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