US Army Corps
of Engineers ®

Water Resources:
Hydraulics and Hydrology

Interview *with*

Jacob *H. Douma*

JACOB H. DOUMA

WATER RESOURCES:

HYDRAULICS AND HYDROLOGY

This manuscript is an edited version of an oral history interview conducted by John T. Greenwood at Great Falls, Virginia, and on the telephone on July 21 and August 14, 18, 20, and 22, 1991. The original tapes and unedited transcript are in the Research Collections, Office of History, Headquarters, U.S. Army Corps of Engineers, Alexandria, Virginia.

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Preface

The United States Army Corps of Engineers significantly contributed to hydraulic and hydrologic engineering over the last two hundred years. Exploiting theory, innovation, and mechanical ingenuity, Corps civilian and military engineers studied the behavior of rivers and the motion of water. They investigated hundreds of streams in the United States, many more than once, collecting data on the physical, chemical, and biological characteristics of rivers; regional precipitation; and local runoff. Their work vastly improved the nation's ability to predict floods and to take preventive actions.

This interview is one of several being produced in a special series covering engineers who shaped the Corps' hydrology and hydraulics program. Understanding the experiences, contributions, and thoughts of these individuals illuminates the past and provides guidance for the future. We commend this interview to all those interested in the development of twentieth century research in river hydraulics and hydrology.

Earl E. Eiker, P.E.
Chief, Hydraulics and Hydrology

Paul K. Walker, Ph.D.
Chief, Office of History

The Interviewer

Dr. John T. Greenwood is the Chief, Field Programs and Historical Services Division, U.S. Army Center of Military History in Washington. D.C., and was the Chief Historian of the U.S. Army Corps of Engineers from 1978 to 1988. Dr. Greenwood specializes in U.S. and Russian military and aviation history, is the author of a number of articles and book reviews, and has conducted a numerous interviews with civilian and military personnel of the Corps of Engineers. His interview with Maj. Gen. Hugh J. Casey appeared in 1993 as *Engineer Memoirs: Major General Hugh J. Casey* (EP 870-1-18). Dr. Greenwood received his doctoral degree in history from Kansas State University.

Contents

JACOB H. DOUMA

Jacob ("Jake") H. Douma concluded a long and distinguished career in the U.S. Army Corps of Engineers when he retired on January 12, 1979. His retirement merely marked the formal end of his civilian service with the Corps of Engineers after more than 41 years. He continued on at full tilt for another 12 years, until 1991, before he finally decided to halt his active consulting career. Thus ended his 61 years of active involvement in engineering and hydraulics that had begun with his enrollment in the College of Engineering at the University of California at Berkeley in 1930.

Born in Hanford, California, on May 30, 1912, Jake Douma's interest in civil engineering and hydraulics was sparked by his summer job of irrigating alfalfa fields. As he toiled in the fields, young Jake kept thinking "there must be a better way to irrigate ..." His thoughts about irrigation led him to read about the Bureau of Reclamation and the Central California Project. He decided that to learn the better ways of irrigating he had to get an engineering education. So off he went to study engineering at the University of California at Berkeley, then one of the preeminent schools of engineering in the country. After five years at the University, where he studied under Morrough P. O'Brien and Bernard Etchevary, he graduated with the Bachelor of Science in Civil Engineering and majors in hydraulics and irrigation.

After graduation, he accepted a position at the US. Army Corps of Engineers Waterway Experiment Station (WES) at Vicksburg, Mississippi, in the summer of 1935. There he worked on the Mississippi River Model and did model research on Conchas Dam, New Mexico, before moving to the Bureau of Reclamation in Denver, Colorado, in 1936. Jake Douma soon tired of the routine of tabulating rainfall and runoff records to determine flow hydrographs in the Project Investigation Branch and maneuvered himself into a position working for Jacob E. Warnock in the Bureau's Hydraulic Laboratory in Denver. Here he became familiar with the Bureau's hydraulic model studies and design standards for dams, canals, and irrigation structures and came to know many of the leading hydraulic engineers in the country.

In 1939, Jake Douma joined the Los Angeles Engineer District as a hydraulic engineer in the Hydraulic Design Section of the Hydraulics Branch of the Engineering Division. Before he even settled himself, he was off to the Nashville Engineer District for a short, three-month assignment as a hydraulic designer on the Wolf Creek Dam project. Soon back in the LA District, he rose to be Chief, Hydraulic Design Section, and was responsible for hydraulic model testing and design of high-velocity flood channels, flood and debris dams, and appurtenant hydraulic works in the Los Angeles area. He did pioneering work on the Tujunga Wash channel for which he developed the design criteria for spiral, super-elevated, high-velocity flood channels.

At the personal request of Chief of Engineers, Lt. Gen. Raymond Wheeler, and Gail Hathaway, Special Assistant to the Chief of Engineers, Jake Douma moved to the Office, Chief of Engineers (OCE), to work as a hydraulic engineer. For the next 15 years he worked in the Hydraulic Design Section of the Structural Branch in the Engineering Division of Civil Works. He was responsible for the final review of the hydraulic design of the Corps' water resources projects and for the development and coordination of hydraulic research programs that supported hydraulic design. He played a major role in the Corps' major hydraulic design and construction projects and was instrumental in the organization and operation of a number of Corps-wide committees and research projects.

From 1961 through 1975, Jake Douma was Chief, Hydraulic Design Branch. In this job, his duties included the final review and approval of all hydraulic design and research programs. He was the Corps' top technical advisor to the Engineer Divisions and Districts and hydraulic laboratories on hydraulic planning, research, design, and operation of multi-purpose dams, flood control channels, inland waterways, navigation locks and dams, and coastal engineering projects. From 1975 through his retirement in 1979, he headed the Hydraulics and Hydrology Branch where he was responsible for both hydraulic and hydrology activities of Civil Works.

During his career in OCE, Jake Douma was instrumental in the establishment of a number of important programs, organizations, policies, and committees, including:

- Hydraulic Design Branch, Engineering Division, Civil Works
- Hydraulic Design and Analysis Division, Hydraulic Laboratory, Waterways Experiment Station
- Tidal Hydraulics and Channel Stabilization Committees
- Corps-wide Hydraulic Design Conferences
- Numerous Engineer Regulations, Manuals, and Technical Letters that provided design guidance, criteria, and procedures for all phases of hydraulic design and coastal engineering
- Training programs at U.S. and foreign universities for the continued education and development of hydraulic design and coastal engineering engineers

His overall guidance and concern were critical to the development of the WES, North Pacific Division, Mead (Omaha District) and San Francisco Bay hydraulic laboratories into recognized world leaders in the use of physical and mathematical models as engineering tools for designing complex water resources projects. His activities in this area led to the development of less costly and more efficient planning, design, and maintenance procedures and improvements in the functional adequacy and cost effectiveness of flood control channels, spillways and outlet works, navigation locks and dams, navigation channels and control works, shore protection measures, ports and harbors, and water quality studies.

Drawing on his Bureau of Reclamation experience, he pioneered the development of hydraulic design standards and criteria for the Corps of Engineers by outlining a long-range program of literature review, prototype measurements, data analysis and publication of hydraulic design charts on standards and criteria. Many counties around the world have accepted these design criteria as standard and use them as the basis for their water resources development projects.

His extensive experience and knowledge in planning, design, operation, and research made Jake Douma a highly valued advisor and consultant throughout the Corps and the world. His advice was often sought by U.S. and foreign governmental and engineering agencies as well as by commercial engineering and construction firms. Jake attained a national and international reputation in hydraulic research and design. He made many significant contributions to engineering science--he personally developed the design for spiral, super-elevated, high-velocity flood channels, under designed spillways, sloping bridge nose piers to reduce flow constructions and shed trash, stilling basins with upstream baffle blocks and end sill and a trouble-free 45-degree lip for vertical high-head reservoir outlet works gates. These and other developments were adopted as standard practice in the Corps of Engineers and throughout the world.

He also helped to organize the Tidal Hydraulics and Channel Stabilization Committees to bring together the experts in the Corps and outside consultants to solve complex and difficult technical problems. These committees developed research programs and advised field agencies on major tidal hydraulic and channel stabilization projects. The numerous reports of the committees and their advisory work have substantially advanced engineering and scientific knowledge in both areas.

Jake Douma's outstanding and continuing contributions to the Corps of Engineers were acknowledged in his numerous Sustained Superior and Meritorious Civilian Service Awards. In 1971 he was elected to membership in the prestigious National Academy of Engineering. In June 1982, Jake Douma was inducted into the U.S. Army Corps of Engineers Gallery of Distinguished Civilian Employees in recognition of his many contributions to the Corps of Engineers.

Biographical Information

Professional Societies and Affiliations:

American Society of Civil Engineers (1935)
- Life Member (1977)
- Task Committee on Gates and Valves (1954-61)
- Research Committee (1959-64)
- J.C.D. Stevens Award Committee (1958-61)
- Task Committee on Standardization of Hydraulic Structures (1963-65)
- Executive Committee of the Coastal Engineering Research Council (1967-87)
- Member and past Chairman, Hydraulics Committee
- Hydraulic Division Executive Committee (1969-75)
- Member, Waterways and Harbors Division

U.S. Committee, International Commission on Large Dams (1948-)
- Technical Activities Committee (1969-73)
- Hydraulics Committee (1975- 1987)

U.S. Committee, International Commission on Irrigation, Drainage and Flood Control (1948-)
- Technical Activities Committee (1969-72)
- Hydraulics Committee (1972-75)

International Association for Hydraulic Research (1948-)
- Committee on Gates and Valves for Dams (1966-72)

Permanent International Association of Navigation Congresses(1948-)
- Paper Selection Committee (1965-68)

Council on Wave Research
- Member

National Academy of Engineering (1971-)
- Marine Board (1972-79)
- Committee on Safety of Existing Dams (1982-84)

Honors and Awards:

Chi Epsilon Civil Engineering Honor Society
Tau Beta Pi Engineering Honor Society
National Academy of Engineering
Who's Who *in Engineering*

Selected Consulting Services:

1951-61	Technical advisor to hydraulic engineers of India on the design of gates for dams.
1954-55	Consultant to Tibbetts, Abbott, McCarthy, and Stratton (TAMS), New York, on hydraulic design of Peligre Dam, Haiti.
1958-65	Consultant to National Institute de Obras Sanitarias, Caracas, Venezuela, on development of comprehensive plans and design of flood control channels and dams for the protection of the City of Caracas.
1961-69	Consultant to CASECO, Consultants, Ltd., Vancouver, Canada, on Mica Creek Dam.
1967-71	Consultant (Member of Board) to New Brunswick Power Commission, Frederickton, Canada, on Mactaquac Dam.
1967-71	Consultant to Quinones Associates, San Juan, Puerto Rico, on design of flood control channels.
1967-73	Consultant to TAMS, New York, on Tarbela Dam, Pakistan.
1973-78	Consultant (Member of Board) to Water and Power Development Authority, Pakistan, on Tarbela Dam.
1976-82	Consultant (Member of Board) and Special Hydraulic Consultant to Engineering Consultants, , Inc., on Magat Dam, National Irrigation Administration, Philippines.
1978-79	Consultant to Harza Engineering Company of Reza Shah Kabir Dam, Iran.
1978-85	Consultant (Member of Board) to Saskatchewan Power Corporation, Canada, on Nipawin and Saskatchewan Forks Dams.

1980-83	Consultant to Corps of Engineers, Los Angeles District, on the San Jacinto and Batista Creek levee failures.
1980-91	Consultant (Member of Board) to C .A. De Administracion Y Fomento Electricio (CADAFE), Venezuela, on Uribante-Caparo Project of four dams and three hydroelectric plants.
1980-83	Consultant (Member of Board) to Alaska Power Authority on Susitna Project consisting of an 800-foot high earth dam, a 640-foot high concrete dam, and two hydroelectric plants.
1982-83	Consultant to Cadillac-Fairview Homes West on flood protection for a large urban development in Riverside County, California.
1982-84	Consultant to Riverside County, California, on a court case involving claims for $20 million in flood damages.
1984-86	Consultant to the World Bank on Kalabagh Dam, Pakistan.
1985-87	Consultant (Member of the Board) to East Bay Municipal Utility District, Oakland, California, on the safety of Pardee Dam and Spillway.
1985-88	Special hydraulic consultant to the Salt River Project Authority, Phoenix, Arizona, on spillway erosion problems at Horse Mesa Dam.
1986-91	Consultant (Member of Board) to Saskatchewan Power Corporation, Canada, on two multi-purpose dams on the Souris River.

Selected Professional Publications:

"Model Study of Green Mountain Dam Spillway," *Civil Engineering*, March 1940.

"Testing Theoretical Losses in Open Channel Flow," *Civil Engineering*, November 1947.

"Hydraulic Design of Slide, Vertical-Lift and Tainter Gates for High-Head Reservoir Outlets, " *Proceedings, International Commission on Large Dams,*1951.

"Tidal Hydraulic Problems of the Corps of Engineers," *Journal, Hydraulic Division*, ASCE, 1953.

"Hydraulic Design Criteria for Reservoir Outlets," *Proceedings, International Association for Hydraulic Research, 1965.*

"High-Velocity Flow in Open Channels," *Proceedings, International Association for Hydraulic Research, 1965.*

"United States Lock Design Practice," *Proceedings, International Association of Navigation Congresses, 1969.*

Contributions to Davis and Sorenson, *Handbook of Applied Hydraulics (1969)* and National Research Council, *Safety of Existing Dams (1983).*

Registration:

Registered Professional Engineer in the State of Virginia.

JACOB H. DOUMA

Interview with

Jacob H. Douma

Childhood

Q: Would you tell me a little bit about your childhood and education in Hanford, California?

A: All right. Let me think a moment. I'll first start by saying my parents were married--they were from Holland-- they were married in Holland. Three days later, they sailed for the United States. They went to the Immigration Office in New York and, checking through there, the Immigration officer asked my father how he pronounced his name, and he said, "Douma [pronounced Dow-ma]." The Immigration Officer told him, "No, in English, it's Douma [pronounced Due-ma]." So I've been Douma [Due-ma] ever since, but it should be Douma [Dow-ma].

Then my mother and father took a long train ride all the way across the United States, arrived in Fresno, California, where they were met by an uncle of mine, who proceeded them by about a year. My father got a job milking cows on a farm, and in about a year and a couple of months I was born on May 30, 1912. Then about a year after that, my father got a job in the Coalinga oilfields, working to raise hogs, chickens, and vegetables for food for the Shell Oil Company field workers.

He bought a buggy and two horses, packed up my mother and myself and our belongings, and headed for the Coalinga oilfields, which are about 50 miles from where we were living near Hanford. We started early one day and got to the Kings River at about dark, and my father decided, "Well, we'd better stop here."

So he built a big bonfire. The coyotes were howling, and my mother got scared. The next day, we got over to Coalinga, and my father worked at that job for a couple of years. Then, after saving some money, we came back to Hanford where my father bought 40 acres of land and started out with a little dairy farm.

Well, we'll skip some time. My father gave me a milk bucket for my eighth birthday, and I had to get up at 5:00 o'clock in the morning to help him milk the cows. He had about 16 cows, and I milked the cows with him before catching a bus and going to school.

Went to Hanford High School. One of my jobs during the summer was to irrigate alfalfa land. I was the irrigator, and I kept thinking, "Oh, there must be a better way." We had a big, ten-horsepower gasoline motor engine with a belt, and a 5-inch pump down at the well. The engine turned the things that pumped a 5-inch pipe full of cold, clear water, which was enough to irrigate 40 acres. We kept rotating by mowing one cutting of alfalfa every four weeks, and after getting the hay off, irrigating again. But I got the idea then, there must be a better way to irrigate than the way I was irrigating. I had to dig ditches by shovel to get the water to where it needed to be. When I got to my senior year in high school, I'd read enough about the Bureau of Reclamation projects right there in the Central Valley of California to know that they had better ways of irrigating. I decided my first effort would have to be to go to a university and get an engineering education.

Q: So your interests in engineering, civil engineering specifically, came from your irrigation work on your own farm?

A: Right.

Q: Did you have any science or math teachers in high school who were particularly influential on you?

A: Well, I guess another thing that influenced me is that I liked science and math. I could get A's in all of those courses, and I hated English. [Laughs] I did well to get a B- one time.

In fact, before enrolling at the University of California, during my last month in high school, I still had to take a test to determine how well I knew the English language. It was called the "bonehead" English test. If I'd had straight A's in English, I still would have had to take the test. In about two months, the test results came back stating that I didn't pass it and had to take this English course the first semester of my freshman year. I said, "Well, that's bonehead English."

So when I enrolled at the University of California, I signed up for physics and chemistry and math, and said, "Well, here, this piece of paper says I have to take this English course." I was told I had to take the English course without credit until I passed the "bonehead" English test.

So I took the course, but I hated it. We went through the same stuff I'd gone through about three times before in high school. I must have paid a little better attention to the course because I passed the test after completing the course. English has always been my weakness. I could express my engineering thoughts quite well, but I was seldom satisfied with my English.

My wife was a schoolteacher, and her English was always very good. It got so that I'd say, "This is an important paper. You read it over and suggest what I ought to do about its English. I know that I don't have the commas in the right place." She would help me out a lot. I think I can do a little better job now, but I just don't like to write.

Q: Well, did your parents speak Dutch in the home all the time?

A: Yes.

Q: So did you?

A: That's right. They spoke Dutch all the time, and when their friends came over, they spoke Dutch. In fact, I got so I could speak Dutch pretty well. All of my relatives, except one uncle, were still in Holland, and the first time I met any of them was in 1968. I was in the Chief's office, and I attended the International Association of Hydraulic Research conference, which was held in Holland. After the meetings, I spent some time with my relatives there.

The overseas flight went to London first, and I spent a few days there visiting a hydraulic laboratory. Then I took a flight to Holland and landed in Amsterdam. I'd notified my uncle of that beforehand and, after going through immigration and customs, I saw this man who looked just like my younger brother. I introduced myself, and we shook hands. He didn't know a word of English, and talked to me in Dutch, and I understood a little bit of what he was saying.

We had to take a train ride of about 40 minutes or so to the town of Utrecht where he lived. During that time, he talked in Dutch, and by the time we got through with that train ride, I could understand almost everything that he said.

To get back to your question, I am certain that children who first learn to talk in a foreign language have more problems learning English. Certainly, those kids who grow up in a family that speaks English all the time are much more able to handle the English language than a person like me.

University of California at Berkeley

I decided to go to the University of California at Berkeley. I enrolled in engineering, and was there five years, majoring in civil engineering. I was interested in astronomy and economics, so I took several courses in those subjects as well.

Q: What was the curriculum like in the School of Engineering at the University of California when you enrolled?

A: Well, the first two years I took basic courses in physics, chemistry, and mathematics. After that I concentrated on basic civil engineering courses on surveying, sanitary engineering, bridge design, and hydraulics. I had to go to one two-week summer camp to learn surveying for staking out a railroad. I had one course in sanitary engineering. I learned a little about sewers but never used it.

I should have had a lot more hydraulic engineering courses. One semester before I graduated, I went to the professor who taught me a couple of hydraulic engineering courses, and said, "I'm wondering whether I should come back and get a doctorate in hydraulic engineering and spend more time on the design of dams? I want to learn more about dams. Also, since you don't have any courses on dams, would it be possible for me to do a lot of reading of the literature about dams, and give you some kind of report after the semester?"

He said, "Yes, that's fine. You pick out what you want to read." He suggested a few books. So I read a lot, and wrote a summary report of what I read, and I gave it to the professor. He didn't even give me an examination. He gave me three credits with an A for what I read.

I learned more about dams than I did in any of the courses I took from him. I said to him, "Do you think it would be worth my while to come back and get a doctorate and emphasize the design of dams?" He said, "Get a job where they design dams. You'll learn more there than going back to school." So that's what I did.

Q: So you had really decided when you went to California that you were going to go into civil engineering.

A: Yes.

Q: There were never any alternatives?

A: I had no interest in mechanical or electrical or any other type of engineering, only civil engineering.

Q: And yet Morrough O'Brien, one of the outstanding hydraulic engineers in the whole United States at that time, was then at the University of California, teaching mechanical engineering.

A: Yes, that's right, but he taught hydraulics.

Q: Did you take hydraulics from him?

A: Yes. I took his hydraulics laboratory course, and his basic hydraulics course in fluid dynamics, which mainly covered theoretical hydraulics and very little hydraulic design.

Q: So that's what he taught? He taught the theoretical aspects?

A: Yes, theoretical. That's right.

Q: What was he like?

A: He was a very good man to work with. He did a lot of things. I still remember, after working at the Waterways Experiment Station for a year and then before going back to Denver to work for the Bureau of Reclamation, I went to visit my folks in Hanford. So I thought I'd pay him a courtesy call and tell him how I liked the Waterways Experiment Station, because he was the one who got me there. I went down the hall of the Civil Engineering Building, and knocked on his office door. He said, "Come in," so I opened the door and went in.

He recognized me, but I'm not sure he remembered my name. I said, "Hello. I thought I'd just come and talk to you a little bit.," He said, "Well, you have to go to the other room and come through my secretary's office, and she'll set it up for you." So I went into the secretary's room and told her I wanted to see Professor O'Brien. About two minutes later, she said, "You may go see him."

We had a very good talk. He was interested in what hydraulic research the Corps of

Engineers was doing. I told him about the various hydraulic model tests being conducted at the Waterways Experiment Station. He later served for many years on the Corps' Coastal Engineering Research Board [CERB]. We used to see him down at the Waterways Experiment Station one or more times each year. He always had something constructive to say about the laboratory work there.

He died just a few years ago in Mexico. He did some consulting work in Mexico, and he found a place there in [Baja] along the ocean front that he liked very much. I'll bet that was a very healthful place, so he moved there two or three years before he died.

Q: Was Richard Folsom there when you were there?

A: Yes. Richard Folsom was there when I was there. He's now president of Rutgers University.

Q: He's the hydraulic engineer that worked with O'Brien, and then you worked with him in Los Angeles, didn't you?

A: Folsom?

Q: Because he was with the Los Angeles ....

A: Folsom?

Q: Yes.

A: Oh, he must have been there ahead of me.

Q: About '33, I think.

A: Yes, he was ahead of me. I didn't get to Los Angeles until '39.

Q: And he went to there, I think, after that.

A: Yes. I hadn't seen him since I left the University of California, 1935. Richard Folsom.

I think it's the same Richard Folsom that ...

Q: He's the one that worked down on the Los Angeles Flood Control?

A: Yes. He did. I read someplace where he did that.

Q: Maybe you would have run across him in some of your work down in Los Angeles district.

A: Yes.

Q: What about the hydraulics laboratory that O'Brien had?

A: That was just a small laboratory in one of the university buildings. He had some water running in a flume with a sand bottom that could be tilted. The students measured water surface profiles for various flume slopes. There was a small steel flume for testing other water flow conditions.

He also had a little outdoor laboratory out by the University swimming pool where he model tested bay waterfront developments under contract for the City of Oakland. Before I graduated, I worked with him part-time for about two months on those tests.

Q: That must have been interesting to compare what you did in that laboratory and what you did at WES.

A: Oh, yes. His laboratory was very small compared to WES. He didn't have enough money to do anything large, but it was fine for training students. The Oakland job that I worked on was a good, authentic model study.

Q: But you found that kind of thing interesting, and that's what you led you eventually to get into it?

A: Yes. I was interested in that.

Q: So Morrough O'Brien was critical in your undergraduate education, but you had mentioned some other professors that were particularly influential?

A: Yes. My favorite professor was Bernard Etchevary , who was very practical. Engineering practice meant a lot to him, and he did a lot of consulting work on practical jobs. He consulted a lot for the Los Angeles County Flood Control District and the Riverside County Flood Control District, and was on their consulting boards. They would send him back to Washington to get some money for their projects, and he'd usually come back with some money. That's why they liked him on their work.

Q: Now, was he a structures person in civil engineering?

A: No, his specialty was hydraulics of irrigation, flood control, and hydropower projects. He knew a lot about dam and channel structures, but little about their structural design, as was the case with bridges and buildings. Of all the professors I had, he came closest to representing what I wanted to follow.

Q: Vem Hagen had a similar comment about the professor that most impressed him, or most influenced him.

A: I didn't know that.

Q: He held the same viewpoint--that of a person who had practical experience and did a lot of consulting.

A: I understand.

Q: So you think it is particularly significant for hydraulic engineers to have such an experience with their professors?

A: I think so. But some professors don't use their experience to their students' best advantage, and these students complained, "We don't see the professor enough. He sends an instructor in to talk to us when he's away on a consulting job." But Etchevary never did that. He was always right there. He never had a substitute. Well, in those days, there wasn't that much consulting to do, I guess.

I had a different experience with Derleth, the Dean of Engineering, who was a structural engineer, bridge designer. The San Francisco-Golden Gate Bridge Authority hired him as a member of their board of consultants. I took his class on bridge design. About twice a month, he wouldn't show up at the class because he had to go to a board meeting about some problem. The next time he came to the class, he spent the whole class time talking about the bridge and its problems, and how the board functioned. I thought that was valuable information for the students.

It was more valuable, in many ways, than just him going to the blackboard and showing how to calculate the stress in various bridge parts. He said, "Your assignment for today was to calculate these stresses. I assume you've done it. I have given you something else, so you have learned more out of this one lesson than you would have if I were not at the board meeting." Well, that made sense.

Q: In the area of irrigation, California had for years been involved in that and was leading the country. Did you have some good people teaching you about irrigation structures and theories?

A: The California Department of Water had its own engineering staff which designed most of California's early irrigation projects. They had outside boards of consultants whose members were well-known engineers. The Bureau of Reclamation became involved with them in the early '30's, and the Corps of Engineers became involved about 1940. The Corps built a lot of dams and canals for them. The state operates the canals, but I don't think they're building anything new.

Q: How much did they use that experience of the irrigation of the Central Valley or up in the Sacramento River in teaching courses?

A: Not very much. I think Etchevary mentioned it, but to my recollection, he never took one of the projects and outlined and said, "This is what they're doing, and this is how and why they're doing it." He wrote his own textbooks and covered each chapter thoroughly in his class lectures. The lectures concentrated mostly on basic hydraulic theory and design. He would very seldom discuss the practical aspects related to specific project design, construction, and operation. He should have done a lot more in that respect. He could have shown slides and discussed California State dams and Bureau of Reclamation dams with his classes.

Q: How much did they talk about the large civil projects that were underway, such as the Bonneville Dam, or things that were being built by the Public Works Administration?

A: The professors? Not very much. There were about 25 to 30 students in each class, and they weren't all interested in the detailed design of projects. So his course was a little general.

If he had a course with 10 or 12 students who were interested in projects in greater depth, then he could have given lectures on Bonneville, Shasta Dam, and other specific projects. That would have been good for me.

Q: How would you rate the texts you had for your various civil engineering courses? Were they very good or not.

A: Yes, they were good.

Q: You said Etchevary used his own book.

A: Etchevary used his own book. O'Brien used his own book. O'Brien and [George H.] Hickox wrote a book, just a few years before I took their courses. It was very theoretical, fluid dynamics, mainly. In fact, I have most of those books here in my home office.

Q: The last time we talked, we had gotten to your time at the University of California.

A: Yes.

Q: We had talked about some of your professors--Dean Derleth, Etchevary, and Morrough O'Brien

A: Yes.

Q: I was wondering if, at your time there, you had met any of the Engineer officers who were there for advanced study? That was one of the universities to which they sent Engineer officers.

A: Yes. I remember there were some, but I wasn't very close to them. They took different courses, so I don't remember any of their names.

Q: Okay. I just thought I'd ask.

A: Yes.

Q: What was it like studying hydraulics in the early 1930's?

A: What was it like? What I remember the most now is that hydraulics wasn't very advanced at that time. There weren't very many large dams being designed anywhere. The Corps of Engineers and TVA just started designing and constructing dams. The Bureau of Reclamation started designing dams about 1910, and they started constructing dams a few years later, but the hydraulics part wasn't as far advanced. They only made brief hydraulic model tests of dams at that time.

When I was in the Chief's office in the 1950's and '60's, as I recall, there was a lot more knowledge in the field of hydraulics than they had in the university in 1930-35. University textbooks mostly covered theoretical fluid mechanics and very little on hydraulic design of spillways, outlet works, etc., for dams.

As I mentioned before, when I was in my last year at the University of California, I was already interested in dams, and I asked Professor Etchevary, who taught a couple of courses in irrigation, whether I couldn't go to the library and study whatever material was available on dams. So I did that.

Q: Were there very many books on those subjects?

A: Not on dams, no. Not any that covered the hydraulics or design of spillways and outlet works. As I said, the textbooks covered mostly fluid mechanics for the basic equations used to calculate flow of water in a channel or a river, over spillways, and through outlet works, but didn't cover the design of these structures nor problems such as cavitation erosion by high-velocity flow. I didn't know anything about cavitation erosion until I went to work for the Corps of Engineers.

I haven't gone back to the university to see what their courses are like now, but I think there still is a need for a very thorough book on design of hydraulic structures, like dams, high-velocity channels, and so on. Over the years, I've thought of writing such a book. When I got all of my engineering reports, etc., together, I realized it would be excellent reference material for writing the book. If I really went to work, I could write a good hydraulics book, or maybe two or three of them. But it's just too big a job. I can't do it at my age. If I were sixty years old and had ten years to do it, I think I could produce some good hydraulic design books for the universities.

Q: So most of what you learned, you sort of learned on the job, then?

A: That's right. Learned on the job. Just before I graduated from the university, I asked Professor Etchevary, "What do you think I ought to do? Go out and get a job, or come back and get a doctorate degree, study another year or two?" He said, "You'd do a lot better to go get a job, go get the practical knowledge, and you'll learn more than you'd learn getting a doctor's degree." So I did that.

Q: Did you have any exposure to foreign texts or books on hydraulics and hydrology?

A: Not at the university, no.

Q: I was thinking that your background with Dutch, you might have looked at the work that the Dutch have done in that area.

A: Although my parents were Dutch, I didn't know anything about Holland. I'd never been there until the 1960's when I went there several times and got acquainted with the university people. They do have good reports, but not on dams, because they don't build any dams. They've got good reports on tidal hydraulics and estuaries for the problems they have in Holland.

Waterways Experiment Station

Then, at Berkeley, one month before graduation, I was thinking about where I might get a job. I went to one professor, who taught me two classes in irrigation, and asked him about where I could apply for a job. I wanted a job having to do with irrigation, the design of dams, and things like that. He said, "Well, I know the chairman of the Tennessee Valley Authority [TVA]. I'm on their board. You should write him a letter." So I wrote him a letter. They replied, and, of course, they stated how much they were going to pay. They would start me out at $105.00 a month.

A day or two after Professor Etchevary gave me the letter, he asked, "Are you going to take that job?" I said, "Well, I'm going to wait until I hear from the Waterways Experiment Station." Professor Morrough P. O'Brien was on the consulting board for the Waterways Experiment Station [WES], and he said he thought they would have a job there, and for me to write them a letter, which I did. About another week or so, that letter came. They would pay me $110.00 a month. So that was my decision, I go to the Waterways Experiment Station for five dollars more.

After graduation in May 1935, I took a long train ride through the south. When I got to the Mississippi River in New Orleans, the river was in flood. The train was broken up into four-car sections. Each section was towed on a trestle to put the four cars on a barge, and the barge carried the cars across the flooding Mississippi River to land at New Orleans.

I didn't know what the heck I was getting into because one place the water was one foot over the rail where we had to go to get to the barge. Well, we made it on the barge all right, and New Orleans was right straight across the river, but this barge went up river and kept going up river. I said, "Where are we going? This barge doesn't go to Mississippi, Vicksburg, does it?" Vicksburg is about 200 miles upstream. The bargeman said, "No, we've got to do this because the current's so fast, when we start to cross the river, the current will carry us back where we started from, right at New Orleans". And sure enough, that happened.

Then I took the train up to Vicksburg, and I remember Joe Johnson met me there. He had graduated from the University of California a year before I did. He took me to a boarding house where he was staying. I arranged to stay in that boarding house. The next day I got a ride with Joe to the Waterways Experiment Station, located about ten miles south of Vicksburg. He took me into the director's office. The director then was First Lieutenant Falkner. Now the director is colonel, four military grades higher. I introduced myself, and said I received his letter about a job for me here in Vicksburg.

He said, "Well, yes, we have some jobs. " He said, "What job did I offer you? How much did I offer you?" I said, "$110.00 a month." He said, "Where did you come from?" I said, "California. " He said, "God damn. Anybody who comes to this God-forsaken place deserves a raise. I'm going to raise you to $120.00 right now. " He was a native Californian. I found out later that the Federal Government had raised the salary for the job I was offered, with the grade of Gauge Reader Pro-tern, to $120.00 a month since the date of his letter to me.

Q: So when you left the University of California to go to WES in 1935 you were going to do a type of research work with which you already were familiar?

A: Yes, that's right.

Q: Your decision was more a factor of how much money they were going to pay you than what you were going to do?

A: That's right. I was interested in going to either the TVA or WES because I knew what they were doing. The professors told me what kind of work they were doing there, model testing, various kinds of water-oriented projects. I thought those would be good places to learn on the job. WES paid me $5 more than the TVA would, so I decided to go to WES

I found out later that WES was a better place to go than TVA. It had a much bigger laboratory, and it did different kinds of work. TVA only did one kind of model testing, mainly dams, because they were building dams for power. WES had all sorts of model tests for dams, river channels, coastal engineering works, and tidal waterways.

Q: When you first went to WES, you said that you were a gauge reader pro-tern.

A: They had a big outdoor model of the lower Mississippi River. He [Lt. Falkner]] assigned me the task of reading water level gauges on a model of the Mississippi River. The model was about 300 feet long, representing about 600 miles of the lower Mississippi River. They were making studies to determine how high the levees should be to carry a large design flood. The model was constructed to a distorted scale of about one to fifty feet vertically and one foot to one mile horizontally. Water levels were measured along the model for different size floods. By scaling the model measurements up to prototype levels, it was possible to determine the levee heights required along the river to contain the design flood.

My first job at WES was to read water level gauges along the model river. There were about 25 gauges that had to be read about every five minutes. There were about six gauge readers, each sitting at separate point gauges along the model. As the river flow changed we had to read the point gauge and record the water level about every five minutes.

It was just a very simple thing to do, but ... this was in July when the temperature is hot in Mississippi. I thought, "Any grammar school kid could do this. I don't know why a college graduate needs to waste his time doing this." So I went back to Joe Johnson and told him that I would certainly like to get into something that requires a little more effort than sitting there and reading that gauge. So, after a couple of weeks, I got assigned to another job working on model tests of dam spillways and outlet works that was more interesting and challenging. But it was good training, and it didn't last very long.

Q: Wasn't that model one of the first of its kind used in the United States--one that actually tried to scale the lower part of the Mississippi River?

A: Yes. It was the first big model of that kind in the United States. There were other smaller river models, as I mentioned before. Morrough O'Brien had a little outdoor hydraulic laboratory at the University of California, which he operated to study water level problems in Oakland Bay.

Q: From that experience as a gauge reader, you moved on to be a research assistant in hydraulic model studies at WES.

A: Yes. The next job I had was to conduct model studies of Conchas Dam, the first model of a dam that was built at WES. Conchas Dam was a flood control dam in New Mexico. It was a concrete dam, about 250 feet high, with an overflow concrete spillway, a stilling basin, and outlet works.

Since it was the first model of a dam built at WES, we had to learn how to build that kind of a model, which made it more challenging. After it was constructed, it was operated by only one engineer. He made all the model flow measurements and wrote the report. That was really a learning experience.

Q: Do you remember anything that you may have changed in the design of the dam because of these studies?

A: Many times changes were made as a result of model tests. For example, with a chute spillway, high-velocity flow may cause excessive abutment and river bed erosion just downstream of the chute's end. Then a decision must be made whether a stilling basin or a flip bucket should be used. If the rock in the downstream river bed isn't suitable to prevent erosion by the high-velocity flow, then a concrete stilling basin must be used at the downstream end of the chute to produce a hydraulic jump which dissipates the energy before it goes into the river.

However, if the rock isn't excessively erodible and the end of the spillway chute isn't close to the dam, so that the downstream toe of the dam wouldn't be in danger of being eroded, then a flip bucket could be used. The flip bucket flips the water up in the air, so it lands a safe distance downstream of the end of the chute and the toe of the dam. The flip bucket is much less costly than constructing a very expensive stilling basin. That's how changes are made as a result of model testing.

Q: With Conchas, you didn't make any specific changes?

A: That's right. We made no changes on Conchas. Usually, the Waterways Experiment Station constructs the original model based on district office prototype design drawings. Then the tests are made see how the model operates. If the model shows a problem, then WES advises the district designers and suggests changes to correct the problem.

In the case of Conchas, the original design called for a stilling basin because the river was erodible. If instead the original design had called for a flip bucket, it would have been constructed in the model. Also, a model downstream river channel would have to be constructed so that the extent of its erosion could be determined.

If a large hole is eroded and progresses to the toe of the dam, that might endanger the dam. WES would show the model test results to the district's designers and say, "You shouldn't have a flip bucket. You should construct a stilling basin. " Fortunately, the district designers originally selected the stilling basin.

So the purpose of the model there was to have the design flood go over the spillway into the stilling basin and check out to see that the stilling basin dimensions were correct to form a good hydraulic jump and give maximum energy dissipation in the concrete-lined stilling basin before the water flowed down the erodible stream bed.

Q: That was the first of the models that you actually worked on and helped put together.

A: Yes.

Q: When you did your calculations, was it all done by hand or slide rule, or were early mechanical calculators involved?

A: We certainly didn't have computers.

Q: I know. [Laughter].

A: There were mechanical calculators, all right, but I always used the slide rule. I liked to use a slide rule. Figures could be carried out to the second or third decimal point with mechanical calculators. Models don't reproduce nature 100 percent, some only come within five to ten percent. I always found a slide rule to be satisfactory for making hydraulic model study calculations.

Q: You mentioned computers--how much did they enhance your ability to do these calculations when they came into use in significant numbers in the '50's and '60's?

A: I never used a calculator because I never had to make a detailed design where I had to do all the calculations myself. The district designers did that. When I went to the Chief's office, I never used mechanical calculators because I wasn't doing design. I was checking the design by slide rule. In a very short time, I could check something close enough and decide that's all right.

Q: The models that you made, like Conchas, came in from the districts. So they were funded by the districts to WES, right?

A: Yes. District projects are authorized by the Congress and money is made available to the Corps of Engineers for design and construction. Usually, it takes two or three years before districts get enough money, especially if they need to do a lot of geological field surveying, before they can complete the design sufficiently to send it to the Waterways Experiment Station for model testing.

Q: This was not done for all projects, was it? This was just done for certain projects that had questionable design aspects?

A: Small dams are not model tested, if they don't have questionable design aspects. All large dam projects that the Corps and the Bureau designed and built were tested with hydraulic models.

Q: When you were at WES, your friend Joe Tiffany was there. You've known him since then.

A: Yes. He called me up last night at 10:30. [Laughter]

Q: What was he like then, when you first met him in the '30's?

A: When I was at WES, he was the top engineer there. He wasn't outstanding intheoretical hydraulics or anything else, but he had good sense and was a good executive. Everyone respected him. Later, when I was in the Chief's office, I would go to meetings at WES several times a year. I'd always make a point of talking to Joe for an hour or so about things going on. Things that I had to look at and that affected the Waterways Experiment

Station, and we got along very well.

When the Committee on Tidal Hydraulics was established, he was appointed to that committee right from the beginning. Clarence Wicker of the Philadelphia District was elected chairman, but when Clarence retired, Joe was then elected chairman. He was chairman from ‘61 to ‘69, and he was a good chairman.

Q: Was there anything else you wanted to discuss concerning WES?

A: You asked me several times what did I think about WES. I have a letter that I wrote to WES after I was invited to their 50th Anniversary. The invitation is dated ‘79 and signed by Colonel Cannon, Commander and Director.

Twelve years ago. This was shortly after I retired from the Corps. I wrote, “Thank you for the invitation to attend the station’s 50th anniversary. I regret that I shall not be able to attend. I arrived at the station fresh out of the university in July of 1935 when the station was barely five years old. It was small then, and the Engineers were just getting their feet wet in hydraulic models and soils testing. The station has grown tremendously with expansion of its research and engineering investigations in many engineering fields. It is now regarded perhaps as the world’s leading research institution.”

This is a great tribute to the many outstanding directors, staff and employees who have contributed so much to the development of the station’s capability. I am proud to have had a small part in advancing the station’s technical capability in hydraulic engineering in 32 years of service in the Office, Chief of Engineers. My association with the station’s people have always been most cordial and rewarding. Sincerely ...”

Since you asked me what I thought about the station, I am pleased to have the above recorded.

Q: Now, I know that you weren’t at WES when Herb Vogel was there.

A: That’s right. Falkner was there. Vogel--I forget when he left--but I think it was a couple of years after Vogel left. First Lt. Falkner; Francis Falkner, was the director when I came there in 1935, July of 1935. He came from California, and hated Vicksburg. He always said, “Boy, anybody who comes to this God-forsaken place deserves a raise right now.” That’s when I went in to his office when I first arrived. He said he’d raise me $10.

Q: Did you ever work with Herb Vogel after that?

A: No, I never did. I met him a number of times. He was up here working for the World Bank, wasn't it, for awhile?

Q: Yes.

A: He was a consultant there, but I never worked with him, never was on any committees or anything.

Q: How about Gerard Matthes?

A: No, I never worked with him, either. I wasn't at the station in '36.

Q: Yes, he was there for years.

A: Not too many years, because Tiffany got his job. Tiffany's biography states that Matthes was there because the head of the Mississippi River Commission sent him over to be the Technical Director at the Waterways Experiment Station.

Q: Well, Tiffany was there until '69.

A: Yes, he was, but he was Director way before then. He was director in the early '50's. It says here when he was director. Here's what Tiffany says: "I served as WES Acting Director from Pearl Harbor Day in December 1941 when Captain Fields left for active duty until January 1, 1942. Max Tyler finally changed his mind about me continuing as Acting Director and instead appointed Gerard Matthes to the job. I did not talk to anyone about this, but Humfrey Moore told me that General Tyler had pulled a raw deal on me and Bill Turnbull told me he was perfectly satisfied with how I ran things when I was acting director for the preceding six months. These two voluntary statements made me feel pretty good. I figured out later why he did that."

General Tyler sent Matthes there. Tiffany figured out why he did it: "The MRC had two top engineers with exactly the rank and the general had to choose between them. One was Mr. Matthes, who was over 70 years old and a bit senile, the other was Harry Seymour, who was younger and more vigorous. The general sent Matthes to WES to put out to pasture, where he could not do anything harmful."

Q: What other studies did you do when you were at WES? Did you basically stay on dams?

A: Mostly, yes. I was there only one year, and after working two or three months up on the Mississippi River Basin model reading gauges, then I worked on dam models for nine months before I transferred to the Bureau of Reclamation in Denver, Colorado.

Bureau of Reclamation

I stayed [at WES] one year during which time I took a Federal junior engineer exam and passed it with a pretty good grade. I got three job offers, one from the Bureau of Reclamation, one from Brownsville District of the Corps of Engineers, and one from the Savannah District of the Corps of Engineers. The junior engineer grade paid $2,000.00 a year, and I thought, boy, that's a real big increase, from $120.00 to $167.00 a month. The Bureau of Reclamation paid $2 $00.00, but the districts only paid $1,620.00. Well, that didn't make it too hard to decide to go to the Bureau of Reclamation.

So I did, and went out to Denver, Colorado, where they assigned me to the Project Investigations Branch where they studied the feasibility of constructing projects to produce more power or irrigation water. The Bureau was not as flood control oriented as the Corps. I remember that after a feasibility study was authorized I had to take rainfall and runoff records and produce flow hydrographs to determine what large floods could occur and how much water supply could be obtained at specific locations where a dam might be constructed. The trouble was that three of us young engineers had to do all the boring work of looking up records, tabulating and adding them, do this and that, and then bring them into the boss. After about three months of that, I got tired of tabulating rainfall and runoff records, getting a hydrograph, and bringing it into the boss so he could use it and make the decision about what to do with it. He does all the studying, and would say, "Now, you do that and then add this, and let's try a bigger flood." He did all the interesting work and wrote the report on the feasibility of the project.

The Bureau of Reclamation had a little laboratory down in the basement in the old Customs House in Denver. So I wandered down there, and was interested in the models. I found that several Bureau dams were being model tested. I introduced myself to Jake Warnock, who was the director of the laboratory then. He asked if I were interested in working in the lab, and I said, "Yes, I'd just came from Vicksburg where I'd worked in the lab for a year, and I liked lab work." I told him I'd be interested in working in the laboratory whenever he had a vacancy. It wasn't very long, a month or so, when I started to work in the laboratory. He arranged for me to work in the Bureau's lab, and I worked there for about three years, mostly on hydraulic model studies of spillways and outlet works for dams being designed by the Bureau. I learned a lot about hydraulics and dams there because we worked on model tests for about eight different kinds of dams with various kinds of spillways and outlet works.

Q: So this was a critical experience for you, then?

A: It certainly was.

Q: How much did you note the difference between the way the Corps worked and the way the Bureau worked at that time? Or had you spent just too little time with the Corps to understand that?

A: Yes. Well, the impression was in the engineering profession that the Bureau of Reclamation was the outstanding government engineering agency. They knew more about design and construction of dams than any other agency. That's not surprising because the Bureau started at least 20 years before the Corps on designing and constructing dams. When I was working for them, they were doing a lot of things that the Waterways Experiment Station wasn't doing. The Waterways Experiment Station was just doing model testing. I was in the Bureau's head office, where design, model testing, project investigations, concrete and earth dam engineers were all in one building.

Q: Did you discern any kind of institutional approaches on the Bureau's part at that time? Did they have a preference for a type of dam, earth versus concrete, or a specific design?

A: No, I don't think so. A lot of their dams were earth. Of course, the specific factors and conditions many times made it obvious whether an earth dam or a concrete darn should be constructed. In a narrow gorge with rocky abutments, a concrete dam will be the least costly. Construction of an earth dam is difficult in that kind of site. On the other hand, for a low dam in a valley, 500 or more feet wide, usually an earth dam was cheaper. The cost usually determines what kind of dam is constructed.

Q: The cost and the actual physical topography of the area that you're dealing with are also critical, aren't they?

A: Yes. That has something to do with it, too. Topography affects the cost, so, actually, topography, type dam, and cost are interrelated factors. Also, for a fairly high dam, if there is no good rock foundation, it's better to construct an earth dam because the base of the earth dam is much broader than a concrete dam. That's the most important factor to consider in deciding whether an earth or concrete dam should be constructed.

Fort Peck Dam on the Missouri River is an earth dam constructed on a foundation with very little rock. The dam is relatively low and the river is unusually wide. Construction of a concrete dam was not even considered because the conditions strongly favored the earth dam. The spillway and 36-foot diameter outlet tunnels were constructed of concrete to carry the large, high-velocity flows. Concrete stilling basins were constructed at the downstream ends of the spillway ad outlet tunnels to still the water flows before entering the Missouri River's erodible channel.

Q: So, even in those big earth dams, you still have a lot of concrete work that you have to put in?

A: Oh, yes. There's a lot of concrete.

Q: And that's where your skills come in?

A: That's right, the hydraulic engineer is involved with both concrete and earth dams because in almost every case the spillway and outlet works need to be constructed of concrete. Only for low dams and very good rock conditions, can the spillway be excavated in a dam abutment.

Q: I may be jumping ahead here a little bit, but how much different is it in the hydraulics when you have to do a multipurpose dam, when you're going beyond just flood control, when you're starting to put in the penstocks and the hydro. Does that cause a lot more difficulty in the design? You have to look at a lot more things then, don't you?

A: In either case, there's no difference as far as the spillway is concerned. The difference is in the outlet works. For a large dam, like all those on the Missouri that produce a lot of power, one or more penstocks are needed. These are constructed of concrete underneath the dam at its base to the power house and turbines that generate the power. In addition, one or more conduits or tunnels are needed to serve as outlet works. During a large flood, some water can be released through the power penstock, but not nearly as much as through the same tunnel if it is not hooked up to a power turbine.

For example, Fort Peck Dam has, as I recall, about six big tunnels, of which four lead into a stilling basin and are used as outlet works. Maybe it's the other way around--four lead into the power houses, and two lead into a stilling basin. Normally, when water stored in the reservoir was being released to produce power, no water was released through the outlet works tunnels.

But, if a large flood occurred and the reservoir water level increased so the spillway operated, then the outlet tunnels would be operated to control the reservoir level and spillway flow. The spillway and outlet tunnels are designed to be large enough so that their combined maximum discharge will control the probable maximum flood at the dam. This, also, determines how high the dam needs to be to prevent overtopping by the probable maximum flood.

Q: The Bureau, at that time, was involved in a lot of dams. It was working on Grand Coulee, then, in the late '30's, and had just finished Hoover, right?

A: Hoover was finished in about 1936, and Grand Coulee a few years later.

Q: Do you remember any of the dams that you were doing work on in your laboratory work?

A: I remember one especially, Lahontan Dam in Nevada. It had already been constructed with an unusual type of spillway, a step spillway. Instead of having a smooth concrete spillway invert down to the river channel, it had a series of steps. The water flowed about 100 feet on a level floor and then dropped vertically about 10 feet. There were about eight such steps before reaching the river channel.

The dam was operated a couple of times during large flows, which caused erosion at the bottom of those steps. A model study was not made of the stepped spillway during the design stage, so a model was designed and tested to determine what changes had to be made to improve the operation. I did those model tests and found that rounding the top of the steps improved the flow over them sufficiently to eliminate the erosion problem. Tests also showed that some of the steps could be eliminated, but at greater cost.

The prototype spillway was modified in accordance with the model test results. A few years later a large flood occurred, and the spillway operated satisfactorily without any erosion. I haven't heard anything about it since. It's probably still operating satisfactorily.

Q: When you were in Denver, did you do any additional work at either the University of Colorado or Colorado State, both of which apparently offered some advanced work in hydraulics?

A: Yes, they did. The Bureau had done some of their model testing up there at the University of Colorado. E[mory W.]. Lane was in charge of the model testing there.

Q: Was that at Colorado State at Fort Collins?

A: Fort Collins, right.

Q: Yes. That was Colorado State.

A: Colorado State. Oh, yes. University of Colorado is south of Fort Collins, isn't it?

Q: Right. It's in Boulder.

A: Right. Boulder. I didn't do any work in the Fort Collins laboratory.

Q: So you were in there in the Bureau's Denver Laboratory the whole time?

A: Yes. Oh, I did some work in the Denver laboratory on the Boulder Dam tunnel spillway. Joe Bradley was there then. Did you ever hear his name?

Q: No. Who was he?

A: Jake Warnock was head of the laboratory, and Joe Bradley was the assistant. He was in charge of the Boulder model, and I worked with Joe on that. The details of that escape me right now.

Q: Well, you had some fairly important engineers working there in Denver, didn't you?

A; Yes. I think they knew more about the hydraulics of dams than anyone in the Corps at that time.

Q: Well, besides Lane, didn't you have Edgar Houk there?

A: Houk? Yes, he was in the Denver office. He headed one of the design branches. I never was very close to him.

Q: They did a lot of early work there at Denver on modeling and hydraulic modeling.

A: That's right. And design. They did all the design right there in the Denver office, too. They didn't have field offices that did design like the Corps' district offices. They had field offices that did the surveys and, when construction started, managed the construction. The Denver office did all of the design.

Q: We were talking about the Bureau's design work at the Denver office. They apparently were pretty good and pretty far advanced from what you say?

A: Yes, they were. They were known the world over as being the leading dam designers.

Q: So actually, your work in the Bureau was like a post-graduate course in dam design?

A: Right. That's right.

Q: Do you ascribe a lot of your later success to that experience?

A: Yes, I do. After I left the Bureau, in 1938, I went back to the Corps of Engineers, Los Angeles District Office. I remember many times when we discussed a design problem, I'd say, "The Bureau does it this way, and I think that's the way it ought to be." The Corps people recognized that the Bureau knew what it was doing.

Q: How much interaction was there between the Bureau and civilian hydraulics professors, not consulting engineers?

A: I had significant contact with Professors Rouse, Straub, and Ippen, who headed the Iowa, Saint Anthony Falls, and MIT [Massachusetts Institute of Technology] hydraulic laboratories, respectively. They were on a number of Corps of Engineers' consulting boards. I took a course from a professor at Colorado State. It was a good course, closely related to model testing.

Q: So, it was more theoretical or practical?

A: More theoretical. That's right. Other than that, I had no contacts with professors.

Q: I was looking at Hunter Rouse's book on hydraulics in the United States...

A: I first met Hunter Rouse in 1936 when he worked for the Sedimentation Laboratory at the California Institute of Technology. Later, I attended annual conferences in hydraulics at the University of Iowa, which were organized by Rouse.

Q: Was that in the 1930's or later?

A: It was later, I think, in the late 1940's and early 1950's.

Q: Well, Hunter Rouse was already at work there by that time?

A: Yes. I think he became a professor at Iowa in 1939. I've got the proceedings of his hydraulic conferences in a box here, which I plan to donate to the Corps' Office of History. The Corps used hydraulics professors as consultants more than the Bureau did. Maybe it was because I was new at the Bureau, and didn't get involved as closely with professors as I did later when I was with the Corps.

Q: Did the Bureau have so much experience that it really didn't need many professors?

A: That would be the reason, because the Bureau developed its design procedures before the professors came aboard. Rouse was a young man when the Bureau was well into the design of dams. The Bureau engineers were practical designers, and didn't use the theoretical fluid mechanics that Rouse was teaching. I think that's probably the reason.

Q: So again, it's a conflict between theory and practice?

A: That's right.

Q: When you were dealing with Rouse, you were more in the applied area and he was more in the theoretical.

A: That's right. I was on a couple of boards with him. One was a large dam in British

Columbia, Mica Dam. He and I were on the same board for about five years. When a question arose about a hydraulics problem, I said, "Call on Hunter Rouse first, and let him give us the theoretical aspects of the problem, and then I'll speak on the practical aspects of the problem." Everybody laughed. Usually, the practical and the economic method was the one that was selected over a purely theoretical way of solving the problem.

Q: You also mentioned Lane, Emory Lane.

A: Yes.

Q: What kind of a person was he, and how much influence did he have on your subsequent career? Was there any?

A: He didn't have very much influence because I never was close to him. He was up in Fort Collins all the three years I was at the Bureau, and I didn't have very much contact with him.

Q: From your knowledge of his work?

A: He was a well-known man in his field of hydraulics.

Q: How about Warnock? He must have had some significant influence on you?

A: Yes, he did. He was a good producer, and he was extremely practical, but he was short on theory. He didn't like to write reports. Just wanted to get the laboratory work done as fast as possible.

Q: So he was an activist?

A: Yes. Unfortunately, he became ill, and died in his early 50's.

Q: Didn't the Bureau also have a small laboratory out in Montrose, Colorado?

A: Yes, it did. I don't think I ever went there. I don't know anything about it.

Q: Were they mainly working on irrigation?

A: That could be, yes. They did quite a bit of work on development of irrigation techniques. I didn't get into that, at all.

Q: I've got some other names here I'm going to ask you about, and see if you can remember any of them.

A: All right.

Q: Did you do anything with Mr. John L. Savage?

A: Yes. He was the Chief Engineer or Commissioner when I first went to the Bureau. I remember that he wasn't in Denver much of the time because he was already working as a consultant for the Chinese on their big projects. He consulted on a very large Chinese dam, one of the largest in the world. I've forgotten its name. I don't think it's constructed yet. Savage was the first American consultant on it.

About ten years ago, a team of Bureau and Corps engineers went to China to advise on the dam's design. After nearly a year, they produced a report. Now, Lloyd Duscha, who retired from the Corps of Engineers as Chief of the Engineering Division in the Chief's office about four years ago, goes to China as a consultant on their dam projects.

Q: I want to ask you about some other people who were working out there in Denver or at Fort Collins about the same time you were there. John Drisko?

A: Yes, he was there. He worked in the Bureau's hydraulics laboratory the first year I was there, and then he went to New York to work for Tibbetts, Abbott, & McCarthy, consulting engineers. I did a lot of consulting with Tibbetts, Abbott, & McCarthy, and Drisko was there for awhile. He retired about 15 years ago. I don't know anything about what he's doing now.

Q: How about Frank Campbell?

A: Frank Campbell. Yes. Did Frank work at the Bureau?

Q: He was at the laboratory there in the late '30's.

A: Oh, he must have been up at Fort Collins.

Q: He may have been at Fort Collins.

A: He went to work for the Corps in the Omaha District Office in the early 1940's. When I went to the Chief's office in 1946, I met Frank in the Omaha District Office shortly afterwards. He was in Hydraulics Design Branch there. One thing we talked about was the hydraulic design criteria that the Bureau had developed and was publishing in design criteria manuals.

I said that the Corps ought to be doing something like that, too. He agreed, but it was a couple of years before I was able to persuade the people in the Chief's office that we ought to develop our own design criteria. We got plenty of basic information, but we've got to get somebody somewhere to sit down and put it together.

Slichter was Chief of the Engineering Division, and he said, "You think about it, work something out, and come back." I had the idea that Frank Campbell was the type of engineer who liked to collect available information and develop design criteria. Slichter agreed that I should organize the work.

I called Frank and said, "I've got authority to organize the development of the Corps' design criteria. I think the way to do it is to have the work done at the Waterways Experiment Station. Are you interested in going to Vicksburg and working on this?" He said, "Yes, I am." He went there, and arranged for two other laboratory people to work with him. He finished his career working the last 15 years or so down in Vicksburg. He developed and published a lot of hydraulic design criteria. Frank retired nearly 20 years ago and is still living in Vicksburg.

Q: What about Donald Barnes?

A: Don Barnes was in the Bureau's Denver laboratory when I was there. He was Jake Warnock's assistant for a while. I worked with him on several model tests. He was an exceptional person and engineer.

Q: Did he stay in the Bureau then?

A: No. He left about 1945 and went to the Washington office of the Department of the Interior. He retired in the 1950's and came back to Denver. I haven't heard of him for many years. I think he is still in the Denver area.

Q: How about Haywood Dewey?

A: Oh, yes. Dewey and I were very close. In fact, we had desks right next to each other when we were working in the Bureau's Project Investigations Branch. We also worked together in the laboratory. Dewey was an Army reservist, and when World War II started, he served in the Army for about two years. After the war, he went to work for the Corps of Engineers. I don't know where, but in about two years he went to the San Francisco District as head of the hydraulic laboratory.

Q: Was he involved with the San Francisco Bay Model at all?

A: Yes. A very large model of the San Francisco Bay was the only model being tested at that time

Q: The Bay Model was quite intricate, wasn't it?

A: Yes, it was. I never worked there, but when I was in the Chief's office, I went to the laboratory several times to attend review meetings of the model tests results. It was a very good model.

Q: What about Victor Streeter?

A: Yes. Victor Streeter was also at the Bureau of Reclamation's Denver laboratory when I was there. He was very theoretical, and didn't seem to be happy about just running model tests in the basement. It wasn't very long before he left to become a professor at the University of Illinois. He wrote a book on fluid mechanics. As far as I know, he ended his career there.

Q: By the time you had worked with both Streeter and Barnes, they had both been to Germany on John Freeman Fellowships.

A: Yes. That's right.

Q: Did they talk about that experience? How critical was that? Did they pass a lot of information back to you folks?

A: Not very much. I don't remember that they ever gave us a lecture on what they learned in Germany. They had some reading material. I don't really know very much about the Freeman scholarship.

Q: Many experts consider this to have been very critical in the development of hydraulics as far as international technical and scientific transfer is concerned.

A: I think that is correct, probably more with respect to the theoretical aspects.

Q: But you didn't gain anything from them on that?

A: No, I didn't. I don't remember anything.

Q: Is there anybody else you can remember from your days in the Bureau that played a significant role in the development of hydraulic engineering or hydraulics?

A: James Ball. He worked with the Bureau a long time in its Denver and Fort Collins hydraulic laboratories. When he retired, he did consulting and taught part-time up at the university in Fort Collins. The Bureau's laboratory was turned over to the university, and he headed that for a while. They did contract model studies for various clients, and Ball was in charge of making the model studies for a year or two when Richardson took over his place. Ball stayed at the university and taught a course, and then he did some part-time consulting. He and I were together in Iran, just before the Ayatollah took over. [see pp. 79-81].

Q: Let's see. We've now talked about all those folks. You've said several times that this Bureau experience was formative. Then you went from the Bureau back to the Corps and to the Los Angeles Engineer District.

A: Yes.

Los Angeles Engineer District

After working at the Bureau for about three years, '36 to '39, I wanted to get back to California. I knew some fellows who were in the same class as I was at Berkeley who had gotten jobs with the Los Angeles District, so I wrote them a letter. They said, "Jimmy Jobes is Chief of the Hydraulics Branch here, and he runs the lab also, plus the hydraulic design work. Write him a letter."

So I wrote him a letter, and in a short time he replied, "We've got a job in the Hydraulic Design Section paying $2,300.00." Well, that's $300.00 more than the Bureau was going to pay me.

It wasn't very long before the word got around that I was leaving the Bureau to work for the Corps, and Debler, Chief of the Project Investigations Branch, asked me to come and see him. He said, "I hear you're going back to the Corps of Engineers." "Yes, to the Los Angeles District office. I want to get back to California, and they're paying me 2,300. That's more than you folks pay here." He said, "I'm going to tell you one thing. The Corps of Engineers is not a good outfit to work for. They're just crummy. I've got a place for you to work up in Boise, Idaho, where we've got a field office, and I'll pay you 2,300 if you'll go up there."

I said, "Well, no, I appreciate all your kindness, but I want to go back to California. All my family's there." So I did. That's how I got back to California.

Wolf Creek Dam, Nashville Engineer District

Q: I've got some information here that says you went to Nashville District first, in 1939.

A: Well, I went to Los Angeles District, but I was there only a short time when I was sent to the Nashville District. TVA was trying to get money to design and construct the Wolf Creek Dam in Tennessee. The Corps of Engineers thought that its Nashville District should do it.

It got to be quite a hot political item. Roosevelt was president then, and it was all laid out before him. He said, "The Corps of Engineers should do it." It was known that there was something he didn't like about the TVA. The TVA said, "The Nashville District doesn't have any experience designing dams. We do."

Roosevelt asked the Corps representative, probably the Chief of Engineers, what he could do about that. He answered, “We’ve got a lot of good dam designers in the Corps. What we’ll do is get a group together from our districts, our most talented people, and we’ll send them to Nashville for however long it takes to design the dam, probably about a year.” So Roosevelt said, “Fine. Do it that way.”

It wasn’t very long before Åke Alin, Chief of the Engineering Division, Omaha District, was assigned the job of heading up the team. He decided the kind of engineers that were needed: hydraulic, structural, concrete, and electrical engineers. He contacted several divisions and districts, including the Los Angeles District, asking for volunteers to fill the positions on the team. I applied for the hydraulic engineer job and got it.

I was on loan to the Nashville District and was paid per diem by the Los Angeles District. I remember the per diem was $5.00 a day. [Laughter] Holy Moses! $5.00 a day! I was there for about three months. My wife and I were married about a year, and she enjoyed going there. We had a room in a boarding house, which didn’t cost us very much. We saved enough money to buy a new car. First car we owned.

Q: Were there any peculiarities about Wolf Creek that you remember?

A: It’s design was quite simple, much like Conchas Dam. It was a concrete dam, with a center overflow spillway, small sluice outlets, and a stilling basin, which did not require model testing.

Q: Just went in and designed it?

A: My experience with the Conchas Dam and several others made it easy to design Wolf Creek Dam.

Q: You were out there for several months then?

A: I was there about three months. My wife’s sister and brother were still living in Washington, D.C., where she lived for a number of years. We went to Washington and visited there awhile, and it was about four months before we got back to Los Angeles. I went back to work on my previous job in the Los Angeles District.

Hydraulic Engineer

Q: Let's go back to the Los Angeles District now. You went to Los Angeles District in 1939 as a hydraulic engineer. Were you hired to do general hydraulic design work in the district or were you specifically hired for some of that flood control work in Los Angeles?

A: Jimmy Jobes was Chief of the Hydraulics Branch, which had hydrology and hydraulic design sections. There was a small laboratory along the river in the park, about six miles from the office, which also was under the Hydraulics Branch.

Bill Cassidy was in charge of the hydraulic design section, and I worked under Bill. We designed flood control channels for the Los Angeles River, San Gabriel, and other rivers. These channels were mostly concrete-lined, but some were lined with rock riprap. We also did the hydraulic design and model studies for Santa Fe, Hansen, Sepulveda, and several other dams and debris basins.

After a year or so, Bill Cassidy was promoted up to the Division office, ... and Jimmy Jobes got promoted to Assistant Chief of the Engineering Division. I got promoted and I got Bill's job. I was chief of the hydraulic design section, and had the hydraulics laboratory under me. Al Gildea was in charge of conducting the model tests, which were mostly on river channels then.

Flood Control Dams and Channels

Q: These flood control dams were a little different for you, weren't they?

A: They were a little different dams; they weren't as high and were designed to store debris as well as water. Dams which were designed mainly to store debris were called debris basins. The mountain streams carried large volumes of gravel, which, if not kept from passing through the concrete outlet works, would cause severe erosion damage to the outlet.

Another problem had to do with trash racks in front of the outlet works. Normally, large quantities of floating trash would be carried by flood flows to the trash racks. At Sepulveda Dam, during one big flood, there was so much trash blocking the trash racks that only about 20 percent of the design flow was passing through the outlet works. When I went out to study the problem, the reservoir water level was about 30 to 40 feet higher upstream from the trash rack than the water level on the downstream side of the trash rack. This was caused by the large amount of trash blocking the rack.

Q: What was required? Make wider spillways or something that would take that junk out?

A: We had to enlarge the openings in the trash rack so the debris would go on through.

Q: When you do something like line the Los Angeles River with concrete, those floods are very large flows, aren't they?

A: Yes, they are.

Q: Your design has to be specifically gauged to those large flows, doesn't it?

A: Yes. We had what was called a design flood, and we designed the channel to carry the peak flood discharge of that. The channel was constructed wide enough and deep enough throughout its length to carry the design flood.

The Los Angeles River channel is concrete-lined, except for the lower six or eight miles where the slopes were flatter and the velocity is not so high. Here, it was found that a less costly method of rock lining the levees and constructing rock drop structures across the channel every 1,000 or 1,200 feet was a lot cheaper than concrete-lined channels.

Q: What were the problems that you might have had working on those flood control channels? We talked about the debris problem.

A: The drop structures had to be designed so that the water would drop about 10 feet, and they had to be designed as part of a small downstream stilling basin. Even though the velocity was fairly low, the river bed is nothing but sand, which might scour sufficiently to undermine the downstream levees. Model tests were made of the drop structures to be certain there was adequate protection. Downstream of the drop structure, some rock protection was required to prevent excessive erosion of the sand beds.

Q: There was a lot of work going on in the late 1930's.

A: Yes. There was a lot of work going on then. During the time I was there, we designed San Gabriel River channel from the mountains all the way down to the Bay. The Los Angeles River channel construction was already completed. The San Gabriel River channel, which was about three or four miles to the east and ran almost parallel to the Los

Angeles River channel for the last 10 or 15 miles, was not concrete-lined; it was rock-lined all the way, with drop structures. At the same time, we were designing Santa Fe and Whittier Narrows Dams.

Q: So the one we see--mostly on TV--is the Los Angeles River?

A: Yes. That's right. One time someone got the idea that, since the river was dry most of the time, a traffic freeway should be constructed through the City of Los Angeles on the bottom of the river channel. [Laughter]

I pointed out that at least small flows occurred at all times along the center of the channel, so the freeway would need to be placed part way up on the channel banks, with one side going south and the other side north. The problem was how high up on the banks would it need to be to remain in service most of the time and not be flooded by river flows resulting from every rain storm.

Q: Did you get involved in the Santa Ana River work at all?

A: Yes, I did.

Q: That's still ongoing, isn't it?

A: Yes, it is. Prado Dam was built while I was there. I worked on its design. The hydrology of the whole Santa Ana River system was reviewed several years ago. It was concluded that the Prado Dam isn't large enough to take a probable maximum flood. Now the Corps is thinking about constructing another dam at the upper end of the Santa Ana River at the base of the mountains.

After Prado Dam was constructed, the Santa Ana River levees downstream of the dam were raised so the river channel would carry the Prado Dam spillway design discharge. However, those levees are not high enough to carry the probable maximum flood discharge. The levees are so low that if the spillway had gone into its maximum flow, it would have flooded that development downstream from Prado Dam to the ocean. When Prado Dam was built there, much of that was just farmland and so on. But now, it's all houses. The quickest thing they could do was raise the levee all the way down. That hasn't been completed. The design of the second dam and for additional raising of the Santa Ana River levees has been completed, but construction has been delayed because of budget problems.

Q: Were you involved in the San Antonio project?

A: Not in its design. It was already constructed when I was there.

Q: Well, none of those were particularly different, were they? I mean, these are all flood control and debris basins basically.

A: That's right. All the dams in the Los Angeles area were for flood control and debris storage. It was not economically feasible to develop water supply or hydropower in the Los Angeles area because rainfall occurred about three months of the year, so the reservoirs were usually dry.

Q: So mainly there's just flood control there?

A: Yes.

Q: So you spent the time from 1939 to 1946 primarily working on these flood control structures?

A: Yes.

Los Angeles District During World War II

Q: You weren't switched to any of the military construction when the war started?

A: No, no military construction, except that when the war started, a more concerted effort was made to protect airfields from flooding. Moffett Field was one. When it was constructed before the war, nothing was done to protect it from flood drainage. But after the war started, the military decided that flood protection was needed so that the field would be operational at all times. I assisted in the design of drainage ditches to prevent water flows during large rainstorms from flooding the runway.

Q: Do you remember anything else about working in Los Angeles District there during those years? People you worked with?

A: In 1939, Dick Eaton was Chief of the Navigation Section, Los Angeles District. The lower ends of the rivers that ran into the Pacific Ocean or a bay were navigable. Also, many of the bays had navigable harbors. Many of the navigation channels and harbors had to be deepened and maintained by dredging. In about 1941, Dick got promoted to the division office. He was put in charge of harbor design and maintenance for the entire South Pacific Division, all up and down the Pacific Coast. Several years later he came to Washington, and he was technical director of the Beach Erosion Board [BEB], and later, the Coastal Engineering Research Center [CERC].

Q: So he was one of the coastal engineers that you later dealt with. During the war, then, you just kept on working on those flood control projects?

A: Yes. We kept on designing them, but we didn't get money to do any construction. We were told by higher authority that the flood control projects had to be designed and put on the shelf because when the war ends there will be a lot of people, including soldiers, looking for work, and there will be plenty of money to construct these projects. For two or three years, that's all we did. Then after the war ended, it was about another year before construction started again.

Q: What was the Los Angeles District like during the war years?

A: There was a military division in the district. Jack Tyler was in charge of the military work. They designed and managed the military construction of several military airfields and camps. I wasn't involved in that.

Q: That must have been a pretty large district?

A: Yes, it was one of the largest, if not the largest, Corps district. I remember the District Engineer when I first came there. He went to Honolulu and became District Engineer there. After the war started, he came back to the Los Angeles District to recruit engineers to go over to England to help prepare for the invasion of Europe. He spent several days in the Los Angeles District, and then went to other districts for the same purpose. Somehow or another, he got my name, and I was called to go and talk with him. This was in 1942.

He explained that he was enlisting Corps engineering employees, on a voluntary basis, to join him, and form a battalion of engineers in London to help in the crossing of the

English Channel when the invasion took place.

He wanted to know if I'd be interested. I said, "What would I be?" He said, "I can give you a Captaincy." I said, "That sounds pretty good to me." I thought a little while, and said, "You know, I would certainly like to do that, but my wife is in the hospital. Our first son was born yesterday [April 23, 1942], and I don't think I want to leave her right now." He said, "I understand," so that was the end of that.

Q: Was that Ted Wyman?

A: Ted Wyman. You're right. Your memory is better than mine.

Q: Well, I've got some aids here, you know. [Laughter] He was the District Engineer in Honolulu.

A: Yes. He was there, after he left Los Angeles.

Q: I don't think he ended up going to England. I think he ended up in Alaska.

A: That's right. He went to Alaska. I think he just had this one job, to get these people organized, and then his next assignment was up in Alaska. He worked on the All-American highway down to South America.

Q: He had the Alaska Highway, and he had that CANOL [Canadian Oil] Project.

A: Right.

Q: CANOL would have been enough to drive anybody crazy. [Laughter] What was wartime Los Angeles like?

A: Wartime Los Angeles?

Q: Just so I can get a taste for the social aspect of the war era.

A: It didn't seem much different than before the war. Of course, there wasn't much war going on in Los Angeles, those who were involved in the war went across overseas.

Q: So they weren't staying around very long?

A: No. When Wyman came, he talked to another engineer who was in the district, who was in charge of hydrology. I forget his name also. He accepted and went to London. I got word later on that everything worked out all right, and he was promoted to major. But his wife stayed in the Los Angeles area, and we'd see her now and then. Finally, word got around that the two had separated, and that he wasn't going to come back. Later, he married a German woman.

Q: So he stayed in Europe after the war?

A: That's the last I heard.

Los Angeles District Personnel

Q: Is there anything else about the people you worked with in Los Angeles District that you'd like to mention--you have mentioned Jobes.

A: Yes.

Q: You mentioned Dick Eaton and Jack Tyler. Any other people with whom you worked who went on to have significant careers in the Corps of Engineers?

A: Let me see. Jack Tyler was a reserve officer. Dick Eaton was recruited as a civilian engineer, and Jimmy Jobes was a reserve officer who was recruited. He served a couple of years in the Army, and then he came back to the Los Angeles District as a civilian employee.

Q: I've got some names here. Let me run them by you, and see if you can remember them.

A: All right.

Q: You have already mentioned Harry Thompson.

A: Yes, Harry Thompson. He was Chief of the Engineering Division when I left the district in 1946. He was an excellent man to work for. He wasn’t all that strong technically, but he really had excellent judgment and was a very practical engineer.

Q: Did he stay there after the war? I mean, after you left?

A: Yes, I think so. I think he still was there for awhile, and then he retired. Ed Kane took his job as Chief of the Engineering Division.

Q: How about Guy Bebout? Was he there?

A: Yes. Guy Bebout was there when I first came in 1939. He was the top civilian.

Q: Chief of the Engineering Division?

A: Engineering Division, right. Larue was his assistant. Jimmy Jobes was under those two guys as Chief of Hydraulics Branch.

Q: How about an Archibald?

A: Archibald. The name’s familiar, was he an officer?

Q: Not according to this. He was Assistant Chief.

A: Under Bebout, I guess.

Q: Yes.

A: Well, I didn’t have too much to do with them.

Q: This is for the late '30's, so it might not be when you were there--how about Mr. Evans? L.T. Evans?

A: Yes. L.T. Evans. He was the structural man, Chief of the Structural Branch.

Q: Right.

A: Sometime he was kind of hard to get along with. He knew structural engineering all right, but frequently had difficulty in accepting my hydraulic engineering viewpoint.

Q: There are some military folks who were there after Wyman, who may have been there when you were there. Herb Milwit?

A: I don't remember him.

Q: How about George Withers?

A: Yes. His name is vaguely familiar. I don't remember.

Q: Is there anyone else you can remember from those years that left any impression?

A: Oh, that's a long time ago.

Q: Oh, I realize that.

A: I remember the ones that I was closest to.

Q: Well, I realize that. Sometimes I like to give you a few names to see if they strike a bell. Frank Carlson.

A: Oh, yes. Jimmy Jobes and Harry Thompson, and all those. Frank Carlson was structural dam designer.

Q: How do you rate those folks that you knew against today's engineers? I realize that's not a fair question, given the difficulty of doing that kind of thing.

A: I'd rate them as very capable engineers, even though they lacked many of our modern techniques and design criteria. Of course, Harry Thompson didn't have the experience that some of the engineers have today in the Corps' larger districts, where they have been involved with more large projects.

Q: Is there anything else you can remember from your time in LA District that you want to discuss?

A: No, I don't think so.

Involvement in Professional Engineering Organizations

Q: Let me go back and ask you a question about your time in the Bureau, and it applies to LA District, too. Were you encouraged to participate in the professional associations, the American Society of Civil Engineers (ASCE), and other professional engineering organizations? Not only to join as a member, but to prepare papers and go to meetings. Was there a lot of interchange, interaction, espoused by your superiors?

A: Most of my superiors participated in professional engineering organizations and encouraged the younger engineers to do likewise. They never pressured anyone to present papers or attend meetings.

Q: Did you do any writing and publishing at that time?

A: Yes, I did. I spent the last couple of days assembling all the papers that I wrote for publication. I have a total of 34 technical hydraulic engineering publications, of which 32 are papers, and the other two are contributions to the ***Handbook of** Applied Hydraulics* and a book, *Safety of Existing Dams.* The first paper I had published was on Green Mountain Dam, which I model tested during my first year at the Bureau of Reclamation. It was published in the *Civil Engineering* journal, dated March 1940.

While with the Los Angeles District, I wrote several papers on flood control channels and debris basins. When in the Chief's office, I wrote about a dozen papers, of which most were published in the ASCE's *Journal of the Hydraulics Division Journal.* When I joined international associations, like the Commission on Large Dams, Association for Hydraulic Research, PIANC [Permanent International Association of Navigation Congresses], and Irrigation Drainage Congresses, I presented papers at the meetings which were published in the proceedings of the meetings. Luckily, I have copies of those papers. I'm going to have them retyped in the same format and published in a book called my *Career Book.*

Q: You'll have all of your professional papers together in one place.

A: That is the main idea.

Tujunga Wash Rood Channel

Q: You wanted to discuss another project from your time in the Los Angeles District?

A: Yes. I think we covered all the Los Angeles District, but I didn't mention one thing that was developed there, which I think is very, very important to mention. It's brought out in some of the technical papers that I have written and will send to the Office of History. It concerns the design of the Tujunga Wash flood channel. The channel begins at Hansen Dam, where the outlets works discharged into the channel, which was an unimproved, natural channel. Every time large flows had to be released from Hansen Dam, it caused flooding along the Tujunga Wash channel, about 12 miles from the dam to the Los Angeles River. The water eventually got into the Los Angeles River, but flooded many highways and much valuable property along the unimproved Tujunga Wash channel.

In designing the channel improvement, it didn't take long for us to decide that the high velocities required the channel to be concrete-lined. We also made enough preliminary studies to determine that a rectangular concrete-lined channel would be the most efficient, and less costly than a trapezoidal concrete-lined or a trapezoidal rock-lined channel. So we proceeded immediately to design a concrete-lined, rectangular high-velocity channel. We did the preliminary hydraulic studies and then decided we had to model study this channel because of the many sharp curves and the high velocities. We wanted to check to see that the channel was designed properly with sufficiently high walls, especially around the curves.

A 1:40 scale model of the rectangular channel was constructed and tested at the primary hydraulics laboratory in Griffith Park along the Los Angeles River channel. The tests showed that the velocities caused water depths to be significantly greater on the outside walls of sharp curves. The average depth of flow for the design discharge in the straight channel sections was about 12 feet. But going around the sharpest curves the water depth would be four feet higher on the outside wall and four feet lower on the inside wall. That would require the outside wall to be eight feet higher than the inside wall. This wall would gradually taper from the normal height on a tangent to the higher height through the curve and then back down to the normal height on the other side of the curve. On the inside of the curve, the height of the wall could be reduced the same way.

This would add a lot to the cost because a higher wall costs more, and the variable wall height makes construction much more difficult. So we got the idea of designing the channel like a high-speed highway with spiral transitions between straight sections and curves. The spiral transitions gradually change the direction from a straight line to a curve. After passing through the curve, a reverse spiral is used to gradually change back to a straight line. In addition, highway pavements are super-elevated around sharp curves to provide a gravity force component which improves the passage of high-speed traffic around a curve.

We reasoned that flow in a high-velocity channel would be similar to traffic on a high-speed highway. The 1:40 scale model was reconstructed with super-elevated curves and spiral transitions. It was remarkable how much better the water went around the curves. Flow depths were essentially equal in the curves along the inside and outside walls, which made it possible for those walls to be equal in height. Also, the super-elevated transitions reduced wave disturbances which otherwise occurred because of sudden changes in flow direction of the water.

We measured five feet high waves on the outer side of the curve. The waves progressed quite a distance downstream from the curve. Higher walls would be required to take care of those waves. By super-elevating and using spiral transitions in the curves, these waves were greatly reduced in the 1:40 scale model. We decided that this was a very significant improvement that should be tested in a large-scale model.

Fortunately, the outlet works and spillway were already constructed at Hansen Dam. The outlet works discharged on the spillway chute, which was quite flat. A flume was constructed at the end of one of those outlets, in which a 1: 10 scale model of the rectangular Tujunga Wash channel was tested. This model was tested with and without spiral transition curves and super-elevated inverts to compare it with the 1:40 scale model. The 1: 10 scale model generally confirmed the previous 1:40 scale model test results. Only small height waves formed in the spiral transitions and super-elevated curves. Also, the depths of flow were essentially the same through curves as in adjacent straight channel sections. That reduced wall heights and construction costs appreciably. The channel was designed and constructed that way.

We made a great point of spreading this information throughout the Corps. We said, "This is the way high- velocity channels should be designed." That's the way they've been designed ever since by the Corps and others who have designed high-velocity channels. I don't know how much it has saved over the years, but certainly it saved a great deal of money.

Q: So that was a matter of just applying some highway engineering techniques to the hydraulics?

A: Yes. To the hydraulics.

Q: Was that normally done? Had that been done before or was this sort of a pioneering effort?

A: Oh, this was pioneering, as far as I know. It was never done with high-velocity channels. It might have been done with some other problems, but I don't know of any.

Visit of Lt. Gen. Wheeler and Gail Hathaway

Late in 1946, General Wheeler [Lt. General Raymond Wheeler], the Chief of Engineers then, came out with Gail Hathaway, who was then a Special Assistant to the Chief of Engineers [former Chief of the Reservoir Regulation and Hydrology Section in Civil 'Works from 1937-45], for a Board [Board of Engineers for Rivers and Harbors, BERH] meeting to review the Los Angeles projects. General Wheeler wanted someone to brief him on the projects that were in Los Angeles before the Board meeting. The District Engineer sent word down to Harry Thompson, who was Chief of the Engineering Division then, and Harry Thompson picked me out to make the talk, covering what projects we were working on. Most of it was flood channel improvements because there was a lot of channel work there then, in addition to design of several small flood control dams.

I spent half-an-hour talking to him, and I guess I did a pretty good job of explaining the whole thing, at least General Wheeler thanked me. After General Wheeler left, I went down with Harry Thompson to his office, and Hathaway came down there. He said to Harry: "Harry, we need somebody like Jake in the Chief's Office. I need someone in hydraulics. I'm weak in hydraulic design."

So Harry said, "Well, that's up to Jake." So I said, "Give me one day. I'll have to talk to my wife." So when I got home, and I mentioned this, she said, "We're. off to Washington," because she lived in Washington for a good many years. She graduated from high school in the District of Columbia. She didn't like Los Angeles at all. So there was no doubt about it, we were going to Washington. The next day I told Hathaway that I would take the job. I reported to the Chief's Office on December 6, 1946.

Structural Branch, Engineering Division, Civil Works, Office of the Chief of Engineers

I reported to Hathaway. He said, "Well, unfortunately, we've got a new Chief of the Engineering Division, and he wants to keep hydraulic design in the Structural Branch"--my expertise was hydraulic design, not hydrology. Hathaway was an expert in hydrology, but he wanted to grab hydraulic design also and put it all in his branch. It turned out that I didn't work for Hathaway after all. I had to go in the Structural Branch, and I worked for Byrum Steele, who was Chief of the Structural Branch then.

We got along fine, and I enjoyed it. John Harold was there. He was my senior. Just the two of us did all the hydraulic design. We didn't actually do design. We reviewed the District hydraulic design reports.

Q: So you went to the Chief's Office in 1946 to work in hydraulic design?

A: Yes. I previously mentioned that General Wheeler and Hathaway, Chief of the Hydrology Branch in the Chief's office, were instrumental in getting me there. The hydraulic design was in the Structural Branch then. There was only had one man doing hydraulic design, but he was in the Structural Branch. Byrum Steele, who was Chief of the Structural Branch, wanted hydraulics under him.

Hathaway was arguing that it's better to have hydraulic design and hydrology together in one branch. When I got there, I reported to Hathaway first. I thought I was going to be working in his branch, but he said, "Since we talked to you about coming here, the new Chief of the Engineering Division has changed his mind. He agrees with Byrum Steele that hydraulic design should be in the Structural Branch. So you've got your choice of whether to stay here in hydrology or go to Byrum Steele."

I said, "I promised you I'd come and work for you, so I'll work for you for awhile." I was assigned in a job of writing manuals on hydrology, how to compute maximum floods, etc. After about six months of doing that, during which time I wrote the draft of two manuals, I said to Hath, "I'm really not interested in this very much. I like hydraulic design of dams and flood channels much more. Do you mind if I talk to Mr. Steele again?" He had no objection.

I talked to Mr. Steele, and he said, "Yes, I'd like to have you over here." I asked him to get the approval of the Chief of the Engineering Division. He did, and the next day I was sitting in Steele's Structural Branch as a hydraulic design engineer.

In 1961, when Steele retired, Slichter was the Chief of the Engineering Division. I was talking with him, and I said, "We should have a Hydraulic Design Branch, separate from the Structural Branch and the Hydrology Branch. There's plenty of hydraulic design work to do, and the Chief of the Hydraulics Design Branch should be responsible for all the hydraulic laboratory work that's done throughout the Corps. When the districts go to hydraulic laboratory project study meetings, he should be there also." Slichter agreed and obtained the approval of the Director of Civil Works. That established the Hydraulic Design Branch with me as Chief.

Q: When you went over to this Structural Branch, under Steele, what were your duties?

A: My duties were to review the hydraulic design aspects of reports sent to the Structural Branch for review. John Harold, another hydraulic design engineer in the Structural Branch, had the same duties. We also attended division, district, and hydraulic laboratory meetings on the hydraulic design of projects.

The same reports were reviewed by hydrology, concrete, and other OCE branches. The comments from the different branches were sent to the Engineering Planning Branch, which consolidated the comments to be sent to the divisions. They had to be sure that there wasn't any conflict in the OCE branch comments. Sometimes there were quite sharp conflicts, which had to be modified so acceptable review comments were sent to the divisions.

Q: Who was the Chief of the Engineering Division when you first came to OCE?

A: Stuck. I think it was Stuck then. That's right.

Q: We can double check that. As long as you know.

A: All right. So time went on, and then Stuck left. He went up, and was made a special assistant, I think, to the Director of Civil Works. Then, another person, whose name escapes me, was made Chief of the Engineering Division. I'll have to skip a couple of years until Francis Slichter was made Chief of the Engineering Division.

Then we got a new Chief of Engineers, who was the Division Engineer out in the Missouri River Division. He was a gung ho Army officer, I can see him as plain as day, but I can't recall his name. Slichter was Chief of the Engineering Division in the Missouri River Division before coming to the Chief's office.

When this new Chief came to the Chief's office, he brought Slichter along. Everyone thought he was going to have Slichter as his assistant, civilian assistant, but he decided not to do that. He decided to appoint Slichter as Chief of the Engineering Division. It may be that's when Stuck moved on. But anyhow, Slichter became Chief of the Engineering Division, and he was a very good fellow to work with. He understood engineering well. He understood some hydraulics pretty well, too.

Q: Did Slichter come over with Lewis Pick in 1949?

A: Pick. That's who it is. '49. Yes, that's Pick. But anyhow, Slichter was Chief of the Engineering Division for quite awhile [1949-61], and then Hathaway moved. He was a special civilian assistant to the Chief of Engineers. That's when he was also President of the American Society of Civil Engineers.

Q: Well, that's in the early 1950's.

A: 1950's, yes.

Q: Do you remember some of the more bitter struggles you may have had or disagreements in various aspects of some projects?

A: I forget them. Let's see now. What are the bitter things?

One thing I didn't like very well when I was in the Structural Branch was that John Harold, who was sitting next to me, would review a project, write up some comments, and get them typed. Then he said, "Jake, will you take a look at this?" I was doing the same thing on another report. I looked at his review comments and said, "I don't agree with this comment on the high-velocity channel flow." He didn't know too much about high-velocity channel flow. I had difficulty agreeing with some of his comments on that subject. He was there quite a few years before I came and didn't appreciate my writing comments on his comments and handing them back across the aisle. He looked at my comments for some time, but didn't say anything for two or three days. Then he wrote something and gave it to Mr. Steele.

I never had any bitter arguments about review comments made by other branches. For example, if the Concrete Branch said something, I would generally accept it because I am no expert on concrete. It was the same way with hydraulics. I remember, though, once a concrete engineer said, "We never did that at so-and-so dam." I said, "Yes, I know you didn't, but we've learned a few things since then, and this is the way we think we ought to do it."

It had to do with erosion of concrete due to high-velocity flow. He was good at figuring out what kind of concrete was required for strong concrete beams, or mass concrete for an ogee section, but he didn't know very much about concrete erosion by high-velocity flow. He said, "Oh, this stuff is tough. It won't erode."

Q: Not so?

A: Well, it won't erode if you do the hydraulics and construction right, but too many times the hydraulics isn't done right. Like the dam in Iran. They didn't construct it right. The hydraulic design was right, but the construction wasn't right. At each joint, there were small offsets that produced high negative pressures and cavitation erosion of the concrete when high-velocity flows occurred.

Before cavitation erosion was experienced in full-scale structures, it was hard to convince a concrete man, especially in the Corps of Engineers, that concrete would fail that way. I learned [this], called their attention to it, [and] they learned it.

Q: That's interesting, because an organization that has as much experience with construction of large concrete structures, one would assume that they would have some sort of information or track record on that kind of thing already?

A: Well, they did have some. A good example is the Bureau of Reclamation's Hoover Dam. There, the spillway is an overflow spillway, which discharges into a tunnel. The tunnel has about a 400-foot vertical drop. At the bottom, there is a curve in the tunnel to turn the water into a nearby horizontal diversion tunnel. The hydraulics design of the curve was incorrect. The water didn't follow the curve, and you can get cavitation erosion of the concrete. Downstream of that curve, the cavitation erosion scoured a large hole through the tunnel lining into the rock. That happened in 1938.

A model of that tunnel was constructed at the Bureau lab in Denver, and I worked on that model. There was previous experience with cavitation erosion, but not with free, open flow over a spillway.

Later, at the Corps' Pine Flat Dam, cavitation erosion occurred on a concrete splitter block at the downstream end of an outlet conduit to spread the high-velocity flow over a flip bucket. The water would hit the front part of the block, which was at 90 degrees with the side walls of the block. But the velocity was so high that negative pressures occurred which caused low pressures and cavitation on the side walls. A hydraulic model was constructed and tests verified the occurrence of negative pressures on the sides of the blocks. Rounding the upstream corners of the blocks eliminated the negative pressures. The prototype blocks were reconstructed and are now operating without any cavitation erosion.

Q: Well, that's an excellent example of the whole process of testing and modeling.

A: Right. Many large dams do not have high enough velocities to cause cavitation erosion, and some haven't had enough high flows to experience cavitation erosion yet.

It takes a little while for these ideas to develop and have everybody understand them. Hydraulic engineers can understand it a little more readily because they have the fluid dynamics background which concrete engineers do not have.

Q: What were some of the major projects that you were involved with in that first period, when you were in that Structures Branch?

A: Oh, let's see. Structures Branch, 1946.

Pine Flat, Fort Randall, Garrison, and Oahe Dams

Q: Did you get involved in the Pick-Sloan Plan--the big mainstem dams up on the Missouri?

A: Yes. I was involved with Fort Randall, Garrison, and Oahe dams. Also, the Pine Flat Dam, which was designed by the Sacramento District. It was a high gravity dam with two tiers of 5 x 8-foot outlet sluices controlled by slide gates that slid down on the upstream end to close or open the sluices.

It was questionable whether the slide gates could be operated part open under very high heads. To check this question, the gates were operated part open for various heads, as the reservoir filled. The maximum operating head was determined for acceptable gate vibration and low pressures that would not cause cavitation erosion.

That was very successful. It showed that slide gates can operate part open. They won't vibrate too much or cause cavitation erosion, provided the head isn't too high. We found that part gate operation was satisfactory with heads up to about 75 feet. These slide gates were subject to heads up to 225 feet when the reservoir was full at Pine Flat. The conclusion was that, with heads exceeding 75 feet, the gates should not be operated part open, they should be operated either closed or full open.

I think there are eight gated sluices at Pine Flat. All of them could be operated at once part open with heads up to 75 feet. For higher heads, several gates could be operated full open with all other gates closed to pass as much water as desired. Operation of the gates wide open under high heads does not cause excessive vibration nor cavitation erosion because the water coming through that gate section is five feet wide and eight feet high, and that's the same cross-sectional dimension of the conduit all the way through the base of the dam.

Q: So there's no change at all?

A: No change. But if we hadn't made these tests, the dam operator, for example, may have operated a gate three feet open under 150 feet of head. The resulting severe vibration and cavitation erosion may have damaged the gate so that it could not be closed. We highlighted all that in an operating manual which was sent to the dam tender. He had to follow it very strictly. He is required to strictly follow the outlined operation rules outlined in the manual.

Q: Do you remember any of the hydraulic design problems that you faced at Fort Randall?

A: Yes. Fort Randall is an earth dam with a concrete spillway on the left abutment. I think there were four concrete-lined diversion tunnels 30 or 36 feet in diameter. During construction of the earth dam embankment, river flows were diverted through those tunnels. When the embankment was completed, two of the tunnels were modified to connect with hydroelectric power turbines located in a powerhouse. Flows through the power turbines discharge into the power tailrace, which returns these flows to the river downstream of the dam. The other two diversion tunnels were modified to serve as flood control outlets. They have upstream gates for operation and a downstream stilling basin because the downstream river bed and banks were quite erodible.

There was one problem in the stilling basin design that I had not encountered before. We wanted to design the stilling basin so that it would operate satisfactorily with only one tunnel flowing full under high head, and the other one closed. This could occur if the gates for one tunnel could not be operated. We wanted to have a safety factor.

In the design of the stilling basin, it was decided that a concrete-lined trapezoidal basin with sloping walls would cost considerable less than a rectangular basin. Also, we got the idea of placing an intermediate pier midway between the center of the two tunnels. The pier should begin at a point up to the chute, so that if water comes out of one tunnel, most of the water will be kept on that side of the stilling basin. The downstream end of the pier should be located to produce a satisfactory hydraulic jump for either tunnel operation. A model was constructed and tested. After making adjustments in the length and height of the pier, the model indicated satisfactory stilling basin for either single-tunnel or both tunnels operating.

Q: Were those tests done down at WES or were they done at the MRD laboratory?

A: They were done at WES. We had a lot of problems with the Fort Randall gates, too. WES constructed and tested a 1: 10 scale model of one outlet tunnel with tainter gates. An acceptable design was developed based on the model tests.

I recall that some of the mechanical designers favored smaller tainter gates over large vertical lift gates. Smitty , in the Chief's Office, knew more about the design of gates than anyone else in the Corps. He said, "Let's use tainter gates. They'll be larger than constructed anywhere else before, but I think that they'll be within the acceptable size range, and they will be a lot cheaper than vertical lift gates."

The MRD laboratory was very small compared to WES. Most of their work involved small river improvements. They may have made small-scale, about 1: 100, tests of dams. Large-scale tests had to be made done at WES because the MRD laboratory didn't have the facilities nor water supply for large-scale tests.

Q: You mentioned "Smitty." Was that his nickname or was that his real name? Was his name Smith?

A: Yes. His name was Smith. Let's see. G.D. Smith. His boss was Bill Cave, Chief of the Electrical-Mechanical Branch. He was an electrical engineer. Whenever there was a problem with gates we'd talk to Smitty . He would attend meetings, not Bill Cave.

Q: Let me ask you about Garrison Dam now that we've done Fort Randall.

A: All right.

Q: How about Garrison.

A: Garrison is quite similar to Fort Randall, and Oahe is similar, too.

Q: They're all pretty much the same?

A: That's right. All three are earth structures with the same kind of spillway and outlet tunnels. The things that were learned [at Fort Randall] were used in the design of Garrison and Oahe. It was decided that the spillway for Garrison or Oahe, I forget which, had to have a stilling basin because spillway discharges entered the downstream erodible river channel close to the downstream toe of the earth embankment.

Q: So those were the kind of things that you mainly did on those big projects?

A: Yes.

Ohio River Locks and Dams

Q: Were you involved at all in any of the dams on the Ohio, the navigation dams?

A: Yes.

Q: What kinds of problems did they have compared to these big hydropower and flood control dams on the Missouri River?

A: They all have spillways, and the dams are not very high, so the spillway problems were not too difficult. A lot of them were concrete dams, and the spillway consisting of an ogee section near the top of the dam extended nearly all the way across the river. A number of tainter gates, generally about 50 feet long, operated off the ogee crest. Generally, a spillway stilling basin was provided at the downstream toe of the dam. Its design was not very complicated because the drop in the river level at the dam was only 30 to 60 feet.

With respect to the design of navigation locks, there are no particularly difficult problems if the difference in the water level in the downstream and upstream lock lift isn't more than about 30 or so feet. As I recall, on the Columbia River lock lifts are 40 to 50 feet. I think there is one lock that has a lift of about 80 feet.

When the lock lift exceeds, 60 feet, then consideration should be given to constructing double locks. For example, if the total lock lift is 80 feet, then the designer should determine whether it's more practical, more efficient, and more economical to have two locks, each with a 40-foot lift. In other words at the downstream end of the lock structure there is a 40-foot lift and at the upstream end there is another 40-foot lift.

John Davis, who was in my branch in the Chief's Office, was the best lock designer the Corps of Engineers ever had. Any report that had anything on the design of locks was given to John for review. The districts always wanted model test of the locks. WES did all the model testing on locks. John always went to the district design and WES model test meetings. Now, the Corps has excellent manuals on the design of navigation locks and dams. John wrote those manuals.

Q: How much does putting a lock in a structure cause you more difficulties in design? You've talked about the high lift locks, but how about the basic design and the hydraulics of such designs?

A: Let's take a dam, say, 40 feet high, with one lock, like those on the Ohio River. If the dam goes all the way across the river with an ogee section and tainter gates, it would be made of concrete. During a flood, the gates would be operated and most of the water would go over the spillway because not much water passes through a lock.

It doesn't take much water to operate a lock. There is an intake at the upper end of the lock to a conduit and a small lock bay that controls the water to fill the lock bay. The lock has large vertical swing gates at the downstream end that are several feet higher than the 40-foot lift. Similar gates are at the upstream end of the lock, but they are seldom more than half as high as the downstream gates. These lock gates are closed during flood time so all the water goes over the spillway.

When a vessel comes to the downstream end of the lock, the downstream gates are opened so it can enter the lock. Then the downstream gate is closed, and the lock is filled by opening the small gate in the filling culverts. It take as much as 30 minutes to fill the lock so the water level in the lock is the same level as the water level in the river upstream of the lock. Then the upstream lock gate is opened, and the vessel goes upstream. This process is reversed when a vessel passes from upstream to downstream.

Q: What kind of problems does that give the hydraulic designers?

A: If the head is more than about 50 feet and the lock filling gates are not designed correctly, the high velocities with part open gates can cause cavitation erosion in the filling culvert. The filling culverts need to have sharp bends and, if not designed right, may produce cavitation pressures and unstable flow conditions. The intake for the lock emptying culvert must be designed correctly to prevent high negative pressures and cavitation erosion from occurring at the beginning of the emptying cycle, when the culvert gate is part open under maximum lock head. As I previously mentioned, the hydraulic design of a navigation dam with spillway, gates, and stilling basin is very similar to that of other dams.

Q: So that's really not much of a problem?

A: Not much at all. There's no problem there.

Q: Did any of those Ohio River navigation dams and locks give you any particular problems?

A: Yes, there were problems in some locks with vessels that came in from the downstream end of the lock. After the downstream lock gates were closed, if the lock filling valve was opened too rapidly high surges and wave action occurred in the lock which buffeted the vessel all around. It was a simple solution there. Don't open the filling valve too fast.

Q: Let the water in slowly, then?

A: Yes. But there weren't any catastrophic problems, like those that occurred with some dams.

Dams on the Columbia and Snake Rivers

Q: What were some of the other projects you were working on where you had significant hydraulic design problems which you had to model test to correct design deficiencies?

A: Well, there was a significant problem on the Columbia River, with McNary Dam. I can't remember the details of it. It had something to do with the spillway. Bonneville Dam had some problems, too.

Q: How about those dams on the Snake?

A: Oh, they didn't present any major problems. There were small problems that were model tested, but I don't remember any major problems.

Now, I recall one major problem at Bonneville Dam on the Columbia River. A powerhouse, fish ladder, and a ship lift were located near the dam. It was desired to enlarge the powerhouse by extending it on the south side, but then the fish ladder and ship lift would need to be modified or moved and reconstructed.

The designers worked on several modified plans and developed one that was model tested at the Bonneville Hydraulic Laboratory. It was decided that it would not work because everything was too cramped. The fish ladder had to be moved elsewhere, but moving it would make the fish ladder steeper and water velocities down the ladder would be higher. There was serious concern whether the fish would be able to swim up the steeper ladder.

It was decided to abandon the above plan. Instead, the powerhouse enlargement was constructed on the other side of the river as a separate building. The fish lifts, fish ladders, and boat lift are still as originally constructed.

Q: So that's where the decision to model led you to make significant changes in the original proposal?

A: That's right. That kind of model had never been constructed and tested before. There was no way of determining what would happen without modeling it,

Q: So it became pretty standard procedure for you to model about everything on these projects?

A: Yes, that's right. Problems that are not understood and for which there are no precedent solutions are generally model tested to make certain that the proposed plan will work efficiently and be the most economical.

Q: So efficiency and economy are important, but good engineering comes first, doesn't it?

A: Well, but sometimes you can't do good engineering without model studies. If you don't have the criteria, expertise, or prior knowledge, you may not be able to do good engineering until model tests show what will happen and you learn what's going to happen.

Improvements in Modeling

Q: There must have been a significant degree of improvement in modeling between the time you started working in the Chief's Office and when you retired.

A: That's some question! I would say that in this country, the technique and knowledge of modeling improved a lot from 1946 to 1979. When I first went to work as an engineer, the Waterways Experiment Station was still at its infancy. The Bureau of Reclamation knew more about modeling, and they'd done more modeling than the Corps of Engineers, or anybody else in the United States, and I think also anywhere in the world.

But the Bureau also was very limited in their modeling. They only did it for a few dams. They didn't do it for flood control channels, high-velocity channels, tidal hydraulics, or beach erosion projects.

A Prototype Testing and Hydraulic Analysis Branch was established at the Waterways Experiment Station, with Frank Campbell heading it up. He had two or three assistants working underneath him for many years. They gathered available information, analyzed it, and produced design criteria and methods, which are published in Corps manuals. They are used by design engineers, which has reduced the need for model studies. For very important, large projects or one different than anything covered in the Corps design manuals, then there certainly may be a need for additional model studies.

Q: How much has the computer helped in all of this?

A: The computer takes everything to the third decimal point much better than the slide rule. I recall working as a consultant for an engineering firm that was designing some river channel work out in Riverside County, California. All of the calculations of water surface in the river and how high the flood levees would have to be were sent in a report to me for review. All of the computations were done by computer. When the water surface was calculated for a discharge down 10 miles of channel, it was based on a few actual field measurements for several discharges. Then, by using a computer, the few field measurements were used as a basis for determining the design discharge water level at several hundred locations along the 10 miles of channel. There were over 100 pages of computer printout on that project, showing water levels to the third decimal point.

I checked the computer results by using my six-inch slide rule. Starting out with the water level at the downstream end of the channel, I computed the water level to one decimal point every quarter of a mile up the channel. The slide rule computations were within about 5 percent of the computer values. Also, since computer computations are based on certain assumptions, they may not be closer than 5 percent of actual field values. So I claimed that the slide rule computations were just as good as the computer computations for this particular case.

I asked why they wasted so much time using the computer. They said, "That doesn't take any time. You just put a little stuff in the computer, poke here and there, and it just clicks on and on and on, and you get all this stuff printed out to three or four decimal points." [Laughs]. I said, "When you place those computations with three or four decimal points in a report, any engineer who knows anything about water levels in a river will laugh." I always make jokes about engineers who depend completely on computers.

Q: Maybe we have gone too far in that direction?

A: Right. The person who did the computer computations had a doctorate degree, and he always used computers. He was a young man, and that's the only way he knew how to make computations.

Q: That's the way he was trained?

A: That's the way he was trained.

Q: What other technologies beyond computers came in that period of time that significantly improved the way you modeled? Was there anything else that was specifically important?

A: I don't think so. Most of the design engineers in the Corps never sent any computer printouts in their reports. I think they're still doing it the way we did it 30 years ago.

Q: The old way?

A: [Laughs].

Design Criteria

Q: You mentioned design criteria. Developing design criteria is always a critical area, isn't it? How do you go about doing that?

A: Let's take a simple case, an ogee spillway. Water flows over the ogee. The criteria needed to calculate the discharge under different heads is the coefficient of discharge for an ogee spillway of this type. This depends on the height of the spillway and the maximum discharge head.

The coefficients are originally obtained from model tests. Frank Campbell computed the coefficients of different kinds of spillways from available model test data. Then he either plotted a curve of coefficients with respect to head, or produced a table of coefficients. That information and the discharge formula were all placed on one 8 x 10 ½ chart. It was named "Hydraulic Design Criteria for Ogee Spillway Discharge."

I have a large three-ring binder of hydraulic design criteria charts. I'd like to show you its contents. [Pause and then he reads] "Corps of Engineers, Hydraulic Design Criteria. Preface that tells how it's done. Classification Index. General Spillways. Concrete Overflow Spillways. Spillway Crest. Spillway Energy Dissipation. Erosion Below Spillways. Chute Spillways. Approach Channel. Ogee Crests. Spillway Chutes. Spillway at Basins. Spillway Exit Channel. Side Channel Spillways. Morning Glory Spillways."

Let's look at this chart for length of hydraulic jump, which is used to design the stilling basin for a chute spillway. Some text is given about where the information was obtained and defmes the length of jump and the height of tail water, or D_2 depth. D_1 depth is the depth at the start of the jump, which occurs on the chute slope entering the horizontal stilling basin. L is the length of the jump from its beginning to where it reaches full depth. The length of the jump is determined by using the curve shown on the design criteria chart. Generally, the length may be taken as 3 times D_2, so both the length and D_2 depth can be determined by using the chart. Knowing the length and D_2 depth of the jump, the wall height can be designed.

This is the hydraulic design criteria chart for Morning Glory Spillways. By applying the information on the chart, the discharge can be calculated for any head of water over the spillway. Other design criteria charts are used in a similar manner.

Q: So that becomes the book that they use to design.

A: Designers have this book.

Q: Once those design criteria are done and approved, they don't change very much then?

A: That's right. As long as the geometric shapes of structures are the same as those for which the design criteria charts were developed, there are no changes in the design criteria. The design criteria needs to be changed only when structures and other factors are different.

Q: Did the Corps have these design criteria for many years, or did they come in during the '30's and '40's?

A: Design criteria charts were not available in the '30's and '40's.

Q: So they had no design criteria at all then?

A: The Corps had no design criteria charts. The Bureau had some design manuals, and that's how I got the idea that the Corps ought to have some, also. As I mentioned earlier, Frank Campbell was at the Bureau, and he knew about them. Campbell always expressed a very strong feeling about the Corps' having a lot of information that should be used to prepare design criteria charts and manuals. I got him aboard, and his group did that.

Q: Down at WES, you said.

A: Yes. WES still has some people working on that. As more information became available, they put out more design criteria. But not as much as they did the first 20 years after Frank went down there.

Q: It's sort of hard to believe that when you have an organization that's supposed to be as professional as the Corps that they didn't have anything like those design criteria.

A: Well, they were just getting into the business of building dams.

Q: Big dams?

A: Yes. Big dams and other things. They had many other things to do.

Q: You mean like the navigation business?

A: Yes. The Corps had very little experience in designing navigation structures before 1940, so there wasn't much information available for developing design criteria.

Q: It wasn't part of their business?

A: Not until after 1940.

Q: Did you have any problem selling that concept, the need for this?

A: No.

Q: There was no opposition to that?

A: No. Slichter was Chief of the Engineering Division in OCE, and he knew the value of design criteria, of using the information we have better. He sold it to Pick, who was Chief of Engineers then.

Engineering Division, Civil Works, OCE

Q: What were the people like who you worked with in the Engineering Division?

A: What were they like?

Q: Yes. You talked about Slichter a little bit.

A: All like me. [Laughter] Trying to get a job done. They were well-qualified engineers and managers.

Q: How much difference was there between Slichter and Wendell Johnson in the way they ran the Engineering Division?

A: Slichter and Wendell were quite a bit the same. They were both well-organized engineers and managers. They were especially good at talking to the higher-level uniformed people and getting their support. It would have been much harder for me to do it, because--well, they had experience with it. When they came into the Chief's Office, they'd had a lot of experience as Chief of Engineering Divisions. Slichter came from the Missouri River Division. Wendell Johnson, I forget where he came from.

Q: Missouri River Division.

A: Omaha, didn't he?

Q: Yes.

A: He was Chief of the Engineering Division there, and had good training, too. Everyone thought that Wendell was a very nice person. He was easy to talk to, liked to joke, and always gave you a fair shake. He liked to discuss and solve engineering problems

Slichter was a little harsher. Lower grade engineers didn't go out of their way to talk about the weather, or things like that, with him. Discussions of engineering problems with him frequently were brief because he would find solutions quickly.

Wendell always had a very nice personality. Most people would say that Slichter is all right, but his personality's a little rough. That's my assessment.

Q: What were the major issues in the organization of the Engineering Division when you were there? You talked about your own branch and its evolution, and the creation of an Hydraulics & Hydrology [H&H] Branch. Were there any other significant major reorganizations in the Engineering Division during your time?

A: The Hydraulic, Hydrology, and Structural Branches were restructured, but that wasn't a major thing. The major restructuring came after I left the Corps, about ten years ago. The Civil Works' Engineering Division did all of the engineering design, but shortly after I left the Corps, a military directorate [Directorate of Engineering and Construction] was established. I think the Assistant Secretary of the Army for Civil Works initiated the change, because he wanted the Civil Works' Engineering Division to be limited to Civil Works projects.

Lloyd Duscha was Director of the Engineering Division for Civil Works. When all of the military engineering and construction was placed in the new military directorate, Duscha went with them, because they made him deputy director of this Military Engineering Division [Directorate of Engineering and Construction]. This was a promotion for him.

At the very beginning, all of the Civil Works' engineering design branches were placed in the new directorate and several other branches and the Planning Division remained in Civil Works. Hydrology stayed in Civil Works, but hydraulic design was placed in the [Engineering and Construction] Directorate. After a short time, all branches that worked on civil works projects were placed back in the Civil Works Directorate. I think that's the way it is now.

That was a major thing then. There was a lot of hassle about that. A lot of them, especially the Civil Works hydraulic design people, didn't want to go over to the [Engineering and Construction] Directorate because when they reviewed a Civil Works project they frequently had to discuss their review comments with the Hydrology Branch under Civil Works. Their comments would need to be sent to the Engineering Division of the [Engineering and Construction] Directorate, to the Engineering Division in the Civil Works Directorate, and then to Hydrology Branch in the Civil Works Directorate, instead of stepping across the hall to talk to the Hydrology people.

Q: So the time that you were in Civil Works, basically, the functions changed very little.

A: That's right. There were no major changes. No major changes.

Hydraulics and Hydrology Branch, OCE

Q: Hathaway was ASCE president in 195 1, I believe.

A: Yes, it was about then. But what I'm trying to come to now is that when Hathaway moved out of the Engineering Division, I was still with the Structural Branch. Al Cochran got Hathaway's old job, as Chief of the Hydrology Branch, and Al was there for quite awhile. Then, when Al retired in 1975, [they] decided to combine hydraulic design and hydrology and make it the Hydraulics and Hydrology Branch. [They] wanted to combine hydraulic design and hydrology because many of the Districts had already done that. John Harold had retired, and I was made chief of the new branch. I stayed as Chief of that Branch until I retired in '79.

So instead of having a Hydraulic Design Branch and a Hydrology Branch, they were combined and named the Hydraulic Design and Hydrology Branch. Many of the divisions and districts had already combined hydraulic design and hydrology in one branch. Cochran had retired about then, and Vern Hagen was Acting Chief of the Hydrology Branch at that time. He hadn't been appointed, but was in line to take Cochran's place. When the decision was made to combine the two branches, I was the senior man and was appointed Chief of the combined branch. I served as chief until I retired in '79.

Hydraulic design includes all types of dams and flood control channels, navigation dams and locks, tidal hydraulics, coastal engineering projects, and all of the hydraulic laboratory work. Hydrology is not as broad a field. It's limited to the hydrologic aspect of all these design projects. Almost every project requires some hydrology studies to determine flood design discharge.

Vern Hagen was the top hydrologist under Al Cochran, and when Al retired, Vern thought he would be the chief of that branch. Vern was, of course, a little disappointed. I said, "Vern, you're the top hydrologist here. You know a lot more about hydrology than I do. Just continue to operate the way you do, and if you have any problems, administrative problems, or so on, I'll help you out. But don't come to me for answers on hydrology." And we worked fine that way. He appreciated that.

Q: That was the basic information that you would then work with in the hydraulic part.

A: That's right. I didn't know very much about hydrology. I depended on Vern Hagen for the hydrology. I told him, "Vern, you're the Chief Hydrologist, as far as I'm concerned. You go right ahead and operate the way you did before under Cochran, and if you have any problems come to me, and I'll try to help you resolve them."

But, of course, all the administrative work had to go through me, because I was chief of the branch. It worked out fine. When I retired, Vern Hagen mentioned how very agreeable and cordial we were at all times instead of having strong conflicting opinions. I was very pleased to hear him say that.

Q: What was your interaction with the people in Planning? Was there a lot of work with them?

A: Yes, quite a bit. As the Chief of the Hydraulics and Hydrology Branch, I talked with Planning quite frequently about the effect of hydraulic design features on the planning aspects of projects. If Planning saw any hydraulic feature that might have some bearing on their planning, they would come to discuss it with me. We tried to eliminate passing papers up the line and back down again as much as possible. That was with the blessing of every Chief of the Engineering Division I ever worked under.

One time I told Wendell Johnson that I wrote some hydraulic design review comments that were influenced by the project hydrology, and that I was going to discuss it with Al

Cochran. He said, "I got plenty of stuff to do. I don't want to read it if it's just going across the hall to Al Cochran."

Q: No need to see it then?

A: He said, "If you got something you two fellows can settle, why, settle it. If you can't settle it, then come to me." That's the way we operated.

Q: So how many people did you have in Hydraulics and Hydrology then?

A: When I retired, there were about 10; about half hydrology and half hydraulics. Hydraulics included coastal engineering and tidal hydraulics. Two worked on tidal hydraulic problems, another on navigation locks and dams. Neil Parker was the expert on coastal projects, and he dealt mainly with the Coastal Engineering Research Center. He knew more about coastal engineering than I did. Whenever there was a meeting at WES or a district on a coastal engineering problem, I seldom went. Neil went, and I said, "You go, and come back and tell me what the problems and the solutions are, because I have to know in case my boss asks me." When Wendell was Chief of the Engineering Division, and there was a meeting that I didn't attend, let's say on a tidal hydraulics project, the person who attended the meeting would tell me about it in case someone asked him about it.

Q: Did you increase the numbers in the branch over the time you were there?

A: When I first came to the Chief's Office, John Harold, who was in the Structural Branch, was the only engineer who knew anything about hydraulic design of projects. I increased it to two. About 15 years later, when the Hydraulic Design Branch was established, it was expanded to include navigation locks and dams, tidal hydraulics, and coastal engineering in addition to flood control dams and channels. This required the addition of thee more hydraulic engineers, increasing the total to five. Later, when the branch was reorganized to include hydrology, five more hydraulic engineers were added for a total of ten. As I mentioned earlier, the Chief of the Engineering Division and Director of Civil Works were supportive of building up the branch.

Coastal Engineering

Q: We have talked a little about coastal engineering?

A: The coastal.

Q: What about the evolution of that particular aspect of your work, the coastal engineering?

A: Well, it really started when the Beach Erosion Board [BEB] was established in the early '30's. Morrough O'Brien had a lot to do with its being established when he told the Corps that it needed one. For a long time, he was on our consulting board. He was appointed to its consulting board and served many years. Dick Eaton was appointed Technical Director of the Beach Erosion Board quite early. Morrough and Dick became quite close professionally when Dick was in the South Pacific Division Office in San Francisco, and Morrough was a professor at the University of California.

Dick expanded the Beach Erosion Board by initiating coastal model testing there. Later, the Beach Erosion Board was renamed the Coastal Engineering Research Center because they were doing a lot of coastal engineering research. Then it was placed under the jurisdiction of the Chief's Office. Previously, the Beach Erosion Board operated independently of the Chief's Office.

I became involved with the Coastal Engineer Research Center because of its research work. I would attend their meeting until Neil Parker became a member of the Hydraulic Design Branch. So that's how it developed.

Q: With coastal engineering, were you playing the same role you played with the navigation and flood control?

A: Yes, that's right. Coastal engineering expanded to include navigation, harbors, and tidal hydraulics in addition to beach erosion.

Q: In coastal engineering you got into things like harbors and jetties, and they are different types of structures and a different type of engineering, right?

A: Yes. The Coastal Engineering Research Center was not involved in the engineering design of projects, except when a tidal hydraulics problem affected a beach.

Q: Like the effect of a harbor entrance on a beach?

A: Yes, that's right. Tidal flow through a harbor entrance can produce undesirable conditions on adjacent beaches or beaches inside the harbor. The Coastal Engineering Research Center studied the beach problems.

Q: How difficult were those engineering problems compared to your dams?

A: I think they were more difficult; more difficult to model test. The model test data were difficult to analyze and produce similar to that for dams. But by testing enough, and by studying what happens out in the field, the Coastal Engineering Research Center people were very knowledgeable in their area. Joe Caldwell was most outstanding. He became Technical Director when Dick Eaton retired. He served several years and in '65, when Wendell Johnson retired, Joe was appointed Chief of Engineering Division in the Chief's Office.

In filling that job, the Director of Civil Works reviewed a list of Corps people qualified for the job, and selected him. I think General Francis Koisch was Director of Civil Works then. I don't think he was Chief of Engineers.

Q: No.

A: That made him President of the River and Harbor Board [Board of Engineers for Rivers and Harbors, BERH]. That board held meetings at Fort Belvoir, where the Coastal Engineering Research Center was located, which I always attended. One time, during a break in the meeting, Koisch came to me and said, "Jake, I got a problem. I don't know who to offer the job of Technical Director of the Coastal Engineering Research Center to. I've looked at the qualified list, and your name comes up number one. Are you interested?" I said, "No, I'm not interested. Thorndike Saville is acting Technical Director, and he's been working in coastal engineering research for about 25 years. He knows a lot more about coastal engineering than I do. He's the man who ought to be the Technical Director of the Coastal Engineering Research Center." He said, "That makes my job easy."

This was after Koisch had decided Joe Caldwell was top man for Chief of the Engineering Division of Civil Works. Then Koisch had to select the Technical Director of the Coastal Engineering Research Center.

That would have been the wrong thing for me. I knew I wasn't going to be with the Corps for too many more years, and I wanted to stay close to dams and channels. I'd already been doing a lot of private consulting, on dams mostly, and I wanted to continue to do that. If I had gone to CERC, I would be very much involved in coastal engineering, and probably wouldn't have much time to devote to private consulting. When I retired, I was immediately free to do more consulting.

Committees on Tidal Hydraulics and Channel Stabilization

A: I should mention my involvement with the Corps' Committee on Tidal Hydraulics during my service in the Chief's office. I was the Chief's office representative on that Committee from its inception in 1947 until my retirement in 1979--32 years. I initiated the Committee on Channel Stabilization in about 1965 and served as its chairman until my retirement.

This committee operated much like the Committee on Tidal Hydraulics. Members were from Districts and Divisions who had major channel problems, bank protection problems. When I retired, the secretary of the committee on stabilization, who was from the Waterways Experiment Station, was elected chairman. He served as chairman for the next three or four years, until he retired. I think this committee is still operating.

Q: Well, channel stabilization is a problem that hasn't gone away.

A: No, that's right.

Q: Let's talk about this Committee on Tidal Hydraulics now, because we've talked about it before. What was its origin? Where did it come from? Why did you want that set up?

A: All right. There's differences of opinion. My recollection is that Blackmon of the South Atlantic Division and Rhodes of the Savannah District had some problem in a tidal bay, and they wanted to have it model tested. The model was constructed at WES.

While they were at the Waterways Experiment Station looking at the model, Clarence Wicker of the Philadelphia District also got involved. Shortly after that meeting, the Chief's office got a letter from the South Atlantic Division suggesting that a Committee on Tidal Hydraulics be established to review the Corps' tidal hydraulic problems. This committee would consist of a representative from each division and district that had tidal hydraulic problems. In the Chief's office, everyone thought it was a good idea, so the Committee was approved. The first meeting was attended by representatives from several divisions and districts, WES, and the Beach Erosion Board. I did not attend the first meeting. They discussed the committee's membership, operating procedures, and reported to the Chief's office.

The report was well received in the Chief's office, but it was suggested that a representative of the Chief of Engineers should be on that committee. Since I was the top hydraulic engineer in the Chief's office responsible for coastal engineering and tidal hydraulic problems, I was appointed as OCE's representative on the committee. I attended the second meeting and all of the other meetings for 32 years without missing a single one.

When I started to talk about retiring, it was about time to have another committee meeting, but they hadn't set one up. I was trying to firm this thing up before I left the Corps. I called the chairman, Henry Simmons, and he said, "No, I haven't done anything yet, but we need to have one soon. We want to have it down here at the Waterways Experiment Station because I hear you're going to retire, and I'd like for you to attend it, so we can all give you good cheers at our last meeting." That's how it went. It was also my 100th trip to WES while I was in the Chief's office. Number 100. It made a nice, round figure. [Laughter]

Now, the first paper I gave you was the first letter Joe Tiffany sent to me ... He states that he was the one who initiated the idea of having a Committee on Tidal Hydraulics when Blackmon, Rhodes, and Wicker were at WES looking at the Savannah River model. But they decided that Joe should not write the letter to the Chief's office because that office might get the idea that Joe was promoting the committee for WES's benefit. So Wicker wrote the letter, and we in the Chief's office never knew that Joe was the one who first suggested the Committee on Tidal Hydraulics. I always thought it was Ralph Rhodes and Blackmon.

Q: Would you define tidal hydraulics for me?

A: Tidal hydraulics involves the flow of water in waterways that are subject to tides--bays, harbors, and rivers. The Mississippi River is subject to tides clear on up almost to New Orleans. Tides are produced by periodic changes in sea levels.

Q: What are the differences between those kind of hydraulics and those of the normal river or flood?

A: Well, normal river is like the Missouri River. It carries a lot of water and just comes on down. There's no tides to interfere with the flow. In the Mississippi River, normal flow occurs down to the New Orleans area, where it enters the tidal zone. Some distance down from New Orleans, for example, at the Head of Passes, flood tides occur during high winds and hurricanes, which produce higher water levels in the river and reduces the river's discharge capacity. If the levees are not high enough, they will be overtopped because the tides will keep the water from going out of the river.

Q: So those are the problems that this committee looked at all the time?

A: Yes. It wasn't concerned with high-velocity flows, open channels, and reinforced concrete- or rock-lined channels. However, it was concerned about tidal flows that eroded beaches.

Q: So you've worked very closely, then, with both the Beach Erosion Board and its successor, CERC?

A: That's right. That's why they had members on that committee, too.

Q: Apparently, the whole coastal engineering business is very difficult because of the way the sands move around.

A: Yes. It's really more difficult than open channel hydraulics because you can put your finger on and more easily control the flow in an open channel not subject to tides.

Q: What were some of the more important problems that the committee looked at and solutions that were recommended?

A: One project that the committee got very much interested in was the San Francisco Bay. Tests were being made in a model of the Bay to determine water levels during floods when rivers discharged large flood flows into the San Francisco Bay, especially in the Oakland part of the Bay. The storm tides and waves coming in through the Golden Gate had an effect on tidal flows in the Bay. The model would indicate what improvements to construct to prevent yacht harbors from having problems due to the tidal flows. In the lower Mississippi River, high levees go beyond the Head of Passes, and the height of those levees is determined by river channel flood flows and the effect of tides.

The general overall thing that the Committee on Tidal Hydraulics did that hadn't been done before was to identify problems and develop theoretical ways of computing what would happen for various combinations of tides and river flows. Those weren't available before. There was very little in the literature about tidal hydraulics before this Committee on Tidal Hydraulics was established. It published many report that identified a lot of the problems and solutions that are being used by design engineers.

Q: So they, themselves, generated a lot of the solutions and then formalized them in reports?

A: Yes. I don't have many of the committee's reports, but they can be obtained from WES. The Waterways Experiment Station representatives on the committee usually served as secretary of the committee. Joe Tiffany was elected secretary during the second meeting. Clarence Wicker was elected chairman. Tiffany served as secretary all the time that Wicker was chairman. That's about 15 years. Then Tiffany became chairman, and Henry Simmons was secretary until Tiffany retired, when Henry became chairman. He got one of his WES secretaries to serve as committee secretary. All of the records and reports of the Committee on Tidal Hydraulics are in the WES library. I wasn't as interested in tidal hydraulic problems because I was always more interested in dams and high-velocity channel flow. So I didn't keep many of those reports.

Q: You were just sitting in on that committee to provide whatever you could to the Chief's office and the technical expertise you could provide?

A: That's right.

Q: What were your favorite committees, then, if this one was sort of one you just went to?

A: [Laughter]. A few years later the Committee on Channel Stabilization was established, and I was elected chairman at the very first meeting. I was still chairman when I retired, and then they asked me to serve as a committee consultant. Every time they had a meeting, they wanted me to be there and enter into the discussions. I did that for three or four years.

The committee met with districts that had open channel erosion problems. We had several meetings in the Omaha District to discuss erosion problems along the Missouri River. Specifically, most rivers have unprotected banks, which are eroded during floods by too high velocities, so they need to be protected by stone or concrete. Usually, there were several ways to correct a problem, but the question was which way was the most effective and least costly. Most of the time, the committee was able to suggest a solution previously used and proven to be effective, but, occasionally, for new, more complex problems, model tests were needed.

Brad Fenwick, who was a member of the committee, retired one year before I did. After retiring, he wrote a report about all of the problems that the committee had worked on. A copy of the report is in the reference material that I plan to donate to the Corps' Office of History.

Committee on Streambank Erosion Control

Another committee that I worked on concerned the Corps' Streambank Erosion Control Program that was authorized by Congress in Section 32 of a 1960's Flood Control Act. It funded a study on ways of preventing erosion of streambanks... [and] to make field tests to develop new methods of bank protection for big rivers, like the Arkansas, Mississippi, and Missouri Rivers. I was appointed chairman of the committee and served until my retirement. I organized the committee very similar to the Committee on Channel Stabilization.

When funds were provided to do the research, as Chief of the Hydraulics Branch, I was assigned the job of organizing the program, I established a committee which operated somewhat like the Committee on Channel Stabilization. When I retired, all of the field research was completed, and they were going to start to use the methods that we had developed at several different sites. I don't know whether this has been done or not. I didn't follow up on that because most of my private consulting has been on dams.

At its first meeting, the committee concluded that the study should be based primarily on full-scale field tests. Bank erosion sites were selected on several rivers for constructing and testing alternative methods of protecting the streambank. The districts involved did the construction and monitored the test sections. After every flood, they'd check whether there was any erosion and report to the committee on how the different alternative methods stood up.

In this way, the weak alternatives were eliminated and the best methods were identified. Sometimes there wasn't much difference between two or more of the methods. Then, the preferable method would be the one that was the most economical.

Q: So you actually tested the solutions in the field?

A: Yes. The Committee on Tidal Hydraulics didn't do actual field testing of alternative solutions. It asked the districts to make prototype measurements when the river is in flood or the tides are coming in. The committee used the prototype measurements to check the theory that they were using to solve the particular tidal hydraulic problem.

Q: Well, then, the streambank erosion program actually went out and built prototypes?

A: Yes. That could be done more readily in streambank erosion than in tidal hydraulics.

Q: Was that just a matter of the size of what you were dealing with?

A: Yes. Size and simplicity. A good hard rain was all that was needed for producing channel stabilization prototype data. In tidal hydraulics, there may be a lot of flood flow but not much tide to cause wave action, so the prototype data isn't very useful.

Retirement

Then I retired on January 12, 1979, from the Chief's office. At that time, General Morris was Chief of Engineers, and he made his usual talk. "Oh, we're sorry to see you go. You didn't have to go. You're young enough. You could stay here another five years. We can't do without you."

I said, "Well, General Morris, you've done without me for a long time, and I know you're going to do without me for some more time." I think it was only two or three more years until he retired.

Q: He retired the next year, in September 1980.

A: The next year. Then he set up his own firm here in the Washington area. I used to see him about once or twice a year and ask him how he was getting along. "Oh, it's kind of rough sledding, but I'm pulling through all right." Then for awhile he was doing very well, and then for awhile he wasn't doing well anymore.

The first few years I was retired I did some consulting for the Corps. When the Los Angeles District had their board meet on flood control channel jobs, which I worked on while employed by the Corps, they asked me to meet with them as a consultant.

Q: So the consulting kept you busy?

A: It kept me as busy as I wanted to be. My last consulting job was in February of 1990. I said, "Boy, that's 12 years and I've had enough of it. I don't like airline travel anymore."

I had a good consulting fee of $800.00 a day. When I rode an airplane to Tarbela, it was two days going and two days riding back, and if a Sunday came in between, that was five days. Five days at $800.00 a day, that's $4,000.00 for doing nothing. One year I made $80,000 consulting. After paying Federal, state and social security taxes about $40,000 was mine.

Q: You must have wondered whom you were working for after awhile. [Laughter]

A: So I decided that I don't need the money, and I had worked long enough, 56 years in engineering, plus five years at the university. That's 61 years, and I've had it.

But the thing that teed me off altogether is when I came back from Regina, Canada. I was still consulting on two dams for the Saskatchewan Power Corporation. I had to change flights in Toronto to return to Washington. The flight from Regina was late and when I reached U.S. Immigration, it was three minutes before the scheduled departure of the flight to Washington.

The Immigration officer asked me where I lived, and what I was doing in Canada. I told him where I lived, and that I was consulting in Regina. He said, "Are you a citizen of the United States?" I said, "Yes," and started to pull out my billfold. He said, "Don't show me your driver's license. You've got to show me either a birth certificate or a passport."

I said, "I don't have either one because I've been coming in and out of Canada for 25 years, and I always show my driver's license. I show it to the Canadian Immigration officer, and he always says okay. I have showed it to U.S. Immigration officers for 25 years, and you say okay. Now here's the first time you want either my passport or my birth certificate."

Again, I said, "I don't have them." I stared him in the face and said, "What do I do now?" He stared me back a little while and said, "Who chopped down the cherry tree?" I said, "George Washington." "All right. You're an American citizen. Go on in." [Laughter] Oh, boy!

That's stupid. I won't do it again. Next time, maybe I won't remember who chopped down the cherry tree, and they won't let me back in the United States. [Laughter]

Q: Yes. That gets a little silly.

A: That did it. I decided not to do any more consulting.

Q: Enough of that, huh?

A: Had enough of that. Well, my wife was already in a nursing home, and I felt I ought to be here in case something happens. My two sons aren't nearby, so I'm glad I did it.

Consulting Work

Tarbela Dam, Pakistan

I enjoy dams the most, and there was a greater need for consulting hydraulic engineers on dams than on channels. There was plenty of consulting work then for dams, but now most of the large dams throughout the world are built, and this consulting work is limited.

I worked on the Tarbela Dam which is located in Pakistan. The engineering firm of Tibbetts, Abbott, McCarthy, and Stratton [TAMS], located in New York, did the design and followed through on the construction and operation. During the design stage, I served as the hydraulic design consultant and met with TAMS in the New York office on hydraulic aspects of design. Later, during the construction and operations stages, the Pakistanis set up a consulting board, and I was made a member of that board. When I was appointed, four large tunnels had been completed and were being used for diversion, three of them were to be changed to power tunnels, and one of them was to remain as a diversion tunnel. Also, the power house still needed to be constructed.

While all four tunnels were being used for diversion, a tremendous flood occurred and an attempt was made to control the outflow by closing the upstream gates of the tunnel that would not be converted to a power tunnel. Unfortunately, this gate had not been designed for operation under high heads, and the tunnel collapsed. The whole reservoir had to be emptied in order to repair the damaged tunnel.

The consulting board was much involved in design and reconstruction of the tunnel as well as design and construction of the spillways and problems with sink holes in the reservoir. It held meetings at the dam site about every three or four months. I went there 13 times in three years, and believe me, I had my fill of riding airplanes from Washington to Islamabad, the capital of Pakistan [laughs].

I departed from Dulles at 9:00 PM and arrived in London about 8:00 in the morning. I would take a room in a hotel right at London airport, and by the time I got there it would be about 10:00 o'clock. I'd have to check through immigration and customs at London airport before I could get out and go to the hotel.

I'd get four to five hours sleep, and return to the airport in time to catch the 5: 30 PM Pakistani Airlines flight, which arrived in Islamabad at about 6: 30 in the morning. After landing I waited an hour to get my luggage and spent another hour getting through customs and immigration. At about 8:30 or so, I would walk out the front door of the terminal and see a man with a sign, "Douma." He was the driver that drove me by car to the Tarbela dam site. It was a 1 1/2-hour drive, and I would arrive at the dam site about 10:00 AM.

Usually, I would be taken to a large house where TAMS employees lived, and I stayed while at the dam site. If I arrived on a Saturday or Sunday, I would rest the remainder of that day. If I arrived on a weekday, I would rest a few hours and then inspect the site with the resident engineer. Occasionally, the driver said that he was instructed to take me directly to the conference room upon my arrival.

I remember one time when I walked into the conference room, the board members and TAMS and Pakistani engineers were all there. They clapped and said, "Well, we can start the meeting now." I said, "You know, I've been riding airplanes for the last two nights. What time does the meeting start in the afternoon?" I was told that "In Pakistan, we eat lunch late, and then we have to have an afternoon siesta. The meeting will begin at about 3:00 o'clock." I said, "That's allright, I'll see you at 3:00 o'clock." I spent a week there on that trip.

I had another interesting experience on the Tarbela project. After the diversion tunnel was repaired, there were problems with the main spillway, which has large tainter gates on the spillway crest. They wanted to keep a lot of water in the reservoir, so those gates were closed, and the water level was 10 or 15 feet above the spillway crest.

A small amount of water was leaking underneath the gates and along the side of the gates. The chute was wet all the time, and at the upper end, just below the gates, there was moss on the concrete chute floor. There was a ladder from the top of the chute wall to the floor of the chute.

I decided to go down the ladder and take a closer look at the gates. When I reached the bottom of the ladder, I saw the moss and noticed that the chute floor was practically flat there, with just enough slope so the water would run off. So I didn't pay too much attention. When I took my feet off the ladder and stepped on the moss, both feet slipped on the moss, and I fell to the chute floor. I just couldn't gain my footing, and I was sitting there on my rump, sliding on that moss down the chute.

That was about a 300-foot fall, and, luckily, they had drained the plunge pool. I thought, "By God, I hope there's not more than about three or four feet of water in the plunge pool." While sliding down the chute, I had enough sense to keep my feet ahead of me and my elbows spread out so I wouldn't be tumbling every which way. When I hit the plunge pool water, my feet hit first. The water depth was about three feet with a couple of feet of mud on the bottom, which gradually stopped me. I stood up covered with mud, but wasn't hurt at all, except a little scratch on my left elbow.

Some men were working with a large crane over the side of the plunge pool walls. They lowered a cable for me to grab a hold of so they could pull me up. I checked the chute, and found it to be all dry on one side. I decided I would walk up as far as I could. So I told them, "I'm on the way. I'll walk up." Believe me, I walked up all the way back to that ladder.

Q: Is that right?

A: The next afternoon, we had the board meeting to discuss spillway problems. I said, "Well, I want to tell you about an experience that I just had yesterday morning, and I recommend that all of you have that experience so you will know what that water is doing when it's coming down that chute at 50 miles an hour." Then I told them what happened to me.

None of them volunteered to try it. The chairman said, "Oh, all clap because you are here with us. You could have been dead." [Laughter]

Q: That was nice of him, wasn't it? One of the things that must have occurred to you going down there.

A: Yes. Well, I'm just rambling around here.

Reza Shah Kabir Dam, Iran

Q: You got to see a lot of airplanes, didn't you?

A: Yes. [Laughter] Oh, yes. One time, when coming back from Tarbela, a consulting firm in Chicago -- not Acres.

Q: Harza?

A: Harza. You're right. They had designed Reza Shah Kabir Dam [for Iran], a high, concrete arch dam, with a concrete flip bucket chute spillway. The first time the chute spillway went into operation with high flows, a lot of erosion occurred on the chute invert. Harza Engineering designed the dam, and followed through on the construction. Harza wanted independent consultants to evaluate the erosion problem.

The spillway chute eroded and failed. Harza also had a man atTarbela, and they got in touch with us there and asked us to stop by in Iran on our way back to the U.S. and inspect the dam. We'd change airplanes at the capital of Iran, Teheran. That's where we boarded another one-hour flight up to the northern part of Iran. Then we had to take about a 30-minute car trip up the mountains to the dam site.

An Italian construction firm had just finished constructing the spillway for this dam when a large flood occurred which filled the reservoir and caused the spillway to go into operation with six- to seven-foot depths of high-velocity flow in the lower part of the spillway chute. This was about six months before Khomeini took over the Government of Iran.

They called Jim Ball and me, and we both accepted the assignment. After being briefed by the resident engineer and his assistants, we spent several hours inspecting the dam and damaged spillway. .. and saw that the construction was poor. We concluded that the construction people did a poor job of smoothing the floor of the high-velocity chute. It was rough, particularly at construction joints. The invert joints of the chute at the lower end were not smooth. There were places where the joints, either downstream or upstream, would be as much as three-quarters of an inch out of place. With water velocities of about a hundred miles an hour, negative pressures occurred at these joints. The negative pressures caused cavitation erosion of the concrete. There were five- or six-foot deep holes through the concrete invert and into the rock. The concrete slab was only 18 inches thick, and during the course of time, that slab failed, and then water got underneath at high velocity and just ripped the whole thing out.

We wrote our report on what caused the erosion and what should be done to repair the damage. Harza told the client that the construction was at fault, and he should repair the damage at his cost. The damaged chute was repaired. A few years later another large flood occurred, and the chute operated perfectly.

The Harza man had to leave early, but I stayed another day to talk some more with those people about what should be done to repair the spillway chute. I planned to leave the dam site and return to Teheran in time to catch the 2:00 PM flight to the U.S. I talked with the man in charge of transportation at the dam site and said I'd have to leave by car in time to catch the 12:00 o'clock, one-hour short flight back to Teheran to be sure I would catch my overseas flight. This man impressed upon the driver that he had to get me to the small airport in time to catch the flight to Teheran.

Coming down the mountain, the roadway was steep, and the curves were sharp. The driver was going too fast, and frequently had to put his foot on the brake as hard as he could. After about ten minutes, smoke came up from underneath the car.

I told him, "Stop. Stop. Smoke's coming out of here." So he pulled over to the side, and I went over to look, and the wheels were burning. He made the brakes so hot that it caused the grease around them to catch fire. About that time, a bus came up the road. This driver knew that he couldn't get me to the small airport in time to catch the flight to Teheran, so he stopped the bus and talked with the bus driver in their language there, and the bus driver motioned me to get on the bus.

So in about 15 minutes, I was back at the dam site again. I told the transportation man what happened, and he called another driver. I said, "Tell him, 'Go slow. Don't burn up the car. I've got enough time.'" The other driver was very careful, and I got down to the small airfield when the airplane was at the end of the runway, ready to take off.

I went to the main terminal and was told that the next flight to Teheran would be two hours later. I was advised to check with the private and rental airplanes office. Fortunately, I was able to get passage on a private plane about to leave for Teheran. When I got to Teheran, I found that my overseas flight was three hours late.

Q: All that, and you were still on time. [Laughter]

A: Yes, still on time. Holy Moses. What a day!.

That was an interesting job and trip to Teheran. Americans for a long time wouldn't dare go there. I went to Teheran just a few months before the Ayatollah took over. If it had been a year later, I would not have gone. Harza people still went there for several more years. The Iranian government owed Harza about a million-and-a-half dollars. After the Ayatollah took over, they didn't pay any of their debts for a number of years.

All the people who were owed money got together and got some kind of judgment against the Iranian Government. Whenever the Americans got some of Iran's assets, they'd keep them to pay off Iran's debts. Harza, finally, after about three or four years, got their million-and-a-half dollars.

Q: It took a little while to get any money out of those folks. Basically, it's not too easy to get money out of them, I guess.

A: That's right.

Q: It's a long, hard pull. Well, it must be different when you're out in places like Pakistan and Iran versus when you're in a place like Washington, and you have to go out to some district or some site out there. Your connections were a lot more tenuous.

Pardee Dam, East Bay Municipal Utility District (EBMUD)

Q: What were some of the other consulting jobs that you did?

A: All right. I've listed several consulting jobs I'd like to talk about. The first one is Pardee Dam, which was designed and constructed by the East Bay Municipal Utility District [EBMUD or East Bay MUD] in Oakland, California. There is a hydropower plant at the dam, which they wanted by adding several power units.

The dam was constructed before 1930, when there were no Federal safety regulations. Now, whenever a dam is designed, a report must be prepared on the safety of the dam for FEMA [Federal Emergency Management Agency]. If there are no safety questions, FEMA issues its construction approval. When a project change is desired, FEMA requires that the owner hire proper consultants to check the safety of the dam.

EBMUD requested FEMA's approval to add the two additional power units. FEMA said that a study had to be made to show that the dam is safe before approval could be granted. EBMUD established a consulting board to check the safety of the dam. I was a member of the board.

The first thing the board did was to check whether the dam was designed for a large enough flood. FEMA's requirement is that the dam be designed for the maximum probable flood. When the dam was designed in the 1920's, maximum probable flood were not considered. The board determined that the dam was designed for the maximum historical flood, which was only 70 percent as large as the maximum probable flood.

The board was told to determine what needed to be done to the dam so it would safely handle the maximum probable flood. Calculations showed that if a probable maximum flood should occur, the water would flow about 6 feet over the top of the 250-foot high concrete arch dam and about 11 feet over the top of an adjoining low earth embankment. The earth embankment would very likely wash out, and water going over the top of the concrete dam might severely erode its abutment, causing failure of the dam.

The board next looked at the possibility of enlarging the spillway. If the spillway was enlarged sufficiently, the dam would not be overtopped nor would there be any question regarding its safety. The spillway is concrete-lined with eight ungated bays and a 15-foot high ogee crest at each bay. Downstream of the crest, the spillway was lined with a 12-inch concrete slab placed on a 1 on 4 slope.

One method of enlarging the spillway was to increase the crest length by adding more bays. It was decided that this was not feasible because of space limitations. The next method which was considered was to extend the spillway bay piers upstream of the spillway crest about 150 feet and connecting every other one at their upstream ends. The top of the pier extensions was placed at an elevation, so when the spillway operated, the pier extension served as the spillway crest. This elevation was several feet higher than the existing ogee crest. The existing crest would then be cut down about 10 feet to enable more water to flow through the spillway bays. The longer extended pier crest would result in larger spillway discharges for high reservoir levels. The board concluded that this method was feasible. It would not require raising the dam.

The third alternative would be to raise the dam about 12 feet, and make minor modifications of the existing spillway to pass the maximum probable flood without overtopping the raised dam. This method was the most costly of all, so it was abandoned. The board decided that the second method was the most economical way to handle the probable maximum flood without raising the dam. That's extending the spillway bay piers out some distance in front of the existing spillway, and having those piers act as a spillway crest. Then cutting out the existing spillway crest concrete between the existing bays, so that more water could be handled by the spillway.

The board was concerned with a problem regarding the 12-inch concrete slab downstream of the existing spillway crest. It was not anchored to the underlying rock. During spillway flows, high velocities could produce uplift pressures through defective joints that might cause complete failure of the concrete slab.

The board considered replacing the slab with a properly designed slab or adding three feet of concrete on top of the old slab with a large number of anchors into the underlying rock. The latter method would be very costly. The board concluded that the slab should be replaced with a properly designed slab. At our final meeting, the board discussed its studies and conclusions with EBMUD. They said, "We'll think about it and call you back later."

They never called us back. I found out later that they didn't call back because their cost estimate of the work required to make the dam safe was over $20 million. There were other places where the additional power could be obtained for much less cost, so they dropped the whole matter.

Q: On something like that, when you analyze those things, what kind of impression do you get of the people who designed and built that kind of structure?

A: Well, I never knew the people who designed and built that structure. They certainly lacked experience in those structures 50 years ago.

Q: You had a lot of those problems to deal with though, right?

A: Right. I had other similar problems on other projects. The basic problem regarding the design of Pardee Dam was that hydrology wasn't developed in those days to the point where anyone thought of a probable maximum flood.

Q: So one of the big things that changed for you was the definition of probable maximum flood?

A: Yes. The Corps of Engineers and FEMA used the probable maximum flood as the design flood.

Rafferty Darn, Canada

Q: Did you run into similar situations in other consulting jobs where they weren't built because of the costs required to come up to the Federal standards?

A: No, I didn't. In the United States, any dam that failed and caused excessive property damage and/or lose of life is now designed in accordance with Federal safety standards. I was on the board for Rafferty Dam in Canada, which was constructed even though it did not meet FEMA's safety standards. One Canadian member of the board, who was the top hydraulic engineer in Canada, said that designing Rafferty Dam for the maximum probable flood was excessive even though failure of that dam would cause large property damage and lose of life. He wanted to design the dam for the 1 ,OOO-year flood.

The 1,000-year flood was about 30 percent smaller than the probable maximum flood. I said, “Let’s determine the difference in the cost of the spillways designed for those two floods. ”

In the initial design, most of the reservoir at Rafferty Dam was for irrigation and power. Consideration was given to increasing the dam height to provide some flood control storage in order to justify construction of the dam. The Corps of Engineers was interested in this flood control storage because it would reduce the channel design flood in the Souris River at Minot, North Dakota.

The levee heights at Minot, which were initially constructed for a 100-year flood, were frequently overtopped by larger floods. The Corps was in the process of designing the levees for a 500-year flood. Increasing the height of Rafferty Dam by about 20 feet would reduce the 500-year flood at Minot to a 100-year flood, and the levees would not need to be raised. The estimated cost of raising the dam was $47 million. The Corps estimated cost of raising the levees at Minot, if no flood control storage was provided at the dam, was about $112 million. The Corps agreed to pay the cost of raising the dam, thereby saving $65 million over raising the levees at Minot.

Q: So in something like this, would the Corps or the U.S. Government transfer funds to Saskatchewan Power?

A: That’s right. They would transfer funds.

Q: To cover the difference between their original design and the one ...

A: Yes, for the difference in cost of the dam with and without flood control storage. The Corps has an agreement with Saskatchewan Power that it will start paying when dam construction begins. The Corps wanted to review the plans before construction started.

That brings me to the second point I want to discuss, and that is also on Rafferty Dam. It involves the hydraulic design of a fuse plug emergency spillway.

The initial design provided for construction of a concrete-lined spillway with a stilling basin. When design for the maximum probable flood was accepted, this spillway had to be greatly enlarged at a high increase in cost. I suggested that instead of enlarging the concrete-lined spillway, consideration be given to constructing a separate emergency fuseplug spillway to carry part of the spillway discharge at maximum flows.

Fortunately, conditions were favorable for constructing a fuseplug spillway about 1,000 feet from the left abutment of the dam. A 300-foot wide earth channel about 1,200 feet long, with its invert at about the same elevation as the concrete spillway crest, could be excavated. The fuseplug is located near the end of the earth channel. The fuseplug is a low gravel on rock embankment with its base on the bottom of the earth channel. The top of the fuseplug would be 5 to 10 feet below the top of the dam.

When a large flood occurs the concrete spillway is in operation. As the flood increases in size and exceeds the capacity of the concrete spillway, the fuseplug in the earth channel is overtopped and washes out. For the maximum probable flood, both the concrete-lined and fuseplug spillways will discharge at the design discharges.

The Canadians hadn't any experience with fuseplug spillways. I told them about Professor Kenny, who was at Washington State University. He was a consultant for a Pacific Northwest public utility district on the design of a dam in the State of Washington. He recommended that a fuseplug spillway be considered.

He tested the fuseplug spillway in a 1:50 scale model in the university laboratory. His main concern was how to construct the fuseplug, so when it's overtopped, it all won't wash out suddenly to greatly increase downstream discharges. The small scale model tests indicated good performance, but he wanted to test it full scale. He found a small stream where he tested a short length at full height, full base width and full cross-section. It was constructed of what he considered to be the correct mixture of materials. By releasing water upstream, he experimented with the mixture of materials. It was concluded that the correct mixture should withstand 2 to 3 feet of water of the top of the fuseplug before it started washing out, and it should continue to wash out at a slow rate until it is completely washed out.

The board and Saskatchewan Power agreed that the emergency fuseplug spillway should be considered for Rafferty Dam. Since a small-scale model had already been constructed of the dam, concrete spillway and outlet works, the proposed spillway was added to that model. It operated well, and it was adopted as part of the project.

When the Corps reviewed the plans, they raised questions about the fuseplug spillway. "Where has it been used before? Has it been model or prototype tested? Will FEMA approve its use?"

By the way, the fuseplug Kenny developed and tested was constructed as part of the dam project for which he served as a consultant. As far as I know, it's never been overtopped. So the Corps wouldn't be able to go to FEMA and say, "It was done at this dam, it was overtopped, and it worked perfectly."

The Corps made a big issue about Rafferty Dam having an emergency fuseplug spillway. The board decided to consider reducing the size of the concrete spillway required to handle the probable maximum flood. Additional model testing was unsuccessful. It was concluded that it would cost significantly more to pass all the discharge through the enlarged concrete spillway. Saskatchewan Power decided to spend the additional money.

About that time, I was seriously considering retiring from consulting. I wrote Saskatchewan Power advising them that I was terminating my consulting practice and would no longer be able to serve on their consulting board. I immediately got a letter back from them saying, "You cannot retire from this board. You were the one who convinced us that the fuseplug spillway would work and that it would save us a lot of money. Since we're in this big hassle with the Corps, you've got to be on our board to convince the corps." I agreed to continue serving on the board. That was when the fuseplug spillway was still in the plans. In the course of the next six months or so, Saskatchewan Power gave up and decided to adopt the concrete spillway plan.

Q: This example at Rafferty and the Corps' reluctance to go ahead with what they didn't see as a proven design--did you find in your dealing with a lot of the districts and divisions that the Corps was ultra-conservative in their engineering approach?

A: Yes, they were. The Canadians, and many U.S. non-Federal organizations and engineers, frequently said that the probable maximum flood, as defined by the Corps, is ultra-conservative, and many of them don't use it. But when dealing with FEMA, it had to be used because they accepted it.

Q: So, the Corps, while naturally inclined to be conservative, was forced further in that direction by FEMA standards?

A: Yes. However, for some projects, it doesn't cost much more to use the maximum probable flood instead of the 1 ,OOO-year flood.

Susitna Dam, Alaska

Q: Before and after you retired, you consulted on Susitna Dam in Alaska?

A: Right …

Q: Were you involved in working on that before you retired? That project goes back a long way, doesn't it?

A: Well, let's see here. Susitna. I got it on a piece of paper. No, I don't think that … Here it is. I got involved after I retired, 1980 to 1983 I was on the board, and we had meetings in Alaska. I'm sure that the project had been thought of by Alaska Power Authority before that. They desired most of their power by burning oil which was plentiful and cheap in Alaska. However, in the early 1980's, the price of oil increased significantly, and it was being sold in large amounts to Japan. Then, when more power was needed, they decided to take another look at developing hydroelectric power at Susitna. Preliminary designs and cost estimates were prepared, with the board's assistance, for two dams and power plants.

Q: They were just studied then?

A: They were just studied, and they got plans ready to go now, if they decide to. I got word after the last board meeting that their decision was not to go forward with those dams yet.

Q: In hydraulics, what are the differences in considerations in designing a dam in an environment like Alaska or Saskatchewan, and one in, say, southern California?

A: One difference is in determination of the maximum probable flood. The largest flows occur during snow melt time in May and June. A heavy rainstorm on top of melting snow produces larger floods in Alaska. Other than that the greater temperature difference has little effect on the hydraulic design. No concrete construction is done during freezing weather. The construction period is limited to about six months each year.

Horse Mesa Dam

Q: I see you also worked for the Salt River Project.

A: Yes. I was a consultant on Horse Mesa Dam, which was constructed by the Bureau of Reclamation. The Salt River Project Water Authority purchases its hydroelectric power and is responsible for operation of the power plant, and some water releases for down river use.

The dam is a concrete arch dam, about 200 feet high, with two spillways, one on each abutment, and low ogee crests with no gates, but each one of them has three 40-foot gate bays. Each spillway has a concrete-lined channel chute with a flip bucket above the maximum water level downstream of the dam, which flips the water out into the downstream river channel.

The two spillways were not designed to handle the maximum flood. A large 30-foot diameter concrete-lined diversion tunnel was constructed on the right abutment. Large gates were constructed at the upstream end of the diversion tunnel, which, after the dam construction was completed, remained closed to store water in the reservoir, except during major floods when they were opened to assist the spillways in controlling the floods. When a large flood occurred, the gates were opened fully, which caused the tunnel to flow full. A flip bucket at the downstream end of the tunnel flipped the water into the river several hundred feet downstream of the dam.

The tunnel was on the right side of the dam, and it was directed at about a 30 degree angle to discharge in to the river. The river channel wasn't very wide, and both abutments were quite steep. There was a road on the left river bank that was used for access to the powerhouse. Large tunnel flows crossed the river and impacted on the left river bank, washing out the powerhouse road. Each time the road was washed out, it would be several weeks to three months before the road was repaired and the powerhouse was back in service. This resulted in considerable loss of power revenue.

The Salt River Authority decided to study what could be done to prevent the road from being washed out by every major flood. I was asked to serve as hydraulic consultant for the study. They didn't have a board. I met with the authority's engineers, discussed some preliminary plans that had been made and inspected the site. I suggested that a hydraulic model be constructed to test several possible remedial plans. The authority agreed with my suggestions.

The authority wanted to interview several laboratories and select the best qualified one to make the model studies. I suggested they interview the Bureau of Reclamation laboratory near Denver; the Engineering Consultants, Inc., outside of Seattle, Washington; and two other smaller laboratories in California.

These four laboratories were asked to submit prototype proposals for construction of the model and conducting the model tests. After the proposals were received, it was decided that the Bureau and Seattle laboratories were well qualified to do the work. Both of those were interviewed, and it was decided to have the work done in the Seattle laboratory because it was simpler than working with a Federal agency.

Chick Sweeney, who was head of the Seattle laboratory, found that the large tunnel flows in the model washed out the powerhouse road the same way as occurred in the prototype. One remedial measure, which was tested, was to construct a stilling basin at the downstream end of the tunnel. It turned out that the downstream end of the tunnel would need to be realigned and lengthened so the stilling basin could be located in the right river bank. This would be very costly.

The second remedial measure tested was to provide bank protection on the left river bank to prevent road damage. Various sizes of rock, rebars, and concrete blocks were tested. It was found that the best bank protection consisted of large concrete blocks at the toe of the bank with large rock placed on the bank slope up to the road level. A concrete slab was required in the area of major impact because sufficient large rock was not available. The authority adopted this remedial measure and made an estimate of its cost.

About a year later, one of the authority engineers called to inform me that the remedial works designed and cost estimate were completed but construction was not started because of a delay in obtaining construction funds. He said, “Meanwhile, we haven’t had any major floods, and, if none occur in the next few years, construction may be delayed 10 years or more.”

Q: Back to where you started from, huh?

A: That’s right.

Q: Speaking of Arizona, did you have any involvement in either the Indian Bend Wash project or the Central Arizona project?

A: No, I wasn’t involved in that at all.

Q: So you escaped those two?

A: Yes. Another thought about my retiring from consulting service. One of the Salt River Authority engineers called me to inform me that the Bureau of Reclamation was establishing a board of consultants for the design of a dam in Colorado. They were looking for a hydraulic consultant and wondered whether I would be available to serve on the board during the design and construction stages. I said that I would like very much to serve on a Bureau board, but the way Federal dams are designed and constructed it would be about 8 years before that job would be completed. I said, "You know that I am retiring and I can't serve on a board that long." I advised him to tell the Bureau that I was not available.

There were several retired Bureau hydraulic engineers available to serve on that board. I think the Bureau wanted someone outside of the Bureau to make it an independent board, not one with former Bureau employees.

Q: Yes--to give it objectivity?

A: That's right.

National Academy of Engineering

I wanted to mention something I was very, very proud of over the years. I got elected to the National Academy of Engineering in 1971. That's 20 years ago. There weren't very many Corps people in the National Academy then. Hathaway never made it. Slichter never made it. I don't know why.

I started to do my own private consulting in 1958, and the third job I had was in Caracas, Venezuela. That was a very interesting job. I can talk an hour about it, but I won't go off on that tangent now.

One of the jobs I had was for BC Hydro [British Columbia] on a large dam, the largest dam in Canada. The designers were a Canadian firm, and BC Hydro had a consulting board. There were two Canadians on it, and three Americans. Hunter Rouse and I were board members. He was a top professor at the University of Iowa for years. He's known throughout the world as the father of hydro-mechanics. He developed many theories. He's written a number of books on it, and he lectured all over the world on hydro-mechanics. He's retired now, and living in Arizona someplace.

Generally, in board discussions, Hunter covered theoretical aspects, and I covered practical aspects of hydraulic design. So when they suggested something, Hunter would expound on the theory involved. I would question the theory sometimes, and I'll admit sometimes I didn't know the theory, and I had to admit it to Hunter. But also, I would expound on the practical aspects of design based on my knowledge of what's been done before. And that way, we'd get a little tangled now and then, but it usually resolved pretty well.

I found out later, after I was elected, that he was the one who nominated me for the National Academy of Engineering. It was sort of a practice not to nominate people from your own firm or agency. He was a professor, and I was a government man, so that put him in the clear.

As I mentioned, there aren't too many Corps people who are members. Jack Morris is a member, and there are several others. Now, General Hatch [Lt. General Henry J. Hatch, Chief of Engineers, 1988-92] is nominated for election in this next election, which will be this fall. Oh, and another one that got elected was Clarke, one of the Chiefs of Engineers before Morris [Lt. General Frederick J. Clarke, Chief of Engineers, 1969-73].

Q: Frederick J. Clarke?

A: Fred got elected, too. Charles Noble was also elected.

Q: Well, that's a nice distinction to have.

A: I always thought it a great honor to be a member.

Environment and Engineering in the 1970's

Q: Let me remind you about the environmental movement of the 1960's, and ask you what kind of effect the environmental movement had on Hydraulics and Hydrology?

A: The major effect was that for every project the Corps of Engineers had to make an Environmental Impact Statement [EIS] and write a report on what effects the project would have on the environment. The district wrote the report, and it was reviewed by the division and the Chief's office.

In my Hydraulic Design Branch, we'd look at the report to see whether we had any comments on the hydraulic design. For dam projects, the hydraulic design usually would be the same as for dam projects with no environmental problems. But in some cases, the spillway size or height of dam may need to be altered so that too much water would not be released to cause downstream flooding, and environmentalists would say "That's not good for the environment."

I experienced that problem while serving on the consulting board for two Saskatchewan Power Corporation dams [Nipawin and Saskatchewan Forks Dams]. The dams were designed without any regard for possible downstream environmental problems. There were some environmentalists downstream, farmers particularly, who opposed construction of the dams. They said it would change the flow of the water in the river, which would damage the environment. During Provincial elections, some politicians thought they could gain many votes by backing the environmentalists. The problem was the environmentalists, erroneously, thought that construction of the dams with large spillways and outlet works would create larger downstream floods than would occur under natural conditions with no dams. I explained that the proposed dams would reduce the size of downstream floods.

Finally, it was decided to make an environmental impact survey. It was found that a rare species of fish existed in the river downstream of the dams. A large flood might make those fish become extinct. Also, there was a special kind of flower that could be completely destroyed. Those environmental effects were judged to be insignificant, and the dams were constructed.

Q: So it wasn't too much.

A: No, it wasn't too much. I got the impression that environmentalist use any argument to defend their priorities.

Q: Or to stop you from doing what the Corps wanted to do or whoever the developer was of the project then?

A: Yes. If the environmental problems were significant enough, they could have prevented the construction of the dams or required them to be redesigned.

Q: The two in Saskatchewan?

A: Saskatchewan, yes.

Q: Where you involved in any project in which environmental objection may have resulted in changed hydraulic designs?

A: I think there were some projects which had design changes, but they weren't major changes. I can't offhand recall any where the environmentalists controlled what the Corps was going to do on a major project.

Let's see now. There was a channel improvement project in Florida, which was designed and constructed by the Corps. The river channel wasn't large enough, so during major floods, swampy areas and adjacent properties were flooded. The flood damages justified improvement of the river channel to carry more water without flooding any of the land.

The environmentalists didn't like that; they wanted the land flooded because that made good swampland for fish, birds and whatnot. They were able to stop construction. The Corps had already constructed part of the project. The Corps hadn't made an Environmental Impact Statement or report, so they got an injunction against it which required the Corps to stop construction until they made an environmental impact study.

The study found that the channel improvement would reduce the wetlands areas, but there would still be enough swampland, so the environmental impact would be minimal. Then, the Corps got approval to complete construction of the channel improvement.

Q: Were you involved at all in the Florida barge canal situation?

A: The Florida barge ...

Q: Yes, that cross-Florida canal, in the northern part of that state.

A: Well, that's the one I'm talking about.

Q: Oh, that's it?

A: Yes.

Q: Okay. That was a major setback, that one.

A: That's right.

Q: It was just a regular canal with some locks in it, right?

A: Well, yes, I think there were a couple of small locks in there.

Q: But it certainly paled in significance to Tennessee-Tombigbee or something like that.

A: That's right.

Q: One of the major conflicts within the Corps itself that came out of the whole environmental movement was the emphasis on non-structural solutions for flood control. How did that affect your work because you were working so much in the hydraulics area?

A: Non-structural solutions. When the planners, who work with the environmentalists, decided to use a non-structural solution, I didn't get involved because I was only involved with the hydraulic design of structural solutions.

Q: There's a lot of comment in the Corps itself on the conflict in the organization between the advocates of structural and those of non-structural solutions.

A: Yes. Those conflicts occurred in the Planning Division. I never was involved nor had to make any decision one way or the other.

Q: So you only went to work when somebody decided it was going to be a structural solution.

A: That's right. Sometimes it took an act of Congress to decide which solution should be adopted by the Corps. When it's decided to adopt non-structural solutions, districts don't prepare design reports for review by the Hydraulic Design Branch, Structural Branch, and all other OCE Engineering Division branches.

Computer Modeling

Q: If we can move into a little different area--we talked about this before--it's the whole area of computer modeling. How effective and helpful was computer modeling for you? Would you have preferred to stay with actual building of the model?

A: I never got involved in computer modeling. I think that sufficient hydraulic modeling data became available for effective use in computer modeling. Formulas are developed, based on the hydraulic model data, which when used in the computer, reproduces the hydraulic model results.

Q: So, basically, the computer was only sort of programmed with the data that came out of the hydraulic model, and it was done in WES or somewhere else?

A: Yes, hydraulic model or field data. In some cases, computer modeling is used to solve fluid dynamics or other theoretical equations. Most computer modeling was done at WES.

Q: Now, I was looking at something last night, Margaret Petersen's book on river engineering, and she was mentioning that there is a distortion between the model and the reality. There's a reliability problem. Where does that come from, just the natural fact of trying to record these data elements on a small model versus the large actual thing?

A: Well, I think that's what she was talking about. A very small model has a distortion effect. For example, let's consider the determination of water levels for a certain discharge in a river channel. Water surface elevations measured in a small-scale model would not be the same as measured in a large-scale model because the model roughness factor cannot be simulated as well in the small-scale model as in the large-scale model. That is called the distortion factor.

Q: So really a lot of it has to do with the scale of the model you're using

A: That's right.

Impact of New Technology

Q: I know we touched on this, but what other technologies or new technologies and methodologies were introduced while you were at the Corps that significantly affected the way you did hydraulic engineering?

A: New technologies? Technology--instead of using textbooks and theoretical equations, you use model testing. That's a new technology. I suppose the next new technology is taking model test results and using computers. From there on, I don't know of any further advancement of technology.

Q: Well, how about some things in the construction side that would allow you in hydraulics to make different kinds of designs, I mean a superior type of concrete or something like that? Would that allow you to make a better design or a different type of design?

A: Yes, it would. There's been a lot of work in the last 15 or so years to improve the resistance of concrete to erosion. With ordinary concrete, if the physical shape of a high-velocity spillway or outlet works is not designed correctly, cavitation erosion of the concrete can occur quite readily. For example, cavitation erosion can occur on a concrete spillway floor when the velocity exceeds 50 feet a second and there is misalignment at a floor joint.

If the upper edge of a downstream monolith is higher than the downstream edge of an upstream monolith, then the high-velocity water striking the misalignment edge creates negative pressures just downstream of the misalignment. The negative pressure area is extended downstream a short distance by the high-velocity flow to positive pressures, which cause the negative pressures to collapse very rapidly. The rapid collapse of negative pressures produces high-tensile stresses. The high-tensile stresses are exerted on the concrete floor a few inches from where the cavitation pressures are developed. The concrete is porous enough so that the high-tensile pressures enter the concrete a short distance, and progressively, erodes the concrete floor.

There has been considerable work on developing superior concrete to withstand cavitation erosion. Epoxy solutions have been added to some concrete mixtures. It makes a stronger concrete that withstands cavitation pressures much better.

I think that has been developed fairly well on a small scale, and it's used where cavitation pressures are likely to occur. It seems to me there could be more effort made to make the concrete stronger. I don't know how, but right now the concrete is not very strong compared to steel.

Q: So that's an area that requires additional research?

A: I'm sure there's been considerable research done on it. It may well be that sufficient research has been done to decide that the cost of making concrete approach the strength of steel is beyond reason.

Cavitation Erosion

Q: Well, it sounds from the discussions of Tarbela and other projects that a lot of the problems that arise in these cavitation erosion areas arise from less than adequate construction techniques. That means the construction is not the way it's designed. How much did you get involved in that kind of thing with the Corps?

A: While a job was under construction, I very frequently went to see how things were coming along. I remember when I was on the consulting board for Magat Dam in the Philippines. The last time I was there to inspect, it was under construction. The spillway had a concrete ogee section, followed by a long concrete chute, about 1,500 feet long and 300 feet wide, on a 1 on 10 slope.

I walked over the spillway with the man who was in charge of construction inspection there. Construction of monolith joints was not done very well. I showed the inspector one joint that was a half inch higher on the upstream end of the monolith than it was on the downstream end of the monolith just upstream.

I explained the whole thing about cavitation erosion at monolith joints that I just explained to you. I said to the inspector, "Normally, this wouldn't be called good construction, but this dam isn't high enough and the velocity isn't high enough, to cause serious cavitation erosion. Also, the spillway will operate about once in 5 years, so there will be plenty of time to repair any cavitation erosion between floods."

Q: But it was an important requirement for you to get out and look at these construction projects?

A: That's right.

Q: Also, from what you say, it's only the areas where you had a lot of high-velocity discharge that you had the problems.

A: That's right. When the velocity was under about 50 feet-per-second, or there was not a lot of discharge with velocities over 50 feet-per-second, cavitation erosion was not a big problem. I told the districts that anytime large flows occur, they should check to see if there's any cavitation erosion.

Q: You've mentioned cavitation erosion repeatedly as being a major problem in high-velocity spillways, and with destructive consequences. What other kind of problems do you find in high-velocity spillways that are destructive as that?

A: Sometimes there is a destructive problem with high-velocity spillways that have a concrete stilling basin. For example, if a high dam having four spillway crest gates discharges with only two gates on one side of the spillway, most of the water enters the stilling basin in that side. The hydraulic jump would be very erratic with considerable return flow on the other side of the stilling basin where there is no flow from the spillway. The return flow on that side was caused by higher tailwater downstream of the stilling basin. When the river bed and banks downstream of the stilling basin consisted of loose gravel and rock, return flows would carry that gravel and rock into the stilling basin where it would erode the concrete floor of the stilling basin.

The Corps had this problem occur at quite a few stilling basins. The solution was, after the flood was gone, remove all the gravel and rock from the stilling basin, repair any concrete erosion, remove gravel and loose rock in the downstream river channel, and, in some cases, place some concrete or large stone protection downstream of the stilling basin.

Q: Despite all of the modeling, some of this correction only came from practical experience with the design.

A: That's right, after operation of the project.

Design Considerations: Spillway Gates

Q: We talked about this before, but was this a matter of experimenting with various configurations of the gates?

A: Yes.

Q: It sounds like an exotic science. Let me ask you about some key projects and see if you have any particular memories of some of these. The Arkansas-Red-White project. Were there any particular hydraulic design problems in that project that caused you any consternation?

A: The relatively low dams were constructed with concrete all the way across the river. There were no particular problems with the spillway, crest gates, or outlet works. There is a fairly good size navigation lock located at one end of the dam. One of the problems we had was that when large spillway discharge occurred with the spillway gates operating, high velocities in the downstream river channel made it difficult for vessels to approach the lock. Design changes had to be made, such as extending the spillway stilling basin wall on the lock side farther downstream or extending the lock approach channel and, in some cases, moving it farther into the river bank away from the main river channel. Usually, model tests were necessary to check the design.

Q: All that was normally done at WES?

A: That's right.

Q: Now that was all remedial work though, wasn't it?

A: Yes, most of it, but I was involved with the design of one or two later navigation dams and locks on the Arkansas-Red River project.

Q: So some of the later ones would have picked up those solutions.

A: Yes.

Q: When I was talking to Vern **Hagen**, he said that the Arkansas project presented a lot of problems for them because of the amount of sedimentation in that whole system.

A: Yes.

Q: When you designed things, how much did you account for sedimentation?

A: The old spillway crests weren't very high. The most critical condition with respect to sedimentation was assumed for hydraulic design. That occurred when the sediment level upstream of the dam was at the same level as the spillway crest. This would result in the smallest spillway discharge for any reservoir level. Vern was concerned about the maximum height of the reservoir water levels for the maximum possible flood, because of upstream flooding. He attempted to determine the actual sediment level in the reservoir, instead of assuming the most critical condition, as was done for hydraulic design. I think that's what he had in mind. Did he make any specific comment? He said he had a lot of problems.

Q: Yes, I think that's basically what he was doing and what he was talking about.

A: All right.

Q: I was just wondering when it passes over from hydrology to hydraulics. What kind of consequences did you have to consider?

A: If Vern had been successful in determining the reservoir sedimentation level for a spillway design flood, that level would have been used in the hydraulic design to determine the size of spillway and height of dam required to pass the maximum possible flood. Model tests indicated the difference to be relatively small, so the worst sedimentation condition was assumed for design.

Q: On the conservative side, then?

A: That's right.

Q: Was there anything else about the Arkansas-Red-White that you can remember?

A: No, not specifically. That was quite awhile ago.

Q: In the design of locks or dams--the other day we talked about tainter gates and vertical lift gates in various types of dams.

A: Yes.

Q: I've also noticed that the Corps has built roller gate dams and these double-lift gates, and this is what we were talking about the other day. McNary apparently has double-lift gates.

A: That's right.

Q: Could you discuss these various types of gates and why they're chosen, the pros and cons of the various types?

A: A tainter gate is a very simple gate. It should be used in the open and shouldn't have any water flowing over the top. When the gate is closed, no water flows underneath. When releasing water over a spillway or into a flood tunnel, the gate is raised and water flows underneath with very little gate vibration. Tainter gates should not be operated with large flows over the top of the gate because that causes excessive gate vibration.

I was on a consulting board for a large dam in Puerto Rico where that had three tainter gates on top of the crest. Unfortunately, a large storm made the water level rise quite suddenly and water started over the top of the gates which were closed. The operator started opening the gates, but they got jammed part open. The storm developed into a hurricane that caused large flows over the gates from many hours. The gate vibration caused all three gates to fail. The consulting board studied the problem and recommended what should be done to repair the damage.

Now a roller gate. A roller gate is something used on the crest of a dam. It's round like a drum, so that water can go over the top. Structurally, it's stronger because it's a solid body. Large flows can go over the top without producing excessive gate vibration. Primarily, though, the gate is lifted and large flows go underneath.

What other kind of gate did you want to talk about?

Q: Well, the vertical lift gate.

A: Those are used on spillway crests, also. When they're closed, they sit on the crest. When the reservoir water level rises above the spillway crest, the gates are raised so water flows underneath the gates and over the spillway. Water should never flow over the top of vertical lift gates.

Tainter gates are 10 to 20 feet high, but they may be 30 to 60 feet wide. The vertical lift gates are the other way around; they're not more than about 15 or 20 feet in width, but they can be 40 to 50 feet high. Tainter gates are more economical for wide spillway bays and vertical lift gates are more economical for narrow spillway bays.

Q: So the selection of the gate is based on the basic overall design of the project.

A: That's right.

Q: And the conditions. Are there physical conditions that prevent the use various types of gates?

A: No, economy is the main consideration. For example, vertical lift gates could be used for any dam, provided the width of spillway bays are limited to 20 feet, instead of50 feet for tainter gates. But the cost of using vertical lift gates would be considerably larger because over twice as many costly gate piers would be required. On the other hand, if a spillway located in one abutment of a dam is, say 60 feet wide, it may be more economical to use three vertical lift gates with two gate piers than a 60-foot wide tainter gate.

Q: What about the double-leaf lift gates? Now what are they--they're vertical lift gates, right?

A: Yes. Double-leaf gate. I know that such gates were used by the Corps.

Q: McNary Dam apparently has them.

A: McNary Dam, that's right. Well, double-leaf means that the gate is constructed with independent upper and lower sections. As the reservoir water level rises gate operation begins by raising the top part of the gate. If the reservoir continues to rise so large flows go over the bottom gate leaf, then it is raised up out of the flow.

Q: So it's sort of like a sectional lift rather than a single piece?

A: Right.

Q: Okay. I was looking at this picture, and it had various things like that where more water comes out of one gate than the other.

A: Yes.

Q: Okay. Well, I learn something every time.

A: Well, I'm learning, too--that I've forgotten a lot of things.

Q: You know a heck of a lot more than I'll ever know.

A: It may come to mind though, if I think for a few minutes.

Miscellaneous Civil Works Projects

Old River Control Structure

Q: Let me ask you about a project you probably know quite well--the Old River Control Structure on the Mississippi River.

A: Yes. The Old River Control Structure was built to control the Mississippi River so the whole river wouldn't go down, what's the name of it.

Q: Atchafalaya?

A: Atchafalaya, right. I was involved with that project. The control structure consisting of a diversion channel, spillway, and large gates, was constructed in the right levee of the Mississippi River to control the amount of water that would discharge into the Atchafalaya. The district's design was model tested at WES.

One question that arose was whether a stilling basin was needed to prevent excess erosion downstream of the control structure. After looking at the model, it was decided that a stilling basin was needed because the Atchafalaya channel banks for some distance downstream were erodible. Significant erosion in the Atchafalaya could undermine the whole control structure.

Oh, one further thing. The control structure was located several hundred feet downstream from the old structure, which was the best location for other than hydraulic design reasons. This required flow to make almost a 90-degree turn from the Mississippi River into the approach channel. When the flow reached the control structure, the water level was much higher on the left side of the structure than on the right, if the gates were not operated uniformly, which probably would cause erosion of the left approach channel banks for some distance upstream of the control structure. Some concrete and rock bank protection was provided to prevent that erosion. The sharpness of the 90-degree turn at the upstream end of the approach channel was reduced based on model tests, to improve flow conditions in the approach channel.

Q: That had to be a very difficult engineering problem--trying to control the Mississippi River from going where it wants to go?

A: That's right. There's no theory about that. You've got to figure out what might happen based on experience. Then test a model and see if you're right. If you're not, improvements in the design should be made as indicated by the model tests.

Q: Were you involved at all in the solutions to some of those problems that occurred there in the '73 floods when they had that big erosion on the old structure?

A: Yes, I remember that. I went out after the flood to look at what had happened. Improvements of the old structure so it wouldn't fail were discussed, but it was decided that a new large control structure that could handle more water was the best solution.

Q: It takes a lot of work on the engineering design of something like that because you're playing with a pretty powerful force there?

A: That's right. Yes. There's no great structural and concrete design problem. With respect to hydrology, the size of large floods and how high the water levels will be in the river are known. But when flows from a large river are diverted and controlled so the whole river won't go down the Atchafalaya, that is a difficult hydraulic problem. But it's still there, I guess.

Q: It hasn't washed away yet.

A: No.

Q: On something like that, you really have to very seriously look at your foundation structures, don't you?

A: That's right. I recall that there was a foundation problem underneath the concrete control structure. Sheet steel pilings were driven down about 60 feet, and the top of the pilings were imbedded in the base of the concrete control structure. This greatly strengthened the foundations.

Sacramento-San Joaquin River System

Q: Did you get involved at all with the Sacramento-San Joaquin River system in California?

A: Sacramento-San Joaquin? Yes, I did. Friant Dam was constructed by the Bureau of Reclamation on the San Joaquin River. The Bureau also constructed Shasta Dam on the Sacramento River and Folsom Dam on a river that discharges into the Sacramento.

The main problem on the Sacramento concerned the hydraulic design of rock and riprap bank protection. The Section 32 Program legislation was passed by the Congress authorizing the Corps to make studies of streambank erosion control. A Steering Committee to carry out the studies was established. I was the chairman until I retired in '79. One or two meetings were held in Sacramento to inspect the Sacramento River bank protection works. It was suggested that several alternative bank protection works be tested. Several test sections were constructed and evaluated for several years.

Q: Was there any particular difference between those kinds of projects and some of the other ones you were involved with, say, on the Missouri River?

A: The Corps did not construct as much bank protection on the Missouri River as on the Sacramento because the velocities weren't as high and the bank erosion not as extensive. Also, there was a lot of readily available rock on the Sacramento, which made rock bank protection quite economical. On the Missouri, rock for bank protection usually had to be hauled 200-300 miles, which made the protection costly.

Q: So there was a price consideration there, I imagine?

A: Yes.

Tunnel and Reservoir Project (Chicago)

Q: Did you have anything to do with the Tunnel and Reservoir Project, the TARP project, in Chicago?

A: What project is it called?

Q: It's called TARP--the really deep tunnels that act as a reservoir?

A: Right. The deep tunnels were constructed underneath the city's streets and buildings to collect storm drainage and sewage water.

Q: Right.

A: No, I never got involved with that project. I don't remember whether that project was under the Corps or not; 1 don't think it was.

Q: But I was wondering if that kind of thing ever came across your desk.

A: That's right. The Corps had to get involved because of the impact studies. The Environmental Impact report was sent to the Chief's office for review. The project consisted of many small drainage and sewer outlets discharging into a large underground tunnel. The tunnels were large enough so they never ran full. The tunnels served as a deep reservoir, storing water during storms which sank into the underground afterwards.

Passamaquoddy Tidal Power Project

Q: I was just thinking of another problem--somewhat like Susitna Dam I imagine with water and concrete and cold weather--were you ever involved in the Passamaquoddy Tidal Power Project in Maine?

A: Not very much. When I first came to the Chief's Office, there were a lot of studies being made on that in New England Division. Reports that came into the Chief's Office were on planning and were sent to the Planning Division. No detailed design was being done. Consideration was given to providing a low submerged dam that would control the tidal levels and increase upstream water levels. The power plant would be downstream, and water would be released at a slower rate so that more of it could go through the power plant. I wasn't involved with any detailed design.

Bonne Carré Spillway

Q: Okay. Since we talked, I was thinking a little bit about the lower Mississippi River projects we talked about the other night. I was wondering if you ever got involved with the Bonne Carré spillway.

A: The Bonne Carré? That name is very familiar.

Q: That's that big spillway from the Mississippi River to Lake Pontchartrain.

A: Yes. I got involved in that. Model studies were not made because the spillway is long and the head is low. As I recall, a low lift lock was constructed.

Q: Okay.

A: But I do remember looking at the plans when they came in.

Jetties at the Mouth of the Columbia River

Q: Any other one of these projects that you wanted to talk about that you have been thinking about?

A: We haven't talked much about navigation channels. I listed here "navigation channel at the mouth of the Columbia River." Maybe we can talk about that a little bit. Are you familiar with the Columbia River? It's a wide river at the mouth and a long distance. ..

Q: It's got those long jetties going out, doesn't it?

A: Yes. It's got long jetties going out, a south jetty and a north jetty. One of the problems involved the jetties. When they were first constructed, large rock was used to extend the jetties seaward. The jetties were subjected to 10- to 15-foot high waves during storms, which damaged the jetties by undermining the rock or eroding it away, particularly at the ends.

For a long time, the jetties were repaired by placing more rock at the damaged areas. The rock was very costly, because it had to be hauled a couple of hundred miles on barges. So the Portland District was studying other more economical ways of maintaining the jetties. The Committee on Tidal Hydraulics was asked to meet in Portland to discuss the problem. The Committee suggested that consideration should be given to using artificial protection like concrete tetrapods. A tetrapod is similar to a jack, made out of concrete, with legs about 12 feet long, and they're very heavy. Their size and the weight depend on the forces that they have to withstand.

In constructing the jetty protection, a rock base is first placed at the toe of the slope and up the slope to the top of the rock jetty. Then one or two layers of tetrapods are placed on the rock up to the top of the jetty. Most of the tetrapod protection is required on the channel side of the jetties. When high waves attack the back side of a jetty, as frequently. occurs at the seaward end of jetties, then similar tetrapod protection should be provided there.

The use of tetrapod protection was accepted. Tests were made at Bonneville Hydraulic Laboratory on a sectional model of the jetty. Different rock and tetrapod sizes were tested for different wave heights. This provided design criteria for rock and tetrapod sizes for different wave heights.

Another problem involved maintenance of the navigation channel which was 40 feet deep. Vessels coming in from the ocean passed through the navigation channel for several miles to the seaward end of the jetties, then passed between the jetties for several miles and then continued up the navigation channel to Portland. The jetties are 800 to 1,000 feet apart at the seaward ends. During large storms, 15-foot waves would cause the vessel to pitch so much, that if its draft was more than about 25 feet, it would strike the bottom of the 40-foot channel. The navigation interests and the Corps in the Pacific Northwest came up with the idea of enlarging the depth of the channel to 48 feet, increasing the depth by 8 feet. The next question was how to do it.

One plan was to dredge it. The second plan was to construct spur dikes near the inside end of the jetties. The spur dikes would be attached to the jetties, and aimed toward the navigation channel. Those spur dikes would constrict the opening between the two jetties, which would reduce the amount of water flowing up the river, during rising tides and storms. Also, less sediment would go up the river, so the amount of dredging required would be less. It was concluded that the dredging probably would not be completely eliminated, but it might be reduced enough for the 48-foot channel to justify the construction of the spur dikes.

Another question that was raised was whether the constriction at the end of the jetties caused by the spur dikes would produce erratic wave patterns and sandbar erosion with the navigation channel. It was concluded that the only way to answer this question was to make a model study of the whole thing. The last time I had anything to do with this project, the decision had been made to adopt the first plan of dredging the 48-foot channel to determine how much more dredging would be required than for the 40-foot channel. If the increase is not excessive, then the channel would continue to be maintained by dredging. If the dredging is greatly increased, then a cost estimate would be made of the construction of the spur dikes.

Hydraulic model tests would need to be made to determine whether one or two spur dikes are required. It'd be more uniform. With only one, the amount of dredging I think would be considerably more than if you had two. But if you had two, then it'd cost twice as much to build one. Then you run into costs of building those against the reduction in the amount of dredging that you would expect. The model could give some idea how much reduction in dredging. As far as I know, the model has been constructed and the navigation channel is being maintained by dredging.

Q: Are there any other coastal projects like that that you have been involved with--navigation channels or harbors of refuge that have had similar problems?

A: Yes, there are several small ones. Grays Harbor on the Pacific Coast is a much smaller harbor with similar problems. A model was constructed and tests indicated that jetties and some bank protection within the harbor were required.

Head of Passes, Mississippi River

There was a navigation problem on the Mississippi River at the Head of Passes. That's where part of the flow leaves the Mississippi River navigation channel and goes down another pass--I've forgotten its name. The problem concerned what type of control structure was required to prevent excessive flows from leaving the main Mississippi River to cause greatly increased maintenance dredging of the navigation channel. Tests made on the large Mississippi River model at WES indicated that a flow control structure was necessary at the Head of Passes, similar to the one constructed farther upstream.

Q: The Atchafalaya?

A: Atchafalaya, right. There were problems on other navigation channels, but not as large or important, cost wise, as on the Columbia River.

Humboldt Bay Jetties

Q: Did you get involved with the Humboldt Bay jetties?

A: Humboldt Bay jetties?

Q: Yes, in California.

A: Yes. They were built before I got there.

Q: Yes, they were pretty old; they go back to the 19th Century.

A: That's right. The only thing I remember is that they were constructed of rock and considerable erosion occurred during major storms. They are maintained by continually repairing eroded areas with more rock.

Most Difficult Hydraulic Engineering Problem: Mica Dam

Q: What was the most difficult hydraulic engineering problem you ever faced? We talked about your Tujunga Wash flood channel problem.

A: That wasn't hard at all. I think one of the most difficult hydraulic engineering problems was on Mica Creek Dam, which is on the Columbia River in British Columbia, Canada. I served on the consulting board for that project.

Mica Dam was designed by BC Hydro. It's a large earth dam about 450 feet high. It required a large concrete chute spillway on a good rock abutment on the left side of the dam. A large tunnel, which led to a powerhouse, was located on the right side of the dam. A large 36-foot diameter diversion tunnel was located at streambed level near the center of the dam. Lastly, outlets were required to release flood flows with high reservoir levels.

One solution which was considered was installation of gates in the diversion tunnel. By constructing two gate piers at the tunnel, three large gates could be installed to control outlet releases, except for one problem. Whatever type of gate that would be installed could not operate under the 400 or more feet of maximum head. The next consideration was to install two levels of smaller slide gates; one level at the tunnel entrance and the other halfway up the dam. The upper level of gates would be a second entrance and a separate small outlet conduit discharging into the large diversion tunnel. This plan had several hydraulic problems and would be costly.

Finally, the plan that was adopted consisted of constructing two concrete plugs in the large diversion tunnel; one at the entrance and the other about 400 feet downstream of the entrance. Two 7 x lo-foot slide gates were installed in each tunnel plug. The part of the diversion tunnel between the two tunnel plugs served as an expansion chamber.

The two sets of gates can be operated under equal heads for any reservoir level. For example, for the maximum reservoir head of 450 feet with both sets of gates fully open, the upstream set of gates discharges into the expansion chamber which produces 225 feet of back pressure, and the downstream set of gates discharges into the open diversion tunnel. This way, the maximum head that either set of gates need to discharge under is 225 feet, which is about the upper limit for slide gates.

To our knowledge, that had never been done before. Hunter Rouse and I were on that board, and Hunter, who was a theoretical expert, said, "It will work." I said, "Hunter, I think we've got something here. Let's model test it."

A large 1: 10 scale model was constructed in a Canadian laboratory in Vancouver. The model was constructed with clear plastic so flow conditions in the expansion chamber and downstream open diversion could be observed. Pressures were obtained at critical locations. The model tests verified that this plan would be satisfactory.

A City of Vancouver water supply pipe was near the laboratory. It had considerably higher pressure than was used for the 1: 10 scale model tests. I said, "Let's hook that up to the model and see what happens." The City of Vancouver was reluctant to give its approval because of possible damage to their water supply. But the laboratory finally got approval and the hook-up was made. The model operated very well under the higher head.

That plan was constructed at Mica Dam. I don't know of any other place in the world where a large outlet tunnel with an expansion chamber in it has ever been constructed. It has operated satisfactorily under high heads several times since construction was completed 15 or so years ago.

Q: In reaching a solution like that, is that purely you sitting there and saying, "This might work; here's the problem and let's look at this"?

A: Exactly. The thing I had to go on was that I knew that these slide gates would operate under 250 feet maximum head. Slide gates like these are installed at Pine Flat Dam, where the Corps has operated them under 250 feet of head.

Initially, there was one question that brought forth a lot of discussion concerning flow in the expansion chamber. The question was whether excessive surging back pressures in the expansion chamber just downstream of the upstream set of slide gates would cause excessive vibration and difficult operation of the slide gates. Fortunately, the model tests showed that those pressures did not surge excessively, and that good flow occurred in the expansion chamber.

Q: Would your model have shown you that it was going to behave well?

A: Yes. The model showed that good flow occurred in the expansion chamber, and that there were no great surgings of any kind. Model piezometers indicated no serious pulsations of pressures in the expansion chamber. Without the model results, I don't think we would have dared construct that plan.

Q: Nor would BC Hydro have paid the money.

A: Yes. But they were glad to see that it worked because the other plan that was considered would have cost a lot more money.

Q: Well, I guess that's why they hire consultants like you, right?

A: I don't know. I think they went with Hunter Rouse first because he was known all over the world in hydraulics and hydro-dynamics. I think Hunter said, "You better get Jake Douma here to help me."

Q: It's nice to have a guy like that you could give a couple dollars back to for helping you.

A: Yes.

Q: I don't have any more questions here; we've gone over a lot of things.

A: That's for sure!

Q: Would you like to discuss anything else? I think we've pretty much gone over everything I had to ask. I want to thank you for having me in your house, for talking, and for spending the time to do this interview.

A: Well, that's fine. I enjoyed it.

GLOSSARY

ASCE	American Society of Civil Engineers
BEB	Beach Erosion Board
BERH	Board of Engineers for Rivers and Harbors
CANOL	Canadian Oil Project
CERB	Coastal Engineering Research Board
CERC	Coastal Engineering Research Center
EBMUD	East Bay Municipal Utility District
EIS	Environmental Impact Statement
FEMA	Federal Emergency Management Agency
MIT	Massachusetts Institute of Technology
MRC	Mississippi River Commission
MRD	Missouri River Division
OCE	Office of the Chief of Engineers
PIANC	Permanent International Association of Navigation Congresses
TAMS	Tibbetts, Abbott, McCarthy, and Stratton
TARP	Tunnel and Reservoir Project
TVA	Tennessee Valley Authority
WES	Waterways Experiment Station