Daryl B. Simons—Hydraulic Engineer, Researcher, and Educator

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Introduction

Daryl B. Simons is remembered for his hard work, dedication, and perseverance as an hydraulic engineer. This article describes his life and professional contributions to sediment transport, river engineering, and fluvial systems. It also briefly covers his education, teaching, and research activities; and his contributions to the development of research facilities and to the profession of hydraulic engineering. This Forum article portrays Daryl from the professional interactions with the authors in the past five decades.

Early Life

Daryl Baldwin Simons was born on February 12, 1918. His parents, Ezra Ord and Effie May, lived in Payson, Utah. He had four sisters, Geneve, Frances, Catherine, and Florence, and two brothers, Keith and John. Daryl lost his parents in 1923 at the early age of 5 when his oldest brother Keith was 17. However, he and his siblings stayed together during their formative years and managed their farm in Salem, Utah. Daryl became handy with the short handle hoe, thinning sugar beets, picking tomatoes, milking cows, harvesting peas, and using the irrigation shovel. He knew what it was like to be at the end of the ditch with a good water right but having upstream neighbors with a shovel.

When Daryl graduated from high school, he had decided that farming was not for him. A local carpenter who earned $10 a day building granaries, chicken coops, and a few homes became his role model. The family plan was for him to attend Utah State Agricultural College (now Utah State University) at Logan, Utah, and complete a two-year trade school course in carpentry. Working as a farm hand, he accumulated $150 and finished his first year in carpentry. In the second summer, working with his younger brother John, they saved another $150. It was decided that Daryl would use it all to complete his carpentry education, which he did in 1940.

To gain more experience in carpentry, he hired out in the summer of 1940 with two other graduates of the carpentry class to George Clyde, dean of engineering at Utah State Agricultural College, to build a house. Clyde was a very profane taskmaster and was upset about losing tools from his locked compound. Coming to check on the work one morning, Clyde found a person inside the locked compound. Clyde entered and promptly threw the intruder over the fence. It turned out that the intruder was one of the carpenters he had hired. When only Daryl was left, Clyde asked him why he put up with him and had not quit. Daryl replied, "You don't know my older brother." That fall, Clyde convinced Daryl to return to school and become an engineer. That meant four more years, but Clyde assured him that the means would be forthcoming. The following spring (1941), the war in Europe triggered a building boom in Ogden, Utah. Daryl was able to earn $1.10 an hour and work up to 100 hours a week. It looked like the wealth of the Incas, and his financial troubles were over. He had the means to concentrate on his studies and excel as a student, where he moved to the top of his class.

After the attack on Pearl Harbor on December 7, 1941, Daryl's ROTC unit was called up, and his studies were interrupted until 1946. He entered the U.S. Army in April 1943. Through combat in the 83rd Division of Patton's Third Army, he advanced to the rank of first lieutenant in command of an 81-mm mortar platoon. He was quite proud of his U.S. Army stint and never hesitated to enlighten his colleagues, students, and others regarding his experiences during this challenging time of his life. After combat, he was retained in Europe as a captain and unit commander in the U.S. Army Corps of Engineers. Near the end of World War II, he attended engineering classes in England. His persistence in asking questions during a lecture resulted in him being admonished that, in England, you do not interrupt the professor, period.

Engineering Education

Daryl received a B.S. in civil engineering from Utah State University, in Logan, Utah, in 1947. Daryl continued his education at Utah State University, completing his M.S. in civil engineering in 1948, specializing in hydraulics and structures. After his master's degree from Utah State University, Daryl joined the University of Wyoming in Laramie, as a professor of civil engineering. During this time he served as a consultant for Banner and Associates, a Wyoming engineering firm. He worked on the design of airports, water supply network, flood control, drainage, sewage systems, and other civil engineering infrastructure works.

In 1957, Daryl earned his Ph.D. in civil engineering under the guidance of Professor Maurice Albertson at the Colorado A&M College (now Colorado State University) in Fort Collins, Colorado. His area of specialization was irrigation, hydraulics, and river mechanics. His dissertation was entitled "Theory and Design of Stable Channels in Alluvial Materials" (Simons 1957). Daryl always remarked that his mentors, Emory Lane, Paul C. Benedict, Donald Bondurant, and Whitney Borland, set the course of his career. His paper based on his Ph.D. dissertation (Simons and

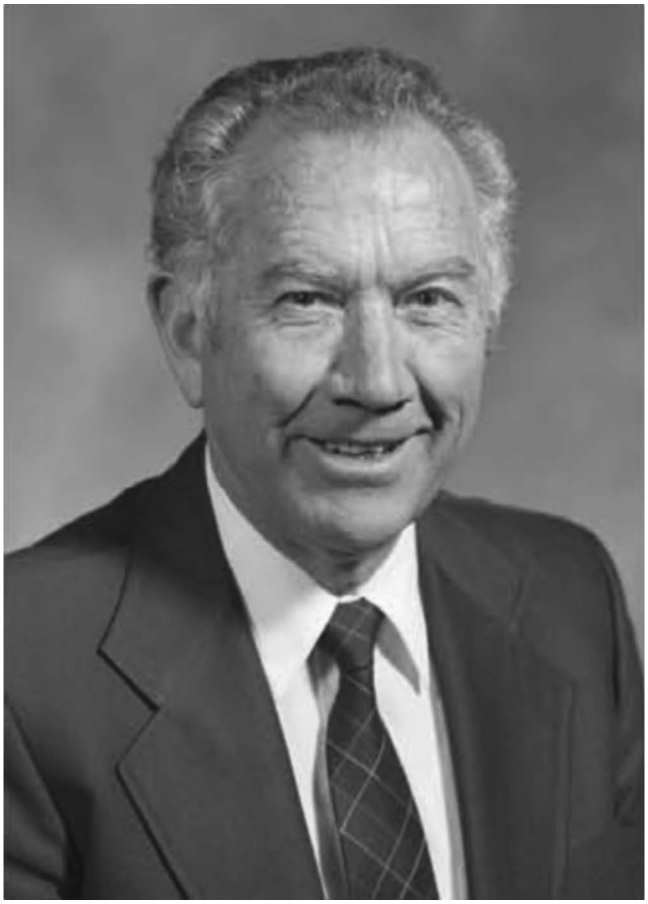

Fig. 1. Dr. Daryl Baldwin Simons (Courtesy of Mary Jo Simons)

Albertson 1960) was published in the Journal of the Hydraulics Division of ASCE and has been extensively used and referenced by numerous students, professionals, and consultants. Their subsequent paper in 1964 was awarded the ASCE's Croes Medal for an article contributing to advances in engineering science. Daryl's education never stopped after receiving his Ph.D. He continued his thirst for knowledge by exploring, reviewing, and reading advances made by others. Throughout his career, Daryl had an enjoyable personality (Fig. 1) and always welcomed good discussions and new ideas.

The USGS Years

From 1957 through 1963, Daryl took a position as project chief with the U.S. Geological Survey at the Colorado A&M College in Fort Collins, Colorado. This is the time when Daryl, with his colleague Everett V. Richardson, conducted what was probably one of the most comprehensive laboratory and field experiments on sediment transport within the U.S. Geological Survey. Daryl was hired to lead the research by Paul C. Benedict, director of research for the Quality of Water Branch of the Water Resources Division of the U.S. Geological Survey (WRD/USGS). Richardson was selected for the research by Rolland Carter, director of research for the Surface Water Branch. The objective of their research, as explained to them at a meeting under a tree on the Oval at Colorado A&M College by Dr. Luna Leopold (then recently appointed Director to the WRD/USGS), was to unravel the many complexities of surface water flow in alluvial channel flow.

Fig. 2. Meeting with Daryl Simons (far left), Tom Blench (second from left), Hans Albert Einstein (third from left), Whit Borland (fourth from right), Vito Vanoni (far right), and others

In a hydraulics division paper based on his own Ph.D. dissertation under Vito Vanoni at California Institute of Technology, Norman Brooks had stated that there was no relation between discharge and depth, width, and slope in alluvial sand bed channels. This caused quite a stir with much discussion by Dr. Hans Albert Einstein (Fig. 2). The whole story is given in the 1958 *ASCE Transactions* (Brooks 1958). In a nutshell, Simons and Richardson's tasks were to determine if Brooks was right and to determine a relationship between water and sediment discharge in alluvial sand channels.

From 1956 to 1961, they conducted 343 flume experiments (runs) on sediment transport and resistance to flow in alluvial sand bed channels. The d_{50} of the sand sizes ranged from 0.19 mm to 0.93 mm. They also conducted field studies on the Rio Grande, the Low Flow Conveyance Channel in New Mexico, and Middle Loup River in Nebraska as well as reviewed other sand bed rivers worldwide, e.g., the Indus, Ganges, Brahmaputra, Padma, Rio San Francisco, and Orinoco Rivers and their tributaries. From their research, they determined that there is a relation between discharge, slope, depth, and width in alluvial sand channels if the bed configuration (bed form) is known. Based on their experiments shown in Fig. 3, they proposed a bed form classification in Fig. 4. The classification identifies sand bed streams into a lower flow regime and an upper flow regime, with a transition between the two on the basis of bed configuration, bed material transport concentrations, and resistance to flow (Simons and Richardson 1961). The lower flow regime had a bed form of ripples and dunes with low bed material concentrations and large resistance to flow. The upper flow regime had high bed material concentrations and low resistance to flow. Some of the classic technical papers based on their experiments include Simons et al. (1962), Simons and Richardson (1962), Simons et al. (1963), and Simons and Richardson (1966). The authors of this article know that several dozen M.S. and Ph.D. dissertations were completed in the U.S. and around the world based on these data collected by Simons and Richardson (Richardson and Simons 1961; Guy et al. 1966). Many other papers and articles were subsequently written by Simons and Richardson in collaboration with Haushild, Nordin, and many others on this laboratory experimental work.

Dawdy (1961), Colby (1960), Beckman and Furness (1962),

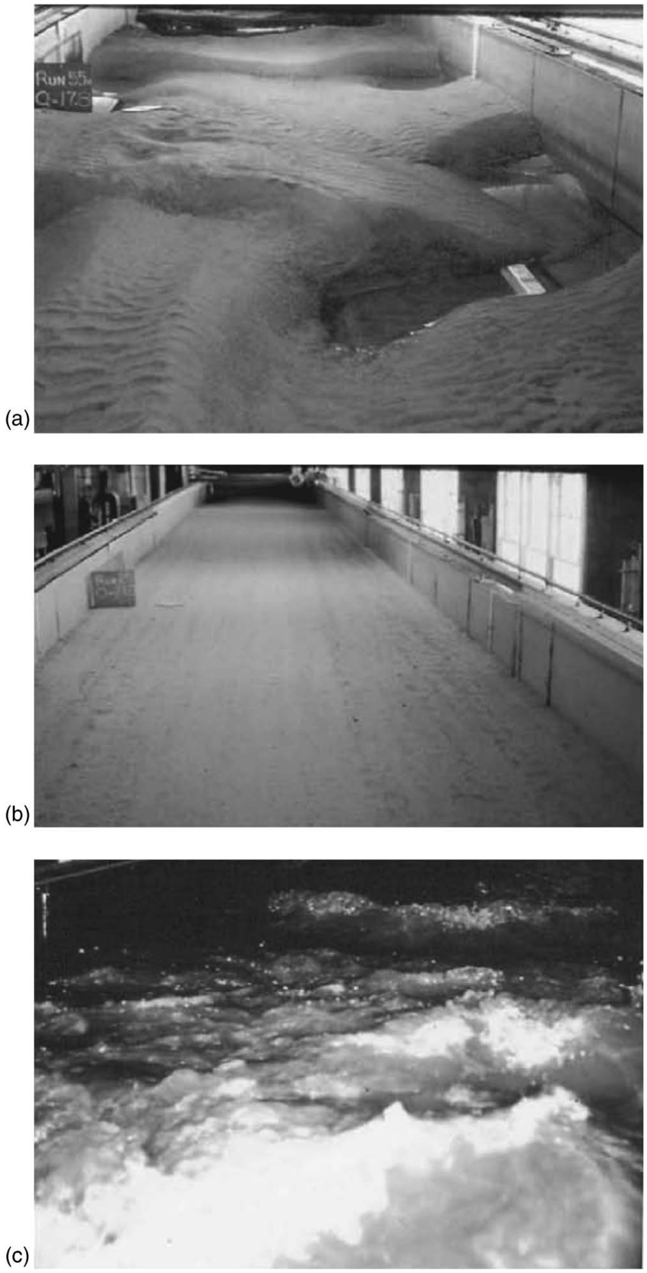

Fig. 3. Bed form in 8 ft flume at Colorado State University (Courtesy of E.V. Richardson)

and Nordin (1964) classified bed forms and related resistance to flow on the basis of Simons' and Richardson's research papers. They analyzed the available stage discharge relations for alluvial sand channels. Their analysis revealed that there were discontinuous rating curves in alluvial sand channels and that indeed the shape of these rating curves were similar to those predicted by Hans Albert Einstein in his discussion of Brooks' 1958 ASCE paper. Some of the early pioneers of the sand bed channel research team are shown in Fig. 5.

A little known fact about Daryl Simons is that in 1955 he conducted a study and wrote a special report for Emory Lane on the angle of repose of non-cohesive rock. The rock ranged in size from 0.25 mm to 0.61 m and in shape from very rounded to crushed ledge rock (Simons 1955). The figure he developed (Fig. 6) for his report to Lane was reproduced in the Federal Highway Administration (FHWA) report and has been reproduced in many other publications (Richardson et al. 2001).

The CSU Years

In 1963, Daryl left the U.S. Geological Survey and joined the Civil Engineering Department at Colorado State University (CSU) as a professor teaching erosion and sediment transport, river mechanics, hydraulic structures, characteristics of rivers, mechanics of sediment and water discharge in alluvial streams and rivers, soil mechanics, fluid mechanics, and related subjects. Daryl, with his students Michael Stevens, Gary Lewis, and Fred Watts, developed equations and design methods for flood protection at culvert outlets and the sizing of riprap to protect stream bed and banks from erosion. The riprap design incorporated the bank slope, angle of repose of the rock material, and a safety factor, which was a first (Simons and Lewis 1970; Stevens and Simons 1971; Stevens et al. 1971, 1974) in the design of riprap work. Working with Michael Stevens and Stanley Schumm, Daryl quantified the changes of the middle Mississippi River as the result of flood control and navigations improvements (Simons et al. 1974; Stevens et al. 1975). They showed that the construction of levees decreased the river stage at low flow but increased the stage during floods.

In 1965, in addition to his teaching, research, and graduate student supervision, he assumed the responsibility of director of the Hydraulics Laboratory, head of the Civil Engineering River Mechanics and Hydraulics Program, associate director of the Experimental Station, and associate dean for research for the College of Engineering (Rouse 1980). He retained all four positions until he retired in 1983. During this period he was involved in the areas of administration, teaching, research, consulting and public service.

Daryl was also deeply involved in many national level committees including numerous Sedimentation and River Engineering committees of the ASCE; the International Commission on Irrigation and Drainage (ICID); the International Association for Hydraulic Research (IAHR); the American Association for the Advancement of Science (AAAS); the U.S. Committee on Irrigation, Drainage and Flood Control; the American National Standards Institute (ANSI); the Highway Research Board; the National Research Council; the International Affairs Committee of National Association of State Universities and Land-Grant Colleges; and the UCOWR Committee on Education and Research in Water Resources Engineering. Daryl is pictured with Abel Wolman (Fig. 7) and with Hunter Rouse at his CSU retirement symposium in 1986 (Fig. 8).

By the end of the 1970s, Daryl's teaching had become highly innovative and popular. For instance, his summer short course on "Analysis of Watershed and River Systems" attracted more than 50 graduate students and practitioners every summer. He would provide ample lecture notes (a three-inch thick binder with material printed back to back) for this one-week short course. He showed films on laboratory experiments on flows in alluvial channels and video footage of computer modeling results for complex flows around locks and dams and a variety of flood control structures.

Daryl authored or coauthored more than 450 scientific publications, including the following books and manuals:

- *Fluid Mechanics for Engineers* by Maurice L. Albertson, James R. Barton, and Daryl B. Simons, 1960.

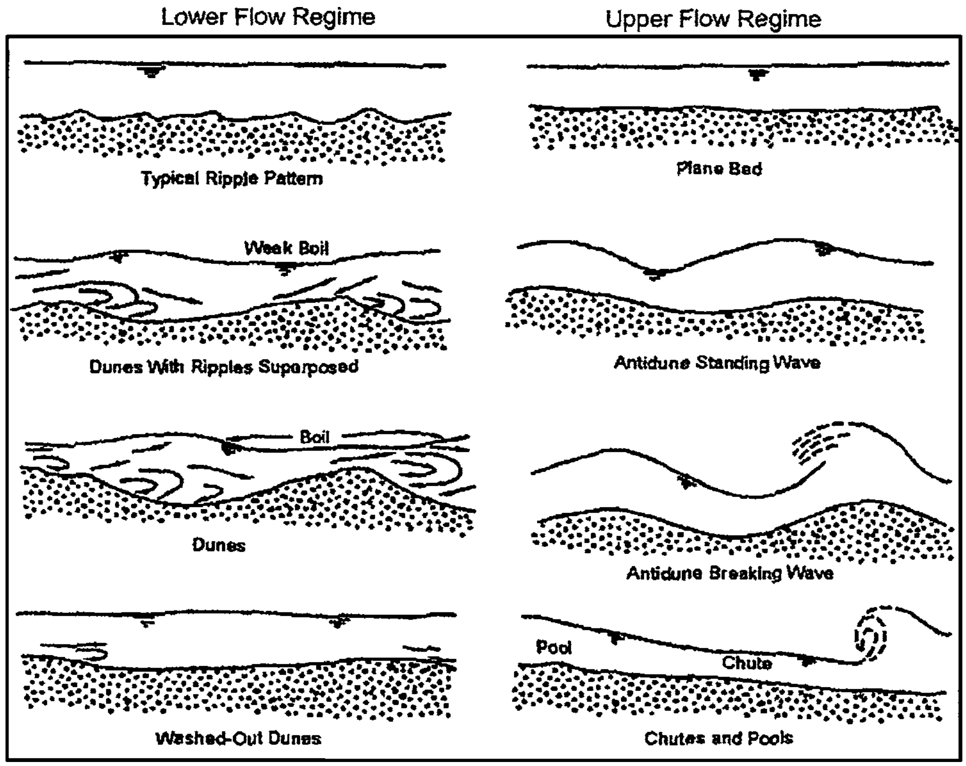

Fig. 4. Forms of bed roughness in sand channels (Simons and Richardson 1963)

- *Sediment Transport Technology* by Daryl B. Simons and Fuat Senturk, 1977 (new edition released in 1989).
- *Engineering Analysis of Fluvial Systems* by Simons, Li and Associates, 1982.
- *Highways in the River Environment, Hydraulic and Environmental Design Considerations* by Everett V. Richardson, Daryl B. Simons, Susumu Karaki, Khalid Mahmood, and Michael A. Stevens, 1975; Revised edition in 1990 by E.V. Richardson, D.B. Simons, and P.Y. Julien.

Fig. 5. From left to right, Frank Ames, Daryl Simons, Thomas Maddock, James Brice, Paul Benedict, Maurice Albertson, Powder River, Wyoming, 1958 (Courtesy of E.V. Richardson)

- *River Engineering for Highway Encroachments* by Everett V. Richardson, Daryl B. Simons, and Peter F. Lagasse, 2001.

Selected publications by Daryl include Simons and Richardson (1961), Bhowmik and Simons (1969), Simons (1975, 1979), Simons et al. (1979), Simons and Li (1979), Julien and Simons (1985a,b), and Richardson et al. (2001). Numerous other reports and papers were also published by Daryl and his associates.

Research Facilities

As Associate Dean for Research, he played a critical role in the design and funding of the Engineering Research Center at the Foothills campus (see Fig. 9). In 1963, Dr. Morgan, president of Colorado State University, and his administration wanted the site of the Hydraulics Laboratory on campus for a newer and bigger Student Center. The original Student Center was built when Colorado A&M student enrollment was less than 2,000. With an enrollment of over 5,000 students and visions of a much larger student population, a new Student Center was vital for this growth. A very active research program at the Hydraulics Laboratory was under way. Daryl, working with Ray Chamberlain, Maurice Albertson, and the Administration, was able to move the Hydraulics Laboratory to a site below Soldier Canyon Dam of Horsetooth Reservoir on the Foothills campus by obtaining the needed additional financing from the State Legislature. The site was ideal for a hydraulics laboratory as it provides a large discharge (up to 14 cm) at very large head (107 m). In all, Daryl was able to obtain funds for and oversee the construction of the 36.6×85.4 m freestanding hydraulics, the fluid dynamics and diffusion laboratories, and a three-story office building (Fig. 9).

During this time (1963 to 1968), Everett Richardson, with funding from the U.S. Geological Survey and support from Daryl,

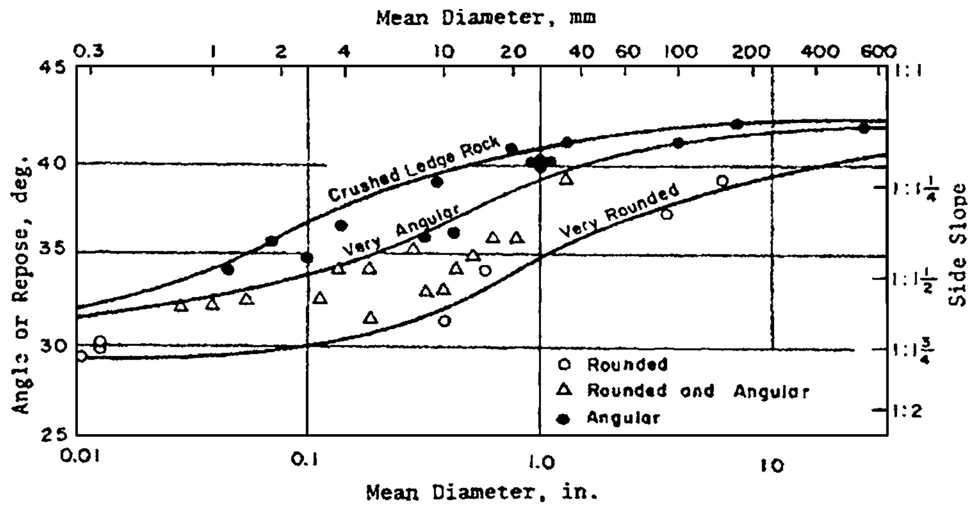

Fig. 6. Angle of repose of noncohesive materials (Simons 1955)

built the large sediment recirculating tilting flume at the Engineering Research Center (Foothills Campus). The flume measured 2.44 m wide by 1.22 m deep and 61 m ft long with a maximum discharge of 2.8 cm. The flume, which the graduate students in those days called the "Grand Canyon," became one of the focal points of research not only for the students, but also for the U.S. Geological Survey, U.S. Army Corps of Engineers, Federal Highway Administration, National Transportation Safety Board, and U.S. Bureau of Reclamation. Under Daryl's direction and efforts, a hydro-machinery laboratory, two very large outdoor flumes, a rainfall/runoff faculty, a structure laboratory, a solar research village, and atmospheric science center were built.

From 1960 to 1983, Daryl had enough time and energy to supervise 47 M.S. and 50 Ph.D. students (he completed several more Ph.D.'s at CSU after retirement). He was the recipient of many awards including the ASCE 1960 J.C. Stevens Award, the ASCE 1964 Croes Medal, the ASCE 1991 Hunter Rouse Award, and corecipient of the ASCE 1979 Karl Emil Hilgard Hydraulic Prize. In 1973, he was named outstanding professional engineer for Colorado.

International Contributions to Hydraulic Engineering

With a professional career spanning 55 years, Daryl B. Simons was an internationally recognized expert in the fields of hydraulics, hydrology, geomorphology, river mechanics, sediment transport, and hydraulic modeling. His teaching and research on sediment transport, river mechanics, and hydraulic structures at CSU and his supervision of hundreds of water-related projects around the world had contributed to this international reputation.

Daryl never stopped serving the people in his entire professional career. He began doing independent consulting following the completion of his Ph.D. and continued through the years in consulting projects throughout the world for the United Nations, the World Bank, the Inter-American Development Bank, the U.S. Bureau of Reclamation, the U.S. Army Corps of Engineers, the U.S. Forest Service, the Federal Highway Administration, and other federal and state government agencies and international groups. One of his first projects involved the design of the Link Canals, part of the Indus Basin Plan to redistribute water between India and Pakistan. Other locations for his work have included Egypt, Spain, Bangladesh (Simons 1970), Pakistan, India, Nepal (Simons 1979), Afghanistan, and many South American countries including Venezuela (Simons et al. 1971), Peru, Brazil, Chile, Argentina, Ecuador (Simons 1975), as well as much of the United States, Canada, and Mexico. In Egypt, he was asked to evaluate the potential degradation of the Nile River after construction of the High Aswan Dam (Simons 1965). His estimate was one of the

Fig. 7. Daryl Simons pictured with Abel Wolman

Fig. 8. Daryl Simons and his brother John (far right) pictured with Hunter Rouse (second from left)

Fig. 9. The Engineering Research Center

least conservative but still twice the maximum measured degradation of 1 m.

Daryl made many contributions to the engineering profession. Two very important international contributions deserve particular recognition: the Link Canals in Pakistan, which prevented one if not several wars between India and Pakistan; and his experimental research on the design of the flood control levees in East Pakistan (now Bangladesh).

Design of the Link Canals in Pakistan (1960s)

The design of the Link Canals in Pakistan was needed to provide water to the 2 million plus acres of irrigated land in the Punjab region of old India. In 1947, England relinquished its former colony, India. The "Old" India was partitioned into East and West Pakistan and India on the basis of religion (Karpov 1964). Using census figures and not geographic boundaries, Lord Mountbatten, Viceroy of India, divided Old India into MuslimEast and West Pakistan and Hindu India. The division, based on religion, disconnected the headwaters of the four rivers that furnished irrigation water to Pakistan's Punjab region. This had the potential of drying the Pakistani Punjab region up if India built dams on the headwaters to divert the water to irrigate her Punjab lands. The four rivers were the Sutlej, Chenab, Ravi, and Jhelum. These rivers were tributaries to the Indus.

Pakistan could not stand to have the potential of being deprived of her lifeblood (irrigation water) for her part of the Punjab. The World Bank developed the Indus Basin Plan for Pakistan. The essence of the plan was to build a dam on the Indus River at Tarbela (Tarbela Dam) to store water and large canals (221 cm to 935 cm capacity) from the Indus River to the four rivers that served the Pakistan Punjab. These Link Canals would furnish water from the Indus to the four rivers above the existing irrigation canals diversion structures. The Link Canals essentially replaced the water that India might take in the upstream area.

A major consideration was the design of stable canals to move the water (Simons 1970). A stable canal is one that has the proper slope, depth, and width to convey the irrigation water without erosion or deposition. Daryl (as a member of a committee composed of himself, Sir Gerald Lacey, and Thomas Blench) had a major role in the successful determination of the slope, width, and depth for these stable Link Canals (Fig. 10). India did construct dams on the headwaters of these rivers and used the stored water

Fig. 10. Construction of the Link Canals in Pakistan with (a) heavy equipment; (b) extensive labor

to irrigate the part of the Punjab that was within her borders. Thus, the Indus Basin plan contributed to the prosperity of both countries.

An interesting side light to Daryl's work on the committee occurred on his first trip to London. Daryl flew to London with Mr. Tipton of Tipton and Kalmbach, a civil engineering firm located in Denver, Colorado, to attend the first meeting of the Stable Canal Design Committee. He and Tipton were met at the airport by Sir Gerald Lacey. Sir Gerald Lacey's greeting was "You thought I was dead, didn't you?" In his dissertation, Daryl had referred to Sir Gerald Lacey in the past tense. Sir Gerald later visited Daryl and stayed at his home.

Flood Control in Bangladesh

Every year the peak flows of the Brahmaputra, Padma (Ganges), and Megna Rivers, which surround Bangladesh, flooded a major

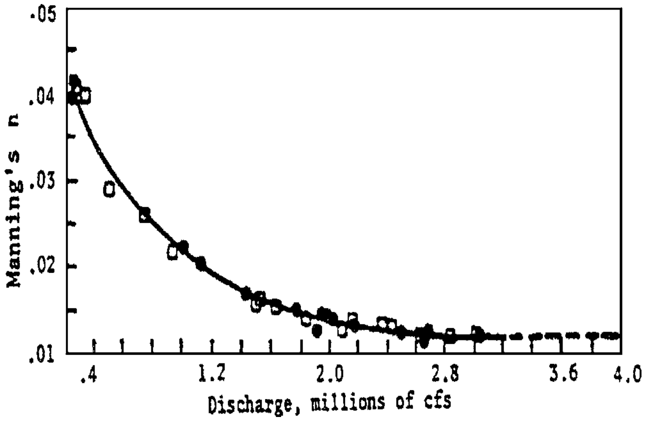

Fig. 11. Manning n versus discharge for the Padma River in Bangladesh (Simons and Senturk 1977)

portion of her farmland and cities for a couple of months. With the floods, the major crop of floating rice had very low yields (10 to 15 bushels per acre). To protect the lands from flooding, the World Bank proposed building levees on the banks of these three rivers. With the lands protected from flooding, a crop of high yielding rice could be grown (70 to 100 bushels per acre). Also, during the dry season, water would be pumped from the rivers to irrigate another crop of rice. In addition to the rice, other crops and vegetables would be grown. However, the design height of the levees was so high that the project was not economically feasible. They took too much land out of production and cost too much to build.

Daryl was a consultant to the World Bank for irrigation and flood control in Bangladesh. The original design of the levee height used a rigid boundary Manning n of 0.04. Based on his experiments at CSU, Daryl knew that this measurement was too large. He expected that the bed of the Brahmaputra, Padma (Ganges) and Megna Rivers would plane out at the very large flows in these rivers, flows up to 70,800 cm. At his suggestion, the United Nations Authority that was collecting flow data on these rivers measured the Manning n over a range of discharges at their gauging stations. Their engineers determined that Manning n decreased from 0.04 at low flow (113.3 cm to 283.2 cm) to 0.012 at high flows (56,640 to 70,800 cm) (see Fig. 11). The lower Manning n decreased the height of the levees to the point that flood control was economically feasible (Stevens and Simons 1973a,b).

Consulting Practices

Daryl was a registered Professional Engineer in Colorado, Wyoming, Arizona, New Mexico, and Nebraska. His professional society affiliations included the American Society of Civil Engineers (ASCE), the International Commission on Irrigation and Drainage (ICID), the International Association for Hydraulic Research (IAHR), and the American Geophysical Union (AGU).

In 1977, he started his first consulting firm with Everett Richardson, John Andrew, and Ronald Thaemert. He left that firm in 1979 to start Simons and Li Engineering, with Ruh-Ming Li (Simons and Li 1979). They changed the name in 1980 to Simons, Li and Associates, bringing in other people to work with them. By the time the firm moved to California in October 1984, it was employing approximately one hundred people. The firm

Fig. 12. Building Dedication Ceremony at Colorado State University, August 27, 2005

did extensive work for the U.S. Army Corps of Engineers, mostly focusing on the Mississippi, Ohio, Missouri, and Colorado Rivers. This work included development of a short course on geomorphology and river mechanics, a two-dimensional mathematical model for the upper Mississippi River, and several short films illustrating the dynamics of the river. Daryl then formed the firm of Simons and Associates in October 1984, and D.B. Simons and Associates, Inc. in 1998, which he closed in June 2004.

Daryl spent a major part of his late career as expert witness on more than one hundred court cases. When approaching Daryl to testify, one was always well advised to find out which side he would serve. Daryl had a tremendous record, winning just about 95% of his cases. Well past his eightieth birthday, he still had all the concentration required to withstand a day filled with five to six hours of grueling questions. His relentless energy is a trademark of the legacy he left to those who worked with him.

Epilogue

Daryl passed away on March 3, 2005, in Fort Collins, Colorado. On August 27, 2005, Colorado State University dedicated the Engineering Research Center Building at its Foothills campus as the Daryl B. Simons Building (Fig. 12). The dedication was in recognition of his lifelong contributions to the hydraulic engineering profession.

Acknowledgments

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