VITO A. VANONI (1904–1999): LEADER IN SEDIMENTATION ENGINEERING

Norman H. Brooks, Honorary Member ASCE[1]

A LONG CAREER

Vito Vanoni, born on August 30, 1904 in Somis, Ventura County, California, attended Caltech, earning a B.S., M.S., and PhD in civil engineering. After ten years in a research position in hydraulics at Caltech, Dr. Vanoni was appointed assistant professor of hydraulics at the California Institute of Technology in 1942, promoted to associate professor in 1949, and served as professor from 1955 until becoming professor emeritus in 1974 (Fig. 1). He remained professionally active almost until age 90, and died at age 95 on December 27, 1999.

Professor Vanoni was a world-renowned authority on the mechanics of transport of sediments by streams and rivers. His teaching and research were not only in the area of mechanics of sediment transport, but also included advanced hydraulics, hydraulic structures, and coastal engineering. In his quiet determined way, he contributed greatly to the robust development of the field of sedimentation engineering, especially through his pioneering flume experiments of suspended sediment transport of fine sands in the late 1930s (Vanoni 1940, 1946), and the publication of the famous book *Sedimentation Engineering, ASCE Manual No. 54,* edited and written in part by Vanoni (1975).

He encouraged fundamental research on sediment transport using modern fluid mechanics, and recognized the need for much more graduate-level education to support the advances in research and applications of sedimentation engineering. In his later years he was the recognized distinguished patriarch of his field in the United States.

Youth on the Vanoni Farm

Vanoni was raised on the family farm developed by his unusually enterprising father, Battista Vanoni, an immigrant from Italy. They grew lima beans, then walnuts and citrus fruits. Early problems on the ranch included drainage of flood waters, erosion control, and sediment management. His father was the first in the area to bring the industrial revolution to the farm—during Vanoni's boyhood—first various horse-drawn machines, then trucks, tractors, and other motorized machines.

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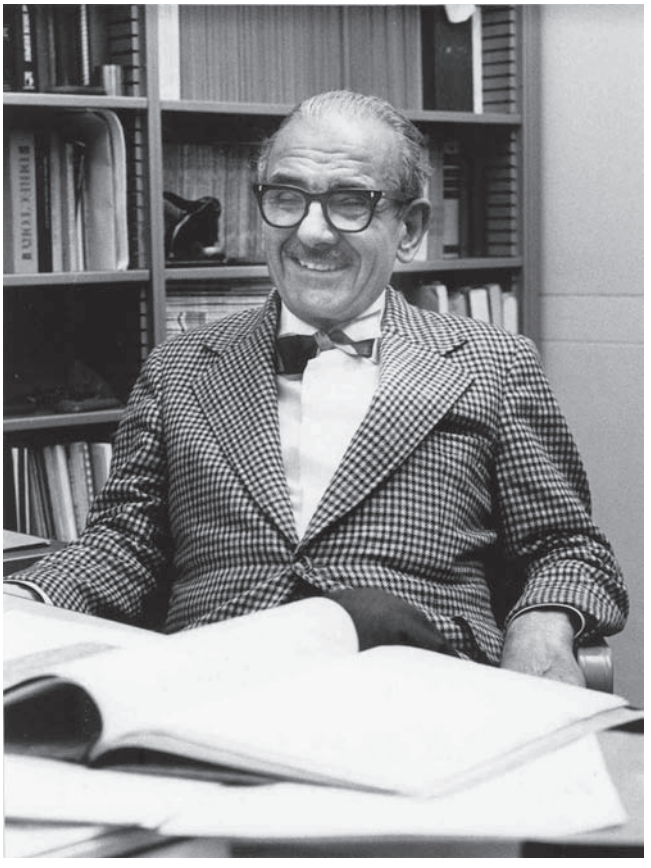

Fig. 1. Prof. Vito A. Vanoni in his office, 1974. (Photo credit: Caltech)

His father believed strongly in getting his many children the best education possible. After high school Vanoni enrolled in 1922 in the newly established California Institute of Technology, majoring in civil engineering, and graduated with a Bachelor of Science degree in 1926. His early experiences on the farm profoundly affected his attitudes and interests throughout his life. He loved the soil and had an active half-acre farm behind his large home lot in Pasadena for 50 years, right up to his final year. His future professional work in sedimentation must have had its common-sense intuitive roots in his early years on the family farm.

The Structural Engineer

As a new civil engineering graduate from Caltech, Vanoni worked five years for a consulting engineering firm doing structural steel design in Ohio, then returned to Caltech in 1931 to obtain a Master of Science degree in civil engineering in 1932, specializing in structural engineering. When he looked for a job in that depression year he got an offer from Professor Robert Knapp to work at the Hydraulic Structures Laboratory, then mostly outdoors. This was the starting point for his hydraulics career, first in hydraulic model studies of various proposed structures, often with sediment problems, and then into sedimentation research. At the same time he continued his graduate study toward his PhD.

The Hydraulic Researcher

From 1935 to 1947 Vanoni supervised the cooperative Sedimentation Laboratory of the Soil Conservation Service (SCS) and Caltech in a large one-story wooden building on the Caltech campus. The SCS sponsorship stopped in 1947, but research on sediment transport in open channel flumes and

turbulent diffusion in a low-speed water tunnel continued. In 1961 the new W. M. Keck Laboratories became the home for this program.

His meticulous experimental PhD research on transportation of suspended sediment in a 60-foot recirculating flume is still regarded as one of the classic contributions in his field, and was recognized by the American Society of Civil Engineers (ASCE) with the Hilgard Hydraulics Prize for the most outstanding paper in hydraulic engineering published by the ASCE in 1946.

During the war years, Vanoni did defense-related research for the National Defense Research Committee and the U.S. Navy, primarily related to the investigation and control of wave action in harbors using hydraulic models on the campus and later in a large off-campus facility in Azusa. He was also active in the design and testing of hydraulic structures such as drop structures for energy dissipation. When Lake Mead was being filled after the closure of Hoover Dam, he and his colleagues demonstrated qualitatively in the laboratory the newly recognized phenomena of inflowing density currents and selective withdrawal in density-stratified reservoirs.

Sediment research continued after the SCS sponsorship stopped in 1947, but at a reduced level. Five more doctoral students completed PhD research on sedimentation topics in the Sedimentation Laboratory up until 1960 (in chronological order): Hassan Ismail, myself, George Nomicos, Ronald McLaughlin, and John Kennedy. Vanoni was the thesis adviser for the first three of these.

In the late 1950s Vanoni and I planned the new Keck Hydraulics Laboratory, which opened in 1961. (Professors Fredric Raichlen and John List joined the laboratory group in 1962 and 1969 respectively.)

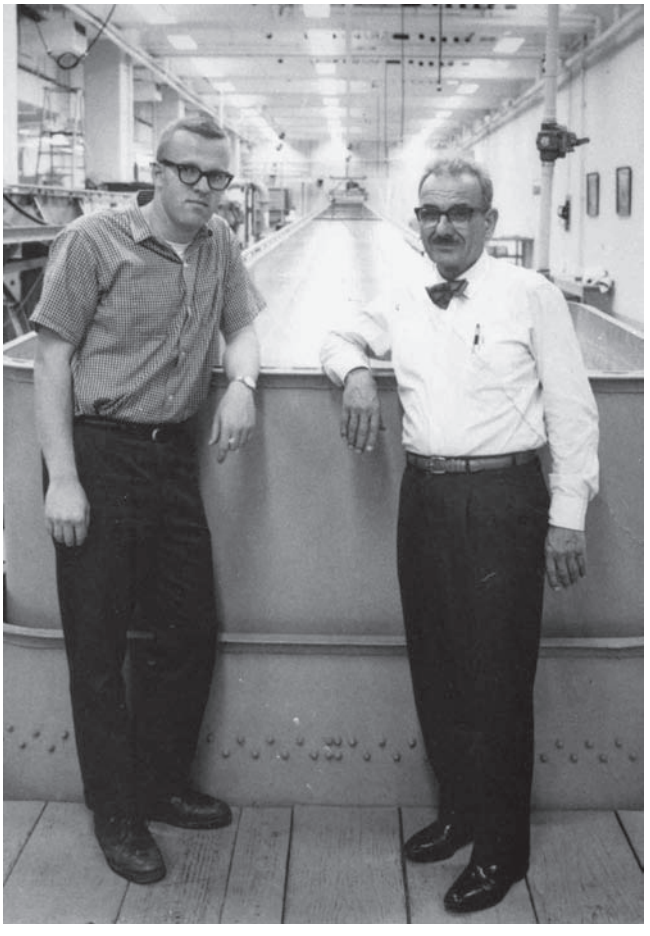

Fig. 2. Vanoni with Ph.D. student Richard Brock at the downstream end of the 40-meter tilting flume in the Keck Hydraulics Laboratory, approximately 1965. (Photo credit: Caltech)

Fig. 3. Members of the Missouri River Division Sediment Advisory Board (July 26, 1950). From left to right: H. A. Einstein, Univ. of California, Berkeley; T. H. Means, consulting engineer, San Francisco; E. W. Lane, Bureau of Reclamation, Denver; L. G. Straub, University of Minnesota, Minneapolis; G. A. Hathaway, Corps of Engineers, Washington, D.C.; and V. A. Vanoni, California Institute of Technology, Pasadena. Picture taken while on inspection trip of Missouri River below Fort Peck Dam. (Credit for photo and legend: Corps of Engineers, Fort Peck District, Photo No. 17920)

Under Vanoni's leadership, the program of the new Keck Hydraulics Lab focused on sediment transport, coastal engineering, and the emerging area of environmental hydraulics. Basic hydraulic structures and model studies became secondary. In the Keck Lab years, the PhD students he supervised were Alexander Sutherland, Li-San Hwang, Richard Brock (Fig. 2), and Brent Taylor.

One of Vanoni's fine attributes, starting from his earliest research work, was his extreme care in crediting other people's ideas and work, while claiming the minimum for himself.

The Sedimentation Engineering Manual

As a major contribution to the profession, he organized, partially wrote, and edited the 730-page definitive ASCE Manual 54, *Sedimentation Engineering* (Vanoni 1975). As chairman of the special Task Committee, established in 1954, charged with writing the manual, Vanoni worked very hard for two decades and set a high standard, persuading many contributors to do major rewrites as needed or doing them himself. In an unusual publication procedure, many of the sections of the original manuscript for the book were first published in the *Journal of the Hydraulics Division, ASCE;* they received consider-

able discussion, which was taken into account in the final manuscript. His effort was an example of strong multi-year persistence and unlimited patience with slow contributors.

The book has received worldwide recognition and widespread use in academia and practice, and was awarded the ASCE Hilgard Award for the best publication in hydraulics in 1976. The success of that book has inspired the current ASCE Sedimentation Committee, under the leadership of Professor Marcelo Garcia (University of Illinois), to write this second volume to document the progress of the past three decades.

The River Hydraulics Consultant

Dr. Vanoni served as an expert individual consultant on river channel and sedimentation problems for many government agencies and consulting firms, extending for almost twenty years into his retirement. Most notable were the several consulting boards he served on for the U.S. Army Corps of Engineers, dealing extensively with sediment problems on the Missouri, Mississippi, and Sacramento Rivers (Fig. 3). After the eruption of Mount Saint Helens in 1980, he served the Corps for several more years to advise on coping with the huge sediment inputs to the Toutle, Cowlitz, and Columbia Rivers.

More Honors in Retirement

In recognition of his outstanding lifetime work, Dr. Vanoni was elected to the National Academy of Engineering in 1977, and became an Honorary Member of the American Society of Civil Engineers in 1980.

In 1983 he was honored by his selection by ASCE to be the distinguished Hunter Rouse Hydraulic Engineering Lecturer (Vanoni 1984). In 1989 he was named the first recipient of the ASCE's Hans Albert Einstein Award. This prize is awarded annually for a "significant contribution to the engineering profession in the areas of erosion control, sedimentation and/or waterway development." It is interesting to note that both Rouse and Einstein had been Vanoni's colleagues at the Sedimentation Laboratory about 60 years ago. (Also Arthur Ippen and James Daily were among Vanoni's contemporaries at Caltech in the late 1930s.)

Personal Life

Vanoni and his wife, Edith, enjoyed many activities together, especially foreign travel to all the continents, and camping in the Sierra Nevada mountains in California. They often opened their home and wonderful patio and "farm" to colleagues, students, and visitors. They are remembered by many for their friendship and warm hospitality. After 61 years of marriage, Edith died in 1995. Although they had no children, Vanoni (or Uncle Vito) is survived by many relatives in his extended family in his native Ventura County and in Santa Barbara.

VANONI'S RESEARCH ON SUSPENDED SEDIMENT TRANSPORT IN FLOWING WATER

In the 1930s basic fluid mechanics was rapidly being infused into civil engineering hydraulics as well as all the other fields of engineering dealing with fluids. For his PhD research, Vanoni was the first to make definitive experiments to measure the transport of fine sand in suspension in turbulent flows of water in an open channel flume. He made his meticulous experiments using the new 60-foot-long steel recirculating laboratory flume, which he designed and built in the Sedimentation Laboratory. (He also designed the building.) His previous experience in structural steel design had proved to be very useful.

In his flume experiments Vanoni (1940, 1946) measured the vertical distribution of suspended sediment concentration along with velocity profiles for a number of experiments using fine, well-sorted sand. The flume bottom was artificially roughened to reduce the effect of the smooth sidewalls with a single layer of 0.88 mm-sand grains stuck to the steel bottom. He compared his measurements with the now well-known equation for the variation of the concentration of suspended sediment over the depth in an open-channel flow, first presented by Rouse (1937), who was also at the SCS Sedimentation Laboratory at Caltech at that time. The results confirmed this new equation derived from von Karman's logarithmic velocity distribution leading to a parabolic distribution of the diffusion coefficient—that is, for the upward diffusion of the sand grains to balance the gravitational

settling. In his PhD thesis he acknowledges both Professors Theodore von Karman and Robert Knapp for guidance in his research.

From the velocity distributions, Vanoni determined that the von Karman constant κ was decreased from its normal value of 0.40 by the presence of suspended sediment; the greater the concentration, the greater was the reduction in κ. This result has attracted the attention of numerous subsequent investigators.

To fit experimental results to theory, Vanoni had to determine the fall velocity of his carefully sorted sands by dropping hundreds of grains in water. Previous investigators had paid little attention to fall velocity of sands. He found that the sedimentation diameters are slightly larger than the sieve diameters for his sands (ranging from 0.10 to 0.16 mm mean diameter). He also observed longitudinal streaks of small sand deposits on the bed of the flume, indicating definite secondary circulations. This was probably one of the first observations of streaks in flumes and prompted much discussion of his ASCE paper (Vanoni 1946).

Another by-product of Vanoni's work was the acceptance of recirculating flumes for sediment transport experiments. Previous to his work the prevailing approach was to feed sediment at the upstream end of the flume and remove it at the downstream end. In Vanoni's experiments the water and sediment were collected at the downstream end in a hopper and pumped together through a return pipe to a well-designed diffuser and inlet section. The recirculation in a closed circuit allows control of the total volume of water in the system, thereby fixing the mean depth, while the flume slope remains adjustable (by a flume jacking system). With a discharge regulated by the speed of the pump, the velocity is also then predetermined in such experiments. This has interesting implications for transfer of results to the field in terms of which variables are independent or dependent.

It should be noted that in Vanoni's experiments the stream was really starved for sediment, namely there was not a sediment bed in the flume. This meant that no bedforms (ripples or dunes) were allowed to develop and there was no question about separating the resistance into skin friction and form drag.

With his students in the subsequent years, he continued to work on the effects of suspended sediment and bedforms on the flow resistance (friction factor) and the velocity profiles. In the 1950s the Sedimentation Laboratory had support from the Corps of Engineers and the Agriculture Research Service to continue flume studies of roughness and suspended load in alluvial channels. For example, in Vanoni and Brooks (1957), we showed clearly how greatly the friction factor changes in an alluvial stream as the bedforms change. Added form drag on the bed completely overwhelms any of the damping effects of sediment in suspension.

In the 1950s Vanoni was a collaborator with the Corps of Engineers in a large field study on the Missouri River, which again confirmed the basic equations for suspended sediment distribution at a much larger scale.

VANONI'S OVERVIEW OF PROGRESS IN SEDIMENTATION RESEARCH IN 1963

With the passage of so much time it is hard to get a good perspective on the developments that occurred during Vito Vanoni's prime years. This is also confounded by the burst of computer programs for solving lots of problems in alluvial channels in the last two decades. Vanoni had a time mismatch with the computer age because he was well into his 80s before the first user-friendly PC's came along. Nonetheless, he was a fan of the pocket calculators from Hewlett Packard and always bought the latest version as soon as it came out.

It is interesting to go back to see what the research progress in this field looked like before modern instrumentation and computers became available to process the data and run model simulations. An important conference held in 1963 in Jackson, Mississippi—the Federal Interagency Sedimentation Conference—provides this historical perspective. The 933-page proceedings volume is a very good summary of all the facets of U.S. sedimentation engineering work in progress at that time. Vanoni presented a paper titled "Review of Research Activities in Sedimentation" (Vanoni 1965) in which he summarized in six pages what he considered the significant advances in the previous 15 to 20 years. His paper is also a valuable source of 46 key references from the mid-1930s to the early 1960s. These will not appear in typical computer searches today.

Vanoni's remarks have relevance today. The following paragraph from the summary of his paper gives an example of his thinking in the early 1960s:

> I have pointed out three developments which in my opinion have keynoted the work of recent years. These are (1) the theory of turbulent suspension, (2) the clarification of the role of bed forms, and (3) the discovery of the great difference between flow in curved and straight channels. The first of these differs from the other two in that it is expressible theoretically in equations in concise and quantitative form. As such, it is readily understandable, and can be assimilated into textbooks and preserved permanently. The other two items are qualitative ideas, expressible only in words, and hence their true significance is appreciated only by those with some familiarity with sedimentation. Because of this they are more difficult to incorporate into textbooks and are in danger of being lost and then rediscovered, as was the work of river engineers of several generations ago.

Vanoni urged that information about peculiar behavior of streams be documented in the literature even if the investigator can't yet explain it. He was also a great promoter of more interaction between laboratory and field research, and believed that one of the reasons for good progress in the 1950s was increased collaboration on a personal level. He also encouraged university research as a way to increase the number of highly-qualified researchers and practitioners to handle the ongoing sedimentation problems, which he thought would be with us for many years.

His last significant research paper showed how to predict what type of bedforms occur (ripples, dunes, flat, antidunes) from dimensionless hydraulic parameters describing the characteristics of the flow and the bed sediment (Vanoni 1974). The paper presented graphs showing large quantities of sediment data which had been hand-calculated and hand-plotted, just before the advent of good computer-driven plotters.

In his retirement, Vanoni continued to publish excellent comprehensive review papers, most notably the monograph "River Dynamics" in *Advances in Applied Mechanics* (1975), and the ASCE Rouse Hydraulic Engineering Lecture, "Fifty Years of Sedimentation" (1984).

CLOSING REMARKS

It was a great privilege to have had Vito Vanoni as a mentor, faculty colleague, and friend—he had a tremendous impact on my career and life over 49 years. When I first came to Caltech in 1950, I was immediately attracted to work with him because of his knowledge and inspiring approach to hydraulics—and life in general. I was fascinated to learn the mechanics of rivers and how they were being disturbed by the works of man. He seemed especially enthusiastic when he took me out in the field to inspect local flood events and damage, which is a tradition I kept up with my students.

As a thesis adviser he showed me that careful observations trumped theories if they disagree. He turned me from being a young, idealistic theorist into a careful observer and pragmatist. I was trying to solve the problem of how to predict C_a, the sediment concentration at a small height "a" above the bed, which was needed to make the suspended load equation useful for applications. I worked out what I thought was a good theory first, then set out to "confirm" it with experiments. But when I started making flume experiments with a sand-covered bed, small sand dunes appeared, and I was distressed because they had no place at all in my theory. I consulted with him as to how I could get rid of the pesky dunes, so I could check my theory. Vanoni said, "Young man, that's the way it is, so that's what you should study." So right then and there my focus shifted to studying these bedforms and their impact on sediment transport and stream roughness.

After I became a faculty member in 1954, Vanoni never made me feel like a junior colleague. He shared many responsibilities of the lab with me and encouraged my initiatives. I had fun planning the new Keck Hydraulics Laboratory with him in the late 1950s. He sent me on a tour to visit other prominent hydraulics labs in the United States to pick up ideas of what to do or not do in designing a hydraulics lab. The visits also allowed me to meet numerous other hydraulics researchers around the country and find out what they were doing.

As Vanoni approached his mandatory retirement date at age 70, he was still impressing the students with his energy and enthusiasm. Vanoni was in a stage of life that I call "young old age," which lasts until you transition to "old old age." Vanoni made "young old age" last for about 20 more years, going

to the lab almost daily, writing papers, doing consulting work well into his 80s. He greatly enjoyed consulting with the Corps of Engineers after the Mount St. Helens eruption in the early 1980s about what to do with all that extra sediment.

Throughout his career and well into his retirement, he was always interested in visiting all the hydraulics research students in the lab (not just his own students); he wanted to hear and see what they were doing, make suggestions, and almost always offer words of encouragement. His comments were always quick and to the point. We miss his cheerful visits, as he seemed to represent the heart and soul of the Keck Hydraulics Laboratory at Caltech.

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