, and Unit 1 was shut down at the end of 1997. Unit 3 continued operating until December 2000.[68]

In *The Truth about Chernobyl*, author Grigori Medvedev reveals controversial truths and secrets about the Chernobyl disaster.[69] The book was published in the Soviet Union in 1989 and translated into English in 1991. Medvedev reveals extensive incompetence in the Soviet nuclear power industry. Moreover, secrecy and political infighting were common. For example, while Western nuclear experts studied, discussed, and debated the causes of the 1979 Three Mile Island nuclear accident, the Soviet state bureaucracy suppressed the circulation and publication of this information. The few highly placed individuals who had access to the Three Mile Island accident reports were not trained well enough to apply the information effectively.

Medvedev's book was reviewed by *Maclean's* magazine, where it was observed that the cult of secrecy continues. The reviewer noted that official sources admit to fewer than 50 casualties, but "Vladimir Chernousenko, the scientific director now in charge of the 32-km exclusion zone surrounding the Chernobyl power station, recently estimated that fatal casualties to date number between 7,000 and 10,000."[70] Unofficial estimates placed the number of fatal casualties even higher.

DISCUSSION OF THESE NUCLEAR ACCIDENTS

It should be noted that nuclear power engineering has matured significantly in the decades since the accidents described above and that regulatory procedures are more rigorous. Although the CANDU reactors have had problems with zircaloy pressure tubes that were prone to corrosion and required replacement,[71] the Canadian CANDU reactor was designed to be safer than the Soviet RBMK design and safer even than the American light-water reactor (LWR) design. Canadian nuclear power plants use heavy water, not graphite, for moderation. The heavy water is needed for the fission to proceed. Loss of heavy water causes the fission process to stop automatically.[72]

Three Mile Island and Chernobyl warned us that the possibility of disaster in a nuclear plant may be extremely small, but it is not zero. These tragic accidents also exposed the danger of making design decisions for political or military reasons, and the danger of secrecy in engineering and geoscience decisions. Sadly, some of these features were seen in the Fukushima disaster, described below.

CASE HISTORY 14.3

GEOHAZARDS: THE FUKUSHIMA TSUNAMI

Geohazards—earthquakes, floods, and storms—damage property and cause thousands of deaths annually. For example, the 2004 "Boxing Day" tsunami killed over 250,000 people in Southeast Asia, and the 2011 Fukushima tsunami killed about 18,000 people in Japan. The Fukushima disaster was actually a unique sequence of tragedies: a record earthquake caused a massive tsunami, which, in turn, caused the destruction of a nuclear power plant, triggering a huge release of nuclear pollution. Although the earthquake and tsunami were unavoidable, the nuclear disaster was preventable.

THE FUKUSHIMA EARTHQUAKE, TSUNAMI, AND NUCLEAR DISASTER

The residents of northeastern Japan suffered a magnitude 9 earthquake at 2:46 p.m. on Friday, March 11, 2011. The earthquake was the most severe ever recorded in Japan and the fourth largest worldwide in the past century. The epicentre was about 130 km offshore and about 180 km from Fukushima. At the time of the earthquake, 11 reactors were operating at four nuclear plants near Fukushima. Six reactors were located at the Fukushima "Daiichi" (or Number 1) plant. When the earthquake occurred, all the reactors automatically shut down and apparently suffered only moderate quake damage. If the tsunami had not occurred, the reactor damage would likely have been repairable.

Photo 14.3 — The Fukushima Disaster. *The wave from a tsunami crashes over a street in Miyako City, Iwate Prefecture, in northeastern Japan, on March 11, 2011. A magnitude 9 earthquake had struck the area about 40 minutes earlier and caused the tsunami. The earthquake and tsunami devastated northeastern Japan and destroyed the Fukushima nuclear power plant. The release of radioactive material from the Fukushima plant is second only to that of Chernobyl.*

Source: AP Photo/Maini chi Shimbun, Tomohiko Kano

However, about 40 minutes after the earthquake, a huge 15 m tsunami engulfed Fukushima, and several smaller waves apparently hit minutes later. The seawater flooded three of the six nuclear reactors at the Fukushima (Daiichi) plant and destroyed electrical equipment, such as backup generators and heat exchangers. Without electrical power, the reactors were unable to maintain proper cooling and water circulation. The 125-volt DC batteries in reactors 1 and 2 were flooded and failed, leaving the operators without instrumentation, control, or lighting, although reactor 3 had battery power for about 30 hours. The crisis affected Fukushima reactors 1, 2, and 3 most seriously; reactors 4, 5, and 6 were not online when the accident occurred.

The earthquake automatically shut down the reactors, but residual heat still had to be removed. The heat created steam in the reactor pressure vessels, and the steam vented into the dry Primary Containment Vessel (PCV) through safety valves. As the water level dropped, hydrogen began to be created and was vented with the steam.

A formal Nuclear Emergency was declared about 7 p.m. on March 11, and at 8:50 p.m., the Fukushima Prefecture ordered people within 2 km of the plant to be evacuated. At 9:23 p.m., the Prime Minister extended the evacuation to 3 km, and at 5:44 a.m. the following day, he extended it to 10 km. The Prime Minister visited the plant the next day and extended the evacuation zone to 20 km around the plant.

Eventually, the high temperatures in nuclear reactors 1, 2, and 3 caused their cores to "melt down." The accumulated hydrogen (above the reactor 3 containment building) exploded, blowing off most of its roof and walls and demolishing the top part of the building. This explosion injured six workers and created a lot of debris—some of it very radioactive. We can only imagine the terror the technicians must have faced as they fought to control the unstable nuclear reactors with no electricity, lighting, or communication, while surrounded by debris, much of it radioactive.

On the following day, two more hydrogen explosions occurred, destroying the top of the building housing reactor 4 and further damaging reactor 2. As the days passed, workers tried increasingly desperate measures to cool the reactors. As Japan recovered from the tsunami devastation, hundreds of firefighters and fire trucks were despatched from neighbouring cities to spray water directly into the reactors with high-pressure hoses. Electrical power was restored gradually, but much of the equipment was severely damaged, would not operate, and had to be replaced.

The seawater sprayed onto the reactors to remove heat became contaminated by nuclear waste, but the technicians were forced to let most of it flow back into the ocean. Cooling the reactors and the spent fuel ponds took many weeks and required hundreds of employees, contractors, firefighters, and soldiers. Most employees were moved into temporary accommodation at the start of the recovery and were at constant risk of radioactive contamination. Many of them lost their homes and families.

Reactors 1, 2, and 3 stabilized in about two weeks (from the water sprayed on them, as they had no heat sink to remove heat). In July 2011, recycled water from a new treatment plant began to cool the reactors. Reactor temperatures fell below 80°C by the end of October, and an official "cold shutdown" was announced in December 2011.[73]

AFTERMATH

The Fukushima (Daiichi) power plant was a boiling water reactor (BWR), designed and built by General Electric for the Tokyo Electric Power Co. (TEPCO). The reactor began operation in 1971. The total number killed in the Fukushima tsunami was about 19,000 (15,880 dead and 2,994 presumed dead). In addition, 6,135 were injured, 128,931 dwellings were destroyed, and 269,045 buildings were seriously damaged. A simple statistic emphasizes the extent of personal disruption: in March 2013, a full two years after the disaster, 315,196 people were still living in temporary housing.[74]

The severity of the disaster is classified at Level 7 (the highest level) on the International Nuclear and Radiological Event Scale (INES). The radiation is second only to Chernobyl, which was about six times greater. Three TEPCO employees were killed directly by the earthquake and tsunami, but no fatalities have been directly attributed to nuclear releases (as of yet). The tsunami disabled almost all the radiation monitoring stations at the plant, so precise radiation levels during the disaster are unknown. Japan set a 20 km "no-go area" around the plant.[75]

TEPCO is removing (undamaged) fuel rods but estimates that complete removal may take 25 years. The four reactors (1 to 4) will not be completely demolished for 30 or 40 years (as for most nuclear plants). However, after removing the nuclear fuel, the reactors will likely be sealed for a decade or two while radioactivity decays. U.S. experience at Three Mile Island may help in the demolition process.

The Japanese government set up a 10-member Nuclear Accident Independent Investigation Commission (NAIIC) in December 2011 to re-examine nuclear safety, based on an investigation of the Fukushima accident.

> . . . NAIIC reported in July 2012, harshly criticizing the government, the plant operator and the country's national culture. After conducting 900 hours of public hearings and interviews with more than 1,100 people and visiting several nuclear power plants, the commission's report concluded that the accident was a "manmade disaster," the result of "collusion between the government, the regulators and Tokyo Electric Power Co." It said the "root causes were the organizational and regulatory systems that supported faulty rationales for decisions and actions." The NAIIC criticized the regulator for insufficiently maintaining independence from the industry in developing and enforcing safety regulations, the government for inadequate emergency preparedness and management, and TEPCO for its poor governance and lack of safety culture. The report called

for fundamental changes across the industry, including the government and regulators, to increase openness, trustworthiness and focus on protecting public health and safety.

The NAIIC Chairman wrote: "What must be admitted—very painfully—is that this was a disaster 'Made in Japan.' Its fundamental causes are to be found in the ingrained conventions of Japanese culture: our reflexive obedience; our reluctance to question authority; our devotion to 'sticking with the program'; our groupism; and our insularity." The mindset of government and industry led the country to avoid learning the lessons of the previous major nuclear accidents at Three Mile Island and Chernobyl. "The consequences of negligence at Fukushima stand out as catastrophic, but the mindset that supported it can be found across Japan. In recognizing that fact, each of us (every Japanese citizen) should reflect on our responsibility as individuals in a democratic society."

NAIIC reported that TEPCO had been aware since 2006 that Fukushima Daiichi could face a station blackout if flooded, as well as the potential loss of ultimate heat sink in the event of a major tsunami. However, the regulator, NISA [the Japanese Nuclear and Industrial Safety Agency] gave no instruction to the company to prepare for severe flooding, and even told all nuclear operators that it was not necessary to plan for station blackout. During the initial response to the tsunami, this lack of readiness for station blackout was compounded by a lack of planning and training for severe accident mitigation. Plans and procedures for venting and manual operation of emergency cooling were incomplete and their implementation in emergency circumstances proved very difficult as a result. . . .*

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Chapter 15
Environmental Sustainability

Environmental sustainability means protecting our huge (but finite) natural resources, using them wisely, and leaving a fair share for future generations. Unfortunately, our present resource consumption is unsustainable. To avoid irreversible environmental damage, we need a long-term strategy and aggressive action. This topic is controversial, and remedies are unpalatable, so sustainability may be a key battle of the 21st century.

This chapter defines "sustainability" and gives a brief overview of the history of sustainable thinking. The chapter then discusses the two greatest threats to sustainability—climate change and the depletion of fossil fuels—and suggests what we must do as engineers and geoscientists (and as citizens) to make our lifestyle sustainable. The chapter concludes with a discussion of Canada's oil sands.

15.1 A DEFINITION OF SUSTAINABILITY[1]

Sustainability is a very simple concept, although it has serious implications for society. In 1987, the Brundtland Commission of the United Nations defined sustainable development in its report *Our Common Future*: "Sustainable development is development that meets the needs of the present, without compromising the ability of future generations to meet their own needs."[2]

Paul Hawken, in *The Ecology of Commerce*, defined sustainability more personally: "Sustainability . . . can also be expressed in the simple terms of an economic golden rule for the restorative economy: leave the world better than you found it; take no more than you need; try not to harm life or the environment; make amends if you do."[3]

Unsustainable lifestyles threaten our future security, but many people do not understand (or do not believe) this crucial fact. Two symptoms of unsustainability are climate change and peak oil, and these key problems are both threats.

- **Climate change:** The careless disposal of waste, specifically carbon dioxide and similar fossil fuel emissions, is causing global warming and climate change, with predictions of dire global consequences within a few decades.

- **Peak oil:** Our excessive consumption of oil has forced us to maximize the rate of production of this finite natural resource. Oil production is approaching a peak.[4] At some point, easily accessible oil will become scarce and oil prices will rise, leading to energy shortages. Our lifestyle depends on the intense use of oil and its byproducts for transportation, heating, electricity, and manufacturing, so a crisis lies ahead unless we move to a more sustainable exploitation of energy.

15.2 A BRIEF HISTORY OF SUSTAINABLE THINKING

The Industrial Revolution in the 1800s began the mechanization of industry and increased society's living standards. Newly invented machinery, driven by steam and fuelled by coal, magnified the productivity of unskilled workers. By the turn of the century, machinery was gradually shifting from coal to oil as a source of energy. In the early 1900s, drilling for oil was common in the southern U.S. states, and the need to control oil was one cause (of several) for the First and Second World Wars (1914–1918 and 1939–1945).

When the Second World War ended in 1945, Canada looked forward to an era of peace and prosperity. Industries, geared for war, converted their factories to appliances and vehicles. Petrochemical industries provided a selection of magical new plastics, and agro-chemical industries promised profitable farms and an end to world hunger, using new pesticides, herbicides, and fertilizers—all made from petroleum feedstock. The average person could fuel a car and heat a home effortlessly, using oil or natural gas drawn from massive reservoirs in the Canadian west.

In the 1950s, nuclear reactors were developed for power generation and added to the electrical supply from hydroelectric and fossil fuel plants. Cheap electric power was available to almost everyone. Jet engines, which were in an early experimental stage before the Second World War, provided easy international travel, and low-cost vacations abroad became the norm. Air-conditioning units and television sets, which were non-existent in pre-war days, became common. During this period, world population grew exponentially (from less than 1 billion in 1800 to about 6.5 billion in 2007, as discussed in Chapter 14). Everyone aspired to a lifestyle that consumed more resources in a month than our pre-war ancestors consumed in a year. Few observers saw any problem with this consumption-oriented lifestyle, for almost two decades.

SILENT SPRING In 1962, Rachel Carson described the dangers associated with pesticides in her book *Silent Spring*.[5] Carson, a trained biologist, was trying to explain why songbirds did not return in the spring from their winter migration. She discovered that bird populations were dying because pesticides were being applied indiscriminately. Her book led to recognition that indiscriminate use of agricultural chemicals could be hazardous to bird, fish, animal, and human life. In our current terminology, such use was unsustainable.

THE LIMITS TO GROWTH The Club of Rome, an organization concerned with the problems of humankind, published a report in 1972 titled *The Limits to Growth*, which warned that uncontrolled human activity had the potential to make our planet uninhabitable.[6] The book described a very early computer simulation of human behaviour. A simple "world model" simulated the creation or consumption of five basic quantities as a function of time: population, capital, food, non-renewable resources, and pollution. Feedback loops and complex relationships between the quantities were included, yielding a mathematical model of the planet. The authors ran the simulation many times, with varying inputs and controls; the goal was to find the levels that yielded sustainable equilibrium. In brief, the model showed that the 1972 lifestyle was unsustainable. The simulation, although naive, encouraged further research in sustainability.

THE UN STOCKHOLM CONFERENCE In 1972, the United Nations, at the urging of Sweden, convened an environmental conference in Stockholm chaired by Canadian Maurice Strong and attended by delegates from more than 110 countries. The Stockholm Conference was a turning point in public awareness and attitudes toward the environment. The following excerpt explains the motivation for the conference:

> . . . We see around us growing evidence of man-made harm in many regions of the earth: dangerous levels of pollution in water, air, earth and living beings; major and undesirable disturbances to the ecological balance of the biosphere; destruction and depletion of irreplaceable resources; and gross deficiencies, harmful to the physical, mental and social health of man, in the man-made environment, particularly in the living and working environment. . . . [We] must shape our actions throughout the world with a more prudent care for their environmental consequences. . . .[7]

The conference ended with a *Declaration* of 26 environmental principles, an *Action Plan* with 109 recommendations, and a *Framework* for environmental action.

THE BRUNDTLAND REPORT In the following decade, the United Nations created the Brundtland Commission to investigate growing concerns about the environment. In 1987, the Brundtland Commission issued a report titled *Our Common Future*. This report defined the concept of sustainable development and proposed that industrial development must not impair the ability of future generations to enjoy equal prosperity. The Brundtland Report still guides the philosophy of sustainability.

IPCC REPORTS In 1988, the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) established the Intergovernmental Panel on Climate Change (IPCC). The IPCC is composed of scientists and experts from many countries. IPCC reports involve many researchers, with the goal of being comprehensive, scientific, and balanced. The IPCC does not conduct the research itself, but monitors world research on climate change, as well as its causes, its consequences, and how to reduce these effects or adapt to them. IPCC reports are guiding documents for discussing global warming and climate change. The IPCC released its Fifth Assessment Report in 2014, as discussed later in this chapter. The IPCC is a co-recipient of the 2007 Nobel Peace Prize.

MONTREAL PROTOCOL The Montreal Protocol on Substances That Deplete the Ozone Layer was signed in 1987 to take effect in 1989.[8] The purpose of the Montreal Protocol is the eventual elimination of chlorofluorocarbons. These compounds, commonly called "freons," are effective refrigeration gases, but they interact with ozone. Although ozone is a pollutant at ground level, a layer of ozone in the stratosphere filters out harmful ultraviolet rays (as explained in Chapter 14). The ozone layer is essential to life on Earth, but freons destroy it. Fortunately, the Montreal Protocol has been remarkably effective in restoring the ozone layer, and scientists predict that it will return to normal in a few decades. Developing countries had, on average, a 10- to 15-year grace period to match Canada's commitments under the Protocol. The Montreal Protocol is probably the most successful international environmental treaty in terms of acceptance and compliance by all signatories. The struggle to implement the Kyoto Protocol (discussed below) is in stark contrast to the success of the Montreal Protocol.

THE EARTH SUMMIT IN RIO In 1992, an "Earth Summit" was held in Rio de Janeiro, Brazil, where 165 nations, including Canada and the United States, voluntarily agreed to reduce greenhouse gas (GHG) emissions, the main cause of global warming and climate change. This agreement, called the UN Framework Convention on Climate Change (UNFCCC), set a goal of reducing GHG emissions to 1990 levels by 2000. The goal was not achieved.

THE KYOTO PROTOCOL In 1997, more than 160 countries met in Kyoto, Japan, to negotiate new GHG emissions targets. Over 80 countries agreed to reduce their GHG emissions to an average level of 5.2 percent *below* 1990 levels by the year 2010. Each country was allotted a different target. Disputes resulted over issues such as credits for carbon dioxide "sinks" (such as forests, which absorb carbon dioxide); whether countries could pay credits instead of reducing emissions; and whether these rules were fair for developing nations. In March 2001, the United States announced that it would no longer participate in the Kyoto Protocol, but in December 2002, Canada's Parliament voted to endorse the Kyoto Protocol. Canada's target was to reduce its emissions of greenhouse gases to 570 Mt (megatonnes) of carbon dioxide by 2010. The target was 6 percent lower than Canada's total greenhouse gas emissions in 1990. Sadly, our emissions have increased since 1990. In fact, Canada's predicted emissions for 2010 were about 810 Mt, about 42 percent higher than our 2010 goal. In 2007, Prime Minister Harper announced that Canada could not meet the Kyoto target and would be negotiating a new international agreement with more realistic "aspirational" goals.

BALI ROADMAP In 2007, the UNFCCC adopted the Bali "roadmap," which established a process for negotiating a post-Kyoto, international agreement on climate change to take effect in 2012.[9] Canada's position on future emissions targets in the Bali talks was consistent with Canada's Clean Air Act, tabled in 2006, which sets *intensity-based* emissions targets. These targets are in contrast with the *total emissions* targets in the Kyoto Protocol.[10] Intensity-based targets require a decrease in emissions per joule of energy consumed, but permit total emissions to increase. Canada also insisted that developing countries should not be exempt from emissions targets. After the UN Climate Change Conference in December 2011, Environment Minister Peter Kent announced that Canada was withdrawing from the Kyoto Protocol. Kent explained that the Protocol "would force Canada to spend about $14-billion buying carbon credits abroad because the country is so far behind in meeting its targets."[11] The Kyoto Protocol expired in 2012, but the Doha Amendment to that protocol extended its scope to 2020.

PARIS AGREEMENT In 2015, the 195 UNFCCC member states adopted the Paris Agreement, the aim of which was to reduce future GHG emissions and limit the increase in the global average temperature "to well below 2 degrees Celsius above pre-industrial levels."[12] Unlike the Kyoto Protocol, commitments from each country are not binding legally; the "nationally determined contributions" (NDCs) are set by each country on a regular basis, and subsequent NDCs should exceed the previous targets.All nations, whether developed or developing, must report every two years on their mitigation efforts, resulting in a "name-and-shame" system of enforcement.In June 2017, U.S. President Donald Trump announced that the United States would withdraw from the Agreement; under article 28, the earliest possible U.S. withdrawal would be November 2020—the date of the next U.S. election.

15.3 CLIMATE CHANGE

GHG emissions are important because of their role in climate change. Although global warming has been observed for three decades, debate on the *cause* of the warming has been strong and often harsh on all sides. The Intergovernmental Panel on Climate Change (IPCC) tried to settle that debate in its comprehensive Fifth Assessment Report (AR5) in 2014. The AR5 took five years to prepare, with contributions from more than 830 scientists in 85 countries and subject to 3,600 expert reviews. The four-part report is very technical, but summaries are freely available on the Internet.[13] The IPCC report concludes with 95 percent certainty, based on extensive evidence, that climate change is linked directly to global warming and caused by greenhouse gases, resulting mainly from human use of energy, particularly fossil fuels. Climate change comes about in the following way.

From Carbon Emission to Climate Change

- **Gas emission:** The combustion of coal, oil, natural gas, and other hydrocarbon fuels creates waste gas, mainly carbon dioxide, emitted into the atmosphere. Decaying foliage has always emitted carbon dioxide and methane, but prior to the Industrial Revolution, the process of photosynthesis (which absorbs carbon dioxide) was adequate for equilibrium. Over the last two centuries, however, human activities, such as burning coal, oil, natural gas, or wood to heat homes, drive automobiles, and generate electricity, have upset this equilibrium.
- **Greenhouse effect:** The atmosphere is transparent to most of the sun's radiation, which passes through to warm Earth's surface. The energy absorbed by the surface is eventually re-emitted but as a lower frequency thermal radiation, which the atmosphere partially absorbs. This is the "greenhouse effect"—the atmosphere acts as a thermal blanket. Certain "greenhouse gases" (GHG) increase the heat absorbed. The most common is carbon dioxide (CO_2), which persists in the upper atmosphere for decades. Other greenhouse gases are methane (CH_4), nitrogen dioxide (NO_2), ozone (O_3), and the chlorofluorocarbons (CFC).[14] These gases are even more effective in absorbing radiation than carbon dioxide, and they may persist even longer.
- **Global warming:** The greenhouse effect is essential to human life, since it insulates Earth from the stark temperature extremes that exist on planets without an atmosphere. However, over the past two centuries, the concentration of greenhouse gases in the atmosphere has increased sharply and Earth's global mean temperature has increased. IPCC research shows that the atmospheric carbon dioxide level was approximately constant at 280 ppm (parts per million) for two thousand years, until about 1800, when the level began to rise to the 2011 level of approximately 390 ppm. Some of the effects of global warming, such as the melting of glaciers and the decrease of Arctic sea ice, are already observable, as shown in the 2005 documentary film *An Inconvenient Truth*. In 2007, a film titled *The Great Global Warming Swindle* was produced to refute the conclusions in the 2005 film, a sign that the debate continues over the existence and cause of global warming and the action needed to combat it.[15]
- **Climate change:** Human-caused global warming produces only a small increase in Earth's solar energy balance. However, it has large nonlinear effects that can lead to potentially dramatic climate changes, such as severe storms and changes in precipitation patterns that trigger droughts and severe flooding. Climate change will have serious negative effects on all life, as predicted below.

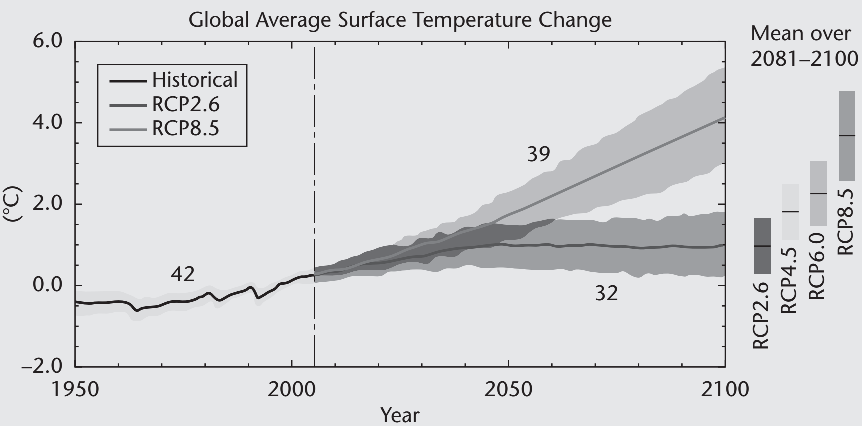
The Implications of Climate Change

A few conclusions from the 2014 IPCC Fifth Assessment Report (AR5) follow.

- **Human cause:** Global atmospheric concentrations of carbon dioxide, methane, and nitrous oxide have increased markedly because of human activities since 1750, and now far exceed pre-industrial values (determined from ice cores).

- **Temperature rise:** The IPCC has estimated that the global temperature will rise over the next century in the range of 1.0°C to 3.7°C, depending on future fossil fuel use, technological change, economic development, and population growth. The graph in Figure 15.1 shows the predicted range of temperatures for various scenarios of greenhouse gas emissions. The graph shows that even with stringent mitigation of GHG emissions (Scenario RCP2.6), a warming of about 1°C will occur in the next century as a result of greenhouse gases already emitted. The temperature rise may not appear to be great, but the effects are surprising.
- **Sea level rise:** If present trends continue, sea level is predicted to increase in the range of 40 cm to 63 cm (16 to 25 in.) under Scenarios RCP2.6 and RCP8.5, respectively. Much of this is due to melting of the Greenland and Antarctic ice sheets. These predictions have dire consequences for low-lying islands around the world.

FIGURE 15.1 — IPCC Predictions for Temperature Change in the Next Century



The graph above shows the expected global average surface temperature increase (relative to the average of years 1986–2005), due to global warming, until the year 2100. The line prior to 2005 is historical data, and the lines from 2000 to 2100 represent two scenarios, RCP2.6 and RCP8.5, which are computed using 32 and 39 different models, respectively. Scenario RCP2.6 represents stringent mitigation of GHG emissions, whereas RCP8.5 is a scenario with very high GHG emissions. Solid lines indicate mean values and shading represents the 5% to 95% range across the distribution of model results. Note that the baseline period 1986–2005 is already 0.6°C warmer than 1850–1900 values.

Source: IPCC, *Climate Change 2013,* page 21, Figure 7(a), http://www.climatechange2013.org/images/report/WG1AR5_ALL_FINAL.pdf (accessed July 27, 2017). Reprinted with permission.

- **Current observations:** Numerous long-term changes in climate have been observed. These include changes in Arctic temperatures and ice, widespread changes in precipitation amounts, ocean salinity, wind patterns, and aspects of extreme weather, including droughts, heavy precipitation, heat waves, and the intensity of tropical cyclones. Each of the last three decades has been successively warmer at Earth's surface than any preceding decade since 1850.
- **Other consequences:** The IPCC lists many possible consequences of climate change, including, but not limited to, greater intensity and severity of inland floods, drought, glacier and sea ice melts, and possibly even major changes in ocean currents, such as the Gulf Stream, which moderates the temperature of Europe. The increased temperature has other unexpected effects, such as insect plagues, extinction of species, and bleaching of coral reefs. For example, in the past, freezing winter temperatures in British Columbia and Alberta used to kill pine borers, but in recent years, the temperature rise permits them to destroy tens of millions of hectares of valuable trees.[16] Similarly, a small temperature rise in the south Pacific Ocean in 2004 bleached and killed part of the Great Barrier Reef, and by 2050, even the most protected coral reefs will suffer massive damage.[17] Other examples abound.
- **Feedback loops:** An important factor in the science of global warming is the role played by feedback loops. This concept is familiar to engineers and geoscientists, but not well known to the average citizen. Positive feedback loops can cause rapid and nonlinear magnification of small changes. For example, forest fires release carbon dioxide and other GHG into the atmosphere, leading to global warming, even higher temperatures, and drier conditions that cause more forest fires. The melting of Arctic sea ice has an even more dramatic feedback effect: ice reflects sunlight back into space, but as the ice melts, the darker water absorbs more energy from the sun, thereby causing more ice to melt. Many such feedback loops exist. In his book *Heat: How to Stop the Planet from Burning*, George Monbiot warns that if the warming reaches 2°C (compared to pre-industrial levels), positive feedback loops will be activated. For example, vast peat bogs in the subarctic, presently under permafrost, will begin to decay, releasing carbon dioxide and causing irreversible warming.[18]

The emission of greenhouse gases is changing our climate and damaging our environment, and unless serious efforts are made to reduce these emissions, climate change will harm future generations.

Fighting Climate Change

To combat climate change, the IPCC recommends that we reduce our use of fossil fuels, but what goal we should aim for is debatable. The Paris Agreement aims to keep global temperature increases to less than 2°C, but it is a nonbinding Agreement that relies on voluntary reductions from each country.

Canada's GHG emissions in 2015 were 722 megatonnes (Mt) of carbon dioxide equivalent, about 18 percent higher than in 1990—the baseline year for the Kyoto Protocol. In the foreword to the Canadian edition of his book *Heat*, George Monbiot criticizes Canada's failure to reach its Kyoto goal and our lack of "binding and immediate targets." Conversely, a 2008 APEGA survey of members' opinions about climate change showed that, while almost all (99.4 percent of 1,077) respondents agreed that the climate is changing, the majority (68 percent) disagreed with the statement that "the debate on the scientific causes of recent climate change is settled."[19]

PRECAUTIONARY PRINCIPLE In the absence of agreement on the causes or the action needed, society should follow the "precautionary principle." In other words, we should take reasonable precautions when harmful results may threaten human health or our environment, even if the precise cause-and-effect relationship is not yet clearly established. This approach applies to climate changes that are "possibly dangerous, irreversible, or catastrophic." Therefore, in spite of doubts and objections, we should make reasonable efforts to follow the IPCC recommendations to reduce GHG emissions.

ADAPTATION But even if we apply the best *mitigation* (or reduction) methods, some *adaptation* is also essential, according to the IPCC report. Adaptation means that we must learn to live with warmer temperatures, modify our building codes, and design our infrastructure (roads, drains, bridges, highways, and so forth) more robustly to withstand the intense storms, hurricanes, floods, and droughts to come in future.

EMISSION REDUCTION The IPCC AR5 report urges emission reduction and energy conservation in seven key areas: energy supply, transport, residential and commercial buildings, industry, agriculture, forestry, and waste management. The paragraphs below summarize the IPCC report, but please refer to the report itself for the projections and recommendations for your area of practice.[20]

- **Energy supply:** Without effective policy changes, global CO_2 emissions from the energy supply sector are predicted to double or triple by 2050 compared to 2010 levels. A wide range of cost-effective energy saving is possible, including switching to low-carbon fuels, improving power plant efficiency, and building nuclear power and renewable energy systems. Carbon capture and sequestration (CCS) is cost-effective at higher carbon prices. CCS uses existing technology to separate the carbon dioxide from exhaust gas and inject it into underground storage wells. A number of CCS power generation plants are already in operation worldwide, including the Boundary Dam Power Station in Saskatchewan. Other options still under development include improved nuclear power, advanced renewable energy sources (hydropower, solar, wind, geothermal, and bio-energy), and the possible use of hydrogen as an energy carrier.

Photo 15.1 — Wind Farm, Crowsnest Pass Area, Cowley Ridge, Alberta. *A growing number of wind farms harness the strong winds in the Crowsnest Pass area of southwestern Alberta. The wind turbines feed the electrical grid, reducingthe need to generate electricity using fossil fuels. The environmental effects of wind power are generally minor, although bird mortality has risen.*

Source: © Danita Delimont/Getty

- **Transport:** Global transportation activity is expected to grow robustly (unless there is a major shift away from current patterns), with carbon emissions projected to double by 2050 over 2010 values. Significant improvements in efficiency are possible for light-duty vehicles and airplanes. Substituting bio-fuels for conventional fossil fuels can reduce emissions, but raises the ethical question of diverting food crops to transport. Clearly, we need more fuel-efficient vehicles, hybrid and electric vehicles, cleaner diesel vehicles, shifts from road transport to railway and public transport systems, increased non-motorized transport (cycling, walking), and better land-use and transport planning.
- **Buildings:** Energy consumption and GHG emission in buildings vary significantly, depending on the country and region. Between 2010 and 2050, CO_2 emissions are predicted to grow by 50 to 150 percent, and this range is taken as the baseline. There is a potential to reduce this projected baseline emission growth by 50 percent in developed countries from lifestyle and behavioural changes. Almost all studies show that improved insulation in the colder climates and greater efficiency in space cooling and ventilation in the warmer climates come first in reducing emissions. Other measures with high savings potential are solar water heating, efficient appliances,

and energy-management systems. Efficient cooking stoves rank second after efficient lighting (shift to fluorescent bulbs) in developing countries.

- **Industry:** The industry sector accounted for over 30 percent of global GHG emissions in 2010, which is more than the building or transport sectors. The projections for industrial CO_2 emissions for 2050 are a further increase of 50 to 150 percent over 2010, assuming that no further action is taken to control these emissions. Many older, inefficient facilities need investment to improve energy efficiency and reduce emissions. The IPCC report recommends reducing energy consumption and CO_2 (and other GHG) emissions through energy efficiency, fuel switching, power recovery, renewables, feedstock change, product change, and material efficiency. Options for mitigation in waste management include reduction, re-use, recycling, and energy recovery. In fact, waste can be a commercially valuable source of energy, through incineration, industrial co-combustion, landfill gas utilization, or anaerobic digester biogas. Waste has an economic advantage in comparison to many biomass resources, because we collect it regularly at public expense.
- **Agriculture, Forestry, and Other Land Use (AFOLU):** The AFOLU sector accounts for about a quarter of GHG emissions, mainly from deforestation, soil and nutrient management, and livestock. Recent estimates indicate a decline in carbon emissions, largely due to decreasing deforestation rates and increased afforestation. Net carbon emissions from AFOLU are projected to decline in the future, with net emissions potentially less than half the 2010 level by 2050, and the possibility of AFOLU becoming a net carbon sink before the end of the century.
- **Urbanization:** Urbanization is a global trend and it is associated with increases in income. Unfortunately, higher urban incomes are correlated with higher consumption of energy and GHG emissions. By 2050, the urban population is expected to increase to 5.6 to 7.1 billion; it is therefore critical that effective mitigation strategies be developed and implemented for these urban areas. Doing so can be achieved by urban planning (e.g., co-locating high-density neighbourhoods near high-density employers) and improvements in public transport. While federal governments dither, thousands of cities are already implementing their own climate action strategies.

Climate change is a serious challenge, but several authors have suggested many other ways to fight it, adapt to it, or even profit from it.[21]

15.4 OIL AND GAS DEPLETION

Oil and natural gas are critical raw materials, essential to our contemporary lifestyle. We need them to manufacture and transport products, to generate electricity, to heat and light our homes, to cook our food, and even to entertain us. Any depletion of oil or gas is therefore a threat to our lifestyle and to sustainability. However, experts warn that oil and gas production is approaching a "peak oil" tipping point. After that point, analysts expect oil and gas prices to rise sharply, creating crises and turmoil.

Definition of "Peak Oil"

The term "peak oil" is often misunderstood. It does not mean that we are running out of oil—it means that we are approaching the halfway point. There is much more oil in the ground; the world's gas tank is still about half-full. However, peak oil warns us that we have used most of the easily found oil, so prices may soon start to rise.

Professor M.K. Hubbert showed, about 50 years ago, that the rate of production of an oil or gas well follows a roughly symmetrical distribution curve over time. (The distribution is similar, but not identical, to a bell curve.) An oil or gas discovery requires time to exploit, so initial flows are low, rising to a peak of production and then gradually decaying as the well becomes exhausted. If we sum the production of all the wells in an oil field, we see a similar bell-like pattern, rising to a peak and then decaying.

The world's total oil and gas follow the same pattern as wells or oil fields. Therefore, when an oil reservoir reaches its production peak, it is approximately half depleted. This knowledge is significant—the peak marks the start of the decline. It is important to note that the world's production peak will likely occur in the next decade—and the consequences are dire. In the past century, we consumed the easily accessible oil—the "light, sweet crude." We must now squeeze out the less accessible oil by offshore drilling, mining the oil sands, and "fracking" the depleted oil fields for "tight oil." Oil and gas production costs have already risen, and competition for dwindling reserves will push prices higher.

Figure 15.2 shows the total global production rate since 1930, with predictions to 2060, based on the theory developed by Hubbert. In 1956, Hubbert applied his theory to predict, correctly, that U.S. oil production would peak between 1965 and 1970. The United States (lower 48 states), the Middle East, Russia, and Europe have all passed their peak oil production dates.

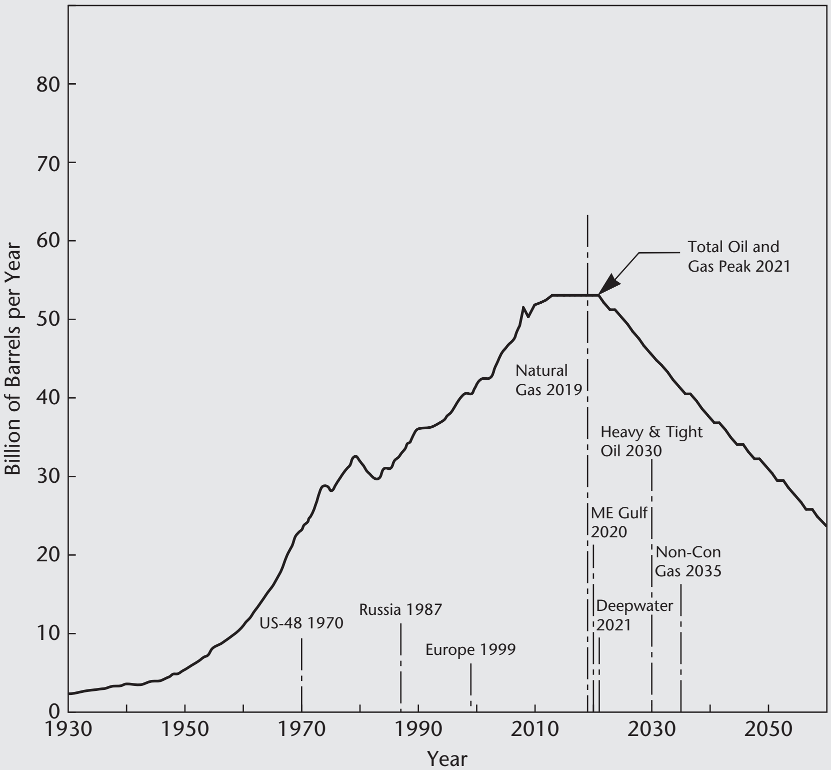
The total global oil and gas peak was previously predicted to occur in 2010, using Hubbert's theory. However, technical advances in oil recovery (such as "fracking") have delayed the date of the oil peak for a decade, to about 2021, as Figure 15.2 shows.

The Implications of Peak Oil

When the peak passes, the easily accessible oil and gas will have been consumed, and oil prices are expected to rise, perhaps sharply.[22] The less accessible oil (such as Alberta's oil sands) cannot be produced as easily or as quickly as oil from the Persian Gulf. The less accessible oil fields will not be profitable unless oil prices rise. However, world demand for oil will not decrease. In fact, as China and India adopt higher living standards, the demand for oil may accelerate. The gap between oil demand and oil supply will likely widen, causing scarcity and even higher prices.

We saw this problem before in the oil crisis of 1973, when the Organization of Petroleum Exporting Countries (OPEC) reduced oil deliveries, and oil prices

FIGURE 15.2 — TOTAL OIL PRODUCTION RATES, AS FORECAST BY C.J. CAMPBELL



This simplified figure shows total global production of oil (including the oil equivalent of other hydrocarbons) from 1930 to the present, with forecasts to 2060. The graph predicts that the total oil peak will occur in 2021; it also shows observed or predicted dates of productivity peaks in other oil deposits.

Source: Figure based on data from Professor C.J. Campbell, director of ASPO-Ireland, ***from Campbell's Atlas of Oil and Gas Depletion***. Reprinted with permission.

rose by a factor of four in about six months. Simultaneously, gasoline prices soared, cars lined up at gas stations, people hoarded gasoline, gas stations sold out of gasoline, and tempers flared. The stock markets lost billions of dollars. Western nations saw a combination of stagnant growth and inflation that persisted for years, damaging their economies.[23]

The oil peak will affect us all. Oil and natural gas are essential for heating our homes and as the feedstock for most plastics, fertilizers, solvents, and adhesives. Our industries, electrical supply, transportation, and lifestyle itself will slow down as prices rise. Natural gas will have a similar peak, because as oil becomes scarce, industries will switch, where possible, to natural gas.

In summary, the world may not run out of oil for another century, but the easily produced oil is disappearing. When the production rate peaks, we will pay higher prices for the less accessible oil that remains.

Adapting to Oil Depletion

Although the precise date of global peak production is uncertain, a peak is coming. New techniques make wells more productive, but fossil fuels are undeniably finite. Many analysts, including Heinberg and Campbell, predict that the peak will occur within the next decade.[24]

This date is important, because, according to a U.S. government report, commonly called the "Hirsch Report," a serious reduction program would take 20 years to implement.[25] In other words, if society, industry, and government cooperated fully to reduce energy consumption and to develop alternatives, we would still need 20 years to avoid energy shortages and crises. Fortunately, recent developments in renewable energy are promising, and the recovery of energy through "fracking" may give us some leeway. We do, however, need to act!

Obviously, to combat the peak oil crisis, we must reduce our fossil fuel consumption. Coincidentally, this is also the action recommended by the IPCC to mitigate the effects of climate change. Therefore, the IPCC recommendations for improving efficiency and reducing emissions (summarized earlier) also apply to the peak oil crisis. To achieve sustainability, we must commit to energy efficiency.

A draft protocol (or international agreement) has been proposed to reduce consumption of fossil fuels on a global scale in a fair and orderly way.[26] However, to date, no major nation has seriously considered adopting it. Mark Jaccard made a bold proposal in his book *Sustainable Fossil Fuels: The Unusual Suspect in the Quest for Clean and Enduring Energy*. Jaccard proposes a strategy for sustainable energy in which fossil fuels continue to play their role for many years. By using carbon capture and sequestering (CCS) technology, we can continue to use fossil fuels without emitting greenhouse gases, thus avoiding economic woes.[27] Jaccard's book is a Canadian opinion on reaching a sustainable future; it won the prestigious 2006 Donner Prize for the top Canadian book in public policy. If we can sequester GHG, we might avoid destructive climate change. We should consider his proposals seriously.

15.5 THE ETHICS OF CLIMATE CHANGE AND PEAK OIL

The Brundtland Commission concluded that environmental degradation leads to poverty and economic disparities. The 2014 IPCC report shows that climate change makes the problem worse, because the economic loss caused by climate change will fall disproportionately on the poorest people. Developing countries will be affected most by climate changes that cause droughts and floods. Although peak oil will affect rich countries because they depend on oil and gas for their lifestyle, poor societies will suffer most. Factories will close, prices will rise, and unemployed people will be unable to pay their bills. This scenario raises basic questions of fairness. Is it fair for richer countries to use fossil fuels indiscriminately, thus creating GHG emissions, and indirectly

- creating millions of "climate change" refugees when droughts reduce crops in Africa, or sea levels rise and flood low-lying countries, such as Netherlands, Bangladesh, and the Pacific islands?
- creating an energy crisis for future generations, who will struggle to find scarce, high-priced oil and gas after we deplete the easily accessible oil?

These ethical problems are very similar to the "tragedy of the commons," discussed in Chapter 14. Therefore, it is instructive to review climate change and peak oil, using the basic ethical theories first outlined in Chapter 9.

- **Mill's utilitarianism:** The excessive use of fossil fuels, which lies at the root of both of these problems, is the philosophy of utilitarianism in reverse. Utilitarianism seeks the solution that produces the maximum benefit for the greatest number of people, with the benefit widely distributed among the people affected. Therefore, utilitarianism would require a sacrifice by the general population, in the form of reduced use of fossil fuels, to benefit the quality of life for society in general. Reducing fuel usage is a small sacrifice in comparison with the deprivation and economic upheaval predicted for future generations.
- **Kant's formalism or duty ethics:** Kant observed that we should act only in ways that would be acceptable as universal principles for everyone to follow. In the case of climate change and peak oil, the wasteful or excessive use of fossil fuels is not a principle that everyone can follow. In fact, wasteful actions are the problem. The universal principle must be to reduce the consumption of fossil fuels and to encourage the development of alternative energy sources. Some people challenge this argument on the basis that we have no duty to future generations. However, civilized humans value the lives of their children and grandchildren as highly as their own. Kant stated that respect for humanity was at the base of his formalism: we should always treat life as an end or goal and never as a means to achieve some other purpose.
- **Locke's rights ethics:** This theory states that every individual has rights, simply because he or she exists. The right to life and the right to the maximum possible individual liberty and human dignity are fundamental; other people have a duty not to infringe on those rights. However, we recognize that rights are limited and can be taken away if justice is served by doing so. We already have laws against water and air pollution, as explained in Chapter 13, because people have no right to waste or destroy a resource that is in the public domain. If we reduce our dependence on oil by reasonable behaviour changes, we can avoid infringing personal rights.
- **Aristotle's virtue ethics:** Aristotle believed that humans would achieve true happiness by developing virtues (or qualities of character) using thought, reason, deduction, and logic. He visualized each virtue as a

compromise between two extremes. In the case of climate change and peak oil, the extremes are the wasteful use of fossil fuels that our society has permitted (perhaps even encouraged) for the past century and the future environmental degradation and fuel scarcity, which will lead to shortages, hardship, civil unrest, and possibly wars. In this case, the "golden mean" between these extremes is the recognition that wasteful practices must end. Ideally, we need new energy sources with a fairer distribution of benefits.

In summary, sustainability is simple fairness. It is unethical to harm others through inefficiency, negligence, greed, or abuse. In this case, the "others" are future generations, particularly those living in poorer countries.

15.6 THE NEED FOR SOCIETAL CHANGE

Climate change and peak oil are both technical and societal problems. Wasteful practices, accepted for centuries, need to change. A sustainable lifestyle requires effort and sacrifice, and that sacrifice includes everyone. Sustainability is a duty for all of society, not just for engineers and geoscientists alone. The first steps are as follows:

REDUCE WASTEFUL CONSUMPTION Examples of inefficiency abound, so the obvious first step is to reduce consumption and waste by conserving, reusing, and recycling materials and consumer goods. Avoiding wasteful consumption is easy: *Reduce, reuse, recycle*. Blue Box recycling systems exist in most parts of Canada but must be expanded and used. We must, however, go beyond the Blue Box and add another mantra: *Rethink and reorganize*. We must eliminate nonessential energy-consuming activities and reorganize our lifestyles to be more independent of fossil fuels.

INCREASE EFFICIENCY The need for increased efficiency is obvious. However, in a 2009 study, a CIBC economist described an "efficiency paradox": for many decades, the United States has passed laws for more efficient automobiles, furnaces, and appliances. Great improvements were achieved. Energy usage still increased, however, because consumers used energy more heavily. The contradiction is most obvious in automobile fuel use. Although auto manufacturers have increased engine efficiency by about 30 percent in the past 25 years, American drivers are simply buying larger, more wasteful vehicles. For example, the sale of light trucks increased by 45 percent in the last decade (greatly in excess of passenger car sales), even though light trucks are much less fuel-efficient than cars. In addition, the distance driven by each vehicle has increased by about 25 percent since 1970. A similar trend exists in home heating and cooling. Air conditioner efficiency has increased by 17 percent since 1990, but air conditioner use has increased by 36 percent. Furnaces are now more fuel-efficient, but house size has doubled in the past 60 years, so more heat is required.[28] To reduce energy consumption, we need limits to growth, not intensity levels based on efficiency.

SUPPORT GOVERNMENT ACTION Very few people give up wasteful or unhealthy habits voluntarily; however, people act positively when encouraged, as tobacco smoking bans prove. Society must pressure governments to limit or reduce GHG emissions and pass laws, regulations, and standards, or impose taxes or charges, to limit fossil fuel use and GHG emissions. Governments, universities, and corporations must stimulate research to find new efficiencies and perhaps even new energy sources. A discussion of these methods and their effectiveness is in the IPCC (AR5) report, cited above.

In summary, if we are to maintain our standard of living without depriving future generations of vital resources, we must reduce fossil fuel consumption now. Ethics and justice require us to share the burdens of climate change and peak oil. Engineers and geoscientists must inform the public of the consequences of inaction. Remedies may be difficult to apply, but old habits must change.

15.7 SUSTAINABILITY FOR ENGINEERS AND GEOSCIENTISTS

Several Associations publish environmental guidelines, as discussed in Chapter 13. However, just following guidelines is not enough. Dennis Burningham, a British oil and gas specialist, emphasizes that sustainability goes beyond mere compliance:

> It is important to distinguish sustainability from environmental compliance. Compliance with environmental regulations is an essential, daily, operational requirement, but sustainability is a long-range strategy to combat a slow-moving, planet-wide terminal condition. Sustainability requires innovative thinking, persistence and possibly some sacrifice. Decades may pass before the social acceptance, legislation and treaties are devised to deal effectively with sustainability. Engineers must, of course, ensure that regulations are followed, but in planning projects and activities, engineers must aim their conceptual thinking at the higher hurdle of sustainability.[29]

Sustainability requires engineers and geoscientists to increase efficiencies in the areas identified in the IPCC AR5 report mentioned above. However, increased efficiency is not enough. We must *rethink and reorganize* our use of energy to

- explore new and innovative ways to reduce our energy consumption, drastically,
- explore new methods of clean consumption of fossil fuels, such as CCS,
- develop renewable energy sources such as solar, wind, and geothermal energy,
- exploit nuclear energy (a non-renewable that will also peak), and
- develop entirely new energy sources and/or distribution systems, such as the hydrogen economy or clathrate technology (mining the abundant methane embedded in ice at great depths around the world, according to Tim Flannery).[30]

Innovation and new ideas are essential! Moreover, as professionals, we must be able to say "no" when environmental degradation is proposed. As responsible engineers and geoscientists, we have a duty to assess projects and activities for their sustainability and decline to participate in projects or activities that are clearly unsustainable.

Engineers and geoscientists should not (and must not) be martyrs in the battle against climate change and peak oil; we need objective methods for evaluating sustainability and legislation to protect whistle-blowers. For example, life-cycle analysis (LCA) is a tool for measuring the environmental impact of a project at the conceptual stage. LCA requires an inventory of all the energy and material inputs and outputs from a project and determines the net result: the energy and resources consumed, and the products and wastes produced. LCA is usually applied for specific emissions, such as CO_2, SOx, NOx, phosphates, or other chemicals, and water and energy consumption. Specific toxic emissions, such as arsenic and lead, are also sometimes calculated, and recent methods include mass and economic considerations.

The International Organization for Standardization (ISO) has published the ISO 14040 (2006) standard for life-cycle assessment (LCA).[31] Engineers and geoscientists are urged to adopt LCA or similar objective tools for evaluating sustainability.

In summary, climate change and peak oil are different problems, but their root cause is the same: the excessive consumption of fossil fuels. Therefore, to maintain our standard of living, we must reduce our consumption of fossil fuels and move to other energy sources. The wasteful use of energy is unethical and a hazard to our way of life. Society must implement regulations and fund research to avoid the worst effects of climate change and to develop sustainable energy sources. Finally, we must speak out in the debate over climate change and help to change attitudes, policies, and laws.

15.8 THE OIL SANDS AND CLIMATE CHANGE

A vigorous ethical debate today among Canadians, especially engineers and geoscientists, is how and when (and whether) to develop the oil sands. The oil sands are almost entirely in Alberta, but developing them has implications for all Canadians. The next few paragraphs examine both sides of the argument.

In a *Maclean's* article, journalist Chris Sorensen describes the oil sands as "the most valuable resource" in Canada's history and laments that it has become "mired in politics, protests, and logistical nightmares," thus jeopardizing Canada's opportunity to become an "energy superpower."[32]

Conversely, in an article in *The New York Times*, scientist James Hansen, former director of the NASA Goddard Institute for Space Studies, stated that Canada's oil sands contain "twice the amount of carbon dioxide emitted by global oil use in our entire history." Therefore, if we exploit the oil sands fully and continue to burn our conventional oil, gas, and coal, it will be "game over" for the climate. The concentrations of carbon dioxide in the atmosphere will eventually reach levels higher than they have been for millions of years, and global temperatures would be intolerable.[33]

This is a complex ethical dilemma, so we cannot solve it easily. We can, however, begin seeking a solution. A methodical, impartial approach was explained earlier (see Section 9.8). Information is everywhere; the oil sands are in the news and debated widely, in Parliament and internationally. In fact, we are swamped with facts.

To begin the discussion, this section summarizes the two opposing opinions on the Alberta oil sands development. They range from positive to negative and have been condensed to meet this book's space limitations. Readers are encouraged to read the full papers, consult other sources, and draw their own conclusions.

The Conference Board of Canada

A report prepared under the auspices of the Conference Board of Canada summarizes the benefits of developing the oil sands. A brief précis of the report follows:

> **Fuel for Thought: The Economic Benefits of Oil Sands Investment**
>
> The development of Canada's oil sands deposits constitutes one of the largest development projects in the country's history. Cumulative investment in the past decade alone has surpassed $100 billion, and hundreds of billions more are expected over the next 25 years. . . . Canada is expected to become the fourth-largest oil producer in the world before 2035. . . .
>
> - **Supply Chain Effects:** Between 2012 and 2035, we expect $364 billion in price-adjusted investment to take place to support oil sands development. In addition to the 880,000 person-years of employment directly supported by these expenditures, we expect domestic supply chain effects of 1.45 million person-years of employment. This is equivalent to 3,970 person-years of employment for every billion dollars [invested]. . . .
>
>   The majority of the supply chain effects will occur inside of Alberta, but nearly one-third will occur in other provinces. Among those provinces, Ontario will experience the largest benefit, accounting for 14.8 per cent of the supply chain employment effects. Ontario is followed by British Columbia (6.7 per cent), Quebec (3.9 per cent), the Prairies (3.7 per cent), and Atlantic Canada (0.8 per cent).
> - **Other Domestic Economic Effects:** The direct and supply chain employment effects are expected to generate $172 billion in wages and salaries. When spent, this money will support an additional 880,000 person-years of employment; this is known as the income effect. The three combined employment effects mean that oil sands investment will support 3.2 million person-years of employment, or 8,800 for every $1 billion in price-adjusted investment. By region, Alberta will experience the largest effects (74.2 per cent), followed by Ontario (11.7 per cent), British Columbia (6.9 per cent), Quebec (3.4 per cent), the Prairies (3.1 per cent), and Atlantic Canada (0.7 per cent). . . .

In total, we estimate that there were 5,200 out-of-province workers in Wood Buffalo-Cold Lake in 2011 and that they earned $280 million in labour income. Newfoundland and Labrador, British Columbia, and Saskatchewan are the largest source provinces for these workers.

Some of the income they earn will remain in Alberta, as the workers will spend some of their earnings on things like food and housing while they are working. However, a significant share of this income will be remitted back to their home provinces. . . .

Beyond the employment impacts, oil sands investment also has significant fiscal implications for the federal and provincial governments in Canada. In fact, oil sands-related investment is expected to generate $79.4 billion in federal ($45.3 billion) and provincial ($34.1 billion) government revenues between 2012 and 2035, on an inflation-adjusted basis. This includes the effects of personal income taxes, corporate profit taxes, and indirect taxes. . . .

In terms of the breakdown by province, the largest benefits would accrue to Alberta, which would receive 76.9 per cent of the provincial total, or $26.3 billion. However, as federal government transfers to the provinces tend to follow a per capita distribution, all of the provinces would experience significant effects once their share of federal revenues is included. For example, Ontario would garner $17.6 billion of the federal fiscal benefits and $3.8 billion in direct provincial revenues.

- **Effects on Trade and Investment:** Oil sands investment will also have significant implications for our international trade and investment. For example, the supply chain effects for international imports will actually exceed those for the provinces outside of Alberta. Most of the imports that result from oil sands investment will be manufactured goods, and the United States will be the largest beneficiary, as it remains the source for more than half of Canadian imports for nearly all of these products. We estimate that 192,000 person-years of manufacturing employment in the US will be supported by oil sands investment and related activities. . . .
- **Implications:** Oil sands development will have wide-ranging effects on Canada's economy. . . . How we respond to these challenges will determine whether or not the economic potential of the oil sands is fully realized.*

The Pembina Institute

The Pembina Institute works to "support the use of renewable sources, maximize energy efficiency opportunities and reduce demand for both electricity and heating sources based on fossil fuels." Excerpts from two recent Pembina reports about the oil sands follow:

"Responsible resource development" must be more than a slogan

. . . Here's the bottom line: there is an urgent need to manage the pace and scale of oilsands development much more deliberately, and simply branding that development "responsible" doesn't make it so.

* Michael Burt, Todd Crawford, and Alan Arcand, *Fuel for Thought: The Economic Benefits of Oil Sands Investment for Canada's Regions* (Ottawa: Conference Board of Canada, 2012), http://www.conferenceboard.ca/e-library/abstract.aspx?did=5148 (accessed June 23, 2017). Excerpt reproduced with permission.

We're already witnessing the environmental problems associated with drawing 1.7 million barrels of bitumen out of the ground in northeastern Alberta: contamination of forests, wetlands and rivers; declining caribou populations; and steadily increasing greenhouse gas pollution, to name just a few.

It's difficult to see how 5 million barrels a day of oilsands production can be achieved responsibly—particularly when the federal government is weakening regulatory oversight, and oilsands approvals are proceeding despite incomplete information about current impacts and without requiring companies seeking project approvals to improve on current practices as a condition of expansion.

Fixing the problems associated with toxic tailings ponds, declining caribou and lagging land reclamation requires time. The approach of letting the market dictate the pace and scale of development—rather than proactively managing to minimize harm and maximize benefits—has failed.

The numbers don't lie. If oilsands operators achieve or exceed the 5 million barrels per day of production that has already been approved without making major changes that aren't even on the drawing board today, "responsible resource development" will be out of reach. As far as slogans go, it's a great catch phrase. The challenge for governments and the oilsands industry now is to demonstrate they can—and intend to—deliver.*

The following headings outline the chapters in a comprehensive Pembina Institute report that summarizes over 20 oil sands issues that create concern. The report defines and explains each concern in detail. The report is freely available over the Internet at www.pembina.org.

Beneath the Surface: A Review of Key Facts in the Oilsands Debate

Climate and air

- Average oilsands production is significantly more greenhouse gas-intensive than conventional oil production.
- Oilsands emissions are a growing problem.
- Oilsands emissions matter on a national scale, and are a significant barrier to meeting Canada's 2020 climate commitment.
- Oilsands emissions matter on a global scale.
- Current regulations do not result in meaningful reductions in greenhouse gas emissions from oilsands development.
- Air quality is starting to be impacted by oilsands air pollution.
- Forecasted growth in oilsands will present very serious air pollution challenges in the Wood Buffalo Region.

* Jennifer Grant, Director, Oilsands, Pembina Institute, "'Responsible Resource Development' Must Be More Than a Slogan," *Hill Times*, August 27, 2012, http://www.pembina.org/op-ed/2369 (accessed June 23, 2017). Excerpt reproduced with permission.

Water

- Water monitoring in northeastern Alberta has been inadequate, yet governments continue to approve new oilsands projects.
- Oilsands extraction uses large amounts of water, despite recycling efforts.
- Oilsands companies are not required to stop withdrawing water from the Athabasca River, even if river flows are so low that fisheries and habitat are at risk.

Tailings

- Oilsands tailings volumes continue to grow due to a permissive regulatory approach.
- Tailings lakes house compounds known to be acutely toxic to aquatic organisms.
- Tailings lakes seep an undetermined amount of toxic waste.
- Capping toxic tailings waste in end pit lakes with water is an unproven and risky concept.

Land and wildlife

- Restoration of wetlands continues to be a major challenge and may never occur.
- The boreal forest will not be restored to its native state following mine closure.
- In situ developments may affect a much larger area than oilsands mining.
- Woodland caribou herds are declining in the oilsands and are on track to be extirpated.
- Oilsands development threatens to harm millions of birds through habitat fragmentation and destruction.

Economics

- Taxpayers may foot the bill for cleanup of oilsands mines.
- The costs and benefits of oilsands development are not spread evenly across Canada.
- Relying on the volatile profits from oilsands projects to fund government and social programs creates financial risks for both the private and public sector.*

The above discussion merely "scratches the surface." In fact, it raises more questions than it answers. Should Canada exploit the oil sands energy windfall to become a superpower (as journalist Chris Sorensen and the Conference Board of Canada recommend above)? Alternatively, should we preserve this valuable one-time inheritance for future generations (as journalist Andrew Nikiforuk recommends in his articles[34] on the ethical challenges of the oil sands)? Is there a "golden mean" in this dilemma?

DISCUSSION TOPICS AND ASSIGNMENTS

1. On April 22, 2010, the Deepwater Horizon, an offshore drilling rig owned by BP and operating in the Gulf of Mexico, exploded, burned, and sank, killing 11 oil workers. The crude oil from the well continued to flow from

* Jennifer Grant, Marc Huot, Nathan Lemphers, Simon Dyer, and Matt Dow, *Beneath the Surface: A Review of Key Facts in the Oilsands Debate* (Drayton Valley, AB: Pembina Institute, January 2013), https://www.pembina.org/reports/beneath-the-surface-oilsands-facts-201301.pdf (accessed June 23, 2017). Excerpt reproduced with permission.

the broken pipe for 87 days, despite the activation of blowout preventers. Workers were not able to cap the pipe stub until July 15, 2010. The total crude oil discharged was almost 5 million barrels—the largest accidental oil spill in history. In 2014, a U.S. District Court judge ruled that BP was primarily responsible for the oil spill; in 2015, BP agreed to pay $18.7 billion in fines, the largest corporate settlement in U.S. history.

Using data from the Internet, compare the Deepwater Horizon disaster with the loss of the Ocean Ranger, the largest oil rig of its time, described in Chapter 13. Which loss was greater in terms of financial loss and human lives? Which loss caused the most environmental damage? Explain briefly the root causes of each accident (on one page each).

2. Sustainability is based on the axiom that we have a duty to future generations. However, some philosophers challenge that axiom, arguing that future generations will likely have superb technical and scientific resources and will be "better off" than we are. To illustrate: Past generations could never have imagined nuclear energy, computers, cell phones, or the Internet and the benefits associated with them. If future generations will be better off than we are, why should we sacrifice for them? Moreover, nuclear war, plague, or collision with an asteroid might erase future generations, making our concerns needless. Discuss this Cornucopian concept, and state whether (and why) you agree or disagree.
3. Population growth is a critical factor in sustainability. China's population of about 1.4 billion people (as of 2015) live on a land area slightly smaller than Canada, which has about 36 million people. From 1979 to 2015, China implemented a severe one-child program to limit its birth rate. Couples who agreed to have only one child received free healthcare for the birth and for the child, whereas couples that did not agree had to pay their own expenses. Under this policy, the birth rate declined to about 1.2 percent in 1981, but by 1991, it had risen to 1.4 percent. As well, there is recent evidence that people refused to comply with the one-child policy. For example, more parents sent unwanted children to orphanages. Discuss the ethics of government policies that limit birth rates, using the ethical theories described in Chapter 9. Can you support the Chinese policy on an ethical basis? Which should take precedence: personal freedom to bear children or the duty-based concept that, in countries such as China, everyone must share the responsibility and limit growth? What is the greatest good for the greatest number? Can you identify a virtue, a golden mean, or a compromise in this case? Consulting "The Tragedy of the Commons,"an article by Garrett Hardin (cited in Chapter 14), may help in your answer.[35]

NOTES

[1] The first four sections of this chapter have been structured based on "Environmental Sustainability," chap. 19, in Gordon C. Andrews, J. Dwight Aplevich, Roydon A. Fraser, and Carolyn MacGregor, *Introduction to Professional Engineering in Canada*, 4th ed. (Toronto: Pearson Education Canada, 2015).

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[35] The authors thank Dr. Jerry M. Whiting, Professor Emeritus, University of Alberta, for providing the ideas in assignment 15.3.

Chapter 16

Writing the Professional Practice Exam

To obtain a licence to practise engineering or geoscience in Canada, every applicant must write a Professional Practice Examination (PPE). The exam tests the applicant's knowledge of the principles of ethics, liability, and Canadian law as they apply to professional engineers and geoscientists. The PPE is a universal requirement for licensing, with very few exceptions. (For example, applicants who have passed the PPE in another province or territory are exempt under Canada's Agreement on Internal Trade.)

Each provincial or territorial Association has the authority under its Act to set a professional practice exam, and the exam format depends on the Association. However, 12 of the licensing Associations adopt some form of the National Professional Practice Exam (NPPE) established by Alberta (APEGA) and only a few Associations (PEO, OIQ, and APEGS) set and administer independent exams.

This chapter explains the licensing process and describes the PPE format in each province and territory. The chapter lists the subject matter recommended by Engineers Canada for the PPE, as well as the scope and syllabus for the National Professional Practice Exam set by APEGA. The chapter concludes with sample questions from many previous exams, which may be particularly useful to anyone preparing to write the PPE.

16.1 THE STEPS IN THE LICENSING PROCESS

To become a Professional Engineer or Professional Geoscientist, you would typically follow the four steps below.

Step 1: Apply for a Licence

- **Apply for membership in your Association:** First, apply for membership in the Association (or *Ordre*) where you wish to work. The textbook lists the 15 Associations (below, and in Appendix A). You should apply for a licence (or membership) as soon as you graduate from university, even if you have not completed the experience requirement. Depending on your

Association, you will be enroled in an internship program as, for example, a Member in Training (MIT), Engineer in Training (EIT), Geoscientist in Training (GIT), or *Ingénieur junior*. The internship has a small cost, but it puts you in immediate contact with professional colleagues, gives you guidance on work experience, and activates the licensing process. (In fact, several Associations encourage student participation even before graduation, as discussed in Chapter 18.)

- **A note on academic requirements:** The application process may take longer for an applicant whose university program is not CEAB-accredited. Associations have international mobility agreements with many countries, but evaluating credentials takes time. To speed up the process, internationally educated applicants should contact their intended Association before arrival in Canada and apply for a licence as soon as possible. (Chapter 2 has more information on admission rules.)

Step 2: Begin Your Work Experience

- **Acquire work experience:** You usually need two years of experience before writing the PPE. Work experience exposes you to professional practice, ethics, and law in the workplace, making the PPE more relevant. You should document your work experience as outlined in Chapter 2.
- **Apply to write the PPE:** Apply on your Association's website to write the PPE as soon as you are eligible. If you are working outside the province, contact your Association to ask if you may write the PPE in your location. The PPE is a universal requirement for all new applicants. (You cannot take a course instead of the PPE.) Note that the fee you pay to your Association for the PPE is deductible from income for tax purposes under Canadian law.[1]

Step 3: Prepare for and Write the PPE

- **Obtain the study materials:** Your Association will send you study advice when it approves your application to write the PPE. In addition, most Associations prepare and sell a Study Material Kit containing the textbooks and reference materials. The law and ethics textbooks are essential for proper study and are extremely useful references for your professional library. If you borrow or buy used textbooks, be sure to obtain current editions, as laws and procedures often change. In addition, all Associations publish free professional *Guidelines,* available over the Internet. A few Associations, such as Professional Engineers Ontario (PEO), do not sell textbooks.
- **Prepare for the PPE:** Generally, you must prepare for the PPE by personal study;however, a few Associations (such as APEGBC and APEGS) now organize and offer excellent PPE preparation seminars. Check your Association's website, as offerings change without notice. A preparatory PPE seminar offered by your Association is good value.
- **Attend a preparatory PPE seminar:** Preparatory PPE seminars by private companies may help. If your Association does not offer preparatory

PPE seminars, you might consider a seminar offered by a private company. Use your own judgment: you should not need a seminar if you have prepared properly for the PPE. However, a seminar is advisable if you previously failed the PPE, if you are writing the PPE in your second language, or if you have never taken a law or ethics course and are unfamiliar with these concepts. You can usually find PPE seminars advertised on the Internet; simply search for "Professional Practice Seminar."

- **Complete the PPE:** Write the PPE and wait for the results. On the day of the exam, follow the instructions previously mailed to you. Arrive early and bring extra writing materials. After you write the exam, you must usually wait four to six weeks to receive the results. Associations typically mail PPE results directly to the applicant. Do not call to obtain your results; Associations firmly refuse to release PPE results in advance, by telephone or via email.
- **If you fail to appear:** What should you do in case of accident or illness? As a rule, failure to appear and write the PPE is the same as writing it and failing, and you forfeit the PPE fee. In exceptional cases, involving accident, hospitalization, or death in your family, the Association may credit your exam fee toward the next attempt. If you have an exceptional case, you must contact your Association immediately and provide documents and reasons.
- **If you fail the exam:** What should you do if you fail the PPE? If you do not pass the PPE, you must rewrite it. Each Association has clear rules on the number and timing of allowable exam attempts. Follow your Association's advice.

Step 4: Complete Your Work Experience and Obtain Your Licence

- **If you pass the exam:** When you pass the PPE, you merely need to complete your experience requirement and pay the licensing fee to obtain your professional licence and seal.

16.2 PPE FORMAT: OVERVIEW AND SUMMARY

Fifteen licensing Associations (and *Ordres*) set Professional Practice Exams for engineering and geoscience across Canada, and each Association (or *Ordre*) retains autonomy over its licensing process. Fortunately, the 15 Associations cooperate, with the help of two advisory bodies—Engineers Canada and Geoscientists Canada—to ensure that these exams are fair and consistent.

Twelve of the 15 Associations use the National Professional Practice Exam (NPPE) established by Alberta (APEGA). Some Associations permit candidates to write the NPPE in either French or English. Several Associations modify the APEGA format by adding multiple-choice and/or essay questions to the NPPE; only three Associations set and administer independent exams. The list below is a summary of the exam formats. (WARNING: Exam formats may change at short notice. Check the exam rules on your Association's website.)

Alberta NPPE Format

The NPPE format established by Alberta (APEGA) is a 2.5 hour, closed-book exam with 110 multiple-choice questions. (The NPPE syllabus topics are listed later in this chapter.) Aids are not permitted. The pass mark is 65 percent, and there is no penalty for wrong answers.[2] The NPPE is typically offered four times per year (April, June, September, and November) in the following jurisdictions, but please contact your Association to identify specific dates, obtain information, and apply to write the exam:

- **Alberta** (APEGA)
- **Manitoba** (APEGM)
- **New Brunswick** (APEGNB)
- **Newfoundland and Labrador** (PEGNL)
- **Northwest Territories and Nunavut** (NAPEG)
- **Nova Scotia** (Engineers Nova Scotia)
- **Nova Scotia** (Geoscientists Nova Scotia)
- **Prince Edward Island** (Engineers PEI)
- **Yukon** (APEY)

Modified NPPE Format

The following jurisdictions also use the NPPE format established by Alberta (APEGA), but in a modified format.

- **British Columbia** (APEGBC): APEGBC applies a 3.5-hour computer-based exam, consisting of a 2.5-hour 110-question multiple-choice exam, based on the National Professional Practice Exam (APEGA) format and syllabus, and a one-hour essay question.[3]
- **Ontario** (APGO): The Ontario Geoscience PPE is a 3.5-hour computer-based exam, with 2.5 hours for 120 multiple-choice questions and one hour for an essay question. The first 100 questions are based on the National Professional Practice Exam (set by APEGA), and another 20 questions are specific to Ontario and deal with the APGO Act (8 questions) and other Ontario Acts and regulations (12 questions). The essay question tests the applicant's ability to communicate effectively.[4]
- **Quebec** (OGQ): The PPE administered by OGQ consists of 100 multiple-choice questions dealing with professional law, ethics and legal concepts, and regulations affecting the professional practice of geologists in Quebec. The duration of the examination is two hours. No documentation (paper or electronic) is allowed in the examination room. The test is administered four times a year in French (an English version is provided on prior request). A minimum of 66 percent is required to pass, and there is no penalty for incorrect answers. The exam resultisreported as "success" or "failure." The syllabus and topic weighting are defined in the OGQ guide to the professional exam, *Guide pour l'examen professionnel*, which is available with study material in French on the OGQ website at http://ogq.qc.ca/admission/examen-professionnel.[5]

Ontario Engineering (PEO) Exam Format

The Ontario (PEO) exam is an essay-type examination, although it usually contains a few short-answer questions. The exam is in two parts: Part A—Professional Practice and Ethics, and Part B—Engineering Law and Professional Liability. Applicants receive a total of three hours to write the full exam (90 minutes for each part). The exam contains four questions. You must pass both parts successfully, but if you fail either, only that part must be rewritten. The PPE is a "closed book" examination. No aids are permitted, except copies of Ontario Regulation 941, sections 72 (Professional Misconduct) and 77 (Code of Ethics). PEO staff will distribute copies of sections 72 and 77 with the question papers. Dictionaries are not permitted.

PEO cautions that marking is based not only on academic content but also on legibility and the ability to express oneself clearly and correctly in the English language. If an exam writer has any doubt about the meaning of a question, it would be important to explain how it has been interpreted. The brief Ontario (PEO) PPE syllabus is comparable to the NPPE syllabus, below.[6]

Quebec Engineering (OIQ) Exam Format

The Quebec engineering licensing examination is composed of approximately 110 multiple-choice questions. The duration of the examination is three hours, and question papers are in French and English. The exam has three parts, corresponding to the three chapters of the OIQ study guide (*Notes préparatoires à l'examen professionnel*), which are weighted as follows: Chapter 1—Quebec professional system (32 percent); Chapter 2—Practice of the engineering profession (45 percent); and Chapter 3—The legal environment (23 percent). To pass the examination, a candidate must obtain at least 60 percent of the points allocated to each of the three parts of the examination. If the candidate fails any of the three parts, the exam must be repeated.[7]

Saskatchewan (APEGS) Exam Format

The APEGS Professional Practice Examination is a three-hour closed-book examination on engineering and geoscience law; professional practice and ethics; occupational health; and environmental protection. The passing mark is 65 percent. APEGS offers a two-day Law and Ethics Seminar to exam applicants, and the well-organized APEGS website for the PPE provides extensive source and study material.[8]

16.3 PPE SYLLABUS: ENGINEERS CANADA

Engineers Canada has produced an updated *National Guideline on the Professional Practice Examination* that defines the recommended format and content for the PPE. The *Guideline* advises Associations on how to set, conduct, and administer the PPE; it contains an appendix on the principles of fair testing.

Most notably, the *Guideline* recommends the "Subject Matter" for the PPE. Table 16.1 reproduces this syllabus below, with permission of Engineers Canada.[9] To assist readers, Table 16.1 provides cross-references to appropriate chapters in this textbook. For readers who want more detail, the *Guideline* expands the syllabus topics in an appendix titled "Body of Knowledge." (See Appendix B in the *Guideline*.)[10]

TABLE 16.1 — Subject Matter for the Professional Practice Exam

PROFESSIONAL PRACTICE EXAMINATION SYLLABUS	**WHERE TO FIND IT IN THIS ETHICS TEXT**
MAJOR SUBJECT AREAS—ENGINEERS CANADA	
1. Professionalism	***Part One***
1.1—Definition of the professional	Chapter 1—Introduction to the Professions
1.2—The roles and responsibilities of a professional in society	Chapter 2—Regulation of Engineering and Geoscience
1.3—Professionalism	
1.4a—Engineering in Canada *(Brief history, Associations/Ordre, Engineers Canada, Technical Societies, Iron Ring)*	Also, see Chapter 18—Benefiting from Technical Societies (The Iron Ring and the Earth Science Ring)
1.4b—Geoscience in Canada *(Brief history, Associations/Ordre, Geoscientists Canada, Technical Societies, Earth Ring)*	
1.5—Values of the engineering and geoscience professions	
2. Ethics	***Part Three***
2.1—Overview of ethics in society, cultures and customs	Chapter 9—Principles of Ethics and Justice
2.2—Classical ethical theories	Chapter 10—Ethics Concepts and Cases: Employment
2.3—Modern ethical theories	Chapter 11—Ethics Concepts and Cases: Management
2.4—General ethical principles	Chapter 12—Ethics Concepts and Cases: Consulting
2.5—Codes of ethics	
2.6—Fundamental ethical requirements	
2.7—Ethical decision making	
2.8—Common ethical issues and dilemmas	

Table 16.1 — (*continued*)

3. Professional Practice	***Parts Two and Four***
3.1—Risk management*	Chapter 6—Hazards, Liability, Standards, and Safety
3.2—Standards*	
3.3—Duty to inform	Chapter 4—Basic Concepts of Professional Practice
3.4—Due diligence	
3.5—Legality	
3.6—The corporate world	Chapter 5—Consulting, Private Practice, and Business
3.7—Globalization*	Chapters 13, 14, 15—Environmental Sustainability
3.8—Sustainable development	Chapter 6—Hazards, Liability, Standards, and Safety
3.9—Quality management*	
3.10—Relations with other professionals and non-professionals	Chapter 8—Diversity in the Professional Workplace
3.11—Use of software, computers, and internet-based tools*	Chapter 7—Computers, Software, and Intellectual Property
3.12—Document authentication and control	Chapter 4—Basic Concepts of Professional Practice (Using Your Professional Seal)
3.13—Insurance	
4. Communication	***Part Two and Law Texts***
4.1—Legal, ethical, and practical aspects of communication	Chapter 5—Consulting, Private Practice, and Business
4.2—The professional relationship	
4.3—Communication skills	
5. Law for Professional Practice (province and profession-specific, as applicable)	***See Law Text***
5.1—The Canadian legal system	See Law Text
5.2—Contract and torts in Common Law provinces and territories	
5.3—Civil Law in Quebec	
5.4—Law related to professional practice	
5.5—Business, employment, and labour law	
5.6—International law	

Table 16.1 — (*continued*)

6. Professional Law	***Parts One and Two and Law Texts***
6.1—Legal framework	See Law Text and
6.2—Admission to the profession	Chapter 2—Regulation of Engineering and Geoscience
6.3—Code of Ethics	Chapter 3—Disciplinary Powers and Procedures
6.4—Professional regulations	Chapter 9—Principles of Ethics and Justice
6.5—Illegal practices/Enforcement against unlicensed practice and misuse of title	
7. Regulation and Discipline Processes	***Parts One and Five and Law Texts***
7.1—Discipline of members	See Law Text and
7.2—Professional inspection/practice reviews of individuals	Chapter 3—Disciplinary Powers and Procedures
7.3—Practice reviews of firms	
7.4—Medical control/fitness to practice	
7.5—Control of criminal and disciplinary decisions	
7.6—Continuing professional development	Chapter 17—Maintaining Your Professional Competence

* indicates a topic where differentiation may be required between engineers and geoscientists.

Source: Engineers Canada, “Subject Matter,” *National Guideline on the Professional Practice Examination,* © Canadian Engineering Qualifications Board, 2012, engineerscanada.ca/publications/national-guideline-on-the-professional-practice-examination (accessed June 23, 2017). Reproduced with permission of Engineers Canada.

Note: Engineers Canada is a non-profit organization that assists the provincial and territorial Associations. The National Examination Committee of Engineers Canada prepared this guideline in consultation with the Associations, which have the authority to accept, modify, or reject it.

The Engineers Canada *Guideline* is only a recommendation, of course, but it is a valuable contribution to exam consistency by the National Examination Committee (a committee of the Canadian Engineering Qualifications Board). The Associations and *Ordres* deserve credit for the impressive improvement in licensing procedures over the past decade. APEGA merits particular recognition for achievement in developing the National Professional Practice Examination, discussed below.

16.4 NATIONAL PROFESSIONAL PRACTICE EXAMINATION (NPPE)

Since 1998, the Association of Professional Engineers and Geoscientists of Alberta (APEGA) has provided a National Professional Practice Examination

(NPPE) for engineering and geoscience licensing. Twelve of the 15 licensing bodies across Canada now adopt the NPPE (in various forms), as listed earlier.

The NPPE, consistent with the Engineers Canada recommendations for syllabus and format, consists of a set of 110 multiple-choice questions, selected from a large bank of such questions, and administered in a 2.5-hour closed-book format. All questions are common to engineering, geology, geophysics, and geoscience. Some Associations extend the NPPE by adding multiple-choice and/or essay questions and (in those jurisdictions) candidates are allowed additional time to complete the examination.

The pass mark is 65 percent, with no penalty for wrong answers. The grade is final and cannot be appealed. The NPPE syllabus is listed below, with APEGA permission:

A. Professionalism (10%)

A.1 Definition and Interpretation of Professionalism and Professional Status
A.2 The Roles and Responsibilities of Professionals in Society
A.3 Engineering and Geoscience Professions in Canada; Definitions and Scopes of Practice
A.4 The Value of Engineering and Geoscience Professions to Society
A.5 The Roles and Responsibilities of Professionals to Management

B. Ethics (20%)

B.1 The Role of Ethics in Society; Cultures and Customs
B.2 Classical and Modern Ethical Theories and Principles
B.3 Codes of Ethics of Professional Engineers and Geoscientists in Canada
B.4 Ethical Standards and Codes and Their Relationship to the Conduct of a Professional
B.5 Common Ethical Issues and Dilemmas; Making Ethical Decisions

C. Professional Practice (27%)

C.1 Professional Accountability for Work, Workplace Issues, Job Responsibilities and Standards of Practice
C.2 Relations with Other Professionals and Non-Professionals; Business Practices
C.3 Statutory and Non-Statutory Standards and Codes of Practice
C.4 Insurance, Risk Management and Quality Management; Due Diligence
C.5 Environmental Responsibilities and Sustainable Development
C.6 Use of Software, Computers and Internet-based Tools; Liability for Software Errors
C.7 Documentation Authentication and Control
C.8 Duty to Inform; Whistleblowing

D. Communication (1%)

D.1 Legal, Ethical and Practical Aspects of Communication
D.2 The Professional Relationship
D.3 Communication Skills

E. Law for Professional Practice (23%)

E.1 The Canadian Legal System

E.2 Contract Law—Elements, Principles, and Applications
E.3 Tort Law—Elements, Principles and Applications
E.4 Civil Code in Quebec and Common Law in Rest of Canada
E.5 Business, Employment, and Labour Law
E.6 Arbitration and Alternative Dispute Resolution (ADR)
E.7 Intellectual Property—Patents, Trademarks, Trade Secrets, Software Issues, Copyright
E.8 Expert Witness
E.9 Construction Liens
E.10 International Law
E.11 Environmental Law
E.12 Workers' Compensation and Occupational Health & Safety
E.13 Human Rights and Privacy Legislation

F. Professional Law (8%)

F.1 The Acts, Regulations and Bylaws; Provincial and Territorial Acts
F.2 Codes of Ethics; Conflict of Interest
F.3 Admission to the Professions
F.4 Illegal Practice; Enforcement Against Unlicensed Practice and Misuse of Title
F.5 Professional and Technical Societies

G. Regulation & Discipline Processes (11%)

G.1 Discipline and Enforcement Procedures
G.2 Professional Inspection; Practice Reviews of Individuals
G.3 Response to Complaints
G.4 Licensing Corporations and Practice Reviews of Firms
G.5 Response to Unethical or Incompetent Practice; Consequences of Unethical Practice
G.6 Canadian and International Mobility
G.7 Continuing Professional Development
G.8 Use of Seals and Stamps*

16.5 ADVICE FOR WRITING THE PPE

Some General Hints

If you are writing the PPE, the following hints may help:

- The PPE should test your knowledge of your Association's Code of Ethics, so read it thoroughly before the examination. This hint may be obvious, but some people overlook the importance of the Code of Ethics. (You do not, however, need to memorize it.)

* Association of Professional Engineers and Geoscientists of Alberta, "National Professional Practice Exam Syllabus" (Edmonton, AB: APEGA), available at https://www.apega.ca/apply/exams/nppe/syllabus/ (accessed June 23, 2017). Excerpt reproduced with permission. Please be advised that the NPPE syllabus changes over time to reflect changes occurring in the professions. Candidates should visit the APEGA website or the website of their Association to ensure that they are using the most current information.

- Prepare for the right PPE format: NPPE questions are multiple-choice, so they are usually brief and factual, with one right answer. Essay questions usually describe a hypothetical situation and ask you to suggest a solution, so they often have many acceptable answers. Be prepared to compare and contrast ethical viewpoints.
- Answers to essay questions are more convincing if you can cite a law or a Code of Ethics clause to support your answer.

The EGAD! Strategy for Ethics Questions

Applying the strategy for solving ethical problems described in Chapter 9 may be useful, particularly for essay-type questions, so the strategy is included below in a simpler form. This six-step strategy,similar to a technique taught to law students,[11] has been renamed the "EGAD!" method. You can remember it easily by these three words:

Read—EGAD!—Write

The term "EGAD!" (an old English exclamation of surprise) is an acronym and mnemonic for the four key steps in the solution strategy: **E**thical issues, **G**eneration of alternatives, **A**nalysis, and **D**ecision. The six-step strategy is explained as follows:

STEP 1: READ

Read the problem thoroughly and gather information

Exam questions contain less information than real problems, so read each question thoroughly! Highlight or underline key facts, but do not copy the question into the exam book, since this wastes valuable time. Ask yourself the typical reporter's questions:

- *Who is involved?* (i.e., Who has caused harm to whom?)
- *What harm or damage has occurred* (or may potentially occur)?
- *How has this harm occurred* (or may potentially occur)?

STEP 2: E—ETHICAL ISSUES

Identify the basic ethical issues

The exam question may state the ethical problem directly. For example: "Has Mr. Smith broken the Code of Ethics?" However, some exam questions may say simply "Explain and discuss this case." You must then imagine which ethical issues should apply, and if possible compare the similarities (and differences) of the case with previous cases. If the ethical issue is not obvious, ask yourself "What, exactly, is wrong in this situation? Do any actions contravene the law or the Association's Code of Ethics? What is unfair?" Once you identify the ethical problem, the proper course of action may be obvious. If so, write down your answer. However, for some questions you may have to suggest (or "generate") a proper course of action.

STEP 3: G—GENERATION OF ALTERNATIVES

Generate (or suggest) possible courses of action

Some exam questions simply ask "What should you do?" and you must suggest the proper action. This step requires creative thought, so it may be difficult. Creative techniques such as brainstorming may be useful. You might suggest a compromise, or a totally new idea. You might also try to imagine yourself as one of the participants. What would you do in this situation? The goal is to find a new course of action that is ethically correct and that has a minimum of side effects.

Sometimes an exam question involves an ethical dilemma with only two alternatives, both of which are very nasty. Do not immediately assume that you must choose one of them. In this case, you would list the benefits and disadvantages of each course of action. This may lead you to a third possibility that is better than the two obvious alternatives. If you do not find a better course of action, you would (reluctantly) recommend the "least bad" course of action, but your list of benefits and disadvantages would show that you have considered the dilemma thoroughly.

STEP 4: A—ANALYSIS

Analyze the possible courses of action

The previous step usually yields several courses of action. You must select the simplest course of action that solves the problem without nasty side effects. You should test each course of action as follows:

- Is this course of action legal?
- Is it consistent with human rights, employment standards, and design standards?
- Does it obey the Code of Ethics and maintain the ideals of the profession?
- Can the solution be published and withstand the scrutiny of your colleagues and the public?
- What benefits will result, and are they equally distributed? (Utilitarianism)
- Can this solution be applied to everyone uniformly? (Kant)
- Does this solution respect the rights of all participants? (Locke)
- Does the solution develop or support moral virtues and/or is it a golden mean between unacceptable extremes? (Aristotle)
- Is it fair? Does it have any unfair side effects on those concerned? (Justice)

STEP 5: D—DECISION

Make a logical decision

The previous step should yield at least one acceptable course of action. However, in tough cases, all of the alternatives may be unacceptable. In this case, you must decide which is least negative. If the choices are equally balanced, select the course of action that does not yield a personal benefit to you. This will help you to defend your decision.

STEP 6: WRITE

Write a professional summary of your answer

Finally, you must explain your answer clearly, logically, and neatly. You cannot afford to waste time, so you must practise writing good answers. Start by stating your decision, which answers the question asked by the examiner. Then explain why you came to that conclusion. It helps to cite clause numbers (from the Code of Ethics or regulations) for the ethics questions, just as you would cite past cases (or precedents) for the law questions. Do not copy clauses from the Code of Ethics; identify them by number, if possible. It is also important to write neatly and legibly. The examiners greatly appreciate this courtesy.

An Important Hint

An examiner who sets an essay-type PPE says that candidates using the EGAD! method spend too much time on the EGA steps (Ethical Issues, Generation of Alternatives, and Analysis) and not enough time on step D (explaining the Decision). These short or incomplete answers get lower grades. The EGAD! process helps you to think about the problem in an orderly way, but do not write out all of the steps—your grade depends only on your decision (Step 5), so explain it thoroughly.[12]

16.6 EXAMINATION QUESTIONS

This section contains almost 30 solved examination questions selected from the Ethics portion of previous PPEs in several provinces.* The questions illustrate three formats: essay-type, short-answer, and multiple-choice. (Note: Saskatchewan also includes True/False questions.) For practice, readers should try to answer all questions.

Essay-Type Exam Questions

Remember to read the instructions on your exam paper! Examiners typically allow 20 to 25 minutes to answer an essay-type ethics question, but exam rules may change at short notice. Chapters 10, 11, and 12 contain 18 (solved) ethics cases; Web Appendix E contains over 50 ethics questions (many with answers); and Web Appendix F contains 25 (solved) ethics cases. These cases are an excellent preparation for an essay-type PPE.

1—DISCLOSING SENSOR PATENT DATA

You are a professional engineer employed full time by Autto Tech, a company that manufactures sophisticated electronic products primarily for the automobile industry. You are presently developing motion sensors for automotive

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* The essay-type and short-answer examination questions are adapted from Professional Practice Exams administered by Professional Engineers Ontario (PEO). The authors would like to express their appreciation to PEO for assistance in obtaining these questions and permission to publish them.

safety, such as anti-collision sensing and deployment of airbags. The devices are new and inventive, so Autto Tech is applying for patents.

Recently, a friend and former classmate from engineering school contacted you. Your friend owns and operates a small company called Backswing that sells a range of golf practice aids to help serious golfers improve their golf swing. Backswing needs professional help but is not busy enough to hire a full-time engineer. Your friend offers to hire you as a part-time employee, in your spare time. You like golf, and this is an opportunity for interesting work and more income. You accept your friend's offer and begin to work weekends at Backswing.

Shortly after you start your part-time job, your friend describes a novel device that Backswing is developing to help golfers improve the speed, rhythm, and consistency of their golf swings. Unfortunately, the prototype has technical problems and does not work reliably. You immediately realize that the Backswing device would work perfectly if it were combined with the advanced motion sensor technology being patented by Autto Tech. The improved Backswing design would be worth a lot of money.

QUESTIONS *Discuss the ethical and legal aspects of working for both companies. What actions should you have taken to satisfy your provincial Act and Code of Ethics before you accepted your friend's offer of a part-time job? Can you ethically and legally use Autto Tech's motion sensor technology in Backswing's golf device? Explain the reasons for your answers.*

SUGGESTED ANSWER This question is very relevant, because similar cases occur often. Depending on your actions, the outcome could be immense success or disaster.

The first concern is that part-time professional work (also called "moonlighting") creates a conflict of interest, even if you work in your spare time. The conflict may be real or perceived (as described in Chapter 10), but the only way to avoid this conflict is to reveal it to those affected. Before accepting the job, you must define the proposed arrangement to both companies and ensure that they approve (especially since confidential information may be involved).

Furthermore, although you are a licensed professional engineer, you may need additional licensing or liability insurance in a few provinces. For example, to offer professional engineering services directly to the public in Ontario (even on a part-time or volunteer basis), you must obtain a Certificate of Authorization to ensure that you have adequate experience and liability insurance.

Most importantly, your plan to use Autto Tech's motion sensor technology in Backswing's golf device raises serious patent and confidentiality questions. As an Autto Tech employee, you almost certainly signed a confidentiality agreement that prohibits you from disclosing any details of their devices. If you discuss these devices with Backswing without permission to do so, you will violate your confidentiality agreement. Improper disclosure could interfere with Autto Tech's patent process (as explained in Chapter 7) or with their marketing plans, thus exposing you to serious legal liability.

Conversely, if Autto Tech approves your part-time work and you explain that you have discovered an unexpected application of their motion sensor technology, they may permit you to disclose information to Backswing, and you may have opened up a new and profitable business.

In summary, the key to success lies in disclosing your conflict of interest, following the professional Act and the patent laws, and maintaining strict confidentiality until you receive approval for disclosure.

2—UNAUTHORIZED USE OF SOFTWARE

Epsilon and her husband Delta are both recently licensed professional engineers, employed by medium-sized software development companies. They met in university, as students in software engineering. Epsilon was hired by Softdisk Ltd. when she graduated, and she was promoted to Software Project Manager when she obtained her P.Eng. licence.

Epsilon's promotion included a salary raise, but it also increased her responsibilities and workload. In fact, Epsilon is currently working furiously to meet a deadline for design of a digital control project. The software will soon start a final test before being released. Unfortunately, the simulation program that she is using to test the proposed design is slow and outdated. Epsilon is afraid that she will not meet the deadline and does not want to admit defeat by informing her boss. To add to her stress, she and her husband are parents of a two-year-old, and they recently purchased a new house.

Epsilon's husband, Delta, also a professional engineer, has access to powerful, valuable design software through his employer, HardDisk Inc. Epsilon believes that she could easily meet her deadline using the HardDisk software. She asks Delta to help her get access to it. Delta wants to help his wife. He could easily get access to the HardDisk passwords and online manuals. He doubts that HardDisk would know if she used their software.

QUESTIONS *Discuss the ethical and legal issues that Delta and Epsilon are facing. In particular, is it ethical for Delta to arrange secret, unauthorized access to HardDisk's software so that Epsilon can test her digital control project? What problems could arise from this proposal? What other way could Epsilon and her husband, Delta, solve this dilemma? How should Delta and Epsilon avoid this type of situation in future?*

SUGGESTED ANSWER Family members help each other, but this is not the way to do it. The pressures on Epsilon are clouding her judgment. Her request exposes both her husband and herself to serious penalties—far more serious than a missed deadline.

The secret, unauthorized use of the HardDisk software, if discovered, is a serious violation of every Code of Ethics. The Code requires employees to act faithfully for their employers and to maintain confidentiality (or similar wording, depending on the Code). A professional who thwarts security codes to run proprietary software has no defence against disciplinary action.

HardDisk would likely insist on some disciplinary action if this basic abuse of trust is discovered. Discipline would not just embarrass them—it could limit both their careers. Potential discipline could range from demotion, to dismissal, to charges under the Act, or to criminal charges for theft of electronic services.

The proper way to resolve this crisis is for Epsilon to ask her boss for an extension to the deadline. Doing this may be embarrassing but not as embarrassing as disciplinary action. Another obvious solution is for Softdisk Ltd. to lease or purchase the needed software. If Epsilon needs the software in her work, it is reasonable to ask her boss to provide it. Another approach is for Delta to ask HardDisk openly to use the software. HardDisk might be agreeable to lending or leasing the software directly.

Epsilon must take the initiative to remedy this situation. To prevent it from recurring, she may need better software support, better family support, or better scheduling plans. Most importantly, she needs clearer communication with her boss to set realistic goals and to feel free to communicate problems concerning her work and deadlines.

3—COMPETING WITH AN EMPLOYER

Professional Engineer A takes a job with a manufacturing company. A few months later, the company assigns him to prepare a bid to manufacture replacement turbine runners for a power corporation. While preparing the bid for the manufacturing company, Engineer A, as president and shareholder of his own company, which he runs privately from his home, writes a letter to the power corporation asking to submit a tender on the same project. A few days later, and while continuing to work on the bid for the manufacturing company, he receives an email from the power corporation confirming that a bid from his own private company would be considered. The day after learning this, he resigns from his position with the manufacturing company and submits a bid on behalf of his own company.

QUESTION *Discuss Engineer A's actions from an ethical point of view.*

SUGGESTED ANSWER Engineer A is clearly unethical in his actions. By running a private company in competition with his employer, he is not being fair or loyal to his employer as required by the Code of Ethics. He has taken advantage of inside information, betrayed the trust of his employer, and yielded to a conflict of interest. His private company was apparently unknown to his employer, and failure to disclose his conflict of interest is a violation of the Code of Ethics. It is not relevant to say that he resigned before signing the contract (and therefore did not compete directly with his employer) because the serious conflict of interest occurred during the bid preparation stage. Engineer A has exposed himself to serious disciplinary action for conflict of interest under the provincial or territorial Act. (Chapter 10 gives an overview of conflict of interest.)

4—FORMING A PRINTING COMPANY

You are a professional engineer with XYZ Consulting Engineers. You have become aware that your firm subcontracts a lot of printing and publishing of reports, including artwork and editing. Your wife has some training in publishing, and now that your children are at school, she would like to go back into business. You decide to form a publishing company together with your neighbours, another couple. Your wife will be the president, using her maiden name, and you and your neighbours will be directors.

Since you see opportunities for subcontract work from your company, you believe that there must be similar opportunities to get printing contracts from other consulting firms. You know the existing competitors in this business and the rates they charge for services. You think that this could be a profitable business for your wife.

QUESTION *Can you do this ethically, and if so, what steps must you take?*

SUGGESTED ANSWER You can do this ethically, but like part-time, or moonlighting, activity, it has a potential for conflict of interest. The conflict arises because your activities as a director may conflict with your full-time employment. For example, your wife may want to negotiate printing contracts with your employer. Therefore, as required by the Code of Ethics, you must inform your employer of your conflict of interest.

Your wife, of course, is free to use any legal name in her business; however, if the sole reason for using her maiden name is to conceal your participation, then this is inconsistent with full disclosure. You should explain the reason for this secrecy.

Moreover, other clients may worry about a possible loss of confidentiality. A publishing company often receives confidential reports and must not reveal the contents of those reports to others. Therefore, your wife must somehow guarantee confidentiality. Any sensitive technical or financial information sent to her by other clients must be kept secret—even from you. If you cannot ensure confidentiality, the company may appear unreliable and prove unprofitable.

5—CHEMICAL POLLUTION

Patricia Gamma, a professional engineer, is assistant manager of a chemical plant in a northern Canadian town. One of her responsibilities is to test and monitor the chemicals discharged in the effluent. She observes that inorganic chemicals in the effluent are consistently near the upper limit allowed under provincial regulations. It is okay for daily concentrations to exceed certain levels as long as the monthly average is within the limit.

However, her monitoring shows that if daily discharge levels continue for a few more days, the monthly average will exceed the allowable concentrations, and the plant will no longer be compliant with the regulation. Noncompliance is very serious and must be reported directly to the ministry. She informs her boss, the plant manager (who is not an engineer), about the trend.

The manager says that the problem is the result of low rainfall and the aging processing plant. He says that if the weather changes, the problem will be temporary, and suggests that, to keep the average low, she should "just fudge the numbers for a few days, and next month it will probably average out."

The manager points out that solving the problem requires repairs that would cost the company well over $500,000. And, if Gamma contacts the ministry and reveals the problem, there will be a lot of unfavourable publicity for the plant. The publicity will hurt the lakeside town's resort business and may scare the community. He says that, if she keeps quiet, "No one will discover the problem. It poses no danger to people. At worst, it will kill a few fish."

QUESTIONS *What should Gamma do if the trend continues and the monthly concentrations exceed the ministry regulation? Should Gamma "fudge the numbers" as her boss suggests, or should she report the problem, despite the cost to her company and possibly to her personally? Discuss the ethical considerations affecting her decision.*

SUGGESTED ANSWER Gamma must, legally and ethically, report the pollution levels accurately. She is obliged under the Code of Ethics to consider the public welfare as paramount. If the legal limit for pollution is exceeded and she "fudges" the data, she would be guilty of professional misconduct under the Act.

Gamma must follow the ministry's regulations and report the excessive levels directly to the ministry. Before sending her report, she should discuss it fully with her boss. If the boss reacts adversely, Gamma must explain that the report is required by law and by the Code of Ethics. Employers cannot direct an employee to break the law (as discussed in Chapter 10).

If the employer attempts to dismiss her, Gamma should ask the provincial Association to mediate and should inform her employer of the requirements under the Act. If Gamma is dismissed while acting in good faith, she would have grounds for a suit against the employer for wrongful dismissal. In that event, she should consult a lawyer. (Chapter 13 discusses similar cases under "whistle-blowing.")

6—INVOICE ERRORS

You are a professional engineer employed by a consulting engineering firm. Your boss, who is also a professional engineer, is the project manager. You examine a recent invoice that your boss sent to the client for work done by you and members of your staff. You are surprised to see how much of your time and your staff's time has been charged to the job. You check further by reviewing the time sheets, which show that time that should be charged to other clients has been deliberately transferred to this job. You try to raise the subject with your boss but are rebuffed. You are quite sure something is wrong, but you are not sure where to turn.

QUESTIONS *Explain why this is your responsibility. Which articles in the Code of Ethics are relevant to this situation? What action should you take?*

SUGGESTED ANSWER The first step in solving any problem (as discussed in Chapter 9) is to get all the information. If your boss cannot (or will not) answer your questions, you have an ethical dilemma. The Code of Ethics says that you must be loyal to the employer, but the Code also states that you must be fair and loyal to the client. Moreover, you must avoid any involvement in illegal activities.

You could solve the dilemma in two steps. First, you must ask your boss, again, for an explanation or justification for this transfer. (For example, it may be a simple accounting error.) As a professional engineer, your boss is subject to the Code of Ethics and has a duty to you as an employee. If your boss is completely unwilling to explain the reasons for this action, then the overbilling may be fraud or theft, which are both illegal. If you ignore the discrepancy, you may be implicated in your boss's apparently unprofessional conduct. In this case, your responsibility to the client outweighs the duty to the employer. Second, you must try to resolve the discrepancy internally by going higher and asking your boss's boss to clarify the discrepancy and assure you that the errors are not criminal activity. Unless the problem can be corrected (and the client reimbursed), you will likely have to inform the client who is being overcharged.

7—CHEMICAL SPILL CLEANUP

A consulting engineering firm is preparing to submit a proposal to clean up an area contaminated by a chemical spill during a train derailment. From past experience, the engineers and geoscientists in the firm know the amount of work involved in doing the job properly. The experts will include people with training in ecology, water quality, groundwater, soils, air pollution, and other areas. The methodology that they believe is essential will cost about $5 million. Before their proposal is submitted, however, the federal government, which is the potential client, issues a news release saying that it has budgeted only $1 million for this work.

QUESTION *What can the consulting firm do? To reduce the level of work to one-fifth of what it thinks is necessary would infringe on the firm's perceived ethical responsibilities to the environment.*

SUGGESTED ANSWER It is unethical for the consulting firm to do a substandard or inadequate job within the $1 million limit simply to get the work. This behaviour contravenes every Code of Ethics (either directly or indirectly), which states that the professional engineer must act competently in providing engineering services. Moreover, most Codes of Ethics require the professional engineer to uphold the principle of adequate compensation for engineering work. It is therefore unethical (and obviously unreasonable) for the consulting firm to submit a bid to perform a $5 million job for $1 million.

However, what should the consulting firm do? Every Code of Ethics requires a professional engineer to explain the consequences when non-technical authority overrules engineering judgment (as explained in Chapter 10). Perhaps the financial officials who set the budget are not fully aware of the required engineering work. This fact must be communicated to the federal department that issued the call for tenders, with a request to correct its specifications. If the problem cannot be resolved by simple communication, the consulting firm must evaluate the seriousness of the matter. (To do so requires details not provided in the question.) For example, if an inadequate job will endanger the public, the consulting firm has an obligation to put the public interest first by publicizing the issue. Furthermore, if the consulting firm submits a proper ($5 million) bid, and a competing firm obtains the job for less and thereby creates a dangerous situation, the consulting firm has an obligation to expose unprofessional or unethical conduct.

8—ROAD DEFICIENCIES

Engineer A enters into a consulting contract with a client to provide design and construction supervision of road surfaces in a partially completed residential land development project. He took over from another consultant, who was discharged partway through the job. Before Engineer A can finish the project, however, his contract also is abruptly terminated. Shortly thereafter, it becomes obvious that there are deficiencies in the work done under engineer A's supervision. Investigation shows that hastily paved road surfaces, completed under adverse late-fall weather conditions, are not up to specifications. It seems that Engineer A is aware of this. He intended to require remedial work by the contractor in the spring, but his termination occurred before that time. Engineer A has a partial list of deficiencies, and he intended to re-inspect the roads in the spring;however, he believes that he was unfairly fired and feels that he has no incentive to contact the client and pass on this information.

QUESTION *Did Engineer A act ethically in his dealings with his client, even though he may feel that he was unfairly terminated? Discuss the articles of the Code of Ethics relevant to this case.*

SUGGESTED ANSWER Engineer A, as a professional, is required to act as a faithful agent for the client in spite of other problems that might interfere. Therefore, even if Engineer A felt that he was unfairly terminated, it would be unethical for him to neglect his responsibilities, such as listing the deficiencies (known only to him) so that the road work could continue. This is especially important if the deficiencies might lead to endangering other workers or the general public. The Code of Ethics requires the professional to put public safety first. Finally, it is advisable to follow the Code of Ethics judiciously when you have an unreasonable and demanding client. If the contract ends disastrously, you want it to be obvious that the fault lies with the unreasonable client and not with a negligent professional.

9—CONTRACT CONTINGENT ON BOND ISSUE

A small town wants to construct a new water supply system and contacts a licensed professional engineer/geoscientist who operates a consulting firm in a nearby city. The town proposes a two-phase project. Phase 1 involves preliminary design, field tests, review of alternative sites, and cost estimates, which the professional will summarize in a Phase 1 report. In Phase 2, the professional will prepare final design drawings, issue tenders, and supervise the construction. The town will pay for the new water supply system by a bond issue.

However, the town's bylaws prohibit committing funds for the preliminary (Phase 1) work until the bond issue is approved by a vote of the town council. Approval is not certain, as some councillors may object, depending on the cost. Therefore, the contract provides that if the vote on the bond issue passes, the engineer/geoscientist will be paid for Phase 1 and will be retained to carry out Phase 2 as well, without competition. If the bond issue fails, however, the town will not be obliged to pay for the work and report in Phase 1.

QUESTION *May a professional engineer or geoscientist ethically accept a contract under these conditions? Discuss.*

SUGGESTED ANSWER At first glance, this may appear to be a simple way for a small town to control costs;however, the project is structured to create a massive conflict of interest for the professional. Obviously, if payment for Phase 1 is at risk, the engineer/geoscientist would be tempted to "cut corners" to keep costs low. The water supply is an especially sensitive system to put at risk by such cost-cutting.

Such a proposal is also contrary to the Code of Ethics, which requires professionals to uphold the principle of adequate compensation for their work. The proposed contract creates a double-or-nothing approach in which the engineer/geoscientist would get nothing if the bond issue fails, but would get a double reward (Phases 1 and 2) if it passes. This situation is unprofessional.

The proper way to organize this project is to make each phase a separate contract. The first contract would be for Phase 1 (preliminary work, as listed above). The professional should be paid for this work, regardless of the success of the bond issue. The Phase 2 contract—to prepare plans and specifications and supervise the construction—would be arranged only if the bond issue passed. Moreover, the contract should be offered for open tender, so that all qualified professionals could bid on it, following standard contract procedures.

10—DEFICIENCIES IN BUILDING DESIGN

Engineer X, a civil engineer and an employee of ABC Consultants Ltd., is designated on the company's Certificate of Authorization (also called a "Permit to Practise") as the engineer responsible for ensuring that the company follows the engineering Act and regulations.

ABC Consultants Ltd. prepared the electrical and mechanical designs for a multi-storey building. Although Engineer X had very little to do with this project, he permitted his seal to be applied to the design drawings. These design drawings were later found to be deficient in several respects. Contrary to the Building Code, firewalls were omitted, fire dampers were not shown, and sprinklers were improperly connected, among other things. On investigation, it was found that other professional engineers working for ABC did both the electrical and mechanical designs and that Engineer X merely stamped the drawings.

QUESTION *What is Engineer X's ethical position in this matter?*

SUGGESTED ANSWER As explained in the Act, corporations that practise engineering must identify the individuals who personally supervise the work performed by the corporation. These people are required to be experienced engineers, and their names are designated on the corporation's Certificate of Authorization (C of A, or Permit to Practise). Since Engineer X was designated on the C of A and permitted his seal to be applied to the design drawings, he is responsible for the work. Clearly, Engineer X has been negligent in permitting deficient or unsafe work to be carried out and has failed to supervise the work properly. Engineer X will likely be subject to disciplinary action for negligence (as explained in Chapter 3). Designation on a C of A is not a meaningless title. The other ABC engineers, the ones who designed the deficient electrical and mechanical work, are likely also subject to disciplinary action—for incompetence. Although they were under the supervision of Engineer X, they must produce competent work.

Short-Answer Exam Questions

The Ontario (engineering) PPE often includes a few short-answer questions in the Ethics part, similar to the following:

QUESTION 1 *What is the purpose of the professional seal on a document, and when should you use it? What two elements must you add to the seal?*

ANSWER The professional seal (or stamp) indicates that the document was created under the supervision and control of a licensed and qualified professional (or was thoroughly reviewed by that professional) and that the professional accepts responsibility for its content. You should apply your seal (or stamp) only to final documents; do not apply your seal to non-technical documents (such as contracts). When you seal a document, you must also sign your name and write the date next to the seal. (See Chapter 4.)

QUESTION 2 *Under the Professional Engineering (and/or Geoscience) Act, every Association has responsibility for discipline and enforcement. Explain what enforcement is and how it differs from discipline. Give an example of each.*

ANSWER Enforcement and discipline protect the public in different ways. *Enforcement* prevents unlicensed people from illegally practising engineering or geoscience. For example, your Association enforces the Act by prosecuting unlicensed practitioners in the provincial courts if they practise illegally. Upon conviction, the court has the power to apply penalties. Conversely, *discipline* applies to licensed members who practise negligently or incompetently. For example, a complaint against a licensed member for designing an unsafe bridge will lead to an investigation. A disciplinary hearing by the Association may follow. If the member is found guilty of misconduct (e.g., negligence or incompetence), the Discipline Committee has the power to apply penalties. (See Chapter 3.)

QUESTION 3 *How is the Complaints Committee (also called the "Investigative Committee" in some Acts) different from the Discipline Committee?*

ANSWER The Association must investigate every complaint against a licensed professional. The committee that reviews and evaluates every signed complaint is called the "Complaints Committee" (or the "Investigative Committee," in some Acts). If a complaint cannot be resolved (through various methods, ranging from dismissal of frivolous complaints to voluntary acceptance of guilt), then the complaint is referred to the Discipline Committee as an allegation of professional misconduct. The Discipline Committee conducts a formal hearing, renders a judgment, and has the power to apply penalties if the professional is found guilty. Note that no person may serve on the Discipline Committee if he or she was involved in any earlier stage of the investigation. (See Chapter 3.)

QUESTION 4 *Professional engineering and professional geoscience are "self-regulating professions." What does "self-regulating" mean? In your answer, describe briefly three features (or benefits) of a typical "self-regulating" profession.*

ANSWER Engineering and geoscience are called "self-regulating" professions because, under each Act, the licensed members elect (most of) the Association's governing council. This practice ensures that well-informed members with democratic support establish and enforce the professional rules (for standards of practice, Codes of Ethics, discipline procedures, protection of public safety and the environment). The public also benefits because the Associations run without government funding. Licensing fees pay administrative staff, and licensed members serve voluntarily on the admission, discipline, and other committees.

QUESTION 5 *Several provinces and territories require engineers and geoscientists who offer services to the public to hold a "Certificate of Authorization" (also called a "Permit to Practise"), as well as the P.Eng. or P.Geo. licence. What is a "Certificate of Authorization" and what does "public" mean in this context?*

ANSWER A "Certificate of Authorization" (or "Permit to Practise") identifies, unambiguously, the person in the corporation who has the technical authority. In other words, the certificate identifies the person who provides the services and takes responsibility for errors and omissions. The certificate holder usually must have specified experience (usually five years) and liability insurance. A few Associations (such as PEO in Ontario) require all professional engineers who offer services "to the public" to have a Certificate of Authorization. The definition of "public" is very broad (in Ontario); if you "hang out your shingle," you are offering services to the public and require a certificate. Even if you offer your services to the public only on a part-time, moonlighting, or volunteer basis, you must have a certificate in Ontario. (See Chapter 2.)

QUESTION 6 Name the various licences (typically four) that your Association issues. What are their limitations?

ANSWER ONTARIO Engineering (PEO):

- **Professional Engineer** (no limitations);
- **Temporary Licensee** (issued to non-residents of Ontario for a stated project; for a maximum of 12 months; a Certificate of Authorization may be required);
- **Limited Licensee** (for technologist or scientist with many years of specialized experience; licence is limited to specific functions, products, or applications);
- **Provisional Licensee** (licence complete, except 12 months' Canadian experience).

ANSWER ONTARIO Geoscience (APGO): Practising Member, Temporary Member, Limited Member, Non-practising Member.

ANSWER ALBERTA (APEGA): Professional Engineer or Professional Geoscientist; Professional Licensee (limited licence); Foreign Licensee (non-resident, non-Canadian); Provisional Licensee.

QUESTION 7 *Provide a definition of "ethics."*

ANSWER Ethics is the study of right and wrong, good and evil, obligations and rights, justice, and social and political ideals. (See Chapter 9.)

QUESTION 8 *In a few sentences, describe what a profession is.*

ANSWER A profession is an occupation that requires specialized knowledge and skills obtained by intensive learning and practice, and that is organized or regulated to ensure that its practitioners apply high standards of performance and conduct, commit themselves to continuing competence, and place the public good ahead of narrow personal interests. (See Chapter 1.)

QUESTION 9 *Is your province's Code of Ethics for engineers or for geoscientists enforceable under your professional engineering or geoscience Act? Explain.*

ANSWER Every province and territory (except Ontario for engineers) states or implies that the Code of Ethics is enforced by the Act, and violations of the Code may result in disciplinary action. In Ontario (engineering), the Code is not enforceable, and a separate clause in the Act defines professional misconduct. (See Chapter 9.)

QUESTION 10 *Explain what "conflict of interest" means.*

ANSWER Briefly, a conflict of interest (also called a "secret commission") occurs when a professional receives a benefit (or has a relationship) that is unknown to a client, or that interferes with the duty to the client. For example, a conflict of interest exists when a professional hired by a client to supervise a contract also receives a secret kickback (or fee) from the supplier. Concealing a conflict of interest is unethical. (See Chapter 10.)

QUESTION 11 *Does your province's professional engineering or geoscience Act explicitly restrict a professional to practise in his or her branch of registration only? How does the Code of Ethics deal with the problem of practising outside of one's branch of registration?*

ANSWER Although a few specialties are regulated in some provinces (especially the SER—the Structural Engineer of Record), professional practice is not generally limited to the branch of registration. However, every Code of Ethics forbids practitioners from accepting or performing work for which they are not qualified. Therefore, practitioners must obtain appropriate preparation—such as academic studies, on-the-job experience, and assisted practice—to develop adequate skill and knowledge in the new area. The question of competence is left to the judgment of the practitioner. In the event of a complaint, the practitioner would be expected to demonstrate evidence of adequate preparation in the new area. Failure to show adequate preparation would be a basis for disciplinary action, as either negligence or incompetence. (See Chapter 17 on maintaining competence.)

QUESTION 12 *Your Association of Professional Engineers and/or Geoscientists is the self-regulating organization responsible for the practice of engineering and/or geoscience in your province. What is the principal objective of this organization?*

ANSWER The principal objective of every Association is to protect the public interest by regulating the profession. This is usually stated or implied near the start of the licensing Act.

QUESTION 13 *To obtain a licence to practise professional engineering or geoscience, you must meet certain requirements. Discuss briefly the four most significant of these.*

ANSWER Since age is almost never a problem, the four most important requirements are these:

1. adequate education—an accredited university degree (or equivalent);
2. examinations—typically the Professional Practice Exam;
3. adequate experience—typically four years; and
4. good character, as determined from references.

Note that citizenship (or permanent residence) is no longer required. A non-resident who is not a Canadian citizen may apply for a Temporary Licence (also called a "Foreign Licence" in some provinces—see Chapter 2).

QUESTION 14 *What are the restrictions on advertising professional services?*

ANSWER Advertising must be factual, clear, and dignified. (See Chapter 12.)

QUESTION 15 *Is a civil engineer allowed to perform services that are normally within the scope of mechanical engineering? Explain.*

ANSWER Yes, providing that the civil engineer can show experience, education, or training in the area of mechanical engineering. (See discussion of competence in Chapter 17.)

Multiple-Choice Exam Questions

The National Professional Practice Examination, set by Alberta (APEGA) and administered by 12 Associations across Canada, uses the multiple-choice format shown below.*

QUESTION 1 *According to most Provincial and Territorial Acts, which activity by a professional member would be considered UNETHICAL?*

A. Not charging a fee for presenting a speech.
B. Signing plans prepared by an unknown person.
C. Reviewing the work of another member with that member's consent.
D. Providing professional services as a consultant.

ANSWER B is correct. It is unethical for professionals to sign plans not prepared by themselves or under their direct supervision.

* The multiple-choice examination questions are sample questions for the National Professional Practice Exam administered by the Association of Professional Engineers and Geoscientists of Alberta (APEGA), Edmonton, AB. The authors would like to express their appreciation to APEGA for permission to publish them.

QUESTION 2 *Which of the following is an example of a fraudulent contractual misrepresentation?*

A. A party is coerced into signing a contract by means of intimidation.
B. A party knowingly makes false statements to induce another party into a contract.
C. A party induces his son-in-law to sign an unfair contract.
D. A party unknowingly provides false information about a portion of a contract.

ANSWER B is correct. Knowingly providing false information to induce a contract is fraudulent misrepresentation.

QUESTION 3 *Contractual disputes of a technical nature may be most expeditiously and effectively solved through*

A. a lawsuit.
B. court appeals.
C. contract renegotiations.
D. arbitration.

ANSWER D is correct. Arbitration provides an effective, expeditious resolution to technical disputes.

QUESTION 4 *Which type of original work below is automatically protected by copyright upon creation?*

A. Paintings.
B. Inventions.
C. Clothing designs.
D. Signatures.

ANSWER A is correct. Of the works listed, only a painting is protected by copyright law.

QUESTION 5 *In order for compensation to be awarded to a plaintiff in a tort liability case, the defendant must have*

A. caused injury to the plaintiff.
B. been wilfully negligent.
C. signed a contract of performance.
D. performed under supervision.

ANSWER A is correct. Injury (including financial loss) is one of three criteria that must be met for compensation to be awarded in a tort liability case.

QUESTION 6 *Which of the following is the most common job activity of top-level managers?*

A. Writing and reading corporate financial reports.
B. Developing and testing new products.
C. Designing and implementing production systems.
D. Directing and interacting with people.

ANSWER D is correct. Most top managers spend most of their time interacting with other people.

QUESTION 7 *The professional's standard of care and skill establishes the point at which a professional*

A. may or may not charge a fee for services.
B. has the duty to apply "reasonable care."
C. may be judged negligent in the performance of services.
D. has met the minimum requirements for registration.

ANSWER C is correct. The standard of care is used to judge whether or not a professional has been negligent in the performance of services.

QUESTION 8 *To effectively reduce liability exposure, the professional engineer, geoscientist, geologist, or geophysicist should*

A. pursue continuing educational opportunities.
B. work under the supervision of a senior engineer, geologist, or geophysicist.
C. maintain professional standards in practice.
D. provide clients with frequent progress reports.

ANSWER C is correct. Maintaining professional standards of practice is the most effective way of reducing liability exposure.

Additional Questions

Additional solved case studies are presented in Chapters 10, 11, and 12. Twenty-five solved cases are provided in Web Appendix F. Additional exam questions are found in Web Appendix E-5.

NOTES

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[10] Engineers Canada, *National Guideline on the Professional Practice Examination,* Appendix B.
[11] John Delaney, *How to Do Your Best on Law School Exams* (Bogota, NJ: John Delaney Publications, 1990).
[12] Gordon C. Andrews, *Study Guide for the PEO Professional Practice Exam,* 6th ed. (Waterloo, ON: Distance Education Department, University of Waterloo, 2004). [Out of print]

Chapter 17
Maintaining Your Professional Competence

How can you keep up with all the new techniques, theories, hardware, and software that bombard you daily? Associations urge professionals to take control of their careers and maintain their skills through continuing professional development (CPD). They also ask members to report their CPD activities annually. This chapter explains typical CPD program requirements. For most practising professionals, maintaining competence is surprisingly easy, and it may be a key step in achieving your career goals.

17.1 YOUR CAREER PATH: SUCCESS OR OBSOLESCENCE?

Your university degree is like a valuable radioactive mineral that decays over time. In previous decades, the half-life of a bachelor's degree was about 10 years, but today it is much shorter, especially in high-tech disciplines. Even if you were at the top of your graduating class, your knowledge and skills will eventually be out-of-date without renewal. The good news is that maintaining your competence has real benefits.

- **Personal benefits:** When it is time for promotions, pay raises, new job challenges, or new clients, a good CPD record can effectively move your career forward. Continuing professional development expands your skills and capabilities; increases your value to employers or clients; improves your professional image; increases your marketability to other employers; and permits free mobility to other provinces (most of which have CPD requirements).
- **Professional benefits:** CPD requirements keep professionals up-to-date, protect the public, and raise the image and esteem of the profession.
- **Following the Code of Ethics:** Every professional has a duty to maintain competence throughout his or her career. This duty holds true from coast to coast. Each licensing Act contains a clause (usually in the Code of Ethics) requiring competence. For example, the Engineers Canada Code of Ethics (a national model code) states this quite clearly: professional engineers shall "keep themselves informed in order to maintain their

competence, strive to advance the body of knowledge within which they practise and provide opportunities for the professional development of their subordinates."*

Geoscientists Canada does not sponsor a model Code of Ethics, but the provincial geoscience Codes of Ethics show remarkable agreement. For example, Geoscientists Nova Scotia has an almost identical clause: ". . . Professional Geoscientists shall keep themselves informed in order to maintain their level of competence, strive to advance the body of knowledge within which they practice, and provide opportunities for the professional development of their subordinates."†

- **Maintaining your licence:** Finally, most Associations now have mandatory CPD programs (or are adopting them). This development gives a convincing reason to maintain your competence, because neglecting professional development (or failing to document it) can put your licence at risk.

As you advance in your career, you will want to work on more stimulating and more difficult projects. You must practise within your ability, and an unsuccessful project could be costly and damaging, so this creates a conflict: should you stay with older, established methods (and risk obsolescence) or try new ideas and techniques (and risk failure)? The Associations recommend that you avoid this dilemma entirely by maintaining your competence and expanding your horizons through continuing professional development.

17.2 COMPETENCE PROGRAM REQUIREMENTS

Before the Associations introduced continuing competence requirements, they examined other professions. Law, medicine, accounting, and architecture require continuing professional development. In fact, most professions across Canada have CPD policies, most licensing boards in the United States are introducing CPD requirements, and a similar trend is seen in Europe. In summary, continuing professional development is now commonly expected in the professions, both nationally and internationally.[1]

To encourage consistency, Engineers Canada published a guideline for maintaining competence.‡ Engineers Canada recommends four major requirements for a continuing competence program, as follows:

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* Engineers Canada, "Code of Ethics," *Guideline on the Code of Ethics* (Ottawa: Engineers Canada, 2012), 3, https://engineerscanada.ca/sites/default/files/guideline_code_with_1.pdf (accessed June 23, 2017).

† Geoscientists Nova Scotia, Code of Ethics, available at https://www.geoscientistsns.ca/index.php/for-members/governance/code-of-ethics (accessed June 23, 2017). Used with permission.

‡ Engineers Canada, *National Guideline on Continuing Professional Development and Continuing Competence for Professional Engineers,* October 2004, available at engineerscanada.ca/publications/national-guideline-on-continuing-professional-development-and-continuing-competence-for-engineers (accessed June 23, 2017).

- **Continuing professional development (CPD):** Associations should have a mandatory program of CPD activities, including activities such as professional practice, formal courses, informal study, and service to the profession and the community.
- **Compliance, reporting, and recording:** The Associations should make it easy to document one's CPD activities, preferably by online electronic reporting, and/or should ask licensed members to make an annual declaration that they have complied with the CPD requirements.
- **Practice review:** To ensure that the program is effective, Associations should audit the compliance declarations by selecting a small, random sample of members to undergo a practice review.
- **Practice guidelines and standards:** Associations should also help professionals by publishing practice guidelines and standards. Practice guidelines give useful general advice; standards give specific direction for typical procedures or problems.[2]

Engineers Canada recommends that continuing competence programs should be mandatory and that Associations should sanction members who are unwilling or unable to comply. All provincial and territorial Associations have adopted the *Guideline*, but they do not have identical rules for CPD requirements, reporting, or professional review. APEGA (Alberta) introduced its mandatory CPD plan in 1998 and was the first Association to respond fully to the Engineers Canada *Guideline*.

In fact, while many Associations follow the APEGA plan, CPD program requirements still vary widely. Most engineering and geoscience licensing bodies require full reporting, compliance, and possible practice review; about one-third have compulsory reporting, but no practice review; and a few programs are voluntary. Table 17.1 lists each Association's CPD guideline and website. Consult the website for your Association to see the CPD practices and procedures that apply to you. The Quebec (OIQ) CPD guide is part of OIQ's comprehensive 800-page manual of professional practice, currently available only in French.[3]

TABLE 17.1 — CPD Guidelines for Engineering and Geoscience Associations

ASSOCIATION	CONTINUING PROFESSIONAL DEVELOPMENT GUIDELINES
British Columbia (APEGBC)	***Continuing Professional Development,*** APEGBC Guideline, 2012, and ***Understanding the CPD Guideline***, APEGBC online video,https://www.apeg.bc.ca/Professional-Development/Professional-Development-Requirements
Alberta (APEGA)	***Continuing Professional Development Program***, APEGA Guideline, April 2014, www.apega.ca/assets/PDFs/cpd.pdf

Table 17.1 — (*continued*)

Saskatchewan (APEGS)	***Continuing Professional Development: Members' Guidelines***, APEGS Guideline, revised April 2017, https://www.apegs.ca/Portal/Pages/Continuing-Professional-Development
Manitoba (APEGM)	***Continuing Professional Development Program***, June 2016, APEGM Guideline, www.apegm.mb.ca/pdf/CPDProgram.pdf
Ontario (PEO)	***Voluntary Annual Reporting Form*** for CPD is online in the Members' Area of the PEO website, www.peo.on.ca. Login required.
Ontario (APGO)	***APGO's CPD Program Requirements***, APGO,https://www.apgo.net/about/professional-practice
Quebec (OIQ)	"Guide de développement des compétences de l'ingénieur," ***Guide de pratique professionnelle,*** OIQ, gpp.oiq.qc.ca
Quebec (OGQ)	"Professional Inspection," ***Professional Code***, Chapter C-26, Division VI, sections 109 to 115, ogq.qc.ca/en/about/committees/professional-inspection-committee
New Brunswick (APEGNB)	***Continued Competency Assurance Program***, APEGNB Guideline, May 2007, http://www.apegnb.com/en/home/memberbenefits/publications/continuedcompetency.aspx
Engineers Nova Scotia	***Policy for Continuing Professional Development***, Engineers Nova Scotia, November 2010, https://engineersnovascotia.ca/pd-program/
Geoscientists Nova Scotia	***Declaration of Professional Development***, APGNS form,www.geoscientistsns.ca
Engineers PEI	***Professional Development Manual for Compliance***, Engineers PEI, revised March 2007, www.engineerspei.com/node/35
Newfoundland and Labrador (PEGNL)	***PEGNL Professional Development Policy and Guideline***, PEGNL, January 2011, www.pegnl.ca/professionaldevelopment
Northwest Territories and Nunavut (NAPEG)	***Continuing Professional Development Program***, NAPEG, December 2016,www.napeg.nt.ca/professional-development. (Voluntary)
Yukon (APEY)	***APEY Continuing Professional Development Program***, APEY, December 2008, www.apey.yk.ca/continuing-professional-development-program.php (Voluntary; however, APEY levies a $50 charge on members who do not report CPD.)

Notes: Refer to your Association website for current CPD rules. Websites are valid as of June 23, 2017.

17.3 PROFESSIONAL DEVELOPMENT ACTIVITIES

There are many ways to maintain competence. Several Associations follow the Alberta (APEGA) format, which has six classifications as described below (but check with your Association in case the weighting is different).

Professional Practice

Your on-the-job engineering or geoscience experience, in progressively more challenging tasks, is important for maintaining competence. The Alberta Association (APEGA) allows one hour of professional development hour (PDH) credit for 15 hours of professional practice, to a maximum of 50 professional development hours per year.

Formal Activity

Some formal activity should be included in your program. Formal courses, workshops, and in-house instruction are excellent, particularly if permanent records show your grade or performance. CPD programs may be provided by a university, college, technical society, or an industry educational program (including video or interactive Internet courses). Alberta (APEGA) credits one PDH for each hour of course attendance to a maximum of 30 per year.

Informal or Self-Directed Activity

Informal activities may qualify if they expand your knowledge, skills, or judgment. Examples include self-directed study; attending conferences and industry trade shows, seminars, technical presentations, talks, and half-day workshops; attending meetings of technical, professional, or managerial societies; and structured technical or professional discussion with one's peers. Keep records of such study, attendance, or events. Alberta (APEGA) credits one PDH for each hour of informal activity, to a maximum of 30 per year.

Participation

Activities that promote interaction and/or promote discussion of new ideas or technology are beneficial to the profession and the public. For example, mentoring members-in-training; providing technical service to public bodies; serving on committees for technical, professional, or managerial societies; providing community service, such as an elected public service at any level; and engaging in active service for charitable, religious, or service organizations are valid participation. Alberta (APEGA) credits one PDH for each hour of participation, to a maximum of 20 per year. (Note: Some provinces do not accept community service, and in Alberta, only 10 PDHs may be community service).

Presentations

Technical or professional presentations at conferences, meetings, courses, workshops, or seminars are eligible for credit, whether in-house or sponsored by a technical or professional organization. (Presentations that are given several times count only once.) Alberta (APEGA) credits one PDH for each hour of preparation or delivery, to a maximum of 20 per year.

Contributions to Knowledge

Activities such as writing or co-authoring journal papers, patents, monographs, books, codes, standards, and so forth on engineering or geoscience topics expand the technical knowledge base of the professions. Alberta (APEGA) allows a maximum credit of 30 PDHs per year but gives different credit for each type of achievement, using the following classification:

- Developing codes and standards: One hour of committee work equals one PDH.
- Patent awarded or a paper in a peer-reviewed technical journal: 15 PDHs.
- One thesis at the master's or Ph.D. level (after defence and approval): 30 PDHs.
- Publication of a book: 60 PDHs, claimed over two years.
- Article in a non-reviewed journal or company report: 10 PDHs (max. 10 PDHs/year).
- Reviewing articles for publication: One hour equals one PDH (max. 10 PDHs/year).
- Editing papers for publication: One hour equals one PDH.[4]

17.4 REPORTING AND AUDITING

Reporting and Compliance

Members typically report their CPD activities annually when licences are renewed by simply adding a statement listing the activities completed during the previous year. This requires record-keeping, but in most provinces, members can report their CPD activities electronically on the Association website. In some provinces, members can simply state that they have complied with the CPD requirement and keep their records for possible future review.

Time Commitment

CPD requirements vary, so check your Association website (listed in Table 17.1). The unit of measure may be either the PDH or the continuing education unit (CEU). The CEU is used for formal courses, but the PDH is more useful for informal activities. The following conversion may help:

- The PDH is equal to 1 contact hour of learning.
- The CEU is equal to 10 contact hours of learning.

APEGA (Alberta) requires 240 PDHs over three years, with activities in three of the six categories (above) per year. This implies an average of 80 PDHs per year. APEGA reduces the requirements for special cases, and non-practising members are exempt from the CPD program.[5] As mentioned above, several Associations follow the Alberta program, but consult Table 17.1 for the link to the guideline or website for your CPD program.

Exemption, Deferment, and Reinstatement

Every provincial Association exempts exceptional cases. For example, retired or non-practising members are exempt from the CPD program if the member confirms that he or she is not practising. In addition, members on parental leave, studying full time, working outside of the province, employed part time, unemployed, or disabled may request exemption from CPD requirements (and possibly reduced annual dues), as appropriate. A written request for special consideration is necessary, and decisions depend on the circumstances. When the member returns to full-time professional practice, the full requirements again apply. Note: If a "non-practising" member wants to practise again, the Association must be contacted for permission do so; CPD activities (and possibly other evidence of competence) will be required.

Photo 17.1 — The CANDU Reactor. *The photo shows the operations control room for Reactor 1 at the Darlington Nuclear Generating Plant, about 70 km east of Toronto. Darlington has four CANDU reactors, with a total electric output of 3,524 megawatts, which satisfies about 20 percent of Ontario's electricity requirements. The CANDU (CANada Deuterium Uranium) nuclear reactor is impressive and is on Canada's "top ten" list of engineering design achievements. Darlington is the newest CANDU installation, but it has been supplying electrical energy dependably for 20 years. A virtual tour of the Darlington nuclear plant is available online at http://www.opg.com/generating-power/nuclear/stations/darlington-nuclear/Pages/darlington-nuclear.aspx (accessed July 10, 2017).*

Source: © David Cooper/Toronto Star/Getty

Practice Review

Engineers Canada recommends random checks to ensure that the CPD self-assessment is fair and honest. In most provinces, the Association selects a small sample of members each year and verifies that the records submitted are accurate and properly evaluated. (Of course, in a few provinces where CPD reporting is voluntary, checks are irrelevant.) This auditing process has generated some dissension, since it requires time and effort by the Association and by the licensed members. However, the time spent in practice review can usually be credited as PDHs for the next year.

17.5 TAKING CHARGE OF YOUR FUTURE

Engineers Canada urges readers to follow the guide provided by your licensing Association (see website in Table 17.1). In addition, Engineers Canada has published a helpful step-by-step Guide for preparing a personal CPD plan to achieve career goals.*

- **Creating a CPD program:** The personal Guide is an ambitious document, suitable for both engineers and geoscientists. It encourages you to achieve your career goals using the familiar feedback loop from control theory: define the desired state, measure the gap between the present state and the desired state, and act to reduce the gap.

  To help you through the maze, the personal Guide has several charts and worksheets (in French and English). These are particularly helpful in the early stages of the process to assess your current duties, competence, strengths, and needs. The Guide then helps you to set goals and to create your CPD program. The final step is to check whether you are achieving your goals and to revise your plan accordingly. The steps are summarized as follows:

  1. Define your scope of practice. (Where am I now?)
  2. Assess your competence, strengths, and learning needs.
  3. Set goals and objectives. (Where do I need or want to be?)
  4. Choose CPD activities to fill the gap.
  5. Document your CPD plan.
  6. Record and report your CPD activities.
  7. Update the CPD plan as time passes (back to step 1, 2, or 3).

- **CPD sources:** The best sources for CPD activities are usually nearby. These include your provincial Association, nearby colleges and universities, and the technical societies in your discipline. All of these organizations offer CPD activities, but technical societies may be the most important. As Chapter 18 explains, technical societies provide leading-edge conferences,

* Engineers Canada, *Step-by-Step Guide for the Preparation and Implementation of an Individual CPD Plan,* May 2008, available at engineerscanada.ca/publications/step-by-step-guide-for-the-preparation-and-implementation-of-an-individual-continuing (accessed June 23, 2017).

TABLE 17.2 — Suggested Skills for CPD

NON-TECHNICAL SKILLS	
Communication: written and oral	**Management:** recruiting, training, performance evaluation, human rights, motivational methods, mentoring, harassment issues, time management, workplace legislation, etc.
Interpersonal skills: cultural sensitivity, conflict management, working with subordinates, negotiation, delegation, decision making, etc.	**Lifelong learning:** self-assessment, career planning, self-development, second language, etc.
Project management: project manager's role, documents, scheduling, estimating, budgeting, quality assurance, contract administration, etc.	**Business:** business cases, e-business contract negotiation, financial accounting, risk analysis, corporate culture, law, etc.
Problem solving: problem definition, root cause analysis, factors, criteria, solutions, etc.	
TECHNICAL SKILLS	
Dangerous/hazardous materials management	**Codes and standards**
Environmental regulations	**Regulatory compliance**

Source: Engineers Canada, "Suggested Related Skills," App. C in Guideline on CPD (G05-2004), 43.

seminars, journals, codes, standards, and other useful information, and link you to professionals with interests similar to yours.

- **CPD topics:** Engineers Canada recommends the skills in Table 17.2 for CPD study.[6] However, any topic that advances your career or makes your professional life more effective is suitable.

17.6 POSTGRADUATE STUDIES

Completing a postgraduate degree is also a valid strategy for improving your competence, particularly if your goal is to be a specialist in engineering or geoscience. For example, it is generally easier to enter a specialty, such as biomedical engineering, through a master's program. The degree (or more accurately, what you learn while achieving the degree) may be vital for changing your career direction, and can be a useful (although perhaps costly) activity during an economic recession if you have the misfortune to be unemployed.

A common rule of thumb is that a postgraduate degree extends a professional career by at least 5 or 10 years over a bachelor's degree. However, advanced degrees can be expensive, even when taken part time. To avoid wasting valuable years, you must weigh the costs and benefits, define a clear goal, and commit to achieving it. A half-hearted attempt is risky. Before you make a commitment, decide: Will the effort pay off for you?

Your first steps should be to define your research interests, check out the researchers in that field, contact them, and decide for whom you would like to work, especially if the degree requires a thesis. Ask about research grants and assistantships. Finally, before you accept the challenge, evaluate carefully your enthusiasm for your study topic (or research project), the quality of the supervisor who will mentor you, and the computer and laboratory facilities that will be available to you.

17.7 CLOSING COMMENTS

Continuing competence programs have grown remarkably in the past decade, but not without some criticism and resistance. Many professionals support lifelong learning, but object to mandatory requirements. The key objections are the bureaucratic effort needed to run the CPD system (reporting, record-keeping, and verification by Associations and members); the lack of unanimity on what constitutes competence; and whether CPD efforts can truly measure competence, given the diversity of the engineering and geoscience disciplines. A very few even suggest that continuing professional development is unnecessary as our free enterprise system (or discipline hearings) will gradually eliminate those who do not keep up.

Notably, the largest Association, PEO (Ontario), has a voluntary annual CPD reporting program (as this book goes to press). However, the PEO Registrar observed that

> [w]hile professional discipline plays an important role in ensuring competence, it occurs after the fact. Career-long education, training and assessment of competence help to prevent professional misconduct before it occurs and contributes to safe professional practice. Sound professional practice also reduces complaints and the need for costly and time-consuming misconduct investigations and prosecutions.[7]

To counter objections to continuing competence programs, Associations must recognize CPD's many forms and give credit where it is due. The reporting and verification process must be simple and unobtrusive, and must recognize that some forms of achievement, experience, and education are difficult to document. In some cases, practical experience (even bad experience) may teach more than formal courses.

Provincial and territorial Associations should be encouraged to provide CPD activities. Since engineering and geoscience advocacy organizations are rare, the Associations are in a unique position to advertise CPD courses and activities, even though this task is at the limit of their regulatory duties. APEGA (Alberta) seems to have been successful in a proactive CPD role and has set the standard for other Associations to follow.

DISCUSSION TOPICS AND ASSIGNMENTS

1. Use the Internet to compare the CPD requirements for your province or territory with the rules for Alberta. (Alberta residents should substitute another province.) What similarities and differences do you observe? Which is more demanding?
2. Before Engineers Canada developed their model for continuing professional development, some Associations considered the proposal that professionals should write a formal examination every 5 to 10 years to maintain competence. Compare this formal examination proposal with the Engineers Canada CPD model, based on personal assessment. In your opinion, which is easier to administer, which is simpler for the Association member, and which is more likely to protect the public? In your answer, compare the personal self-assessment process in the Engineers Canada model with the well-known self-assessment process for income tax. Are they similar? Are they effective? Explain and summarize your answers on one page.
3. Under the Act, your Association must monitor professional competence to protect the public. However, as in all self-regulating professions, the Association's members must approve (by a vote) the monitoring process. Your opinion is therefore important. Discuss your Association's CPD or continuing competence program as published on their website (listed in Table 17.1). In your opinion, is the program marginal, adequate, or excessive? Include your responses to the following questions:
   a. Is continuing professional development the best indicator of competence? If not, what is better? Conversely, does the absence of CPD activity indicate incompetence?
   b. Should CPD reporting be mandatory? Reporting and auditing take time and effort, so when does the expense (to the professional and to the Associations) outweigh the benefit to the public?
   c. Should performance be self-assessed by the professional, or should employers and clients judge professional performance and report it to the Association? Conversely, should "free market" competition be encouraged, so that competent members will succeed, but incompetent members will fail and be eliminated? How should the Association detect alcoholism or laziness, which might be as harmful as incompetence?
   d. Should Associations revoke the licences of members who refuse to engage in (or refuse to document) CPD activity? Should random practice reviews be standard procedure?

   Summarize your response on one or two pages. Consider sending it to your Association if your response might improve their present procedures.

Additional assignments can be found in Web Appendix E.

NOTES

[1] PEO, "Continuing Professional Development Research," *Canadian Framework for Licensure,* http://www.peo.on.ca/index.php/ci_id/19389/la_id/1.htm (accessed June 23, 2017).

[2] Engineers Canada, *National Guideline on Continuing Professional Development and Continuing Competence for Professional Engineers* (Ottawa: Engineers Canada, 2004), engineerscanada.ca/publications/national-guideline-on-continuing-professional-development-and-continuing-competence-for-engineers (accessed June 23, 2017).

[3] Ordre des ingénieurs du Québec (OIQ), "Guide de développement des compétences de l'ingénieur," *Guide de pratique professionnelle*, gpp.oiq.qc.ca (accessed June 23, 2017).

[4] APEGA, *Continuing Professional Development Program*, Guideline, April 2014, 5–6,https://www.apega.ca/assets/PDFs/cpd.pdf (accessed June 23, 2017).

[5] Ibid.

[6] Engineers Canada, Appendix C, in *National Guideline on Continuing Professional Development and Continuing Competence for Professional Engineers* (Ottawa: Engineers Canada, 2004), engineerscanada.ca/publications/national-guideline-on-continuing-professional-development-and-continuing-competence-for-engineers (accessed June 23, 2017).

[7] Michael Mastromatteo, "Decision Time for PEO on Continuing Professional Development?" [PEO] *Engineering Dimensions*, March/April 2010, 25, www.peo.on.ca/index.php/ci_id/20788/la_id/1.htm (accessed June 23, 2017).

Chapter 18
Benefiting from Technical Societies

Technical societies are useful and important organizations for professionals. The societies provide a priceless store of well-organized information and link you to other professionals with similar technical interests. This chapter reviews the role of technical societies and explains why every professional engineer and geoscientist should join at least one technical society.

18.1 THE IMPORTANCE OF TECHNICAL SOCIETIES

For almost two centuries, technical societies have encouraged research, collected and classified new information, and disseminated it to members so that it could be put to use. Technical societies are the most important publishers of new research. They publish journals, conference proceedings, codes, and standards. The world's libraries are bulging with useful publications from these societies, and most of it is available on the Internet. The benefit from this free exchange of information is immense.

Technical societies are equivalent to the *learned societies* that stimulate original thought and discourse in the arts and humanities. Technical societies should not, however, be confused with the provincial and territorial Associations (discussed in earlier chapters) that license professional engineers and geoscientists in Canada.

In countries that do not have Canada's strict licensing laws, technical societies may also provide voluntary certification. For example, many British engineering societies began (and continue) as technical societies, but they now award "Chartered Engineer" status. In the absence of other licensing regulations for engineers, this voluntary certification is highly regarded in Britain, even though it does not permit the holder to practise engineering in Canada.

18.2 THE EVOLUTION OF TECHNICAL SOCIETIES

Technical societies originated during the Industrial Revolution when people, eager to reduce physical labour by mechanizing work, came together to discuss ideas and inventions. The first technical society for engineers was the Institute of Civil Engineers, established in Britain in 1818. The Institution of Mechanical Engineers followed, 30 years later. Shortly after that, other societies were established for naval architects and for gas, electrical, municipal, heating, and ventilating engineers.[1] These original 19th-century societies still exist, but they now sponsor many innovative sub-disciplines and specialties.

In the United States, the first engineering society was the American Society of Civil Engineers, founded in 1852. Many related societies were established in the 1800s—the American Society of Mechanical Engineers (1880), the American Institute of Electrical Engineers (1884), the Geological Society of America (1888), and the American Society of Heating and Ventilating Engineers (1894), to mention only a few.

In Canada, engineers and geoscientists have been at work for more than two centuries. The Geological Survey of Canada (GSC), a government institution that dates from 1842, has been called one of the most successful scientific societies of its time.[2]

The first engineering society to be formed in Canada was the Engineering Society of the University of Toronto, in 1885. The "society was, indeed, a 'learned society' and published and disseminated technical information . . . in addition to looking after the University undergraduates in engineering."[3] The Canadian Institute of Surveys was formed in 1882, followed by the Engineering Institute of Canada (EIC) in 1887 (although the EIC name was not adopted until 1917), the Canadian Institute of Mining and Metallurgy (1898), the Canadian Forestry Association (1900), and many others. These societies are still active today and it is easy to make contact with them through the Internet (see lists later in this chapter).

Technical societies grew slowly in the early part of the 20th century, but growth became exponential after the Second World War as the number of Canada's engineers and geoscientists increased. New societies continue to emerge every year, because they are even more important in the 21st century.

18.3 CHOOSING A TECHNICAL SOCIETY

Maintain your technical interests and connections by joining at least one society. Fortunately, the costs of membership are not great, so most practising professionals join more than one. Because of the value and usefulness of societies, membership dues are deductible from personal income (for practising professionals, under Canadian income tax laws).

Technical societies may take different forms, depending on how they evolved. Societies are typically organized by discipline, but a few societies are organized by geographical region, and two Canadian "federations" of societies provide a voice on the national and international levels. In addition, a few government and industrial organizations function as societies. Typical examples follow.

- **Discipline-oriented societies:** Typically, professionals join the society that promotes their discipline, and a society exists for every discipline from geology to nanoengineering. Societies often sponsor undergraduate student chapters, so you may already be a member of the principal society in your discipline.
- **Geographical societies:** Geographical area is important to some societies. For example, the special problems of construction in the Arctic, or development of Arctic resources, may be important to you. In some disciplines, Canadian societies are more effective researching problems that are typically Canadian and promoting Canadian interests.
- **Federations of societies:** Some societies are, in fact, federations of other societies, which have combined to give a united voice on issues of common interest. For example, both the Canadian Federation of Earth Sciences (CFES) and the EIC are federations of technical societies, separate from the licensing Associations, and they provide a national voice for their professions. Individuals usually cannot join a federation directly, but joining one of the societies in the federation gives indirect membership.
- **Government and industrial organizations:** In addition, many government and industrial organizations are extremely valuable sources of information, similar to technical societies. For example, although the GSC is a government organization, it collects and disseminates vital geological data. Similarly, the American Gear Manufacturers Association (AGMA) is an industrial organization, but it publishes the standards used for most gear strength calculations in North America. (A few of these important standards organizations are also discussed in Chapter 6.)

Regardless of your discipline, industry, or personal interests, there is a society that can help you professionally and that needs you as a member. Take advantage of this valuable opportunity. The lists below are a broad sample of the range of societies available. If the lists do not include a society that specializes in your interests, then a simple Internet search will find it. Every society has a website.

Canadian Engineering Societies

Table 18.1 lists several Canadian engineering societies; most of these were established in the last few decades, when the Engineering Institute of Canada, one of the oldest and most prestigious societies, became a federation of member societies. The role of the EIC (and its member societies) is to collect, organize, and disseminate engineering, scientific, and technical information.[4] The EIC has taken on this role enthusiastically and now provides a vital service by certifying and coordinating courses for professional development.

TABLE 18.1 — A Brief List of Canadian Engineering and Related Societies

Acronym	Society	Web Address
EIC	**Engineering Institute of Canada**	www.eic-ici.ca
	The Engineering Institute of Canada is a federation of member societies, including CGS, CSCE, CSME, CSChE, CSEM, IEEE-Canada, CNS, CMBES, CDA, CSBE, IISE, and CSSE (a charitable organization of senior engineers). The EIC is also now a leading provider and coordinating body for continuing professional development.	
CGS	**Canadian Geotechnical Society**	www.cgs.ca
	CGS is an active member of both the EIC and the Canadian Federation of Earth Sciences.	
CSCE	**Canadian Society for Civil Engineering**	www.csce.ca
CSME	**Canadian Society for Mechanical Engineering**	www.csme-scgm.ca
CSEM	**Canadian Society for Engineering Management**	www.csem-scgi.org
IEEE—Canada	**Institute of Electrical and Electronic Engineers—Canada**	www.ieee.ca
CNS	**Canadian Nuclear Society**	www.cns-snc.ca
CMBES	**Canadian Medical and Biological Engineering Society**	www.cmbes.ca
CIC	**Chemical Institute of Canada**	www.cheminst.ca
	The Chemical Institute of Canada is an umbrella organization for three constituent societies for chemistry professionals: CSChE, CSC, and CSCT, listed below.	
CSChE	**Canadian Society for Chemical Engineering**	(see CIC, above)
CSC	**Canadian Society for Chemistry**	(see CIC, above)
CSCT	**Canadian Society for Chemical Technology**	(see CIC, above)
CDA	**Canadian Dam Association**	www.cda.ca
IISE	**Institute of Industrial & Systems Engineers (Canada Region)**	www.iise.org
CSBE	**Canadian Society for Bioengineering**	www.bioeng.ca

Note: All websites are current as of June 26, 2017.

Canadian Geoscience Societies

Table 18.2 lists several Canadian geoscience societies. The Canadian Federation of Earth Sciences (CFES; formerly the Canadian Geoscience Council) is a federation of 13 Earth sciences societies. CFES speaks as a unified voice for

TABLE 18.2 — A Brief List of Canadian Geoscience and Related Societies

Acronym	Society	Web Address
CFES	**Canadian Federation of Earth Sciences**	earthsciencescanada.com
	CFES was called the Canadian Geoscience Council (CGC) until 2007. CFES, like EIC, is a federation of Canadian technical societies. CFES includes basic, specialized, and applied earth sciences societies, and has many links with industry and government.	(alternative link: www.cfes-fcst.ca)
CGS	**Canadian Geotechnical Society**	www.cgs.ca
	CGS is an active member of both EIC and CFES.	
CAG	**Canadian Association of Geographers**	www.cag-acg.ca
AGS	**Atlantic Geoscience Society**	ags.earthsciences.dal.ca/ags.php
CCCESD	**Council of Chairs of Canadian Earth Science Departments**	cccesd.acadiau.ca
CPG	**Committee of Provincial and Territorial Geologists**	n/a
CIM	**Canadian Institute of Mining, Metallurgy and Petroleum**	www.cim.org
IAH-CNC	**International Association of Hydrogeologists, Canadian National Chapter**	www.iah.ca
CANQUA	**Canadian Quaternary Association**	www.canqua.com
CSEG	**Canadian Society of Exploration Geophysicists**	www.cseg.ca
CSPG	**Canadian Society of Petroleum Geologists**	www.cspg.org
GAC	**Geological Association of Canada**	www.gac.ca
PDAC	**Prospectors & Developers Association of Canada**	www.pdac.ca
MAC	**Mineralogical Association of Canada**	www.mineralogicalassociation.ca

Note: All websites are current as of June 26, 2017.

Earth sciences societies in Canada. It promotes their role in environmental, natural hazard, and climate studies, and in securing, and responsibly developing, Canada's energy, mining, and water resources. The Federation helps Canadian Earth sciences disciplines to share ideas, data, and knowledge; it also represents them in IUGS, the International Union of Geological Sciences.[5]

International Societies

Table 18.3 lists several international engineering and geoscience societies. The United States hosts the largest and most advanced technical societies.

The Institute of Electrical and Electronic Engineers (IEEE) is the largest technical society in the world, with more than 423,000 members (including about 117,000 student members) in over 160 countries. The IEEE includes 39 specialty societies, with interests from aerospace electronics to vehicular technology. The IEEE publishes about 200 transactions, journals, and magazines, and arranges or co-sponsors 1,800 technical conferences worldwide each year.[6]

TABLE 18.3 — A Brief List of International Engineering, Geoscience, and Related Societies

Acronym	Society	Web Address
IEEE	**Institute of Electrical and Electronic Engineers**	www.ieee.org
ASCE	**American Society of Civil Engineers**	www.asce.org
AIME	**American Institute of Mining, Metallurgical and Petroleum Engineers**	www.aimehq.org
	AIME supports four member societies:	
	SME—The Society for Mining, Metallurgy, and Exploration; **TMS**—The Minerals, Metals, and Materials Society; **AIST**—Association for Iron and Steel Technology; and **SPE**—Society of Petroleum Engineers.	
ASME	**American Society of Mechanical Engineers**	www.asme.org
AIChE	**American Institute of Chemical Engineers**	www.aiche.org
ASABE	**American Society of Agricultural and Biological Engineers**	www.asabe.org
SAE	**Society of Automotive Engineers**	www.sae.org
ASHRAE	**American Society of Heating, Refrigerating and Air-Conditioning Engineers**	www.ashrae.org
AGMA	**American Gear Manufacturers Association**	www.agma.org

(*Contniued*)

TABLE 18.3 — A Brief List of International Engineering, Geoscience, and Related Societies (*Continued*)

Acronym	Society	Web Address
ASEE	**American Society for Engineering Education**	www.asee.org
AIPG	**American Institute of Professional Geologists**	www.aipg.org
AAPG	**American Association of Petroleum Geologists**	www.aapg.org
IUGS	**International Union of Geological Sciences** IUGS is a non-governmental union of more than a million Earth scientists in 121 member countries and 56 affiliated organizations. IUGS encourages international cooperation and participation in the Earth sciences.	www.iugs.org
AGI	**American Geosciences Institute** AGI is a federation of 51 geoscience societies. It provides information and education services to its members and promotes a united voice for the geoscience community.	www.americangeosciences.org
AEG	**Association of Environmental and Engineering Geologists**	www.aegweb.org
EFG	**European Federation of Geologists**	www.eurogeologists.eu
GSA	**Geological Society of America**	www.geosociety.org
IAH	**International Association of Hydrogeologists**	www.iah.org
AAG	**Association of Applied Geochemists**	www.appliedgeochemists.org
SEG	**Society of Economic Geologists**	www.segweb.org
SGA	**Society for Geology Applied to Mineral Deposits**	www.e-sga.org
IAPG	**International Association for Promoting Geoethics**	www.geoethics.org
CILT	**Chartered Institute of Logistics and Transport**	www.ciltinternational.org

Note: All websites are current as of June 26, 2017.

The IEEE, like many of the international societies, publishes a Code of Ethics and encourages high ethical standards; it does not, however, solicit or otherwise invite complaints concerning the IEEE Code of Ethics.7 In other words, these international Codes of Ethics are voluntary. They should not be confused with the Codes of Ethics in Canadian engineering and geoscience licensing Acts, which are enforceable under the Acts, as discussed in earlier chapters.

18.4 CANADIAN STUDENT SOCIETIES

Student Chapters of Technical Societies

Many of the societies listed in Tables 18.1 to 18.3 maintain student chapters in Canadian universities. These chapters promote undergraduate technical and social programs and usually offer free (or inexpensive) subscriptions to society publications, entrance to society meetings, short courses, and field trips, as well as opportunities for students to meet practising professionals in their fields. If you are a student, contact your society of interest and see if it has a student chapter at your university.

Student Programs by Licensing Associations

Several licensing Associations have introduced programs to improve communication with the next generation of professional engineers and geoscientists. For example, Alberta (APEGA) has the APEGA Student Advantage Program (ASAP), British Columbia has the APEGBC Student Membership Program, and Ontario (PEO) has the Internet-based Student Membership Program (SMP). These programs offer undergraduate students the benefits of membership at little or no cost. The Associations are to be applauded for this initiative, which gives students a smoother transition through the internship (as EIT, MIT, or GIT, for example) to licensed professional engineer or geoscientist. Some provinces also have links to faculty members and networks of mentors to assist students. If you are a student, contact your Association and inquire whether your Association has a student program.

Canadian Federation of Engineering Students

The Canadian Federation of Engineering Students (CFES) traces its history back to a tumultuous inaugural congress of engineering students at McGill University in February 1969. CFES operates in four regions: Western Canada, Ontario, Quebec, and the Atlantic region. The Federation's goals are to improve communication between engineering students and to help them grow culturally, morally, intellectually, academically, and economically. CFES also serves as a liaison between 81,000 Canadian engineering students and Engineers Canada, as well as the National Council of Deans of Engineering and Applied Science (NCDEAS). CFES organizes many student projects, such as the Canadian Engineering Competition, and provides interactive online information about learning opportunities in Canada and Europe.[8]

18.5 CHARITABLE AND HONORARY SOCIETIES

Engineers and geoscientists have generously established many societies for charitable work, such as aiding in disasters or economic loss, assisting development of less fortunate countries, or encouraging students through financial assistance and scholarships. A partial list follows.

Photo 18.1 — The Canadair Waterbomber. *The Canadair CL-215 Waterbomber, designed and built in Canada, is the only aircraft in the world specifically intended to fight forest fires. Canadair designed the CL-215 in the 1960s, and it is capable of scooping 5,760 kg of water (weighing 12,500 lbs.) from a lake, without stopping, and dumping it on a forest fire. A turboprop version, the CL-415, first flew in 1993.*

Source: © AP/Franco Arena/CP Images

Engineers Without Borders— *Ingénieurs Sans Frontières*

Engineers Without Borders (EWB), established in January 2000, is a registered charity dedicated to international development. The mission of EWB is to further human development through access to technology by promoting the involvement of engineering students in development issues. EWB focuses on technology in fundamental areas—water, food availability, health, energy, and communications—in developing communities. It does not bring technology from the West; rather, it encourages simple technology, developed with local input and innovation. Such solutions are longer lasting and promote sustainability and self-sufficiency. EWB is a Canadian initiative, and EWB chapters have been started at most Canadian universities with engineering programs. EWB, now a network of 40 professional and student chapters, has initiated a startling array of successful projects. The achievements of this group speak well for the initiative and idealism of Canada's engineering students.[9]

Geoscientists Without Borders

Geoscientists Without Borders (GWB) was established in the United States by the Society of Exploration Geophysicists (SEG) Foundation in 2008 with several large donations from industrial and individual donors. The GWB mission is to aid humanitarian applications of geoscience around the world. GWB supports projects that will benefit communities in need, where geophysical science is critical to improving poor conditions or where dangerous conditions can be mitigated using applied geoscience technology. GWB projects specifically require the involvement of geoscience students.[10]

Canadian Engineering Memorial Foundation (CEMF)

The Canadian Engineering Memorial Foundation was created in 1990 under the stewardship of Engineers Canada, following the events in Montréal at École Polytechnique that resulted in the deaths of 14 young women, ending their contributions to Canadian society. CEMF is funded entirely through donations from individual engineers, corporations, and the public. Each year the Foundation grants scholarships to outstanding female engineering students at undergraduate and graduate levels.[11]

Canadian Society for Senior Engineers (CSSE)

The Canadian Society for Senior Engineers (CSSE) is a charitable organization affiliated with the EIC. (It was incorporated in 1967 as the EIC Life Members Organization.) The primary function of this group of late-career and retired engineers is to promote the advancement of science and engineering in Canada and to provide benevolent donations in support of youth in the advancement of engineering. The CSSE engages in a wide range of charitable works, including research projects and awards for science fairs. It also assists the Tetra Society, which recruits skilled volunteer engineers and technicians to build devices to assist people with disabilities.[12]

Canadian Geological Foundation

Several foundations have been established to receive gifts and bequests to support Canadian Earth science. The most senior is likely the Canadian Geological

Foundation, incorporated in 1968. The Canadian Geological Foundation is a charitable organization dedicated to the furtherance of geoscience in Canada, and it has played a key role in sustaining geoscience education, outreach, and awareness in Canada.[13]

The Canadian Academy of Engineering

The Canadian Academy of Engineering is Canada's highest honorary engineering society. The Academy, located in Ottawa, is an independent, self-governing, nonprofit organization established in 1987. The Fellows of the Academy are professional engineers from all disciplines, elected on the basis of distinguished service and contributions to society, to the country, and to the profession. The Academy currently has about 496 active, 201 emeritus, 2 international, and 5 honorary fellows. The Fellows of the Academy are committed to ensuring that Canada's engineering expertise is applied to the benefit of all Canadians. They accomplish this in several ways; for example, they promote increased awareness of the role of engineering and give independent advice on engineering education, research, development, and innovation.[14]

The Partnership Group for Science and Engineering

The Partnership Group for Science and Engineering (PAGSE) is a cooperative association of more than 25 national organizations in science and engineering, representing approximately 50,000 individual members from industry, academia, and government. It was formed in June 1995 at the invitation of the Academy of Science of the Royal Society of Canada to represent the Canadian science and engineering community to the government of Canada. PAGSE holds events and undertakes studies and assessments of benefit to government and, among other activities, submits a brief to the House of Commons Standing Committee on Finance each fall to provide consensus views from the science and engineering research community on policy issues and initiatives.[15]

18.6 THE IRON RING: A RITUAL FOR ENGINEERS

The Corporation of the Seven Wardens is a little-known group that has performed a vital role in Canadian engineering for many decades. The wardens arrange the Iron Ring ceremonies held on most campuses just before graduation day. This ceremony is a milestone in the engineer's education. The following account of the Iron Ring was written by J.B. Carruthers, P.Eng., and is reproduced with permission:

> Most engineers in Canada wear the Iron Ring and have solemnly obligated themselves to an ethical and diligent professional career through the Ritual of the Calling of an Engineer. This Ritual is the result of efforts by the Corporation of the Seven Wardens, started in 1922 when a group of prominent engineers met in Montreal to discuss a

concern for the general guidance and solidarity of the profession. These seven prominent engineers formed the nucleus of an organization whose object would be to bind all members of the engineering profession in Canada more closely together and to imbue them with their responsibility towards society.

They enlisted the services of the late Rudyard Kipling, who developed an appropriate Ritual and the symbolic Iron Ring. Rudyard Kipling outlined the purpose in the following words:

> "The Ritual of the Calling of an Engineer has been instituted with the simple end of directing the young engineer towards a consciousness of his [/her] profession and its significance, and indicating to the older engineer his [/her] responsibilities in receiving, welcoming and supporting the young engineers in their beginnings."

The Ritual has been copyrighted in Canada and the United States, and the Iron Ring has been registered. The Corporation of the Seven Wardens is entrusted with the responsibility of administering and maintaining the Ritual, which it does through a system of separate groups, called Camps, across Canada. There are presently 26 such Camps.

The Corporation of the Seven Wardens is not a "secret society." Its rules of governance, however, do not permit any publicity about its activities and they specify that Ceremonies are not to be held in the presence of the general public.

The original seven senior engineers who met in Montreal in 1922 were, as it happens, all past presidents of the Engineering Institute of Canada. There is, however, no direct connection between the Engineering Institute of Canada and the Corporation of the Seven Wardens.

The wearing of the Iron Ring, or the taking of the obligation, does not imply that an individual has gained legal acceptance or qualification as an engineer. This can only be granted by the provincial bodies so appointed and, as a result, it should also be mentioned that the Corporation of the Seven Wardens has no direct connection with any provincial Association or order.

The obligation ceremonies for graduating students are held in cities where Camps are located, and for convenience, in some cases, on the university campus itself. Such ceremonies must not be misconstrued as being an extension of the engineering curriculum. The Iron Ring does not replace the diploma granted by the University or the School of Engineering nor is it an overt sign of having successfully passed the institution's examinations.

The purpose of the Corporation of the Seven Wardens and the Ritual is to provide an opportunity for men and women to obligate themselves to the standard of ethics and diligent practice required by those in our profession. This opportunity is available to any who wish to avail themselves to it, whether they be new graduates or senior engineers. The Ritual of the Calling of an Engineer is attended by all those who wish to be obligated, along with invited senior engineers and, when space permits, immediate family members. A complete explanation of the Ritual, its obligations and history is given to every man and woman before the ceremony so that they may decide in

> advance whether or not they wish to take part in the spirit intended. A few people, for one reason or another, have chosen to refrain from being obligated, and so cannot rightfully wear the Iron Ring. The Corporation of the Seven Wardens feels that this in no way detracts from their right to practise in the profession and further feels that the obligation should continue to be a matter of personal choice, taken only by those who wish to take part in the serious and sincere manner intended.*

18.7 THE EARTH SCIENCE RING: A RITUAL FOR GEOSCIENTISTS

The awarding of the Earth Science Ring is a ceremony comparable with the Iron Ring ceremony and, in fact, adopts some of the format and wording of the Iron Ring ceremony. The following description of the Earth Science Ring and award ceremony was written by Philippe Erdmer, P.Geol., and Edward S. Krebes, P.Geoph., and is reproduced with permission:

> The Earth science ring ceremony, a ritual of welcome into the profession of newly qualified geologists and geophysicists by senior practising Earth scientists, started in Alberta in 1975. This yearly tradition for the university geoscience graduating classes at Edmonton and Calgary has spread to other provinces and jurisdictions in Canada. The ceremony carries many of the same passages written by Kipling for the Engineers' iron ring ceremony and symbolizes the commitment and responsibility that come with wearing the title of a professional.
>
> Like the engineer's iron ring, the Earth science ring's simplicity and strength bear witness to the calling of the geologist and geophysicist. The ring is made of silver and marked with the crossed hammer of geology and with the seismic trace of geophysics—signifying both the immediate and the remote searching out of Nature's knowledge. Without beginning and without end, it also represents for those who wear it the continuous interplay of ideas and of material realities.
>
> The ceremony includes a charge (speech) by senior Earth scientists and an obligation (pledge) taken by the group of newly graduated geologists and geophysicists. The charge reads in part: "We tell you here that you will encounter no difficulty, doubt, danger, defeat, humiliation or triumph in your career which has not already fallen to the lot of others in your calling. . . ." The obligation includes the words: "I will not pass . . . false information or too casual interpretations in my work as an Earth scientist. My time I will not refuse, my thought I will not grudge; my care I will not deny towards the honour, use, stability and perfection of any project to which I may be called to set my hand. . . . My reputation in my calling I will guard honourably. . . . I will strive my uttermost against professional jealousy and the belittling of my co-workers in any field of their labour."

* J.B. Carruthers, P.Eng., "The Ritual of the Calling of an Engineer," *la Revue Projet/CFES Project Magazine*, April 1985, 19. Reproduced with permission.

On a lighter note, following the obligation, new ring bearers are reminded that "From now on, we surrender to you what lies under the earth, and the tools to interpret or misinterpret. Sooner or later, you will drill the holes that bring no return, lose the vein in which lie extra riches and reputation, misinterpret the signal from the depths. This will equally baffle, bewilder and break your heart to your professional and personal education."

Receiving an Earth science ring is neither a prerequisite nor a later condition of professional membership with APEGA. Although there is no obligation to obtain or wear a ring, it is significant that almost no one in the graduating classes willingly misses the ceremony. In addition, the ceremony is not strictly a graduation event, as it has occasionally included already practising geologists and geophysicists in Alberta who express the wish to receive a ring. Like the iron ring of the obligated engineer, the Earth science ring is a symbol of values that lie at the core of our individual beings and of the trust placed in us by society.*

DISCUSSION TOPICS AND ASSIGNMENTS

1. Canadian engineers and geoscientists often debate whether to join the newer Canadian technical societies or to join the larger, older, foreign-based societies that have well-established journals, committees, and conferences. Weigh the pros and cons of the two alternatives from your point of view. Does Canada need distinct technical societies? In your answer, discuss the implications for Canadian sovereignty if Canadian societies should be absorbed into the larger, American-dominated "international" societies. Are these societies truly non-political, or do national interests influence their policies and the content of journals and transactions? Is climate change, and its effects on Canada, relevant to a society's role? Are there uniquely Canadian conditions that would justify uniquely Canadian societies? Give examples (for or against). Prepare a two-page summary.
2. Engineering and geoscience students must study hard to succeed. How can they find time for other activities, such as student government, CFES, Association student participation programs, or charitable organizations such as Engineers Without Borders? Discuss whether the Canadian Engineering Accreditation Board (CEAB) should classify such activities as complementary (non-engineering) studies, which are required for engineering accreditation. How would students earn these credits? Which activities and organizations would be eligible, and how would you weight the various activities?

Additional assignments can be found in Web Appendix E.

* Penny Colton and APEGA, "The Earth Science Ring: Made in Alberta," available at http://74.3.176.63/publications/recorder/2005/02feb/feb05-earth-science-ring.pdf (accessed June 26, 2017). Reproduced with permission from APEGA.

NOTES

[1] L.C. Sentance, "History and Development of Technical and Professional Societies," *Engineering Digest* 18, no. 7 (July 1972): 73–74.

[2] R.W. Macqueen, ed., *Proud Heritage: People and Progress in Early Canadian Geoscience* (St. John's, NL: Geological Association of Canada, 2004).

[3] Sentance, "History and Development," 73.

[4] "Canadian Engineers Close the Ring," [EIC] *Engineering Journal* 60, no. 1 (January 1977): 15–19. The mission statement of the Engineering Institute of Canada is also at www.eic-ici.ca (accessed June 26, 2017).

[5] Canadian Federation of Earth Sciences (CFES), www.cfes-fcst.ca (accessed June 26, 2017).

[6] IEEE Societies & Technical Councils Web page, IEEE, www.ieee.org/societies_communities (accessed June 26, 2017).

[7] Joseph R. Herkert, "*Microethics, Macroethics, and Professional Engineering Societies," Emerging Technologies and Ethical Issues in Engineering: Papers from a Workshop, October 14–15, 2003* (Washington, DC: National Academy of Engineering, 2003), 107–14,www.nap.edu/catalog/11083.html (accessed June 26, 2017).

[8] Canadian Federation of Engineering Students (CFES), www.cfes.ca (accessed June 26, 2017).

[9] Engineers Without Borders (EWB), www.ewb.ca (accessed June 26, 2017).

[10] Geoscientists Without Borders (GWB), http://seg.org/About-SEG/Geoscientists-Without-Borders (accessed June 26, 2017).

[11] Canadian Engineering Memorial Foundation (CEMF), www.cemf.ca (accessed June 26, 2017).

[12] Canadian Society of Senior Engineers (CSSE), seniorengineers.ca/csse (accessed June 26, 2017).

[13] Canadian Geological Foundation, www.canadiangeologicalfoundation.org (accessed June 26, 2017).

[14] Canadian Academy of Engineering, "Mission Statement," www.cae-acg.ca/about-us/mission-statement/ (accessed June 26, 2017).

[15] The Partnership Group for Science and Engineering, www.pagse.org (accessed June 26, 2017).

APPENDIX A

PROFESSIONAL LICENSING: ENGINEERING AND GEOSCIENCE

Engineers Canada
(Engineers Canada is the working name for the
Canadian Council of Professional Engineers—CCPE.)
55 Metcalfe Street, Suite 300
Ottawa, ON K1P 6L5

Tel: (613) 232-2474 / 1-877-408-9273 Fax: (613) 230-5759
Email: info@engineerscanada.ca Website: www.engineerscanada.ca

Geoscientists Canada
(Geoscientists Canada is the working name for the
Canadian Council of Professional Geoscientists—CCPG.)
Suite 200, 4010 Regent Street
Burnaby, BC V5C 6N2

Tel: (604) 412-4888
Email: info@ccpg.ca Website: www.geoscientistscanada.ca

Association of Professional Engineers and Geoscientists of Alberta (APEGA)
1500 Scotia One
10060 Jasper Avenue NW
Edmonton, AB T5J 4A2

Tel: (780) 426-3990 / 1-800-661-7020 Fax: (780) 426-1877
Email: email@apega.ca Website: www.apega.ca

Association of Professional Engineers and Geoscientists of British Columbia (APEGBC)
200 – 4010 Regent Street
Burnaby, BC V5C 6N2

Tel: (604) 430-8035 / 1-888-430-8035 Fax: (604) 430-8085
Email: apeginfo@apeg.bc.ca Website: www.apeg.bc.ca

Engineers Geoscientists Manitoba (APEGM)
(Engineers Geoscientists Manitoba is the working name of the Association of Professional Engineers and Geoscientists of the Province of Manitoba—APEGM.)
870 Pembina Highway
Winnipeg, MB R3M 2M7

Tel: (204) 474-2736 / 1-866-227-9600 Fax: (204) 474-5960
Email: info@EngGeoMB.ca Website: www.apegm.mb.ca

Engineers and Geoscientists New Brunswick
(Engineers and Geoscientists New Brunswick is the working name of the Association of Professional Engineers and Geoscientists of New Brunswick—APEGNB.)
183 Hanwell Road
Fredericton, NB E3B 2R2

Tel: (506) 458-8083 / 1-888-458-8083 Fax: (506) 451-9629
Email: info@apegnb.com Website: www.apegnb.com

Professional Engineers and Geoscientists of Newfoundland and Labrador (PEGNL)
Courier: Suite 203, Baine Johnston Centre
10 Fort William Pl., St. John's, NL A1C 1K4
Mail: P.O. Box 21207
St. John's, NL A1A 5B2

Tel: (709) 753-7714 Fax: (709) 753-6131
Email: main@pegnl.ca Website: www.pegnl.ca

Association of Professional Engineers and Geoscientists of the Northwest Territories & Nunavut (NAPEG)
201, 4817–49th Street
Yellowknife, NT X1A 3S7

Tel: (867) 920-4055 Fax: (867) 873-4058
Email: napeg@napeg.nt.ca Website: www.napeg.nt.ca

Engineers Nova Scotia
(Engineers Nova Scotia is the working name of the Association of Professional Engineers of Nova Scotia—APENS.)
1355 Barrington Street
Halifax, NS B3J 1Y9

Tel: (902) 429-2250 / 1-888-802-7367 Fax: (902) 423-9769
Email: info@engineersnovascotia.ca Website: www.engineersnovascotia.ca

Geoscientists Nova Scotia
(Geoscientists Nova Scotia is the working name of the Association of Professional Geoscientists of Nova Scotia—APGNS.)
Mail: P.O. Box 91
Enfield, NS B2T 1C6
Courier: 181 Hescott Street
Elmsdale, NS B2S 1L9

Tel: (902) 420-9928
Email: info@geoscientistsns.ca Website: www.geoscientistsns.ca

Professional Engineers Ontario
(Professional Engineers Ontario is the working name of the Association of Professional Engineers of Ontario—PEO.)
40 Sheppard Avenue West, Suite 101
Toronto, ON M2N 6K9

Tel: (416) 224-1100 / 1-800-339-3716 Fax: (416) 224-8168 / 1-800-268-0496
Email: See directory on PEO website. Website: www.peo.on.ca

Association of Professional Geoscientists of Ontario (APGO)
25 Adelaide Street East, Suite 1100
Toronto, ON M5C 3A1

Tel: (416) 203-2746 / 1-877-557-2746 Fax: (416) 203-6181
Email: info@apgo.net Website: www.apgo.net

Engineers PEI
(Engineers PEI is the business name of The Association of Professional Engineers of Prince Edward Island—APEPEI.)
135 Water Street
Charlottetown, PE C1A 1A8

Tel: (902) 566-1268 Fax: (902) 566-5551
Email: info@EngineersPEI.com Website: www.engineerspei.com

Ordre des ingénieurs du Québec (OIQ)
Gare Windsor, bureau 350
1100, avenue des Canadiens-de-Montréal
Montreal, QC H3B 2S2

Tel: (514) 845-6141 / 1-800-461-6141 Fax: (514) 845-1833
Email: Contact OIQ via website. Website: www.oiq.qc.ca

Ordre des Géologues du Québec (OGQ)
500 rue Sherbrooke Ouest, Bureau 900
Montréal, QC H3A 3C6

Tel: (514) 278-6220 Fax: (514) 844-7556
Email: info@ogq.qc.ca Website: www.ogq.qc.ca

Association of Professional Engineers and Geoscientists of Saskatchewan (APEGS)
300 4581 Parliament Avenue
Regina SK S4W 0G3

Tel: (306) 525-9547 / 1-800-500-9547 Fax: (306) 525-0851
Email: apegs@apegs.ca Website: www.apegs.ca

Engineers Yukon
(Engineers Yukon in the working name of the
Association of Professional Engineers of Yukon—APEY.)
312B Hanson Street
Whitehorse, YT Y1A 1Y6

Tel: 1-867-667-6727 Fax: 1-867-668-2142
Email: staff@engineersyukon.ca Website: www.engineersyukon.ca
[Note: All Web addresses are valid as of June 27, 2017.]

LIST OF WEB APPENDIXES

The website accompanying this textbook (nelson.com/andrews6e) consists of more than 300 pages of additional information in the following appendixes:

APPENDIX A—Professional Licensing: Engineering and Geoscience
APPENDIX B—Licensing Laws, Regulations, and Codes of Ethics
APPENDIX C—Codes of Ethics for Key Technical Societies
APPENDIX D—NSPE Guidelines to Employment for Professional Engineers
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