DEVELOPMENT FOREST ENGINEERING AND ITS LITERATURE

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First Academic Programs

The Royal Indian Engineering College at Cooper's Hill (Great Britain) was among the first colleges to blend engineering with forestry when in 1884 they established a school of forestry.[1] Headed by William Schlich the school taught its students technical material in preparation for employment in the Colony of India. Forestry program graduates would aid in the harvesting of India's forests. *Schlich's Manual of Forestry* became the definitive English language forestry textbook of that era.[2] In fact the volume on forest utilization written by Karl Gayer, Professor of Forestry at the University of Munich was the recognized standard on forest utilization in Germany. Within this volume the section on wood transportation describes road, rail, cable and water based transportation systems. There are good structural illustrations but no numerical analysis is offered. The academic program at Cooper's Hill was moved to Oxford in 1905, marking a transition toward what we now view as modern forestry instead of an area of applied engineering.

The first American Forest Engineering degree was awarded at Cornell University in 1902, where Dr. Bernard E. Fernow, a German educated forest engineer, led a short lived program (1896-1903). Only 17 students graduated with this degree, which Fernow described as follows: "This degree, it is believed, expresses more adequately . . . the fact that not a science but an art of technical character has been studied as a profession; it is a title indicating practical rather than literary attainments and describes the work for which the student has prepared, namely, the application of technical scientific knowledge to a business and in a productive industry."[3] Fernow clearly identified the engineering aspects of forestry; a profession whose mission reached beyond the logging operation to address such issues as regeneration and protection of the soil and water resource.[4]

In the southeastern United States, the Biltmore Forest School operated from 1898 to 1913 under the direction of another German forestry school graduate, Dr. Carl A. Schenck. The Biltmore School did not have a forest engineering curriculum but did emphasize the practical aspects of forestry, including substantial attention given to logging.[5] Schenck's text, *Logging and Lumbering or Forest Utilization; A Textbook for Forest Schools,* was apparently published in 1912, although the book does not in fact give a publication date.[6] Part I dealt with logging operations while Part II discussed the manufacture of wood products. Part I consists of three chapters and is an excellent descriptive treatment of logging engineering practice during that era. The first chapter covers camps, duration of employment, enumeration, and animals. The discussion is non-technical and is a generally thorough introduction to the topic. The second chapter describes the tools used (including discussion on setting and filing saw teeth), tree felling and bucking. Chapter three, transportation, is quite detailed and covers land transportation (without vehicles), water transportation, vehicles, roads, loading, cable logging, and choosing between transportation systems. The section on roads includes equations for grade, curve layout, cuts and fills, etc., along with prediction equations for the rolling resistance of wheels.

An early textbook by Ralph Clement Bryant, a forest engineering graduate of the program at Cornell, is similar in topical content to Schenck's book.[7] Bryant does not present any engineering

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analysis of harvesting activity but, somewhat unique for that period, he does give an extensive bibliography. Bryant's text was the first widely distributed textbook on logging in North America. This text was followed with a thoroughly revised second edition in 1923.

The Emergence of Logging Engineering

The need for engineering skills in North American logging and forest management continued to grow during the first decade of this century, especially in the west. The U.S. Forest Service responded to this need for engineers when, in 1905, F.G. Plummer was transferred from the Geological Survey to the Forest Service. Plummer was the first engineer in what was to become, in 1907, the U.S. National Forest System. By 1910, activity on the National Forest had produced 320 miles of road, 2,225 miles of trail, 1,888 miles of telephone lines, 464 cabins and barns, and 51 corrals.[8] Industry was similarly responding. Turn of the century loggers in the Pacific Northwest well understood the value of a capable engineer.

Western loggers were contending with steep rugged terrain, big trees, and logging technology that was based on cable systems and railroads. They needed persons who could survey railroad lines and property boundaries as well as oversee road layout and construction. Many civil and mechanical engineers had the necessary educational background, but two problems prevented these engineers from being employed by the logging firms. First, young mechanical and civil engineering graduates were not compatible with the loggers. The Pacific Northwest was extremely rural, logging enterprises operated out of camps, and the climate was, true to the northwest's reputation, conducive to wet socks and webbed feet for those who undertook an engineering career in the outdoors. Formally educated engineers were finding preferable employment in more urban settings at more attractive salaries. Further, the logging business did not know what to do with engineers. It was not appropriate to turn an engineer into an overpaid logger yet with no existing career track for engineers in the business, there did not exist means for an engineer to become sufficiently familiar with the operations of the business.

The second problem impeding the employment of engineers in the logging industry was the poor performance of engineers who had been hired by the industry. When civil and mechanical engineers were employed by the logging industry the results were frequently disastrous. E. T. Clark describes a case where a logging outfit engaged a civil engineering firm to locate some boundary lines. The surveyors, not understanding the nature of logging, located the section corners but, to the loggers' dismay (and too late discovery), did not blaze the boundary lines for the fallers. Clark also told of a logging company that hired a "gang of civil engineers" to survey a few miles of rail line. The construction crew discovered the newly surveyed line would have required excavation at a cost not justifiable by the timber to be extracted. The company then called in their own timber cruiser (Note: probably a college educated forester) to "Spot in a road that could be built without bankrupting the company."[9]

In August of 1908, George Cornwall, editor of a trade magazine called *The Timberman*, and Edward English, an influential logging firm owner from Mt. Vernon, Washington, visited in the Dillar Hotel in Seattle. At that meeting Mr. Cornwall proposed his ideas for a meeting of what was to become the Pacific Logging Congress. The congress would be a "friendly powwow of other loggers for an exchange of ideas (pertaining to logging)." It is evident that Cornwall understood the nature of the men operating logging operations and the importance of their perceptions, thus he allowed that "the idea of this congress was therefore a mutual and simultaneous inspiration."[10]

Cornwall subsequently met with Dean Frank G. Miller and Professor Hugo Winkenwerder of the University of Washington to discuss the upcoming Pacific Logging Congress to be held on the campus of the University of Washington in Seattle. Miller and Winkenwerder had recognized the growing need for engineering talents in the logging camps and were interested in establishing a program in logging engineering. But, they too recognized that the success of their endeavor would depend on acceptance by the loggers, and that the easiest way to attain acceptance was to allow the idea to come from the loggers themselves. George Cornwall, for his part, needed little convincing and took it upon himself to become a champion for the effort to establish a "new" profession. So, the profession and academic field of "logging engineering" became an important component of the Congress' mission.

The first Pacific Logging Congress (PLC) was held July 19-21, 1909 in the Hoo-Hoo House at the Alaska Yukon Pacific Exposition in Seattle. At that first PLC, George Cornwall stated:

> Logging is an engineering science and as such it must be considered in the future to a greater extent than it has in the past. The country is doing bigger things in every department of human activity, and the logging business is no exception to the rule. It takes close application and a high grade of engineering skill to be able to lay out the proper location of roads, which will intersect and draw to one common point the greatest amount of timber in any one tract. The grasp of this one problem is the deciding factor in determining the ability of the engineer, which often can be realized only after the tract is well opened up. There is a growing field on the Pacific Coast for young men with a knowledge of engineering, both civil and mechanical, who will devote their time to a study of the Pacific Coast logging requirements, with a view of being able to present in an intelligent and practical manner a working plan for opening up and logging a tract of timber, This is practically an unoccupied field, and one of the underlaying motives which dominated the congress."[11]

Although Cornwall may well have been the one to coin the term logging engineering, Frank Lamb is one of the earliest to use the term in publication. In a paper presented to the first PLC, Lamb of Lamb Timber Company in Hoquium, Washington, discussed some of the subjects that compose logging engineering and suggested:

> I hope that I have briefly outlined a few of the subjects comprised under the general term logging engineering, and while it would not make us more valuable men or more successful in our business, yet I think that if we practical men were to call ourselves logging engineers instead of simply loggers or boss loggers it might give us greater pride in our profession.
>
> I use the term profession advisedly, because I think the act of drawing logs out of the woods to the markets of the world is fully as elevating, fully as useful an occupation as is the drawing of useless teeth out of another man's head, and if one is a profession, so should the other be."[12]

The following year, 1910, a short course in logging engineering was taught at the University of Washington by Professor W.T. Andrews.[13] One year later Elias T. Clark was hired to take charge of the forest engineering program at the University of Washington.[14] A major strength of that program was in the extensive use of a capstone field exercise that is still the trademark of the program today.[15]

Oregon State University (then Oregon State Agricultural College) established a department of logging engineering in 1913. A well respected logger from industry, J.P. Van Orsdel was hired as the program's first professor of logging engineering and the first logging engineer graduated from this program in 1915.[16] The new curriculum was outlined to the PLC as follows:

In the student's freshman year he is taught, aside from (citizenship, executive training, military training) trigonometry, analysis, general forestry, elementary mensuration, plane surveying, general chemistry, and wood work. In the second year, engineering physics, blacksmithing, tool making and tempering, machine shop, practice, mechanical drawing, topographic surveying, railroad surveying and dendrology and mensuration. In the third year this is followed up by advanced mensuration, forest appraisals and reports, log scaling, logging railroads, logging machine design, elements of steam engineering and steam laboratory, mechanism, lumber rates and tariffs. The senior year is devoted entirely to specialized work and the following ground is covered: topographic logging plans, logging devices and equipment, logging methods, timber technology and testing, and lumber manufacture.[17]

By 1920 logging engineering programs had been established at the University of California (Berkeley), Oregon State University, the University of Washington, the University of Idaho, and the University of British Columbia. These early curricula, like the one described by Van Orsdel, stressed traditional forestry, logging planning and setting layout, surveying (land and railroad), topographic maps, and steam engines. However, by 1920, the very nature of logging engineering was beginning to change.

Re-emergence of Forest Engineering

Two forces were acting to change the fundamental nature of the problem addressed by logging engineering. First, technology was changing. Advances in the internal combustion engine and manufacturing processes during World War I were enabling the development of tractors and motor trucks suitable for logging. The result was a change in logging methods that reduced dependence on railroads. Second, concern for the forest resource was building and with that concern came increased interest in regeneration and selective logging.

In 1919 the Oregon Engineers Registration Law was passed and logging engineering was included as one of the branches.[18] The passing of legislation that provided for professional licensing of logging engineers was an acknowledgement of the importance of engineering to the protection of forest resources.

The primary emphasis of the early logging engineering programs was however directed at the problem of economic development of a timber resource located on difficult terrain. The requisite system of railroads and cable yarders represented a substantial capital investment. Poor harvest design, resulting in high logging costs, were of constant concern. The preparation of boundary and topographic maps, the development of a rail and cable transport system and the actual railroad survey, design and location called for the skills of an engineer. That forestry knowledge was also required in equal measure was not as clear. Indeed it was not until the early 20's when public concern about sustained forest yield became a political issue that forestry skills were accorded significant recognition in the conduct of harvesting operations. In 1922 George Cornwall, writing for the industry observed:

> From now forward the growing of timber will become a recognized and essential part in logging. A good fundamental knowledge of forestry will be helpful, in fact necessary, in conducting logging operations in the future; where the question of how best to remove the present crop with a view of providing for a continuous future supply will be regarded as a test of efficiency.[19]

In 1924 the director of the newly formed Pacific Northwest Forest Experiment Station of the USFS, Thornton T. Munger, called logging without forest replacement "industrial suicide".[20] It was during this period that the term forest engineer first appeared in the Pacific Northwest. As noted by Cornwall in the same paper, it was felt that the name of "logging engineer" should be widened to "forest engineer" to adequately reflect the scope of these new responsibilities. As previously noted the term "forest engineer" had already been introduced by Fernow whose earlier definition of the scope of the forest engineer's activity is consistent with the ideas advocated by Cornwall and Munger.[21]

The confluence of advancing technology and increasing concern about the forest resource had then forced a reconsideration of the role of the logging engineer. If logging (forest) engineers should once again enjoy a high profile in corporate operations, it was thought that it would be because of the broader issues of forest resources management and the ability of forest engineers to address those issues with a uniquely appropriate set of skills. But during the economic depression of the 30's and the second World War, the interest of the forest industry focused on short term economic efficiency. Logging time and cost studies were increasingly applied, and the forest engineer began to use many of the techniques popularized by industrial engineers. Interest in and development of the broader role of the forest engineer in forest resource management seemed to have waned.

The CCC program (Civilian Conservation Corps) initiated in the early 1930's supplied over 250,000 young men to do conservation work. Hundreds of engineers were employed to design and supervise the construction of roads, trails, bridges, etc. While we usually do not think of these CCC related activities as forest engineering per se, this activity provided much of the infrastructure which has been essential to efficient forest transportation, and was a catalyst in stimulating the U.S. Forest Service to publish their own *Engineering Field Tables* in 1935.[22] This handbook concentrated on practical surveying, earthwork, road drainage and surfaces, and concrete and timber construction.

The 1940's brought many advances to steep terrain harvesting technology, which had been the impetus for logging engineering in the Pacific Northwest. The appearance of track mounted steel towers, wide use of rubber and track mounted cable loaders and the wide acceptance of the power chain saw in felling and bucking operations were some of the more significant advances. Along with the improvements in technology came greater interest in forestry as a component of logging engineering. During the 1940's the logging engineering curricula began to show changes reflecting this new emphasis. The program of Oregon State University was renamed to forest engineering,[23] and the program at the University of British Colombia was changed to add more English, technical forestry and forest products in place of the applied engineering courses.[24]

In Washington State, a tax law designed to encourage forestry on private land was passed in 1941.[25] The first forest practices act for the State was passed in 1945 and was directed at achievement and maintenance of adequate regeneration on cut-over land.[26] Further significant forest practices legislation would not be seen again until early in the 70's. In 1949 logging engineering was granted recognition as a distinct branch of engineering, for purposes of professional licensing, by the Washington State Legislature.[27]

Professional Society Activities

The previously mentioned Pacific Logging Congress was, until about 1930, an organization that functioned much like today's technical societies. The annual meetings consisted of presented papers, formal discussion, field trips and a business meeting. The presented papers were very often of high caliber and some of them remain landmark papers in forest engineering research. The fundamental nature of the PLC began to change during the thirties. This change manifests itself as the presentations change from the technical to the business side of logging.

The Canadian Institute of Forestry was founded in 1908 as the Canadian Society of Forest Engineers with the participation of Fernow. The current name, adopted in 1950, more accurately reflects their preponderant professional interest in forestry rather than engineering. This professional society continues to publish the Forestry Chronicle which contains only occasional articles of minor engineering content.

The Society of American Foresters (SAF) is yet another professional forestry association. Lacking a traditional interest in the engineering aspects of forestry it provides only limited support to forest engineering activities. In spite of this limitation it has historically been widely subscribed to as a professional organization by American forest engineers. Its publications such as Forest Science and the regional applied forestry journals (Western, Southern and Northeastern Journals of Applied Forestry) provide an important outlet for forest engineering articles.

The Forest Products Research Society is an organization of researchers with a common interest of solid wood products. Through such publications as the Forest Products Journal and the Timber Harvesting and Merchandising Newsletter the FPRS has been active in the publication of forest engineering research.

In the later 60's and early 70's, protection of the public resources adversely affected by forest harvesting operations became a front page political issue. The increased public awareness sparked interest in forest engineering among other disciplines. The American Society of Agricultural Engineers (ASAE) held two forest engineering conferences in 1968 and 1969. The interest of the ASAE serves to illustrate that 1) the public concern for the forest resources was sparking interests of professionals outside of forestry and 2) the broader scope of forest engineers (outlined by Fernow in 1901 and further discussed by Cornwall and others during the 1920's) was becoming recognized. B.Y. Richardson wrote, in the Forward to the proceedings of the first ASAE sponsored forest engineering conference, that:

> "Good engineering is also required in site preparation, regeneration, cultural and protective functions. These needs take the form of design, development and testing of machines for precise planting, seeding, fertilizer application, nursery operations as well as insect, disease and fire control."[28]

The second ASAE sponsored forest engineering conference, held in 1969, is significant because it was the first conference held since the early Pacific Logging Conferences that was directed at teaching and curricula in forest engineering. (The PLC had, as previously mentioned, evolved so as to place dominant emphasis on the business and occupation of logging as opposed to the profession and discipline of forest engineering.) S.J. Coughran noted in the opening remarks of the conference that " . . . it was quite evident that the subject matter to be explored in this conference is extremely controversial."[29] The controversy he refers to was one of determining whether forest engineers are or should be foresters or engineers. George Cornwall's notion of a distinct profession of forest engineering had perhaps become forgotten.

In 1981, ASAE sponsored a third forest engineering conference, The Forest Regeneration Symposium. This conference was held in Raleigh, North Carolina, and published a Proceedings under the same title.[30] This conference identifies Forest Engineering as a profession which serves all the aspects of forestry, where most previous works concentrated on the removal of timber and the associated transportation systems.

The ASAE's technical journal, Transactions of the ASAE, has served as an important outlet for the more engineering oriented research papers since the 1968 and 1969 conferences.

By the end of the 70's, most of the western states had toughened and enlarged the scope of their forest practice legislation. Companies engaged in the harvest of a very valuable timber resource were operating on difficult terrain under restrictive forest practice acts. Forest engineers were again in high demand. The forest engineering programs in the Northwest were strong and numerous and others had materialized throughout the country. Some of the newer programs had affiliation with Agricultural Engineering Departments. In 1979 a forest engineering conference, independent of any existing organization, was held in Corvallis, Oregon. This conference marked the formation of the Council on Forest Engineering (COFE), a proximate professional organization for persons interested in forest engineering. At that first meeting of COFE it was decided that no affiliation should be sought with either the ASAE or the Society of American Foresters. The "controversy" of the 1969 meeting was still a concern. By the beginning of the 80's, however, even the forest engineering profession was impacted by the industry-wide recession.Academic concerns were replaced by institutional concerns as employment opportunities and student enrollment declined.

Development of the Current Literature

The previously mentioned early texts by Schlich, Schenck and Bryant were followed by J.P. Stewart's 1927 Manual of Forest Engineering and Extraction.[31] At the time, Stewart was a lecturer in Forest Engineering at the University of Edinburgh. His examples draw from extensive experience in north America, Africa and India where he had served as an advisor to various forest managers. His manual provides practical solutions to a variety of forest engineering problems ranging from protection from wild animals and malaria to a variety of logging and transportation schemes. Surveying, sleds, petrol and steam tractors, wire rope operations, slides and flumes, road, railways, trestles, water transport, permanent buildings and timber conversion and seasoning are included. Published with his manual are 24 pages of advertisements for goods commonly needed in a logging camp.

Some of the books by Brown were written as forest engineering texts. These books are generally descriptive of logging practices and contain but little engineering analysis.[32, 33, 34] One point of significance in the 1936 volume is the inclusion of silvicultural considerations within the chapters on logging methods. Only a loose tie is made between forestry and engineering.

In 1942 Professor Donald Matthews published his book *Cost Control in the Logging Industry*.[35] This text reflects the concern for economic efficiency prevalent during the 30's. Among the topics covered are the economic location of roads and landings, economic service standards for roads and the selection of logging equipment by economic criteria. Despite the voluminous research that has been inspired, at least in part by this book it remains the only English language text written specifically on the topic of forest engineering economics. Poorly referenced, a major weakness of this text is its lack of a bibliography.

In 1947, the American Pulpwood Association initiated the Technical Release series oriented toward solving problems and presenting innovative ideas for loggers. Each monthly mailing to the Association membership contained several "Releases," each devoted to a single topic. In many cases these were written by the logger who actually developed the problem solution. Approximately 100 of these articles are published each year. While they normally are not written or reviewed by professional engineers, many do address the art and occasionally the science of forest engineering. These articles, although not of the technical quality exhibited in the early PLC papers, probably served to fill some of the void created as the PLC departed from its strong technical beginnings and became more of a social and trade organization.

A second contribution from the University of Edinburgh appeared in 1951 in the form of *Forest Engineering Roads and Bridges*.[36] James L Harrison had been Forest Officer in India and following his retirement from foreign service he lectured on forest engineering and utilization at Edinburgh. This text discusses road reconnaissance and location, drainage structures, quarrying, retaining walls and river crossings. Harrison points out the essential need for a transportation network regardless of the particular logging system to be used. This textbook is one of the first to offer rigorous engineering analysis directed at bridge and retaining wall structures typical of forestry operations. This book represents an engineering version of the type of text written by Schenck or Bryant.

With the exception of the text by Harrison the previously mentioned books dealt with forest engineering topics in a descriptive fashion, lacking engineering analysis and synthesis. Filling this void are a number of manuals and handbooks.

Logging and forest road construction appeared as chapter topics in the *Forest Handbook for British Colombia* in 1953.[37] The original *Handbook* was primarily written by students at the University of British Colombia, under the direction of John (Jack) Walters. Walters was later to become internationally recognized for his work in developing a mechanical tree planter and serving as one of the first chairmen of the Forest Machine Committee of the American Society of Agricultural Engineers. It is interesting that this handbook had two sections devoted to engineering topics. The first, simply titled "Engineering," dealt with planning issues such as surveying and setting layout. The second section was titled "Logging Safety," and consisted of seven pages of direct quotations from the new British Columbia Safety code, implemented by the Workman's Compensation Board on September 1, 1950. This handbook is currently in its fourth edition.

In 1955 the Society of American Foresters published its first handbook, the *Forestry Handbook*.[38] A committee led by A.M. Koroleff of the Pulp and Paper Research Institute of Canada prepared the chapter on logging. The chapters on road engineering and surveying were prepared by a committee chaired by Anthony P. Dean of the U.S. Forest Service. A total of 167 pages of this handbook are dedicated to forest engineering, which is indicative of the need for published materials at the time. Although not explicitly an engineering handbook the *Forestry Handbook* is a common reference book in the libraries of most forest engineers.

A *Forester's Engineering Handbook* was written by Eric R. Huggard, a lecturer in forest engineering at the University College of North Wales, in 1958.[39] It covered the familiar topics of surveying, road and bridge design and construction, use of explosives, and timber extraction.

The United Nations through the Food and Agriculture Organization has also published a variety of manuals starting with one that gives a good blend of practical application and theory, *Tractors for Logging*.[40] In 1958, the United Nations Economic Commission for Europe (ECE) and the Food and Agriculture Organization of the United Nations (FAO) formed a joint FAO/ECE Committee on Forest Working Techniques and Training of Forest Workers. An International Training Course on Mechanized Forest Operations was held in Sweden in 1959, and a lengthy publication of this work was published by the U.N. in 1960.[41] Topics included equipment analysis, work-study, transportation systems, road standards, detailed descriptions of logging systems, and even human physiological requirements related to woods operations. Many of the topics, including some of the same diagrams, still appear in the current research literature. Several additional manuals of interest have been published by FAO.[42, 43, 44, 45]

A short time later, J. Kenneth Pearce of the University of Washington published the first of several versions of the *Forest Engineering Handbook*.[46] Pearce is a registered civil engineer but his handbook is written for practitioners who may not have had formal engineering training. It also filled an important gap in the literature because it was specifically written for use in western North America where European literature had not gained wide acceptance.

During this same period in Canada Lussier published a textbook dealing with the application of management science techniques to forest engineering problems. This book has stimulated numerous research papers and remains an excellent source of material for both teaching and research.[47]

Another publication which has been reprinted in several versions and has served as source material for several texts is the Skyline Tension and Defection Handbook, by Hilton Lysons and Charles Mann.[48] The authors presented tables and graphical techniques to aid in the design of skyline yarder settings. Presented in 1967, these techniques became the standard yarder setting design guide until they were replaced by computer techniques in the early 1980's.[49]

Several descriptive manuals of logging operations were published by the U.S. Forest Service during the 1970's.[50, 51, 52] Norman Sears was responsible for initiating a continuing series of publications known as *Engineering Field Notes*.[53] While this series is intended as a U.S. Forest Service internal communication network to provide guidance on engineering methods, information exchange, continuing training and awareness of new developments and technical literature, the *Notes* are widely distributed and commonly used by the forest engineering community.

It was not until 1972 when J. Kenneth Pearce and George Stenzel published *Logging and Pulpwood Production* that a textbook was written in the United States as a replacement for the texts of the 1910-40 era.[54] This text addresses the same familiar topics as earlier published handbooks, but with much more attention to referenced research and some attempts to expose basic principles as well as problem solutions. By contrast, Steve Conway's books, *Timber Cutting Practices*[55] and *Logging Practices*,[56] contain detailed descriptions of logging practices, but are of limited scholastic value due to scant reference to research papers and the absence of any discussion of fundamental engineering principles.

In 1974, the Woodlands Research Division of the Pulp and Paper Research Institute of Canada and the Logging Development Program of the Canadian Forestry Service were merged to form the Forest Engineering Research Institute of Canada (FERIC). With a 1990 budget in excess of seven million dollars and a Canadian staff of 84 people, this cooperative government-industry alliance is the largest and most prolific source of forest engineering literature. Major activity areas are harvesting, secondary transportation, silvicultural operations and woodlot technology. They have staff support in the areas of design engineering, instrumentation and computers, and library functions. Their Log Bridge Construction Handbook is indicative of their orientation toward the forestry construction practitioner rather than the design engineer.[57] Although it lacks much needed engineering analysis this manual is an excellent handbook for field design of log stringer bridges.

The following two manuals are characteristic of the vast quantity of published material from a variety of sources. The manual *Trucks and Trailers and Their Application to Logging Operations* by J. McNally represents a good blend of analytical and descriptive material.[58] The *Manual for Roads and Transportation*, most recently revised by David Holmes in 1978 and brought out in two volumes, is an excellent textbook for students.[59] It employs a good blend of numerical analysis with the practical and descriptive. These two manuals and many others of similar high quality have been published but are not widely distributed.

A number of forest engineering texts and references have been generated by European authors during the 1980's. Ivar Samset from the Norwegian Forest Research Institute produced a very complete cable logging text written in Norwegian. Fortunately, *Winch and Cable Systems* was translated into English in 1985.[60]

In 1981, the Skogsarbeten organization in Sweden produced three volumes on forest machinery systems. Unfortunately, the *Terrangmaskinen* series 32 was only available in Swedish until 1989, when the first volume was translated into English.[61, 62] The excellent diagrams used in these books provide a valuable resource even if the reader does not understand the written text.

Tree Harvesting Techniques was written by K.A. F. Staaf from the Swedish University of Agriculture at Uppsala and N.A. Wiksten.[63] This text appears to rely heavily on earlier Swedish works and is clearly a descendent of the FAO/ECE work listed above. The two volumes on *Operational Efficiency in Forestry* edited by U. Sunburg from the Swedish University of Agricultural Sciences at Farpenberg and C.R. Silversides from the Canadian Forestry Service also seem to have grown from the FAO/ECE roots.[64] This is the first book to seriously address such things as ergonomics of forest operations, problem analysis, energy analysis and the interaction between the stand, the prescription and the machine. Measurements and logging systems are confined to four pages.

Another step in the development of the forest engineering literature occurred in late 1989, when *The Journal of Forest Engineering* began to be published under the sponsorship of the Forest Engineering Department at the University of New Brunswick. Representatives of 12 countries sit on the editorial board, so it is clear that an international scope is intended.

Challenges for the Future

The development of the forest engineering discipline and its literature has been influenced by western society's deep concern for the world's forests and by a pragmatic need for wood based products. It is reasonably clear from the literature however that the discipline has spent the last 80 to 100 years responding to the change in technology and the shifting emphasis on environmental concerns, as opposed to building a foundation from which tomorrow's new technology and solutions will arise. The result is a discipline with a body of literature that has never developed a cohesive framework of information that can serve to increase the awareness of a novice or enhance the analytical and design capabilities of advanced students. A perusal of the forest engineering literature would lead one to conclude that forest engineering design, the area of synthesizing new solutions, is not dependent upon analysis but rather upon an orally transmitted collection of field procedures.

The forest engineering profession now faces a serious challenge. Scholars must address the need for a literature that will serve to fully describe and define forest engineering. This new literature must not be merely descriptive nor handbook presentation of known solutions of limited analytical value. This new literature must present a synthesis of the dispersedly published engineering analysis that has been directed at forestry problems.

Practitioners are also facing serious challenges that call for innovative solutions not to be found in the handbooks. Low elevation second-growth stands in the Pacific Northwest are being harvested and are the focus of intensive management activity. These stands, as compared to the old-growth stands of former years, have more homogeneous timber located on gentler terrain. Road location and logging are not as challenging in this regard. The use of computers has greatly reduced office engineering time, thus a given quantity of design activity can be accomplished with fewer engineer hours. Easier conditions for roading and harvesting have reduced the obvious financial benefit associated with careful planning and engineering design.

If planning and conducting the roading and harvesting operation have been made easier by the terrain and technology, in at least two aspects it has become, and will become, much more difficult. First, the large and highly valuable logs of the old-growth forest have been replaced with small diameter lower value logs. This change in log size and value has made log handling critical to the profitability of a logging enterprise. The homogeneous nature of the timber resource better lends itself to mechanized harvesting and handling operations than did the old growth timber. Successful mechanized logging operations are highly engineered systems. Second, increased recognition and legislation for the protection of the public resources of air, water, fish and wildlife have placed major constraints on timber harvesting and other forest management activities. The resources belonging to society at large cannot be dismissed as illegitimate or ephemeral concerns. It is here that the forest engineer can make a substantial contribution to the forestry industry and to society. The engineering design of forest roads, harvest systems, or other forest management operations is the key to the integration of the many constraints currently placed on forest management and utilization. To the extent that engineering skills and accountability can contribute to the identification and implementation of environmentally acceptable, ecologically desirable and financial attractive management and harvesting activities forest engineers must be involved.

The future of the profession depends on practicing forest engineers and educational institutions cooperating to redefine the areas of technology or bodies of knowledge that constitute forest engineering. The continued development of forest engineering should address the technology and problems of today and anticipate those of tomorrow. It is also the time to examine the profession in a new way, not engineering with some forestry, nor foresters with some engineering, not even a hybrid engineer-forester, but as a distinct profession and academic discipline.

References

1. Fernow, B.E. *A Brief History of Forestry*, Toronto: University Press, 1913. pp. 377-78.

2. Schlich, William. 1908. *Schlich's Manual of Forestry*, 2nd edition. In five volumes. Vol. V, "Forest utilization", English translation by W.R. Fisher of *Die Forstbenutzung* by Karl Gayer. Bradbury, Agnew & Co., Ltd., London.

3. Hosmer, R.S., "Forestry at Cornell" Ithaca, N.Y. Dec 1950.

4. Fernow, Bernard E. 1901. "The forester, an engineer". Journal of the Western Society of Engineers VI(5):402-420.

5. O'Hearne, J. "How Shall We Teach Logging Engineering," 8th Annual Session, Pacific Logging Congress, 1913.

6. Schenck, C.A. 1912. *Logging and Lumbering or Forest Utilization; A Textbook for Forest Schools.* L.C. Wittich, Darmstadt, Germany. 189 pp.

7. Bryant, Ralph Clement. 1913. *Logging; The Principles and General Methods of Operation in the United States.* John Wiley & Sons, Inc., New York, N.Y. 590 pp.

8. United States Forest Servie. 1942. *History of Engineering in the Forest Service, 1905-1969.* USFS Engineering Staff. Washington, DC. 777pp.

9. Clark, E.T. "Logging Engineering Should Be Recognized by Institutions of Learning," 4th Annual Session, Pacific Logging Congress, 1912.

10. Cornwall, G.M. "Development of the Logging Industry of the Pacific Coast States," 1st Annual Session, Pacific Logging congress, in *The Timberman,* X:32, 1909.

11. Ibid.

12. Lamb, Frank. "Logging Engineering Requires Skill and Experience for Success," 1st Annual Session, Pacific Logging Congress, in *The Timberman,* X:32, 1909.

13. Andrews, W.T. "Introduction to the Practical Teaching of Logging Engineering and Lum-ber Manufacture at the University of Washington," *Forest Club Annual,* University of Washington, IV:3:34-37, 1925.

14. Clark, op. cit.

15. Fridley, J.L. and P. Schiess. 1989. A successful senior forest engineering capstone design course. ASAE Pap. No. 89-5510.

16. Davies, W. A. "Western Logging Engineering Schools -- Oregon State College," 42nd Annual Session, Pacific Logging Congress, in *Loggers Handbook,* XT:87-89, 1951.

17. Van Orsdel, J.P. Presentation of Logging Engineering Curriculum at the Oregon State Agricultural College, 8th Annual Session, Pacific Logging Congress, 1916.

18. Davies, op. cit.

19. Cornwall, G.M. "The Profession of Logging Engineering." *Forest Club Quarterly,* University of Washington, C:17-19, 1922.

20. Munger, T.T. "Objectives of the New Federal Forest Experiment Station," 15th Annual Session, Pacific Logging Congress, 1924. p. 6-7.

21. Fernow, op. cit.

22. United States Forest Service. *Engineering Field Tables,* Washington: U.S. Government Printing Office, 1935.

23. Davies, op. cit.

24. Besley, L. "Western Logging Schools -- University of British Columbia," 42nd Annual Session, Pacific Logging Congress, in Loggers Handbook, XI:79-84, 1951.

25. Basinger, D.H. "The Status of Forest Taxation in the State of Washington," *Forest Club Quarterly,* University of Washington, XV:2:17-20, 1941.

26. Webster, Lloyd T. "Washington's forest practices act" University of Washington, Forest Club Quarterly XIX(1,2,3):5-7, 1945-46.

27. Markworth, G.D. "Western Logging Engineering Schools -- University of Washington," 42nd Annual Session, Pacific Logging Congress, in Loggers' Handbook, XI:85-87, 1951.

28. Richardson, B.Y. Foreword to the Proceedings of the Forest Engineering Conference, American Society of Agricultural Engineers, Michigan State University, East Lansing, September 25-27, 1968.

29. Coughran, S.J. Opening Remarks, Proceedings of the Forest Engineering Conference on Education, American Society of Agricultural Engineers. Chicago, December 8-9, 1969.

30. ASAE. *Forest Regeneration.* Proceedings of a Symposium on Engineering Systems for Forest Regeneration, March 2-6, Raleigh, North Carolina. ASAE Publication 10-81.

31. Steward, J.P. *Manual of Forest Engineering and Extraction.* London: Chapman and Hall., 1927.

32. Brown, Nelson C. *Logging - Principles and Practices in the United States and Canada.* New York: John Wiley. 1934.

33. Brown, Nelson C. *Logging - Transportation; the Principles and Methods of Log Transportation in the United States and Canada.* New York: John Wiley. 1936.

34. Brown, Nelson C. *Logging; The Principles and Methods of Harvesting Timber in the United States and Canada.* New York: John Wiley. 1949.

35. Matthews, D.M. 1942. *Cost Control in the Logging Industry.* McGraw-Hill, New York, N.Y. 374 pp.

36. Harrison, J.L. *Forest Engineering Roads and Bridges.* Edinburgh: Oliver and Boyd, 1951.

37. Walters, J. *Forest Handbook for British Columbia,* 1st Ed. Vancouver: University of British Columbia, 1953.

38. American Society of Foresters, R.D. Forbes, ed. *Forestry Handbook.* New York: Ronald Press, 1955.

39. Huggard, E.R. Foresters' Engineering Handbook. Bangor: University College of North Wales, 1958.

40. United Nations. 1956. Tractors for Logging. FAO Forestry Development Paper No. 1, Rome, Italy. 189 pp.

41. United Nations. ECE/FAO Joint Committee of Forest Working Techniques and Training of Forest Workers. Geneva, 1960.

42. United Nations. 1974. *Logging and Log Transport in Tropical High Forest.* FAO Forestry Development Paper No. 18, Rome, Italy. 90 pp.

43. United Nations. 1976. *Harvesting Man-made Forests in Developing Countries.* FAO, Rome, Italy. 185 pp.

44. United Nations. 1977. *Planning Forest Roads and Harvesting Systems.* FAO Forestry Paper No. 2, Rome, Italy. 148 pp.

45. United Nations. 1978. *Assessment of Logging Costs from Forest Inventories in the Tropics.* In two volumes: Vol. 1, "Principles and methodology" 50 pp.; Vol. 2, "Data collection and calculations" 74 pp. FAO Forestry Papers 10/1 & 10/2, Rome, Italy.

46. Pearce, J.K. *Forest Engineering Handbook.* Oregon State Office: Department of the Interior, 1961.

47. Lussier, L.J. 1961. *Planning and Control of Logging Operations.* Forest Research Foundation, Université Laval, Québec, Canada. 135 pp.

48. Lysons, H. and C. Mann. *Skyline Tension and Deflection Handbook, PNW 39.* Washing-ton: U.S. Government Printing Office, 1967.

49. Binkley, Virgil W. and John Sessions. 197?. *Chain and Board Handbook for Skyline Tension and Deflection.* USDA FS PNW Region. GPO 799-549. 193 pp.

50. Simmons, Fred C. 1979. *Handbook for Eastern Timber Harvesting.* USDA FS NE Area State & Private Forestry, Broomall, PA. 180 pp.

51. McGonagill, Keith L. 1978. *Logging Systems Guide.* USDA FS Alaska Region, Div. of Timber Management, Series No. R10-21. 362 pp.

52. Studier, Donald D. and Virgil W. Binkley. 1975. *Cable Logging Systems.* O.S.U. Book Stores, Inc., Corvallis, OR. 211 pp.

53. United States Forest Service. *Engineering Field Notes.* Washington: United States Department of Agriculture, 1969+.

54. Pearce, J.K. and G. Stenzel. *Logging and Pulpwood Production.* New York: Ronald Press, 1972.

55. Conway, S. *Timber Cutting Practices.* San Francisco: Miller Freeman Publishers, 1968.

56. Conway, S. *Logging Practices.* San Francisco: Miller Freeman Publishers, 1976.

57. Nagy, Michael M., J.T. Trebett, G.V. Wellburn and L.E. Gower. 1980. *Log Bridge Construction Handbook 1980.* Forest Engineering Research Institute of Canada Handbook No. 3., Vancouver, B.C. 421 pp.

58. McNally, J.A. 1975. *Trucks and Trailers and Their Application to Logging Operations.* University of New Brunswick, Department of Forest Engineering. Fredericton, New Brunswick.

59. Holmes, David C. 1978. *Manual for Roads and Transportation.* Revised Edition in two volumes, British Columbia Institute of Technology, Burnaby, B.C.

60. Samset, I. *Winch and Cable Systems.* (Translated from Norwegian) Dordrecht: Martinus Nijhoff/Dr. W. Junk Publishers, 1985.

61. Malmberg, C-E. *Terrangmaskinen,* 3 vols. Stockholm: Skogsarbeten, 1981.

62. Malmberg, C-E. *The Off-Road Vehicle*. (Translation of Terrangmaskinen, Vol. 3) Montreal: Joint Textbook Committee of the Paper Industry, 1989.

63. Staaf, K.A.G. and N.A. Wiksten. *Tree Harvesting Techniques.* Dordrecht: Martinus Nijhoff/Dr. W. Junk Publishers, 1984.

64. Sunburg, U. and C.R. Silversides, eds. *Operational Efficiency in Forestry,* 2 vols. Dordrecht: Martinus Nijhoff/Dr. W. Junk Publishers, 1988.