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the susitna hydro studies

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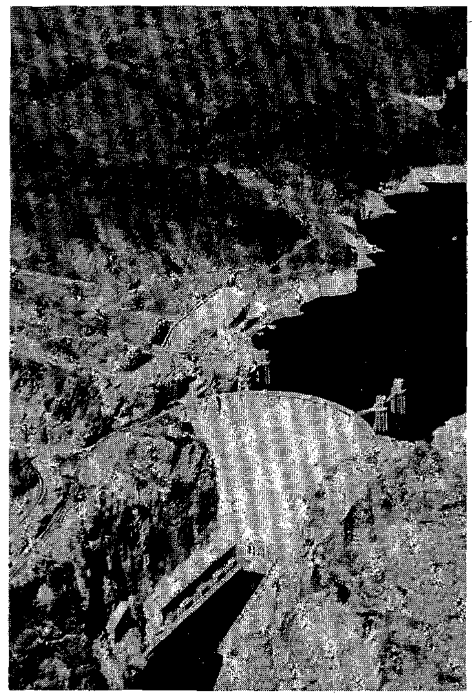
Alaska Power Authority
November 1981

no. 3269

Interviews with eminent scientists, engineers and economist give insight into proposed Susitna hydroelectric project

INSIDE:



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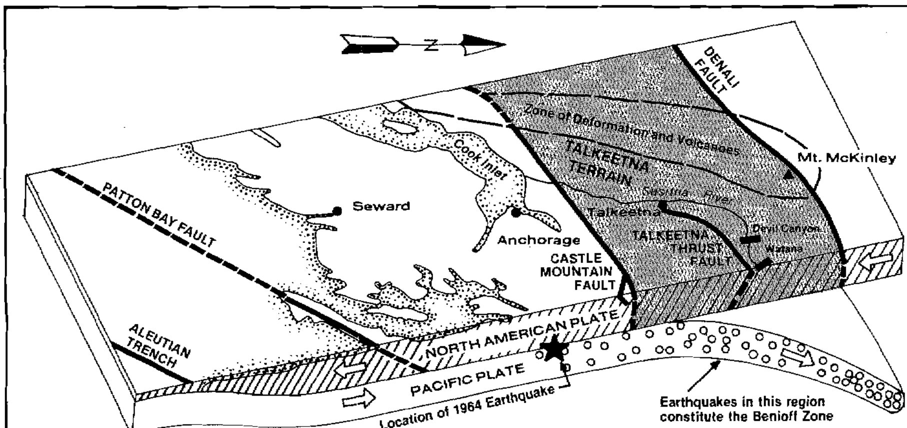

The dots represent the relative concentration of where earthquakes occur in the Benioff Zone.

Alaska Power Authority

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Susitna External Review Panel

INTRODUCTION

In 1979 the Alaska Power Authority Board of Directors created a separate fund to provide for an independent review of the Susitna hydroelectric project feasibility study.

The purpose of the fund is twofold: 1) to provide a second, independent cost estimate of the project; and 2) to hire experts in those areas of concern that are crucial in determining the project's feasibility. To ensure an objective assessment of the proposed Susitna project, an external review panel of eminent scientists, engineers, and economist was selected to review the project.

THEIR ROLE

This group of experts, the Susitna External Review Panel, was selected by the Board of Directors mid-way through the first year of the feasibility study. Although the Power Authority staff provides administrative support to the Panel, the Panel reports and is responsible directly to the Board of Directors. Panel members are encouraged and given the freedom to raise sensitive issues and can conduct separate, independent studies as necessary.

THEIR WORK

The Panel has met as a group three times. Two additional meetings are scheduled. During the first year and a half of the feasibility study, the Panel has focused on the following issues:

- the seismic conditions of the upper Susitna Basin
- potential impacts on fish and wildlife both in the reservoir areas and downstream
- the level of energy conservation incorporated into demand forecasts
- the comparative cost and risk of the Susitna project in relation to other power generating alternatives
- the design and construction of earthquake-safe dams
- the capability and design of spillways to handle high river flows
- foundation conditions and construction materials at the proposed sites.

THE RESULTS

The External Review Panel is scheduled to formally report to the Power Authority Board of Directors during the week of April 12, 1982. The Panel will report on the adequacy of the draft feasibility report and present its own recommendations in advance of the Power Authority's report on the project's feasibility to the Governor and the Legislature.

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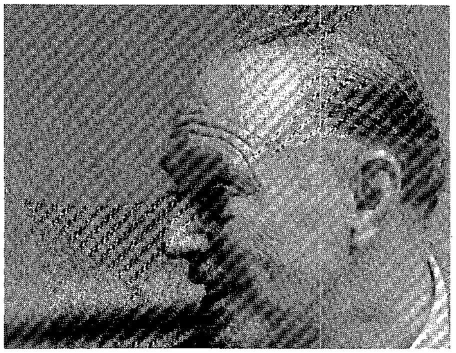
The Interviews*



1 Earthquake-resistant design

Dr. H. Bolton Seed is a former chairman of the Department of Civil Engineering at the Berkeley campus of the University of California. A specialist in earthquake engineering problems, he has consulted on over 80 dams worldwide, most of which are in seismic areas.

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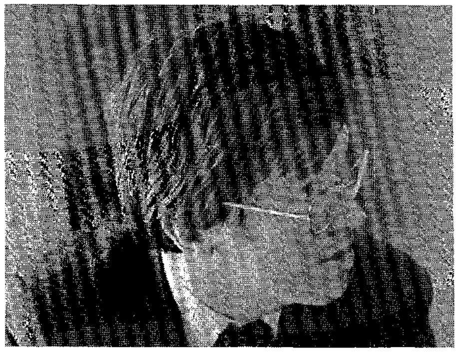

2 Economic analysis

Dr. Dennis M. Rohan is an economist with the Stanford Research Institute who specializes in energy matters. He has been involved in economic analyses of all phases of energy production and consumption.

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3 Environmental studies

Dr. A. Starker Leopold is a distinguished zoologist who has been associated with the University of California since 1946. A one-time vice-president of the Sierra Club, he has served on many wildlife and conservation organizations and has conducted extensive research around the world.

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4 Geotechnical engineering

Dr. Andrew H. Merritt is a geologist who has been involved in the research, design, and review of major construction projects around the world. A specialist in tunnels and rock work, he has extensive experience with hydroelectric and nuclear power projects.

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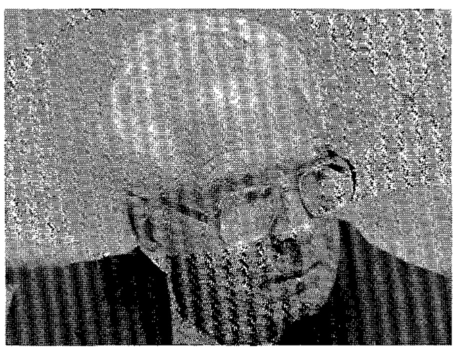

5 Concrete structures

Merlin D. Copen is an expert on concrete dams. He has had major responsibility for the design of the Glenn Canyon Dam on the Colorado River, California's Auburn Dam (proposed as one of the longest concrete arch dams in the world), and many others. He has consulted on numerous international projects as well as other Alaskan developments.

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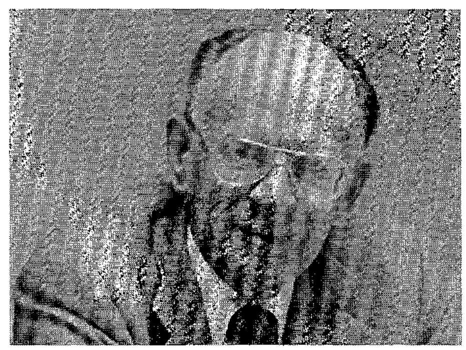

6 Hydraulics and river flow

Jacob H. Douma served as chief of the Hydraulic Design Branch of the U.S. Army Corps of Engineers prior to his retirement from active government service after more than 40 years. In addition to his government work on American dams, he has extensive consulting experience with Canadian hydroelectric projects.

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*The interviews were conducted in February 1981 by Nancy Blunck, Director of Public Participation, the Alaska Power Authority. They are reproduced by special request.

Interview 1

Dr. H. Bolton Seed

Dr. H. Bolton (Harry) Seed is a specialist in earthquake-resistant design and professor of civil engineering at the University of California, Berkeley.

Dr. Seed has been a consultant on soil mechanics and seismic design problems since 1953. Over the years, he has worked extensively with a variety of clients, including the U.S. Army Corps of Engineers, the Executive Office of the President of the United States, the World Bank, the Federal Power Commission, Bechtel Corporation, Woodward-Clyde, the Metropolitan Water District of Los Angeles, the Canadian Ministry of the Environment, and many foreign government agencies.

Dr. Seed has worked on about 80 dams worldwide, most of which are in seismic areas. After a dam failure in California in the early 70's, Dr. Seed authored design procedures for California so that dam failures would not happen again. These procedures are now used throughout the world to produce safe, seismic designs for dams.

Question: What past experiences do you have in Alaska?

Seed: After the Alaska earthquake, the Corps of Engineers was assigned responsibility for studying all the landslides in Alaska, the safety of the areas, the safety of the towns of Valdez and Seward where there were landslides, and other areas. They didn't have the staff to do it, so they contracted much of the work to a company called Shannon and Wilson from Seattle. I served as a consultant to Shannon and Wilson and, therefore, indirectly to the Corps of Engineers on the landslide areas in Alaska.

In deciding on the work and who would do what, I was given primary responsibility for determining the cause of the Turnagain Heights landslide. I must have travelled from here to Alaska about 10 or 12 times in the six months after the earthquake. Each trip was three to six days. I spent a lot of time at Turnagain on drill rigs, studying soil samples as they came out of the ground. I carried samples of Bootlegger Cove clay back on the airplane on the seat next to me so that it wouldn't be unduly disturbed by transportation. We did a lot of testing in our laboratories at Berkeley on the Bootlegger Cove clay as well as other studies. We eventually analyzed the problem and made a report to the government. We also reported our findings in the professional literature, and it seems to be a well-accepted version of the cause of failure at Turnagain Heights. I also studied the Fourth

Avenue slide, the L Street slide, the First Avenue slide, the Valdez harbor slide, and the Seward harbor slide. In addition to that I have served as a consultant to various companies dealing with the design of the Alaska pipeline. I served as a consultant to a structural engineering company who made a study of the safety of the Anchorage port facilities following the 1964 Alaska earthquake, and I conducted a detailed study of the influence of foundation conditions on the damage to bridges, both highway and railroad bridges, in the 1964 earthquake.

Question: What is your personal experience with design of dams?

Seed: Since I am a specialist in earthquakes, I tend to get involved more with dams in highly seismic regions than other areas. So, for example, I've worked on a lot more dams in California than with dams in Texas and Florida, which are nonseismic regions. My experience includes design of, perhaps, 80 dams—50 or 80 dams for earthquake problems of one kind or another. I suspect that I have worked on more earthquake problems related to dams than anybody else in the world.

Question: What other projects are you familiar with that resemble the Susitna project?

Seed: The Oroville dam in California is a cobble and gravel fill dam 700 feet high. The Auburn dam in California is a concrete dam about 600 feet high. Revelstoke dam in Canada has both a concrete section and an earthfill section on the Columbia River. The Uribante-Caparo project in Venezuela is a complex of four dams and three powerhouses, with 400 to 500 foot high dams. The Alicura project in Argentina is a complex of three dams about 400 feet high. The Boruca project in Costa Rica is expected to be a rockfill dam 600 feet high. Dartmouth dam in Australia is a rockfill dam 600 feet high. The Pueblo-Viejo dam in Guatamala is a rockfill dam 500 feet high. Tarbela dam in Pakistan is a cobble and gravel fill dam about 450 feet high. And many others.

I served as a consultant on the earthquake resistant design of all these dams.

Question: How do these projects resemble Susitna, and are there greater or lesser problems?

Seed: The Oroville dam is in California. The region in which it was built was supposedly nonseismic, but in 1965 they had an earthquake very near the dam. So the design earthquake for Oroville is now a magnitude 6.5 (on the Richter scale) earthquake occurring directly under the dam site, which is a very strong earthquake.

Oroville is about the same height as the proposed Watana dam and, as a matter of fact, was the one we suggested in our first report as probably being the best model for that particular dam. I have been on the consulting board for that dam since it became an earthquake problem, which means having responsibility for determining the adequacy of the seismic design.

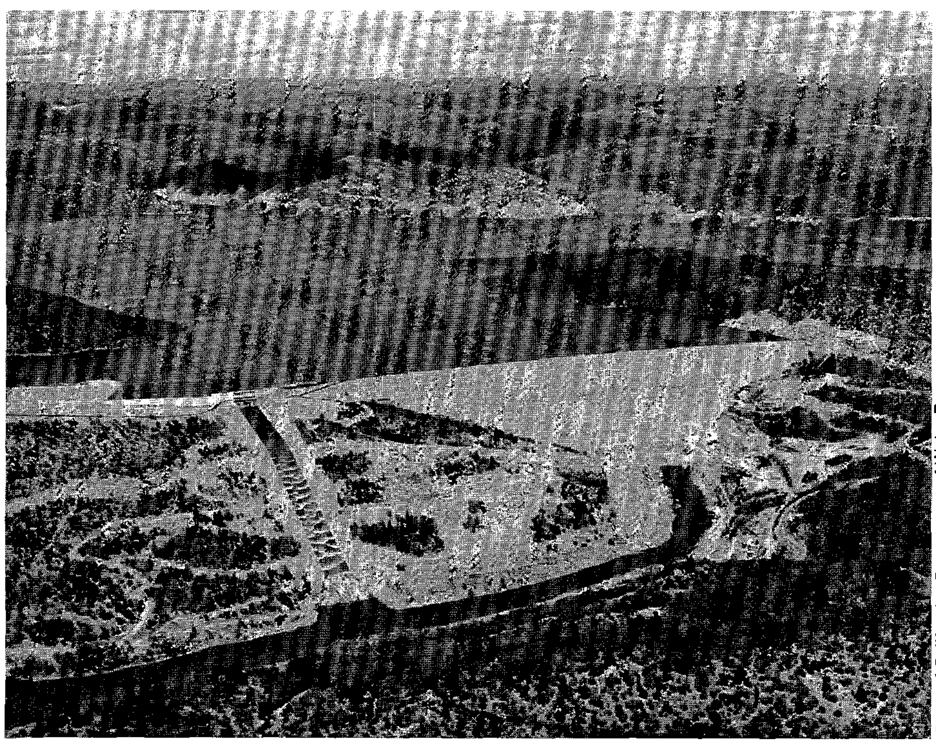
There is a report on the subject which is available to the public and widely disseminated. I also talked about that dam in a special lecture I gave in London called the Rankine lecture which was presented to the Institute of Civil Engineers on the seismic stablility of dams in general, including Oroville as an excellent example of how dams might be investigated.

The Auburn dam in California is a highly controversial dam. Again, the design earthquake is a magnitude 6.5 event directly at the dam site. The complicating feature of that dam is that there is much debate about the possibility of a fault going through the foundation of the dam and, therefore, directly through the dam.

The Consulting Board on which I served determined that the dam ought to be designed for a fault offset in the foundation of about 6 inches. That recommendation led to redesign of the dam from the thin arch dam to a concrete gravity dam. It was a highly controversial decision. In fact, the federal government doesn't normally take advice from the states on how they should do their job. But nevertheless, the State of California did get the Secretary of the Interior to agree to abide by whatever criteria the Consulting Board on which I served would establish for that dam. As a result of those criteria the federal agency designing the dam decided to change the kind of dam they were going to build.

The Uribante-Caparo project in Venezuela involves four dams and three powerhouses and some parts of this project are built about 15 miles from the Bocono fault, which is one of the largest faults in the world.

The seismic design of the project is an important controlling aspect of the project. The materials available for building the dams are not the best in the world. There is a lot of friable sandstone (friable means breaks easily, from solid to sand), and so it turns out that designing the dam to be seismically stable is a critical aspect of the design, and we have been working on



State of California, Department of Water Resources

The design of the Oroville dam in California has been suggested as an appropriate model for the preliminary earthquake design of the Watana dam. It is an earthfill dam like Watana is proposed to be, is in a seismic area, and is of a similar height (Oroville is 770 feet, Watana is proposed to be 880 feet).

The design earthquake for Oroville was a magnitude 6.5 earthquake occurring directly under the dam site. The Oroville dam design accommodates strong motions very near the dam for a relatively large earthquake.

that problem for the past two or three years. One of the design earthquakes is a magnitude 7.5 event occurring about seven miles from the dam. This is almost identical with one of the possible design earthquakes for the Watana dam unless Acres is successful in proving that the Talkeetna thrust is not active. At the present time, the Talkeetna thrust is a fault near the Watana damsite whose activity is questionable but it is believed to be inactive. If it remains in the inactive category, then the severity of shaking for Watana will be less than that for Uribante-Caparo project in general.

The Alicura dam is the highest and one of the first dams in Argentina to be designed for earthquakes using modern approaches.

The fault that affects the dam most is off the coast of Chile. One of the main problems is that we are trying to predict the kind of ground motions that will result from an earthquake with magnitude 8.5 at a distance of about 120 kilometers (72 miles) when there has never been a record of such an earthquake ever made.

The dam also happens to respond very strongly to that kind of motion and so the earthquake-resistant features of the design become a critical matter. Another big problem is to determine whether or not the material in the foundation of the dam needs to be excavated or can be left in place. This decision is affected directly by the design criteria for the dam.

Dartmouth dam in Australia is a rockfill dam 600 feet high (about the same height as the dams that are being proposed in the Susitna project). There is a suspicion of a fault very near the dam which could produce a magnitude 7 earthquake. This would be a more severe condition than we are talking about presently for Susitna, and the problem there has been to produce a design which would safely withstand that kind of earthquake. We have done that.

Incidentally, on all these dams, designs have been produced which have been adequate to accommodate the motions produced by the earthquakes. It is a matter of how you build the dam, how you arrange the dam, what materials you use in the dam, and how you place the materials in the dam. These factors will determine whether the dam will adequately withstand the effects of the earthquake.

The Pueblo Viejo project in Guatemala is designed for a magnitude 7.75 earthquake passing directly through the project site—not the site of the dam, but the overall project site. The fault passes through a power tunnel very close to the dam site. The shaking there is of the order of 0.7g [0.4g for Watana] acceleration, lasting for maybe 45 seconds—one of the most severe seismic environments of any dam in the world. Nevertheless, a safe design has been worked out for that project.

Tarbela is another major dam which has major faults very close by or directly below the dam site, and the shaking there is probably as strong as you would get in many parts of the world. We are working to make sure that the dam will be safe against earthquakes.

Revelstoke dam in Canada is an interesting problem. We had very poor foundation material, and the question there was whether or not the foundation material should be excavated or not. In the final analysis it was decided that the foundation material was not good enough to support the dam, so they made an excavation about 200 feet deep to remove poorer quality material and replace it with good quality material on which to build a safe dam.

"...the earthquake-resistant design of dams has been totally revolutionized in the last 10 years."

Question: What knotty problems have you encountered on other hydroelectric projects?

Seed: Any problems that you encounter are essentially related to three major ones—the amount of water to be stored and the amount of flood water that has to be stored at any given time; the stability of the enbankment and foundation materials; and the possible effects of faults in the foundation. The first is not my area of expertise. It is a hydrological problem and there are other specialists who can handle that part of the problem. I would say the most difficult problems in the earthquake sense are primarily those of evaluating the stability of the foundation materials on which dams are to be built.

For example, there was much debate about the safety during earthquakes of Revelstoke Dam in Canada and what they should do about the foundation. I was invited to be a consultant on that project because of the different points of view about the safety of the dam. There were public hearings. The Ministry of the Environment promised the people that they would ensure that a safe dam would be built. Having made that promise, they appointed a review panel to advise them on how they should proceed to be able to fulfill that promise to the people.

They were dealing with a very difficult foundation soil. As a matter of fact, I told them that the foundation soils in some parts of the dam foundation bore a great resemblance to those at Turnagain Heights in Alaska (the soils that failed in the 1964 earthquake). Some of the foundation material for Revelstoke Dam reminded me a lot of Bootlegger Cove clay. I told them that it was an unstable material, especially at the level of shaking they were designing for. I advised them to excavate the material out, and that's what they elected to do. I would say that was a knotty problem.

Other knotty problems involve faults in the foundation. After the San Fernando Dam nearly failed in the San Fernando earthquake in California, the people living downstream did not want another dam to be built at that site, but it turns out to be a critical point of entrance for water into California for the city of Los Angeles. Therefore, the Department of Water and Power in Los Angeles considered it essential to have a reservoir in that area, and it was necessary to rebuild the dam at that location. There was a possibility of a fault movement in the foundation, so we had to devise a special design which could accommodate a very high level of shaking and the possibility of a fault movement in the foundation both occurring at the same time. That was successfully done.

The Teton dam involved problems with highly erodible soils. The dam failed, but I believe that if the design had been modified, a safe dam could have been built at that site. The knotty problem there was assessing the effect of the jointing of the rock and the simultaneous erodibility of the soils used to build the dam on the safety of the dam. That was a tricky problem. The engineers who made the design thought they had solved it, but as events eventually proved, they had not. The dam failed. I believe we know enough about it now that we could rebuild the dam very safely.

There are knotty problems with many dams to tell you the truth. Under the Alicura dam project is a layer of 50 feet of alluvium. We have spent two years debating whether that material should be taken out or left in place. It is a critical decision because removing it involves lots of money. If it proves unnecessary it would be a waste of money, but to leave it in and make the structure unsafe could be catastrophic. A lot of thought has gone into the question of whether it can be left in place safely or should be taken out in the interest of public safety. I think we have just about reached a decision that it can be left there safely.

To tell you the truth, I don't know of any dam which doesn't involve one or two knotty problems.

Question: What are the major causes of dam failure?

Seed: It is well known that there are only a few basic causes of dam failure. The primary cause is overtopping—someone has not estimated the flood correctly, and you get more water to store than the dam can hold. Second, we have the possibility of slides in earth dams. Third, seepage problems can cause instability of the dam. I suspect that those three cause 80 percent of all dam failures.

The last big dam that had problems with seepage causing instability was the Teton dam. I believe that was the largest earth dam in which a failure has ever occurred. The failure occurred in 1976 in Idaho. Because it was built by a federal agency and because it was such a big dam (about 350 to 400 feet high) and it failed totally, all the water in the reservoir was let out causing a lot of flooding downstream. The Secretary of the Interior and the governor of Idaho appointed a special board to investigate the cause of the failure. I was a member of that 10-member board, and we did conduct the study and came up with a conclusion as to what caused the dam to fail.*

Question: What can we learn from past failures?

Seed: We can learn a great deal. The dam from which we learned most about how to build dams for earthquake safety was probably the Lower San Fernando Dam in California, which had a big slide in it during an earthquake in 1971. As a result of that slide, 80,000 people were evacuated from their homes while the reservoir was emptied or drawn down to a safe level. That could have been a big disaster, but it was not.

I happened to be the person appointed to study the cause of that failure and report on it to the Legislature of the State of California and prescribe and recommend design procedures for California so that a similar event could never occur again. Those procedures are the ones now being used in California and largely throughout the world to produce safe designs for dams.

We have applied these procedures to maybe 16 dams whose performance during earthquakes is known—either the dams have suffered slides or they have not suffered slides. It works out to have given the right answer to every case that we checked it against. So this is now what is called a validated procedure, and there is a growing degree of confidence that we now know how to use the procedure as a guide in arriving at the correct design decisions.

Question: Can you summarize those procedures?

Seed: It is quite a long procedure, and it is hard to summarize in a few words. It involves first determining the kind of earthquakes that will affect the dam and, secondly, how the dam will react and respond to the ground shaking to which the dam is subjected. Third, by means of laboratory tests on samples of the soil which will eventually be used in the dam, we can determine whether those soils will be strong enough to withstand the stresses which will be imposed on them if they were built into the dam. The laboratory tests also determine how the soil must be placed in the dam in order that it can withstand the stresses which will be imposed on it by the earthquake. The last step is building the dam to have the level of strength required.

Question: What about the question of building safe dams in a seismic area?

Seed: First of all, it is comforting that at the present level of knowledge of the Susitna project the intensity of shaking which can be anticipated at either dam site is considerably less than those in areas for which we have already designed dams. Secondly, the people in Alaska, and Talkeetna particularly, should know that dams have been proposed to be built in some extremely critical areas.

The Auburn dam in California has been a source of great controversy. It is planned to be built about 25 miles north of Sacramento. The controversy was over the potential hazard it presented to the people of California. If the Auburn dam were to fail, it has been argued, it would cover Sacramento with water to a depth of about 25 feet in a period of one hour and would kill a million people in the process. That is a very dangerous place in which to build a dam. Nevertheless, the project was studied by a great many boards of consultants and it was determined that a safe dam could be built there if it was built properly—in other words, if the right kind of dam were chosen and properly designed.

Most people now have no fears about it. Even people living downstream of the dam were eventually convinced. In fact, there were some well-known engineers who would live downstream of that dam who testified before the Seismic Safety Commission of California that if the right kind of dam were built by the right kind of people, they would not be concerned about living downstream.

"...it is a comforting fact that at the present level of knowledge of the Susitna project, the intensity of shaking which can be anticipated at either dam site is considerably less than those for some areas for which we have already designed dams."

Question: How often have you had to design to withstand earthquake activity?

Seed: In principle, all dams are designed for some level of earthquake shaking. That is a standard recommendation because until recently it was thought that building a dam and filling a reservoir could trigger earthquakes where there had not been any in recent history. Actually, there has to be some degree of seismic activity for that to happen, but maybe it hasn't happened in recorded history. Filling a reservoir can trigger seismic activity which has been lying kind of dormant for a long period of time so nobody knew much about it. Dam-building agencies now advise that all dams should be designed for a low level of earthquake activity no matter where they may be. And then certain dams which are designed in highly seismic regions should be

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* Editor's note: The conclusions are available in "Report to U.S. Department of the Interior and State of Idaho on Failure of Teton Dam," by Independent Panel to Review Cause of Teton Dam Failure, December 1976. It is available through the Alaska Resources Library at the Federal Building in Anchorage. The panel concluded:

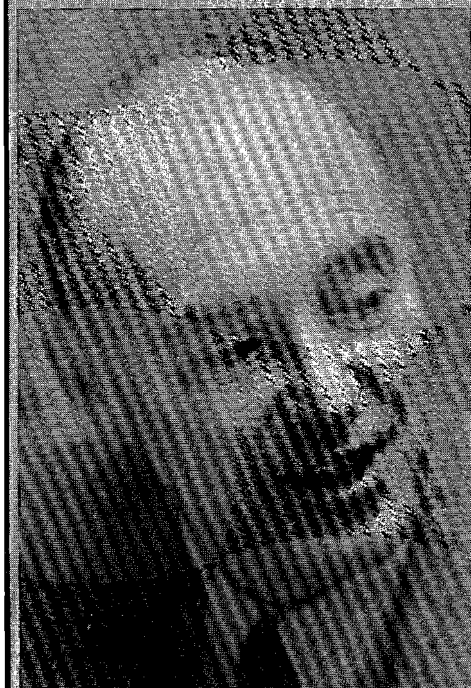
"In briefest summary, the Panel concludes (1) that the dam failed by internal erosion (piping) of the core of the dam deep in the right foundation key trench, with the eroded soil particles finding exits through channels in and along the interface of the dam with the highly pervious abutment rock and talus, to points at the right groin of the dam, (2) that the exit avenues were destroyed and removed by the outrush of reservoir water, (3) that openings existed through inadequately sealed rock joints, and may have developed through cracks in the core zone in the key trench, (4) that, once started, piping progressed rapidly through the main body of the dam and quickly led to complete failure, (5) that the design of the dam did not adequately take into account the foundation conditions and the characteristics of the soil used for filling the key trench, and (6) that construction activities conformed to the actual design in all significant aspects except scheduling."

* * *

"The difficult conditions of the site called for basing the design on the most unfavorable assumptions compatible with the geologic conditions concerning the behavior of the water and its possible effect on the embankment. Instead of placing so much dependence on the key trenches and grout curtain, measures should have been developed to render harmless whatever water did pass, irrespective of the reasons.

"In final summary, under difficult conditions that called for the best judgment and experience of the engineering profession, an unfortunate choice of design measures together with less than conventional precautions was taken to ensure the adequate functioning of the Teton Dam, and these circumstances ultimately led to its failure."

What about reservoir-induced seismicity (RIS)?



1. **What is reservoir-induced seismicity (RIS)?**

   Reservoir-induced seismicity (RIS) refers to earthquakes which are triggered by the filling of a reservoir. Typically these earthquakes occur beneath the reservoir area. Recent studies suggested that RIS earthquakes are triggered in certain geologic and seismologic terrains by the weight of the water in the reservoir and by the reduced friction along fractures (caused by water being forced into the fractures.)

2. **Does that mean reservoirs can cause earthquakes?**

   "A reservoir cannot induce more seismic activity than an area could have produced if the reservoir had not been there. In other words, a seismic event that would have occurred sooner or later is induced to occur sooner."

   "If, at the time of the filling of the reservoir, the accumulated strain energy is small, the corresponding seismic event could be small. Conversely, if the accumulated strain energy is high, the resulting event could be large, but not larger than what would naturally occur sooner or later."

3. **What is the potential for RIS at Watana and Devil Canyon dam sites?**

   The potential for RIS is largely a function of the size and depth of the reservoir. Since the Watana reservoir would be both very large and very deep, Woodward-Clyde Consultants has estimated both the probability of RIS occurrence and the potential magnitude of the resulting earthquake.

   Preliminary results suggest a moderate reservoir-induced earthquake could occur at the Watana site. The estimated magnitude of such an earthquake is 5.5 or less, because no active faults have been found in the immediate area of the Watana reservoir. The probability of occurrence was estimated by comparing the Watana reservoir with other very large and very deep reservoirs that have experienced RIS worldwide.

   Preliminary results indicate a similar likelihood of RIS at Devil Canyon.

   Additional evaluation of the likelihood of reservoir-induced seismicity is currently being done.

4. **Is the potential for RIS taken into account in dam design?**

   Yes. The design criteria for the dam actually exceeds design criteria for a reservoir-induced earthquake.

   Dam design criteria will incorporate both the effects of earthquakes on more distant active faults (the Denali Fault and Benioff Zone) as well as earthquakes which occur near the sites including those which are reservoir-induced.

Source:
Dr. Harry Seed,
Specialist in Earthquake-Resistant Design, University of California, Berkeley

designed to withstand very high levels of seismic activity.

Question: What is "reservoir-induced seismicity?"

Seed: Let me try and put that into perspective for you. A reservoir cannot induce more seismic activity than an area could have produced if the reservoir had not been there. All that a reservoir can do is to make the earthquake that would have occurred sooner or later occur sooner. So reservoirs don't make areas have greater earthquakes than they otherwise would have had. They just make earthquakes which would have occurred later occur sooner. So in any of the dams that we are talking about with Susitna, reservoir-induced earthquakes are not going to be greater than earthquakes which would naturally occur in those regions in the course of time.

Question: What particularly must dam design in highly seismic areas take into account?

Seed: The first thing in a highly seismic area is to study the dam site and find out if there is a fault in the foundation of the dam or very close to the dam. We prefer not to build dams directly over faults, although once in a while we have done that when there is no way to avoid it.

Even if you avoid the faults in a highly seismic region, that doesn't eliminate the problem of the dam being subjected to extremely strong ground shaking in the event of a major earthquake. Accelerations could approach a value of about 0.8 of the acceleration of gravity and persist for some considerable time, as people in Alaska well know if they were located near the epicentral region of the 1964 Alaska earthquake.

So the second aspect of the problem is to design the dam to remain stable even though it is shaken by very strong motions from an earthquake. There are various ways in which that is effected. One is by controlling the materials of which the dam is built. When I say controlling them, I mean selecting materials which are capable of withstanding earthquakes better than others; also, placing them in the dam using construction techniques which enhance their natural ability, and providing a finished product which can safely withstand the effects of the earthquake shaking.

The primary construction procedure involved in placing earth materials in dams is in compacting the material to a high enough density to make it strong enough to withstand the earthquake shaking. That has been done in many areas, but first you must carefully predict the effects of earthquake shaking on the dam and how dense the material needs to be to withstand a given level of earthquake motions.

There is a new problem which has only come to light in the last few years. That is that the most critical time in the life of some dams appears to be not during the earthquake but in periods of minutes to hours following the earthquake. We didn't really fully appreciate that until a dam in Japan failed in 1978. The failure occurred somewhere between six and 24 hours after the earthquake. That was the first time that anybody realized that the critical time for instability could occur some hours after an earthquake. Until then, it was thought that failure would occur during an earthquake if it was going to occur at all. We have now developed procedures for analyzing the failure of the dam in Japan and shown that the critical time for that dam would indeed develop about 24 hours after the earthquake occurred. Those procedures are available for analyzing other dams in other parts of the world.

Question: What's new in the field of earthquake engineering?

Seed: There has been tremendous progress in the field of earthquake engineering, and the earthquake-resistant design of dams has been totally revolutionized in the last 10 years. It is almost like the developments of space technology. Things we can do now, our understanding of the problems now, are so very much greater than they were 10 years ago that we can feel enormous confidence now in comparison. In those days people felt confident because they didn't really understand the problems. Now we feel confident because we have a very good understanding of the problems.

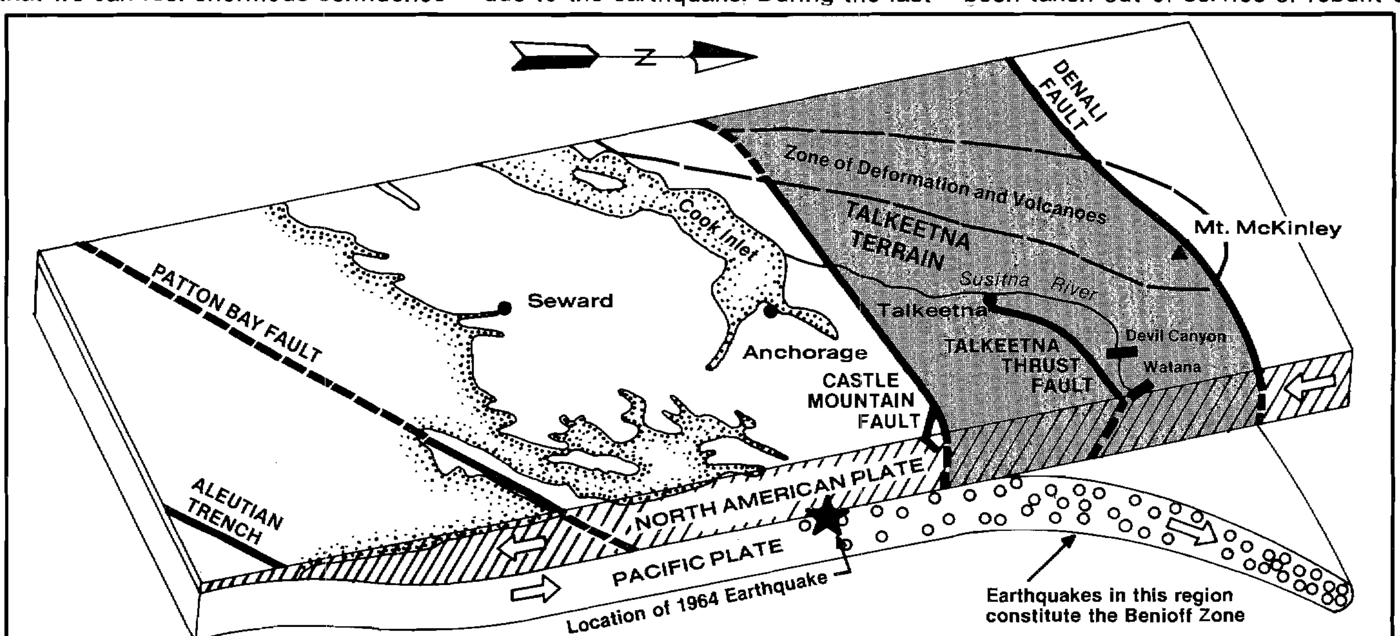
Question: Can you give some examples of why you can be so confident?

Seed: We can point to virtually dozens of dams which have withstood very strong earthquake shaking, even the strongest imaginable earthquake shaking. In California, in 1906 there were at least 15 dams within 5 miles of the San Andreas fault on which a magnitude 8.3 earthquake occurred, and they were built by the rather primitive pre-1900 construction methods. There wasn't a single one of them that suffered any major damage due to the earthquake. During the last 10 years we have learned what the properties of those dams are that enabled them to do that. We can also point to a few dams that have failed during earthquakes and what we have learned over the last 10 years is what made those dams fail as compared with the other ones that haven't failed. There are a lot more dams which have been subjected to strong earthquake shaking and not failed than those that have been subjected to strong earthquake shaking and have failed.

"[Ten years ago] people felt confident because they didn't really understand the problems [of earthquake-resistant design]. Now we feel confident because we have a very good understanding of the problems."

The record is very positive. There have been literally hundreds of dams which have withstood strong earthquake motions. In the total history of the United States, so far as I know, I think there are only four or five known failures of dams during earthquakes, and some of those were quite small dams. Now that we better understand which ones are likely to be vulnerable and which ones are likely to be safe and how to transform the unsafe ones into safe ones, I believe everybody can sleep more peacefully at night.

In the most recent survey of the safety of dams in California (conducted by the federal agency responsible for studying the safety of dams), the conclusion was that there are no dams in California which are a threat to the public, and we could not have said that 10 years ago. In the last 10 years there have been a number of dams in California which have been recognized as earthquake hazards that have either been taken out of service or rebuilt or



The dots represent the relative concentration of where earthquakes occur in the Benioff Zone.

Alaska is part of a large continental landmass (the North American Plate) which lies adjacent to an oceanic mass (the Pacific Plate). The Pacific Plate is moving northwest at a rate of about 2 inches per year.

This 2 inches of movement gets absorbed along a feature in the Gulf of Alaska called the Aleutian Trench. Here one plate is thrust below the other (in a process called subduction) as shown in the diagram. The zone of seismicity associated with the subduction is referred to as the Benioff Zone.

modified in some way to eliminate the threat to the public. As I said, the last report I saw from the federal agency responsible for assessing the safety of dams gave California a clean bill of health.

California is obviously one of the more seismically active states in the United States, along with Alaska, and if we can do it here, you can do it in Alaska, too.

"...if the Talkeetna thrust turns out to be an active fault, then the level of shaking at Susitna would be comparable to that of some of the strongest seismic regions where dams have been built...we have been able to build and design dams which can be shown to be seismically stable in those regions...[those] techniques would be capable of demonstrating the same for Susitna."

Question: How does the seismicity of the Susitna area compare to the seismicity of other projects you have worked on?

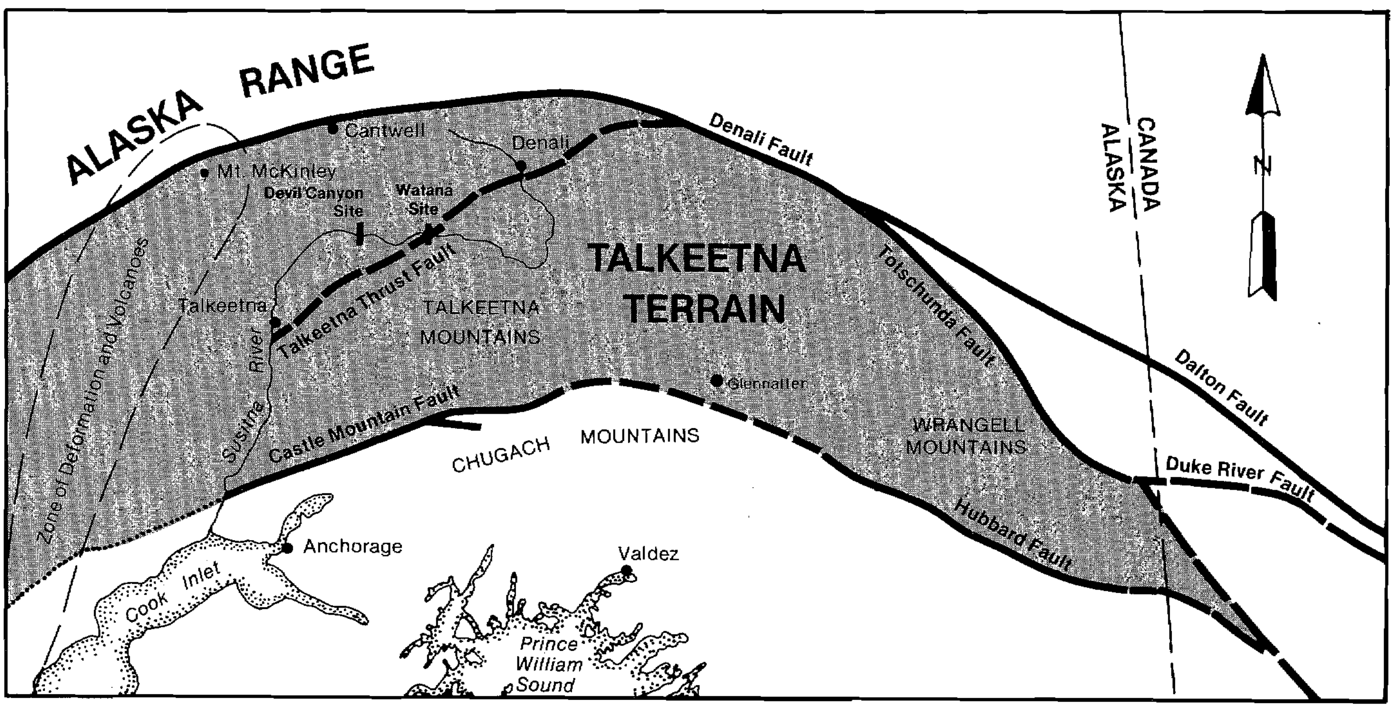
Seed: I would say that the seismicity of the Susitna area as it is presently understood (and if it is established) is somewhat less than that which I have encountered in other parts of the world. There are a number of faults whose activity has not yet been established in the Susitna area. They are believed to be inactive faults, but they are on record for being investigated very carefully during the 1981 summer. The Talkeetna thrust fault is one of these and probably the most important of them. If all the faults that are presently not clearly recognized as active are found to be inactive, then the seismicity of the Susitna area (or the intensity of ground shaking that would develop) would not be as strong as many of the dams that we have already designed. That would be a very nice feature of the project. In other words, if things turn out in the long run (after another year of study) to be the way they presently appear (and that remains to be confirmed), then there will be many dams in the world which have been designed for stronger levels of earthquake shaking than would be necessary for the Susitna project.

Question: And what if the opposite were true?

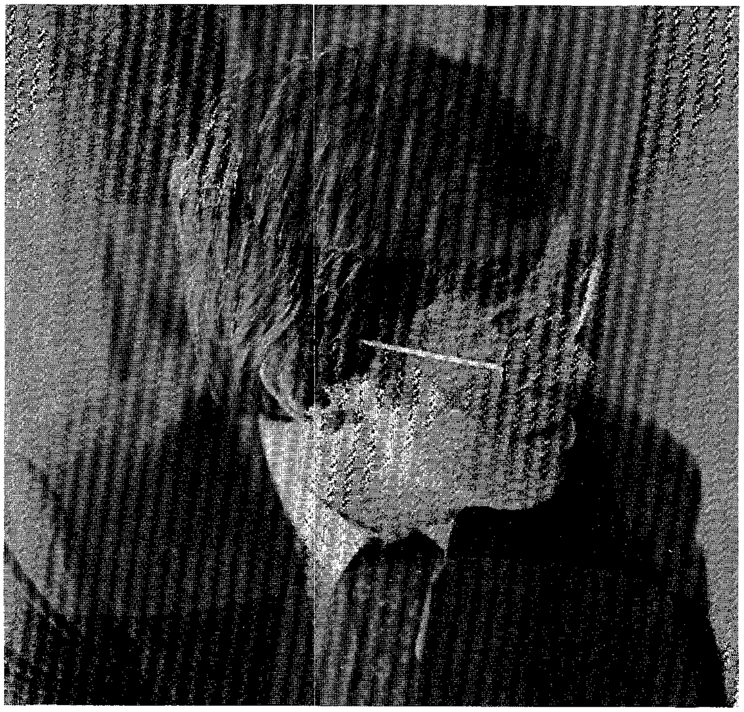
Seed: If the opposite were true, if the Talkeetna thrust turns out to be an active fault, then the level of shaking at Susitna would be comparable to that of some of the strongest seismic regions where dams have been built.

Since we have been able to build and design dams which can be shown to be seismically stable in those regions, then I believe that the same techniques would be capable of demonstrating the same thing for the dams of the Susitna project.

The design in any case will require great care but it would require even more care if those faults like the Talkeetna thrust turn out to be active faults. But I don't see that the dams cannot be designed to withstand these motions. They just have to be stronger dams so they can withstand the motion without in any way jeopardizing public safety.



To date no active faults have been identified in the Talkeetna Terrain itself. Studies in 1981 are further evaluating 13 faults and lineaments (potential faults) in the vicinity of the Watana and Devil Canyon damsites to determine whether or not the faults and lineaments may be active. One of those receiving additional study is the Talkeetna Thrust Fault.



Interview 2

Dr. Dennis M. Rohan

Dr. Rohan has training and experience in both engineering and business. He has consulted with executives in energy and utility companies on the analysis of the markets, economics, financing, politics, and technology of energy and other resource-based industries.

At Stanford Research Institute he has been involved with planning strategies for a large gas pipeline company, a major chemical company, oil corporations, and six major electrical and gas utilities. His work also includes energy forecasting and economic evaluation of many projects in the United States and Canada. Since 1973, he has been a member of the Decision Sciences faculty at Stanford Graduate School of business where he teaches in the areas of quantitative methods, computers, and energy economics.

Question: What Alaska experience do you have?

Dr. Rohan: It has been very limited. As I mentioned, the one project that I did work on was a market and economic feasibility study for Beluga coal.

Question: What other projects do you know about that resemble the Susitna situation?

Dr. Rohan: In terms of similar projects, let me first describe the scope of my energy consulting work. Most of this work has been in the areas of market, financing, economics, and decision analysis—the competitive economics of one type of energy source versus another.

A first group of projects, more on the market side, was for British Columbia Hydro, the Alberta Utilities, Manitoba Hydro, Ontario Hydro, and Hydro Quebec. This work was sponsored by the Canadian Electrical Association to help them to better assess their future markets for electricity.

Another study was for the commission in Minnesota on the need for power. The results were directly related to some expert testimony on the need for two large coal-fired units.

Still another was for Consumer's Power Company, a very large utility in Michigan outside of Detroit. Their questions involved the future markets for electricity and the competitive role of gas.

I also directed a major study for a group of utilities in the Midwest, including Wisconsin Electric, Wisconsin Power and Light, Wisconsin Gas and Electric, and several others. The utilities were trying to better understand their environment and make some important decisions about the need for power and the kinds of units (gas, coal, or nuclear). The issues involved demand, supply, pricing, and financing.

Another study dates back to experience with a hydro facility with the World Bank for the Philippine government. My work involved reviewing the financing requirements, making sure that there was a need and that the financing was in the interest of the Philippine government and participants.

Another study was in the Upper Peninsula Power area. The issue there was over the need for a large coal-fired unit which tied together with some mining activities.

I have had direct experience, fortunately dated, in Iran with the government of Iran, and I was part of an economic planning group to decide amongst some hydro, nuclear, and gas units that were needed in this rapid growth economy.

I directed part of a world energy study which was sponsored by about 50 major energy companies. I obtained an insightful understanding of the energy markets in the Pacific region, and in particular the demands for energy in Japan and Korea, which relate to potential outlets for Beluga coal.

A more recent study of another large project is the marketing of gas for the largest potential synthetic gas plant in the United States. I have conducted similar studies, with a financing decision orientation for one of the largest oil companies in the United States.

Question: Which of those projects most closely resemble the situation at Susitna?

Dr. Rohan: Well, let me describe which resemble and why. The Canadian study is similar on the market side because of similar market conditions. The economic choices relate to those in the Wisconsin study where you are really going through the tradeoffs and financing of gas, coal, and nuclear. In the Philippines, we evaluated the question of direct financing of a hydro facility. The study for the Philippines related to the kinds of guarantees and financing mechanism for the World Bank in funding the proposed dam. Some of the social issues are very similar to some work which I did for oil companies and their policy in synthetic fuel development in the Rocky Mountain area.

Question: Will you elaborate on the commonalities?

Dr. Rohan: Let me describe some of the issues. The Canadian study really looked at one of your key questions—what are your markets going to look like in the future? What will be the demand for power to be produced by the Susitna dams? How elastic to price would be the markets and how would the markets change as you added the facilities? The next kind of question is really of mix of power plants. Given the need, what is the optimum combination of mix of power units that really can satisfy the need?

Question: Have you encountered a situation where the choices before the public were not all centralized choices like coal, hydro, and nuclear?

Dr. Rohan: Yes, in the Wisconsin situation. A real choice, and a creative strategy developed by utilities, was to focus on ways of moderating demand.

"...in the Wisconsin situation...a creative strategy developed by utilities was to focus on ways of moderating demand."

Question: How much were they able to reduce demand?

Dr. Rohan: When I did the work in '74 or '75, the utilities were projecting growth of about 7%.* One of the real findings of the study was that we projected growth to be substantially less. The utilities cancelled several power plants which they were planning to build, and they were able to meet demand with substantially less new capacity. They were able to cut the expected incremental growth in half.

Question: Are there other examples you could expand upon?

Dr. Rohan: Another was in Consumer's Power region. A lot of the strategy on that study came back again to markets for power from the very, very large power unit. The amount of money involved in the construction of one plant was several billion dollars. We tried to assess future markets in relationship to their construction schedule. Basically it turned out that through detailed market analysis, the need for power would not develop as rapidly as projected.

A study that really related to one of your questions about alternatives has been prepared in conjunction with the Beluga coal area. I was involved in a client confidential study (sponsored mainly by Japanese firms) to assess the markets for Beluga coal exported to Japan, Korea, and California. They were trying to get an assessment of the competitive role of Alaskan coal, and how it would fit into Japanese, Korean, and Californian markets. This ties in with how you work through alternatives on Susitna. A critical component will be—and part of the Battelle study will certainly show—the cost and cost structure for coal in the Pacific region.

Question: What knotty problems have you encountered on other hydroelectric projects?

Dr. Rohan: I find very often the really knotty questions can be broadly classified into two problem areas:

1) decision criteria for choosing hydro
2) future markets for electricity.

These decision criteria are in their essence a statement of values of the citizenry of the region, and incorporate a tradeoff between economics and environmental and political concerns. The really knotty area comes down to a statement of these values, and this is not defined in purely direct cost terms.

For example, if we use as criteria, the minimum cost, the decision is usually in favor of hydro or nuclear; however, frequently overriding these cost considerations are other concerns. For nuclear, there is the problem of waste disposal and proliferation; for hydro, its impact on fisheries and wildlife. Even in estimating costs, there are two sides to the coin. There is the side that shows the direct cost of power, but as important is the opportunity cost of not having reliable power. The decision is a tradeoff of values—direct cost, indirect cost, and environmental and political concerns.

"The really knotty area comes down to a statement of these values, and this is not defined in purely direct cost terms."

In planning for future capacity, the principal uncertainty is usually in estimating the future markets for electricity. Approaches to estimating demand can result in different answers.

I have been involved in some work in one western state where it has been, I suspect, something of a game in which political viewpoints are expressed

*Editor's Note: Initial forecasts from the Institute of Social and Economic Research (ISER) project annual growth rate over the next 20 years to average 4.5% a year for the Alaskan railbelt.

through a demand methodology. The methodology is adapted then to project a set of personal values. What happens is that rather than saying we are for or against active conservation, proponents and opponents have special methodologies that predict low demand or high demand, depending upon their political view. The level of demand in turn influences the need for, and choice of power units.**

"I have been involved in some work in one western state where it has been, I suspect, something of a game in which political viewpoints are expressed through a demand methodology. The methodology is adapted then to project a set of personal values."

Question: Do you see that happening on the Susitna issue?

Dr. Rohan: I am concerned about this, although the ISER work on demand appears to be professional and objective. All parties must agree that the best forecast can only give a range of probable demands, rather than a most likely scenario.

This thought process was exactly what we needed on a Minnesota case. A group of farmers attending hearings indicated that there was no need for incremental power. (A latent reason was their desire not to have power lines built through their farm lands.) In this case, each group had to agree on a range of likely forecasts and then the impact to the farming community if it didn't have adequate power.

Question: Can you articulate a number that corresponds to the cost of not having power?

Dr. Rohan: Yes, there is some very interesting research going on currently at EPRI (Electric Power Research Institute). It depends on the class of customers. The loss of power impacts each class differently.

For example, if New York City had a blackout, you have some very high social costs—robbery, thefts and muggings during the blackout period. There have been some estimates made that the cost of not having reliable power is something like three to four times the normal cost, i.e., the normal rate residential customers pay. It is even slightly higher on a commercial building because loss of power disrupts the whole work environment. The most severe economic loss is on industries, such as the classic aluminum smelter, where the impact of not having power is to shut down production. It might take three to four days to get the smelter back in operation. Depending on the specific mix of customers, it can be four, five, or six times more costly than the normal rates.

The issue really comes down to what is your mix of customer groups? The research to date indicates that there is a point where if you underbuild you have some severe costs. It usually comes out slightly in favor of overbuilding.

I think that the real knotty question is the question of values. This is the tradeoff which people make between economic costs and their assessment of the ecology and the environment in which they live in Alaska.

Another factor on the Susitna project is financing. If you obtain tax-exempt financing, it will drive the economics in favor of a capital intensive project like the Susitna dam because you have access to less costly money. Whereas if interest costs are high, the less costly alternative is one which has higher operating costs. That would make the coal or gas unit competitive. Financing will play a role in the choice between hydro, coal or gas.

Question: You have experience with the question of industry's potential use of a new energy source and whether or not to add that new energy source. Could the existence of Susitna encourage industrial activity in Alaska, particularly heavy industry such as aluminum smelting?

Dr. Rohan: Yes, but I don't think you will see that happen. The reason is that your rates will be substantially higher than other alternatives for the aluminum industry. And when you look at your growth scenario (the forecast done by ISER), you'll probably see that the major share of the growth is in the residential sector. The other growth is commercial and this is related to service activities and government employment. I think ISER forecasts show modest industrial growth. I have some serious doubts whether Alaska could attract a smelter because (based on bond financing), your cost of electricity would be too high, at least in the next 15 or 20 years. Some of the developing countries are able to obtain very inexpensive financing through the World Bank, and because they obtain lower financing costs, their electric costs will probably remain less costly than the Susitna project. You may have inquiries by the aluminum industry (and they certainly will inquire about your rates). I have my doubts about whether it would be any more serious than information gathering. This is at least true for the next 10 to 15 years.

Question: Do you see it happening beyond 10 years?

Dr. Rohan: I have been giving serious thought about electric demand projections in the Railbelt region. My analysis indicates that the use of oil for power generation will decline over the next 10 years and beyond. Your oil export revenues make it much more economically attractive to export oil than to use it for power generation. For natural gas, I don't fully understand the Kenai Peninsula situation, although I understand adequate gas to go 15 years or so. Gas as an energy source competes in the industrial heating market, so it is priced on BTU basis comparable to crude oil. Probably as long as you have gas reserves, they will be used in home heating and some industrial use in the Anchorage area.

In 20 or 25 years from now, when the Susitna dam would be in operation, you may experience a change in the railbelt energy market, with gas becoming in short supply. In this timeframe, you may see a conversion to electric heat. My calculations indicate that the heating market could in the long run be the largest single market for electricity, generated by the Susitna dam.

"The research to date indicates that there is a point where if you underbuild you have some severe costs. It usually comes out slightly in favor of overbuilding."

Question: Have you encountered public values against electric heat?

Dr. Rohan: Yes. There is usually a pro-environment group that argues in cogent manner that electricity is a higher form of energy. I can understand this argument. It centers around generation of electric heat from a fossil fuel. Take gas as an example. Burning gas in a power plant generates electricity, but also results in a loss of about two thirds of the energy as waste heat. Legislation could be proposed

**Editor's Note: The same basic methodology that the Institute of Social and Economic Research (ISER) is using is being increasingly used by utilities and government agencies in other places across the country because it explicitly identifies and accounts for the uses to which electricity is put.

Summary of Electrical Energy Alternatives Being Considered in the Battelle Alternatives Study

BASE LOAD ALTERNATIVES
- *Coal Steam Electric*
- Refuse-Derived Fuel Steam Electric

CYCLING ALTERNATIVES
- Coal Gasifier-Combined Cycle
- Natural Gas Fuel Cell Stations
- Natural Gas Combined Cycle
- Natural Gas Combustion Turbine
- Natural Gas Fuel Cell Combined Cycle
- Bradley Lake Hydroelectric
- Grant Lake Hydroelectric
- Lake Chakachamna Hydroelectric
- Upper Susitna Hydroelectric
- Allison Hydroelectric
- Browne Hydroelectric
- Keetna Hydroelectric
- Snow Hydroelectric
- Strandline Lake Hydroelectric

FUEL SAVER (INTERMITTENT) ALTERNATIVES
- Large Wind Energy Conversion System
- Cook Inlet Tidal Electric Project

ELECTRIC ENERGY SUBSTITUTES*
- Micro Hydroelectric
- Small Wind Energy Conversion Systems
- Cogeneration-District Heating
- Passive Solar Space Heating
- *Active Solar Hot Water Heating*
- Wood-Fired Space Heating

ELECTRIC ENERGY CONSERVATION
- Building Conservation

INTERCONNECTION OPTIONS
- Anchorage-Fairbanks
- Anchorage-Glennallen

*Electric energy substitutes include all options that are not interconnected with utility distribution systems.

Source: Working Paper 4.2
Preliminary Railbelt Electric Energy Plans
August 1981
Battelle Pacific Northwest Laboratories

that prohibits fossil fuel generated electric heat because it wastes energy. But if gas or oil are not economically available, then there really are very few choices other than electric heat.

Question: Could you elaborate?

Dr. Rohan: I think the Alaska situation is going to be different from that in the Lower 48. The argument, and it probably is a valid argument, is that if one generates hydroelectricity, it can be transported over a network and then can be used to replace other energy forms. This is true providing you have a network and other markets for electricity. In more remote locations, in particular Alaska, you neither have an integrated network nor another market area to receive excess power.

"Legislation could be proposed that prohibits fossil fuel generated electric heat because it wastes energy. But if gas or oil are not economically available, then there really are very few choices other than electric heat."

Question: Some say that Washington State has developed bad habits of energy use and home construction because of the abundance of cheap hydroelectric power. Would you comment on that?

Dr. Rohan: What has happened in Washington which resembles the Susitna situation is that they achieved inexpensive hydroelectricity mainly through inexpensive bond financing. The result on a BTU's heating basis was that most of the homes in the Washington area were electrically heated. On a per customer basis they use about twice the national average, and the reason for this high usage is electric heat. What is happening now is that there are very few locations in the Northwest where dams can now be built. The marginal unit for new power is nuclear or coal, each of which are substantially more costly than the original hydro facility. The addition of more costly power sources results in escalating the rates which gives customers economic incentives to start a switch from electricity to gas, and to insulate.

Question: In your estimation, did Washington State develop bad habits of energy use?

Dr. Rohan: It depends on your definition of bad—the consumers purchased the least costly form of energy available to them—is that bad? From an economic efficiency viewpoint if rates had reflected the real economic values for electricity, the consumers may have made different decisions.

Question: Will you expand on that?

Dr. Rohan: For example, in the past, it wasn't economically attractive to insulate your home, and now it is becoming very attractive to do so. In the Lower 48, companies are installing, as an example, control computers for monitoring lights in buildings and this reduces consumption. These conservation businesses are prospering and creating new jobs. This might be part of the overall strategy—to exploit some of this conservation technology in combination with the Susitna project.

The citizenry of the State of Wisconsin is very pro environment. When we were thinking through the kind of business strategies for the utilities in Wisconsin, conservation coupled with moderated expansion seemed to make good sense, and I think that this policy has worked well for them. Conservation is beneficial to the utilities themselves as it allows them to build power facilities in a slightly more controlled environment.

The utilities have also developed a rate structure that encourages more efficient use of power generating facilities. That strategy recognizes that there are certain times of day and year that it is more costly to generate electricity. Their rates give economic incentives to customers to moderate usage during these peak periods.

Interview 3

Dr. A. Starker Leopold

A. Starker Leopold, a nationally recognized zoologist, has had a number of experiences in Alaska since the 1950's. At that time, he coauthored the book *Wildlife in Alaska,* which discusses some of the general ecologic problems in the State (the decrease in caribou and the increase in moose and the basic causes for both).

Later, Dr. Leopold acted as an advisor on several major project proposals—the Rampart dam proposal in the 60's and the U.S. Forest Service timber sale to Champion International in Southeast Alaska in the 70's.

Son of conservationist Aldo Leopold, who some call the "father of the environmental movement," Dr. Leopold has advised on a number of issues to the Secretary of the Interior and the National Park Service.

Since 1939, he has published over 100 articles and books, including several on Alaska wildlife and conservation issues.

Question: I understand that you have extensive experience in Alaska. One of those experiences was in evaluating the Rampart dam proposal in the 60's. Will you elaborate on that experience?

Leopold: I have written several papers* on that subject, and I can send you those; then at least you will have my viewpoint in print. I would be glad to discuss it with you right now, too. Construction of the Rampart dam would have been a major catastrophe in terms of Alaskan natural resources. The Susitna dam looks like a very good bet to me, whereas the Rampart was a holy terror as far as everything it would have done to the Alaskan environment.

*Editor's Note: Copies of Leopold's papers are available through the Public Participation Office of the Alaska Power Authority.

1. "Electric Power for Alaska, A Problem in Land-Use Planning," A.S. Leopold. *East African Agricultural and Forestry Journal,* June 1968.
2. "Alaska Dam Rampart Would be Resources Disaster," A. Starker Leopold and Justin W. Leonard, *Audubon* magazine, May - June 1966.
3. "Effects of the Proposed Rampart Dam on Wildlife and Fisheries," 1966, by A. Starker Leopold and Justin W. Leonard. Thirty-First North American Wildlife and Natural Resources Conference, March 14, 15, 16, 1966.
4. "Effects of Land Use on Moose and Caribou in Alaska," A. Starker Leopold and F. Fraser Darling, Eighteenth North American Wildlife Conference, March 9, 10, 11, 1953.

Question: Will you elaborate on that last comment?

Leopold: You bet. The Rampart dam, if you remember the geography of that proposal, would have created an enormous lake, bigger than Lake Erie, which would have flooded the Yukon Flats all the way to the Canadian border. That big, flat marshy area on either side of the Yukon River is one of the major production areas for waterfowl in the whole continent. The loss of waterfowl that would have resulted from the inundation of that area would have exceeded all of the habitat that has been restored since 1934 when the duck stamp bill first went into effect. Now that is pretty serious business.

"...The Susitna dam looks like a very good bet to me, whereas the Rampart was a holy terror as far as everything it would have done to the Alaskan environment."

Additionally, there is a salmon run in the Yukon that goes all the way up into Canada past Whitehorse; that is the longest salmon migration in the world. Indians all along the upper river are dependent upon those salmon. To build a high level dam at Rampart would simply have eliminated the whole run. There is no way that you can get salmon up and over dams and get the little ones back down through a lake as big as Lake Erie. They couldn't find their way out. So, the salmon would have been a total loss. Additionally, there are many other types of wildlife that are abundant and important in that flat area, including moose and bear in particular. These obviously would have been eliminated.

Compare this with Susitna. Although the dams are several hundred feet high, the impoundments are very narrow; they do not inundate any wide alluvium or riparian zone that is important for many other types of wildlife. And, most interestingly, there is no salmon run in the upper Susitna River. The salmon are stopped by the Devil Canyon which is simply too steep and too rough for them to make it up. Therefore, there would be no salmon loss there. And the actual area to be flooded by the two dams is very modest indeed compared with the size of the Rampart proposal. There will be some loss, of course, of habitat for moose. There are 3,000 moose in the upper Susitna basin, and part of those clearly would be displaced. There would be some loss of bears, I imagine, and a few lesser species, but there are no waterfowl that nest in that particular area. The area to be inundated would not result in a large scale loss in terms of the total wildlife values in Alaska. In other words, the upstream effect of those two dams on wildlife would be minimal.

I am assuming that if the dams are built that the timber will be stripped out so that they are clean lakes and not cluttered with floating junk. Unharvested timber coming up off permafrost and floating to the top could become a trap for caribou, for example. Caribou swim freely back and forth over big lakes. But, they could easily become tangled up in floating junk or windrowed timber.

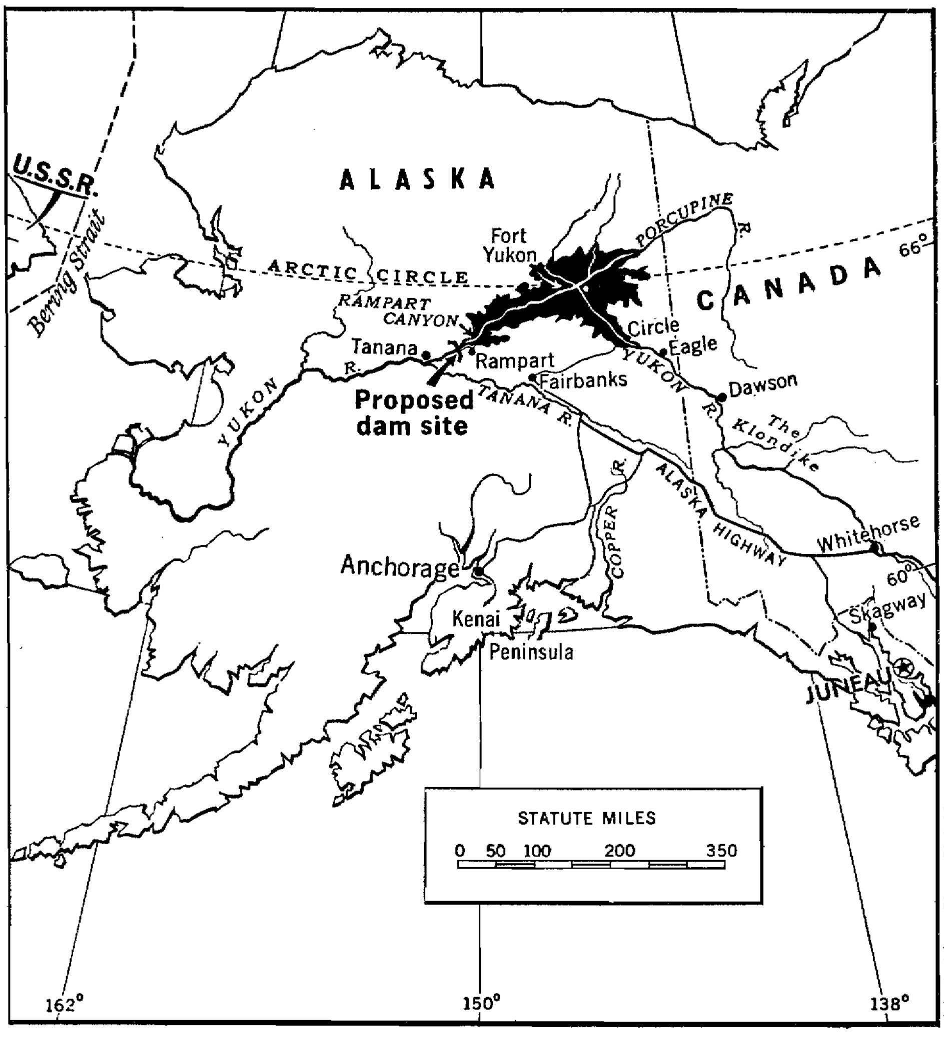
Now we are paying close attention to, and trying to understand better, what might happen downstream from the dams. The other tributaries of the Susitna are very important indeed in salmon production. The run of kings, for example, that people catch in Cook Inlet near Anchorage, come out of this area. We want to make sure that whatever the regime is, the flow of water coming through those dams and down the channel does not adversely affect the survival of the young salmon in that area in the river.

Make sure also that there is enough water downstream to flood the Susitna delta so that it is maintained as waterfowl habitat. It is a very important waterfowl area.

All of these objectives look feasible to me. I can't see any insolvable problems in managing this whole operation with fairly modest adverse effects on wildlife and fisheries.

"Now we are paying close attention to, and trying to understand better, what might happen downstream from the dams."

Question: How did you become a part of the team that came to Alaska to evaluate the Rampart dam proposal?



Adapted from Sierra Club Map

Dr. Leopold reviewed the Rampart Dam proposal for conservation groups in the 1960's and strongly recommended against its construction.

Leopold: I started out by telling you that Frank Fraser Darling and I spent a summer up there about 1951 or '52 travelling all over the territory looking at some of the ecologic problems. On that basis we wrote the book *Wildlife in Alaska.** Although I have not done personal research in Alaska, I have been involved in this general reconnaissance sort of thing. When the Rampart dam proposal came up and looked like it was going to be seriously considered (and of course Senator Gruening was pushing it very hard) an organization of conservation groups in the Lower 48 pooled some money and sent a team of about six or seven of us up to Alaska to look more critically at the Yukon and the Yukon Flats which would be inundated by the Rampart dam and to report on what would be the effect of this dam. If it was indeed bad, which it proved to be, then we would give them some factual ammunition to use in fighting it in Congress. The Wildlife Management Institute, the Wildlife Society, the Sierra Club, the Wilderness Society, and several others were involved. The leader of this group was the Dean of Forestry at the University of Michigan. His name was Stephen Spurr. Steve did some very clever politicking, I thought. Instead of quietly gathering information about what a horror this dam would be, he went straight to Senator Gruening and told him what we were finding out, what sorts of information we were going to put into our report, and that the total effect was going to make Rampart look pretty bad. Gruening, who like any sensible politician didn't want to put something up to a vote and have it voted down, could begin to see that this proposal was liable to be defeated in Congress and, therefore, he quietly withdrew his support for the Rampart dam and got interested in something else.

Atlantic Richfield Company

"I am assuming that if the dams are built that the timber will be stripped out so that the lakes are clean and not cluttered with floating junk. Unharvested timber coming up off permafrost and floating to the top could become a trap for caribou. Caribou swim freely back and forth over big lakes. But they could easily become tangled up in floating or windrowed timber."

- S. Leopold

Question: What conclusions were in your report on the Rampart dam proposal?

Leopold: One of the things that we had to say in reporting adversely on Rampart was that the State of Alaska needs power. But they don't need the fantastic amount that would have been created by the Rampart dam way the hell up there in the wilderness and a very difficult job of getting it down to where it was needed. There were many sites closer to the centers of need—meaning Fairbanks, Anchorage, and Juneau—in which smaller hydro developments could and should be developed, and one of them that was named Susitna. Hence, when the Rampart was abandoned, then the attention, very properly I think, came back to a much more sensible program, namely the Susitna hydro.

Question: Were there alternative hydro sites that your group recommended be looked at?

Leopold: Yes, there was one at the head of the Yukon River in Canada. As I remember, it would have diverted the upper reaches of the Yukon River (this would be just the tributaries way up far above Whitehorse) into the Taiya River and from there run through a 25-mile underground power tunnel to generate power at tidewater at Skagway.

Question: Besides Susitna, did you name any other hydro sites in the vicinity of the railbelt by Anchorage and Fairbanks?

Leopold: No, I don't think so. We talked about coal, of course. It was known that there were some big coal deposits, but it was such a fantastic opportunity for hydro it seemed a much better bet to go for a hydro project such as the Susitna. If there were others that we named, I don't remember and that was several years ago.

Question: What knotty problems have you encountered on hydroelectric projects?

Leopold: I have already mentioned the one that concerns me here. I want to be sure about what happens downstream. You see, once you build a dam, you can then release water in different amounts. You can also release water at different temperatures, depending on

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**Wildlife in Alaska* discusses some of the general ecologic problems in Alaska: the decrease in caribou and the increasing numbers of moose and the basic causes for it. The book was originally published by Ronald Press in 1963 and was recently republished.

whether you draw from the bottom of the lake or the top.

You can sit and look at the Susitna all you want, but it is not going to tell you how those little salmon will fare when the river is running deeper in the wintertime, for example. You are clearly going to be holding water in the summer and letting it out in the winter. These are things in which you have to use your best judgment, and to this extent, I am urging that we take advantage of all of the experiences that have been had in the damming of glacial streams in Scandinavia and the USSR and in Canada. I've looked at some of the similar dams in Argentina, but they are not quite the same. I am sure there must be some in Canada, and I know there are others in Russia that are not unlike the situation here.

Hopefully, there are ways of getting at this information and to find out what they have learned. What happens downstream when you dam a glacial stream and hold the water through the summer and feed it out in the winter when the normal flows are low? Somebody must have some good information on that. I am hoping we will get as much as we can to prognosticate what the effects of this dam may be.

Question: Would you elaborate on some of your experiences in Alaska?

Leopold: Yes, going way back to the beginning, that very first trip in the early 1950's was occasioned by the fact that caribou were known to be decreasing rapidly. The Fish and Widlife Service (this was before Alaska was a state, of course) was in charge of the wildlife program. They considered that one of the major causes of the decrease in caribou was excessive numbers of wolves. So they had a very large-scale wolf control program: some poisoning and some shooting from airplanes. This was going on in the Brooks Range and generally throughout Alaska. They were killing several hundred wolves a year.

Some of us wondered whether this was indeed the basic cause for the decrease in caribou. Obviously, wolves eat caribou, but there have been wolves eating caribou there for a million years. What we were really looking for was any possible changes in the nature of the countryside, the habitat in which the caribou lived. We found one that was certainly important, namely that since the coming of the white man, really since the Klondike gold rush, there had been an enormous increase in the number of forest fires, accidental and deliberate, that had burned the sparse spruce forest and the understory of lichens which constitute one main winter forage of caribou.

"You can sit and look at the Susitna all you want, but it is not going to tell you how those little salmon will fare when the river is running deeper in the wintertime..."

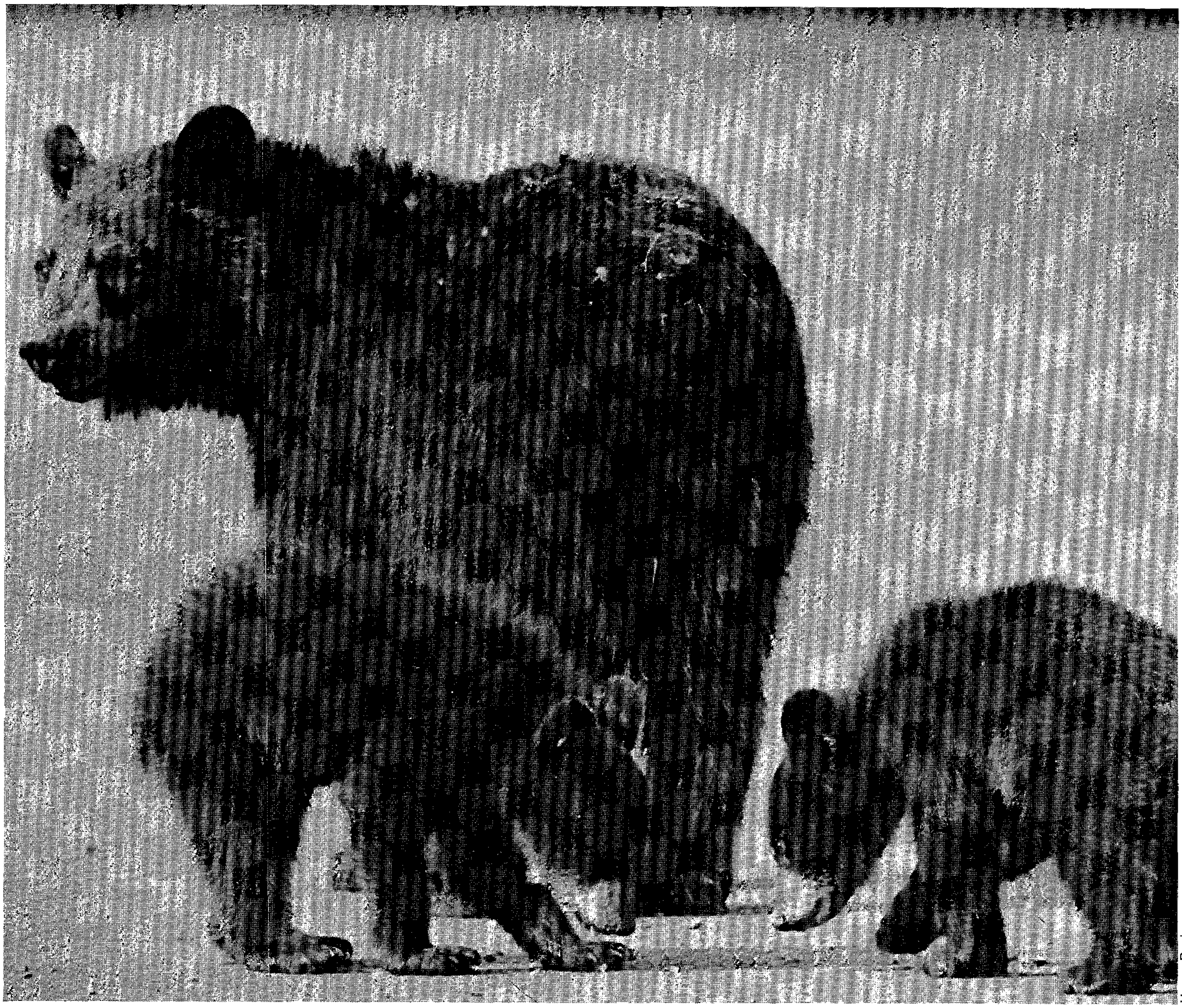
A man from Yale Forestry School by the name of Lutz had made a careful survey of fire history in Alaska. He estimated even at that time that somewhere around 85% of the white spruce forest in Alaska had burned in the previous half century and that these fires pretty much destroyed the value of these woodlands for caribou winter range but conversely made excellent moose range by stimulating willows, aspen, and birch. Those are the principal winter foods of the moose.

This seemed to have some relevance in the sharp decrease in caribou and the concurrent increase in moose in Alaska. I think there were other factors: hunting by Native people, and the sudden availability of high-powered rifles. All of these things were involved, but those basic changes in the habitat of the large part of Alaska I still think was important. Nowadays, with somewhat better fire control, the caribou are holding their own, but they have never increased back into the millions that occurred originally. That was the main thrust of our initial survey up there in the 1950's.

C.D. Evans

"There will be some loss of habitat for moose. There are over 3,000 moose in the upper Susitna basin, and part of those clearly would be displaced."

- S. Leopold


Henry Peck

Question: What more recent experiences do you have in the State?

Leopold: A more recent program involved an appraisal of a timber sale on the Tongass forest south of Juneau, including Admiralty Island and some of the adjoining mainland. The timber sale had been made by the Forest Service to U.S. Plywood, which subsequently became Champion International. The sale provided for 8.6 billion board feet of lumber and specified that a mill would be built south of Juneau to process this lumber. Some of it would be sent to Japan.

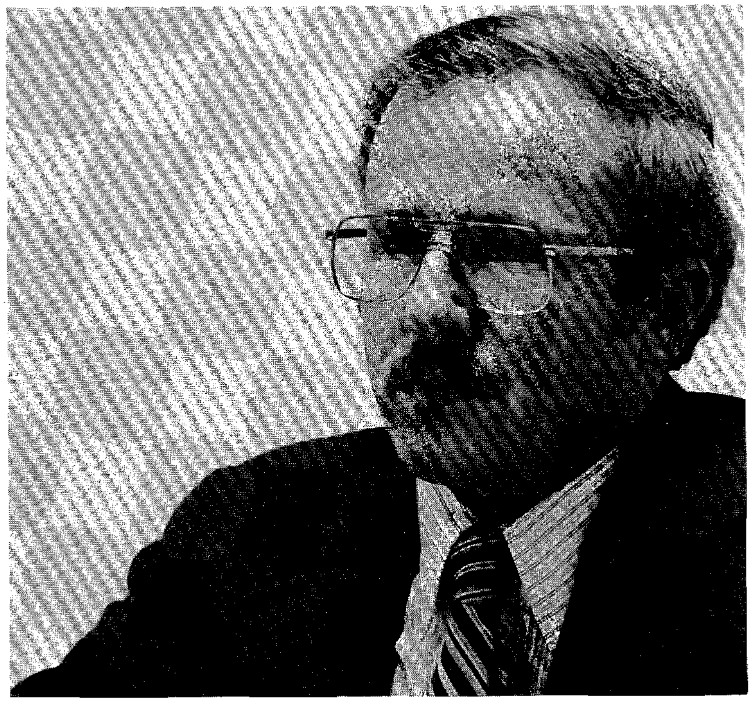
The lumber company set up a small committee of consultants, of which I was one, to advise them on how to operate this timber harvest with the minimum adverse effect on the environment. We all went up there with enthusiasm and optimism, and we were eager to work with the company in developing a good plan to save as much as we could of the bear, deer, salmon, and other wildlife values.

One of my recent PhD's, by the name of Reginald Barrett, went up to Juneau and worked for a whole year in this sale area. We began to realize that the removal of 8 billion board feet of timber would practically take every stick in that whole area, and there would be no shelter left for wildlife of any kind. Certainly the deer population would collapse, and many of the people, local people including some of the Indian tribes like residents of Angoon, depend upon those deer for part of their winter food. The bear population and many other animals would be adversely affected.

In other words, we had to tell the president of Champion International, that in our opinion the Forest Service had over sold that timber, in no way should 8 billion board feet be removed from that area, and we simply could not advise him on how it could be done without adversely affecting wildlife. As you may remember, there was a lot of litigation between the Sierra Club and the Forest Service and the company. This led to reconsideration by the courts of the whole problem and finally the whole project was dropped.

Question: Are there any other projects that you know about that closely resemble the situation on the Susitna?

Leopold: No, I can't really say that I have ever been on one just like this one. We've done quite a bit of work on impoundments here in California in the Sierra Nevada, effects on trout, effects on deer, and so on, but they are quite different really.



Interview 4

Dr. Andrew H. Merritt

Dr. Andrew H. Merritt, a specialist in engineering geology and applied rock mechanics, has worked on geotechnical investigations, design, and construction of hydroelectric projects throughout the world. He has also been involved with tunneling projects for water conveyance and sewerage disposal systems and the development of underground excavations for petroleum storage.

On projects like Susitna, Dr. Merritt has worked as a consultant for engineering companies, contractors, owners, and lending agencies such as the World Bank and the Inter American Development Bank.

Question: What experience do you have in Alaska?
Merritt: Most of my work is in hydro, tunnels, and underground chambers. Since completed engineering projects of this nature are in short supply in Alaska, I have not had the opportunity to work in this area. My experience in northern climates consists of 3 years in Labrador, Canada, during the development of the Churchill Falls Hydroelectric project and more recently as a consultant to B.C. Hydro and B.C. Railroad in British Columbia.

Question: In your particular field, what are the other projects that you've worked on that have similar kinds of problems and issues to Susitna?
Merritt: We have not defined all the possible problems at Susitna yet because the investigation program is still in progress. That is the purpose of the ongoing feasibility studies. If you have read the External Review Panel's report, we highlighted some of the major areas that were of interest to us at this particular time. From my point of view, in the geotechnical field, I am primarily concerned about the general quality of the rock in the underground excavations at the Watana site and also possible seepage away from the reservoir through the buried preglacial valley on the right abutment.

I did not see anything of an unfavorable nature at the downstream site at Devil Canyon.The geologic conditions looked pretty straight forward at this particular stage in the investigation.

We have to realize that all the material available to date (February 1981) is of a prefeasibility level of study and as such is not complete. Our role is to ensure that the studies being done at present will provide answers to the major geotechnical, engineering, and environmental aspects of the project.

"...most of the challenges that we recognize at present have been successfully engineered on other projects."

Question: What other projects do you know about that have similar problems and issues?

Merritt: It is hard to compare Susitna with any other job elsewhere because no two projects are exactly the same. Susitna has aspects very similar to other projects that I have worked on. For example, the underground powerhouse at Susitna is neither larger nor deeper than many others. As a matter of fact, it is fairly typical of eight or ten other underground chambers that I have worked on.

We won't know how typical or unique the conditions are at Susitna until the exploration program has been completed in 1981.

With respect to the dam at Watana, it is on the order of 250 meters (800 feet) high, which is a major structure. But it is not without precedent. I have worked on both concrete arch and fill-type dams that are nearly as high.

Considering the seismic activity prevalent in Alaska, this aspect of the design will receive the detailed attention that it deserves. I have one job in Honduras where the Power Authority is building an arch dam 220 meters (715 feet) high. It was considered to be in a fairly high seismic area; however, analyses are available to design a safe dam under such conditions.

There is a project presently under construction in Guatemala which contains a rock fill dam about 130 meters (423 feet) high. The earthquake conditions in Guatemala are much more severe than are believed to exist at Susitna. This dam was also carefully analyzed for seismic effects and the engineers, owners, and international lending agencies are satisfied that the structure is completely safe.

In summary, at this particular time I don't see anything unique about the Susitna project. There is no doubt that it contains many challenging and interesting aspects, but most of the challenges that we recognize at pre-

Shown here is the construction of the underground powerplant at Oroville Dam in California.

Underground powerhouses are proposed at both Watana and Devil Canyon. The cost analysis of underground vs. surface powerhouses showed that underground was more economical because shorter tunnels can be used and because there is no need for the extra cost of structures at ground level.

sent have been successfully engineered on other projects.

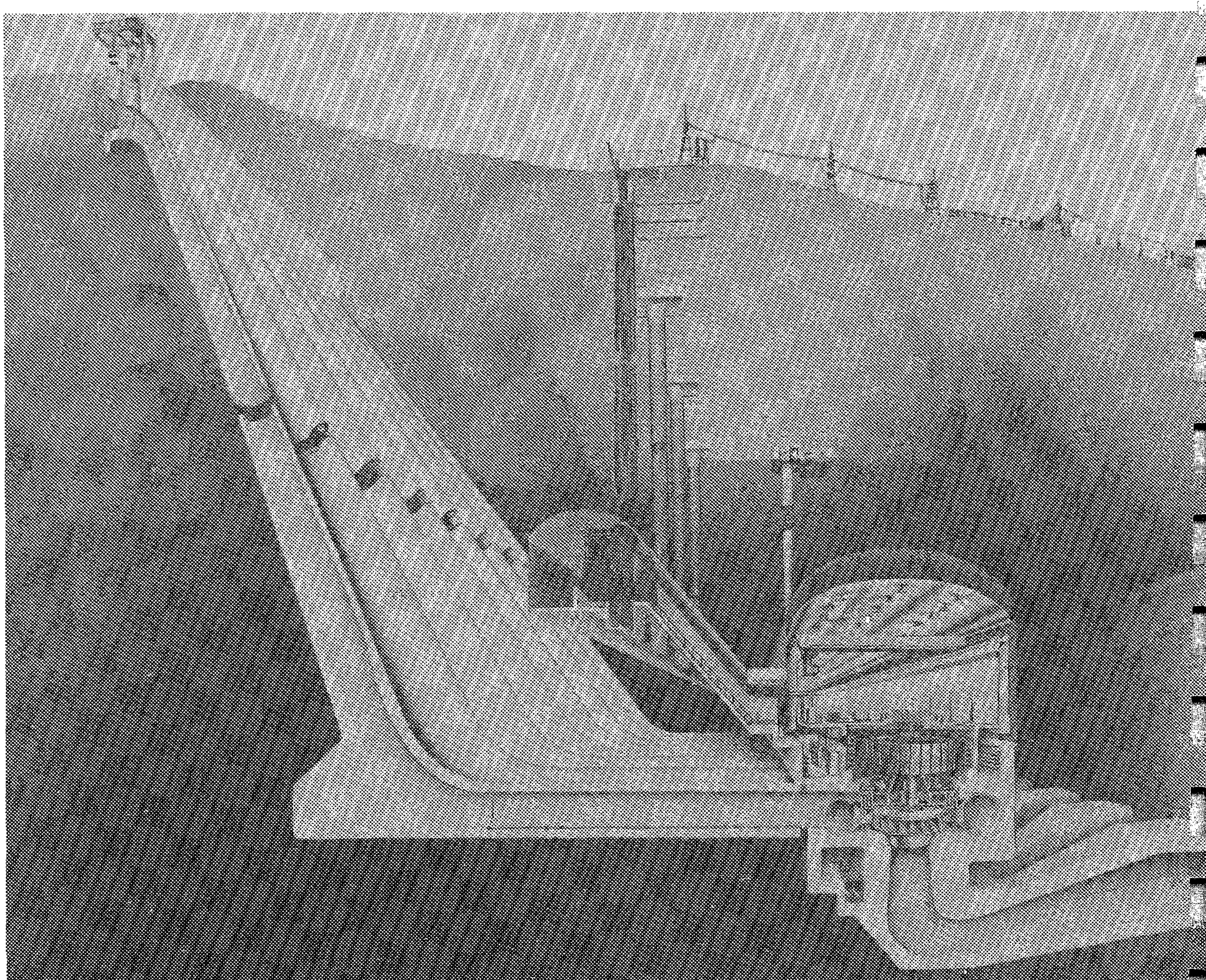
Question: What kinds of knotty problems have you encountered on hydroelectric projects?

Merritt: Some of the major problems that have occurred with dams or reservoirs happen with those structures located in very pervious rock foundations, such as karstic or cavernous limestones. These pervious rocks do not exist at Susitna. Other problems have occurred in reservoirs or abutments with slope stability problems. The topography at Susitna appears to preclude any slope stability problems.

Other knotty problems include the evaluation of the seismicity of a site. As you may be aware, there has been a great deal of attention given to seismicity over the last 5 to 10 years for the design of dams. Many of the projects being built or in the design stage in Central and South America are located in active seismic areas. As I said earlier, the jobs that I am working on in Honduras, Guatamala, and in Columbia are in seismically active areas and the designers are all using the most modern equipment to measure the potential earthquake hazards and the most up-to-date analytical design tools to ensure a safe structure. All similar methods and techniques will be used at Susitna.

A third kotty problem might include the inevitable unknowns associated with underground excavations such as chambers for powerhouses and long tunnels. The exploration program as planned for Susitna will go a long way in determining the unknowns and reducing such contingency items. The borings and geologic mapping should define the geologic conditions in the proposed underground chambers with a high degree of confidence. I am working on three underground powerhouses at present. Two are proceeding smoothly. The third one is having serious problems of a geologic nature. It is interesting to note that this last one had very little preconstruction exploration because of a lack of funds. Fortunately, that doesn't happen very often and it is not the case with Susitna.

"Our role is to ensure that the studies being done at present will provide answers to the major geotechnical, engineering, and environmental aspects of the project."



Another interesting aspect at Watana, as I mentioned before, is the old river valley on the right abutment. The river at one time in the geologic past swung away from the present valley just upstream of the Watana site and cut across the plateau on the right side and exited just downstream in Tsusena Creek. The former course of the river deeply eroded the bedrock. This channel was then backfilled with what I assume to be glacial deposits and alluvium. The bottom of this rock valley lies below maximum pool level of the proposed reservoir. We have to be sure that the water doesn't enter this old valley and make an end run around the dam. This interesting aspect is going to be given a large amount of study in the feasibility phase. It is a problem that I have run across in projects in Ecuador, Argentina, and Canada where we have similar geological terrain.

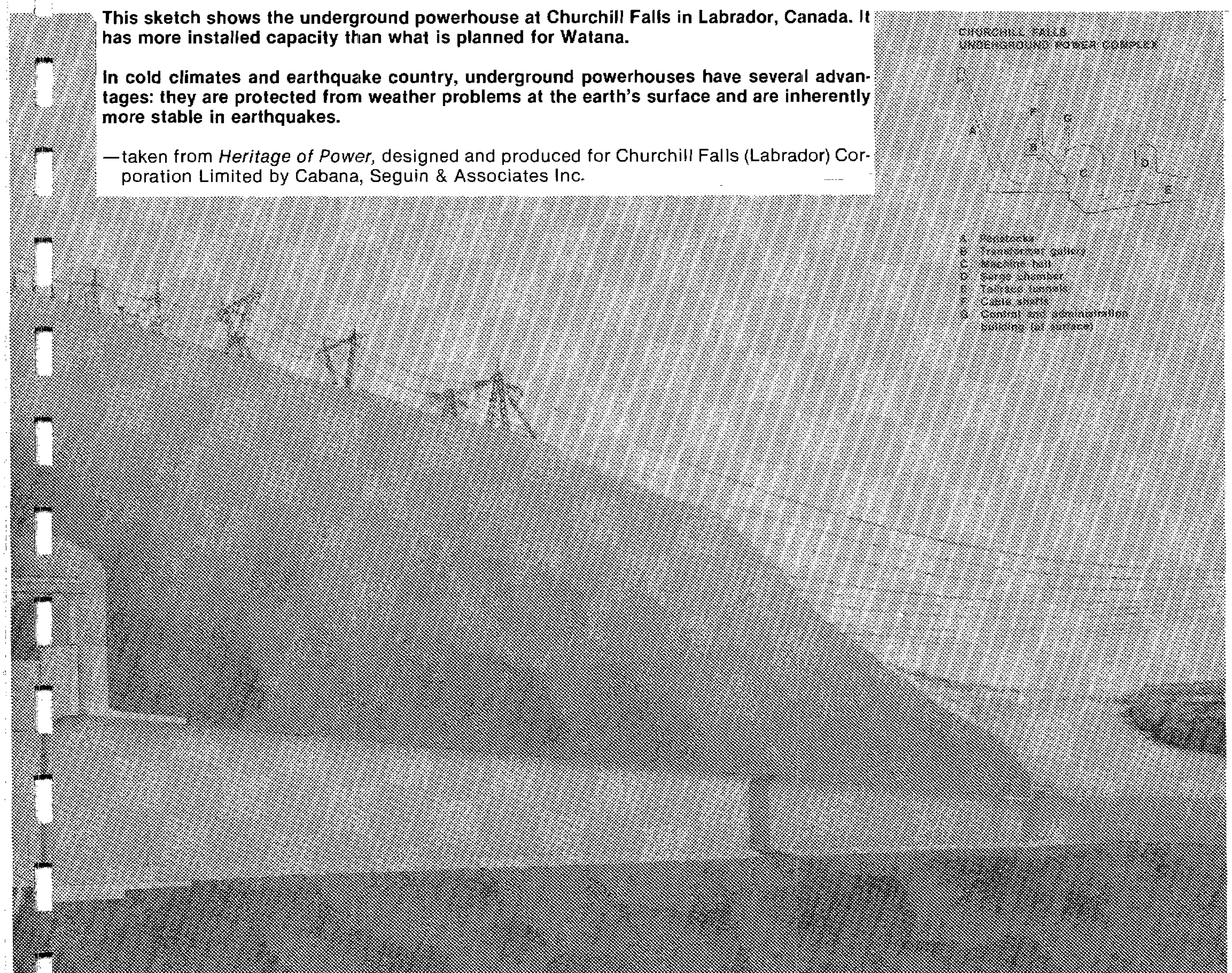
On another matter, I do not expect to have any particular problems with barrow material for the Watana dam, even though the volumes are quite large. I think that the glacial deposits and bedrock will provide completely acceptable materials for construction.

Question: What involvement will you have in evaluating seismicity for the proposed dams?

Merritt: The aspect of seismicity that I would generally get involved in is the assessment of possible faults and how large the design earthquake could be.

I will add that the Alaska Power Authority is expending a great deal of effort to resolve the seismic question. The techniques include measuring micro earthquakes, performing detailed geologic mapping, and evaluating the historical earthquake record. As I see it, you are using techniques and methods accepted throughout the world in the profession.

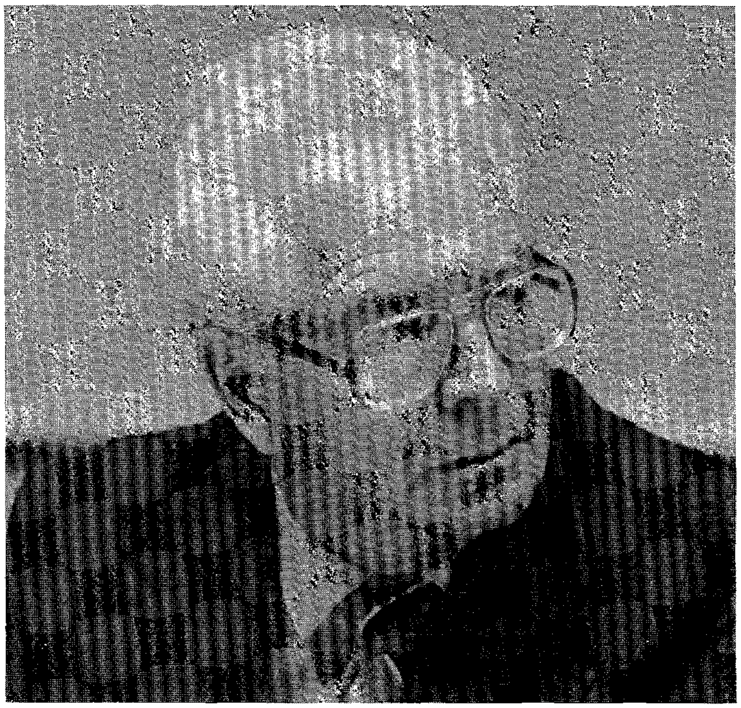
> **"It is hard to compare Susitna with any other job elsewhere because no two projects are exactly the same. Susitna has aspects very similar to other projects that I have worked on. For example, the underground powerhouse at Susitna is neither larger nor deeper than many others. As a matter of fact, it is fairly typical of eight or ten other underground chambers that I have worked on."**



This sketch shows the underground powerhouse at Churchill Falls in Labrador, Canada. It has more installed capacity than what is planned for Watana.

In cold climates and earthquake country, underground powerhouses have several advantages: they are protected from weather problems at the earth's surface and are inherently more stable in earthquakes.

—taken from *Heritage of Power,* designed and produced for Churchill Falls (Labrador) Corporation Limited by Cabana, Seguin & Associates Inc.



Interview 5

Merlin D. Copen

Mr. Copen has over 40 years of experience as a civil engineer with the design and analysis of about 70 concrete dams and other concrete structures. For 33 years he was with the U.S. Bureau of Reclamation, becoming Head of the Concrete Dam Section in 1968.

While with the Bureau, Copen had major resposibility for numerous large dam projects, including the Auburn dam in California, one of the longest arch dams in the world. The Auburn dam is upriver of Sacramento. It is a large concrete structure in a highly seismic area. Controversy surrounded its design.

Mr. Copen was also responsible for evaluating the behavior and safety of all concrete dams constructed by the Bureau. He had assignments on concrete arch and gravity dam problems in India, Thailand, Laos and Korea.

Currently, Mr. Copen is a private consultant on various projects around the world. He is also a consultant on two other Alaskan projects: Green Lake in Sitka and Swan Lake in Ketchikan.

Question: What experience do you have in Alaska?

Copen: Presently, I am on the board of consultants for Green Lake dam near Sitka and for Swan Lake dam near Ketchikan. During my work in the Bureau of Reclamation, I had experience in the design phase of essentially all of the projects that you are now considering in Alaska, including Susitna.

Question: What projects have you worked on that resemble Susitna? That means, in your case, from the point of view of a civil engineer.

Copen: I have worked for the Bureau of Reclamation for more than 33 years, during which I was responsible for the design of Glen Canyon dam, which is over 700 feet high; Yellowtail dam, which is more than 500 feet high; Flaming Gorge dam, which is more than 500 feet high; Morrow Point dam, about 470 feet high; and many other smaller dams. These cover the range of complexities regarding foundation, size, and local conditions such as cold and warm temperatures. They also represent quite a range of designs and sizes.

Question: Other review panel members referred to dam structures in Russia but did not know the names, locations, or other details. Do you know anything about hydro projects in Russia?

Copen: Yes, from a recent short article in the *Denver Post.* One of these structures, I think it is Nurek, is a completed arch dam 984 feet high. The other structure, which is under construction, is an embankment-type dam, which will be almost 1,100 feet high, (1,099 as I remember the figure). These are the largest dams in the world. Grande Dixence, a Swiss dam, completed in 1960 or '61, is slighty smaller — 938 feet, I believe. It is a concrete gravity dam.

Question: When you said that the Russian dam was an embankment dam, is that the same as an earth-filled dam?

Copen: An embankment structure can be earth or rock filled, and I'm not sure which this is.

Question: Were you involved in the review of any of those dams?

Copen: No. I was in the Bureau of Reclamation when we received news reports from Russia, which were translated and made available to me, and I have watched the progress of the dams, but I was not involved in reviewing them.

"So far as earthquakes are concerned, we had probably a more difficult problem at Auburn than you have on Susitna."

Question: What kinds of knotty problems have you encountered on hydroelectric projects?

Copen: The Auburn dam was designed under my supervision completely. I left the Bureau of Reclamation just before the contract was awarded for the foundation treatment, so I worked only on the design. The river diversion was also completed before I left the Bureau.

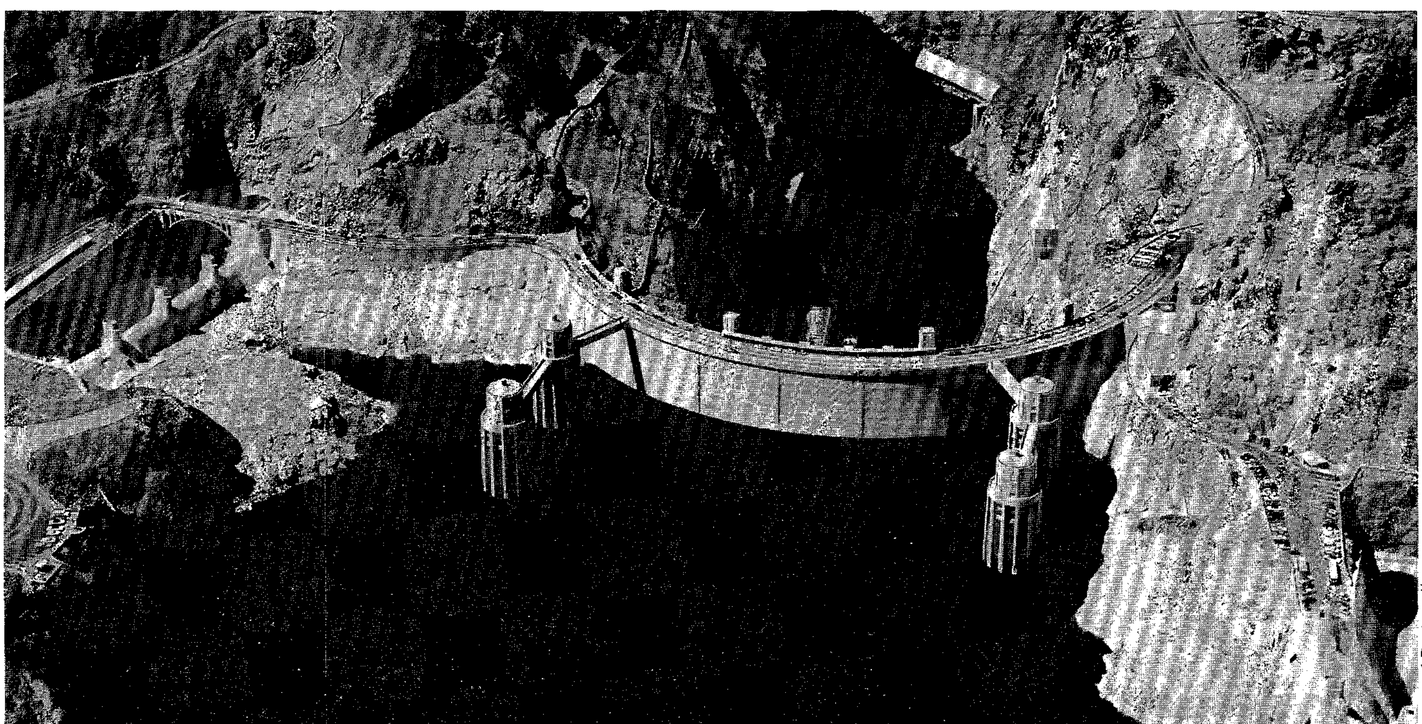
The problems with the Auburn dam were largely with seismicity, and we will have a similar problem on Susitna with seismicity. At the present time, it has been recommended by Woodward-Clyde that provision be made for ground accelerations of 40% of gravity, which can easily be handled in the concrete dam. Now, the thing that caused the most trouble at Auburn was the problem of displacement. Displacement in the foundation of Susitna could occur if an active fault were found under one of the dams. This particular problem is being investigated at the Watana site.

Another problem that will be experienced will be the problem of temperature. The very low temperatures are something that have to be considered and included in the design. We have the capability of doing that. Low temperatures result in concrete shrinkage and thus downstream movement. These movements are controlled by properly shaping the arch dam.

The third and sometimes the most important problem is the foundation. We have to know the anomalies in the foundation, such as joint foliation, bedding planes, seams, or anything that might cause a problem of instability in the foundation resulting from the pressures that would be applied to the foundation by the dam.

So again, the major problems are earthquakes, low temperatures, and foundation abnormalities. All of these can be handled with proper design and construction procedures.

The contracts for foundation treatment and river diversion were completed. Because of the intense controversy which developed regarding earthquake magnitudes and displacements, the dam has not yet been constructed. I do not believe a schedule for construction has been established.



Bureau of Reclamation

Hoover is a thin arch concrete dam—like what Devil Canyon is proposed to be.

Question: How do those three problems on Susitna compare to the range of problems you have encountered in your 33 years of experience with the Bureau of Reclamation?

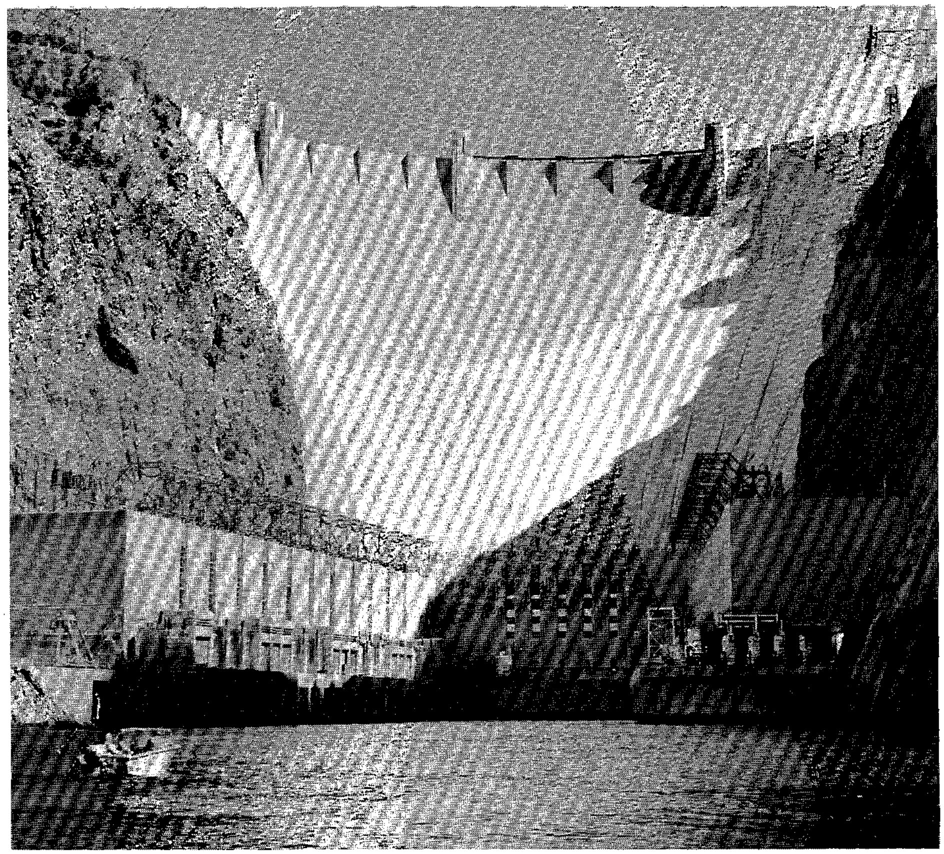
Copen: I have encountered all of them. I haven't worked specifically with temperatures as low as we are experiencing here. However, in the western part of the United States, we do have extreme temperatures which go down to 40, 50, and 60 degrees below zero and will go as high as 100 degrees above zero Fahrenheit. The range that you are concerned with at Susitna is in the lower part of this temperature spread and doesn't include the higher part. I would say, so far as temperatures are concerned, that I've had experience with a much wider range than will be involved on the Susitna project.

"So again, the major problems are earthquakes, low temperatures, and foundation abnormalities. All of these can be handled with proper design and construction procedures."

So far as earthquakes are concerned, we had probably a more difficult problem at Auburn than you have on Susitna. I am presently involved (and have been for about six years) with construction of a dam in Taiwan. It is a smaller dam and has many problems with its foundation and with earthquakes. We have successfully designed this structure, and construction is proceeding. It is only about 400 feet high but has very difficult foundation and earthquake problems. The foundation problems cover all those that I have already mentioned—the possibility of instability in the foundation and rather wide seams in the foundation that have to be treated in order for there to be stability of the dam.

At the time I left the Bureau, we knew of 27 faults or shear zones in the foundation of Auburn Dam. I understand three more were found bringing the total to around 30, all of which were accounted for in the analyses and were treated to make the dam safe.

Comparison of Proposed Devil Canyon Dam and Hoover Dam



Bureau of Reclamation

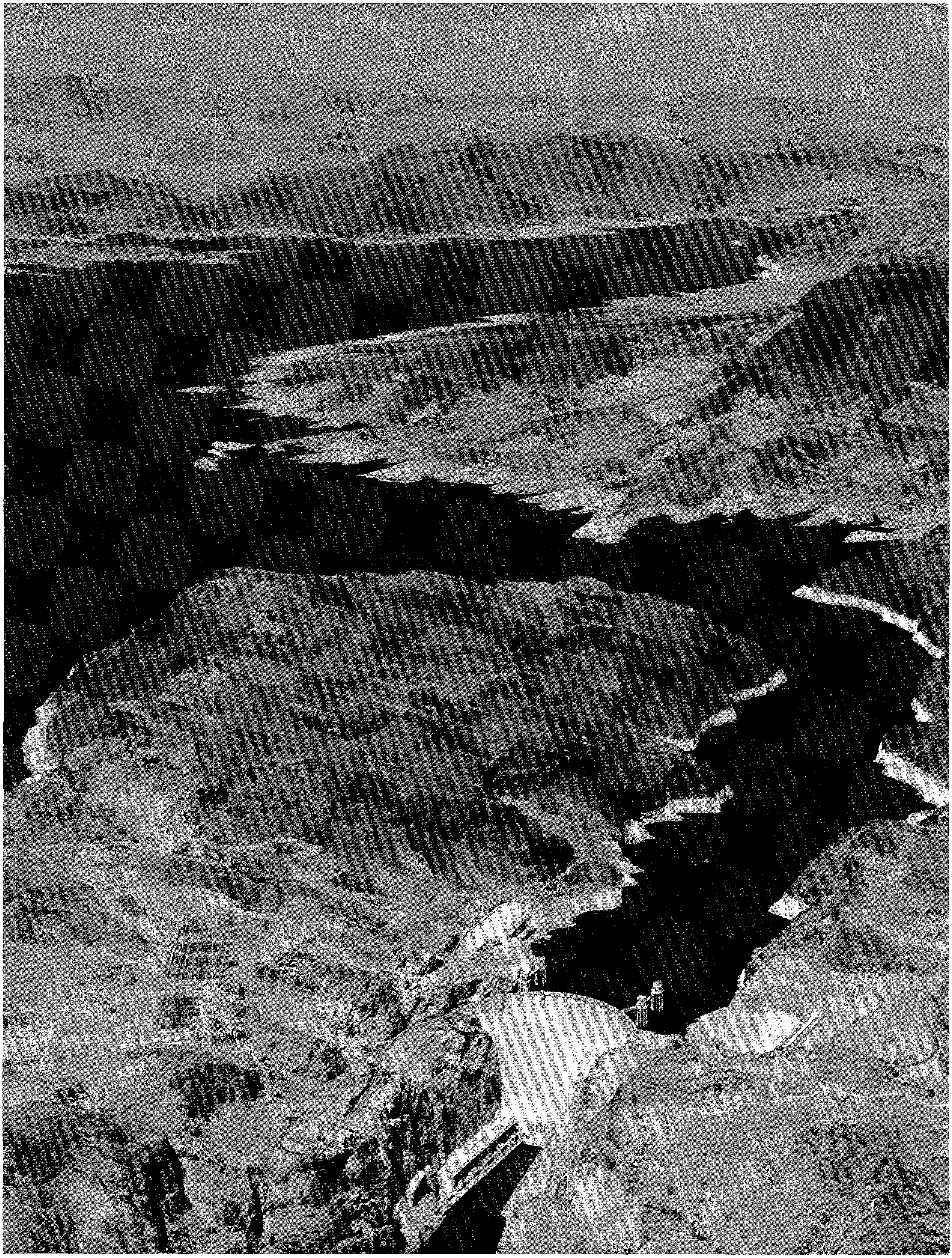
Hoover Dam is about 100 feet higher than Devil Canyon is proposed to be. Both dams, however, would be almost exactly the same width at the top crest. A surface powerhouse is shown below Hoover Dam on the left. Underground powerhouses are proposed for the Susitna dams.

The shape of the reservoirs formed by Hoover Dam and the proposed Devil Canyon Dam would be quite different.

Shown here is an aerial view of Hoover Dam and Lake Mead. Notice that the reservoir is initially very narrow, then takes a turn to the left and opens up into a broad expanse of lake.

By comparison, the Devil Canyon reservoir would remain narrow (about ½ mile wide) for its entire length of 28 miles.

The total reservoir capacity of Devil Canyon would be about 1/30 that of Lake Mead.



Water & Power Resources Service

Interview 6

Jacob H. Douma

Jacob H. Douma, an internationally recognized hydraulics expert, served with the U.S. Army Corps of Engineers for more than 40 years. He was Chief of the Hydraulic Design Branch in Washington, D.C. and was responsible for the final review and approval of all hydraulic design and research programs. For the past 30 years, he has been consulted on dam projects in India, Pakistan, Iran, Haiti, Venezuela, Argentina, Canada, and elsewhere.

Question: What is your Alaskan experience?

Douma: I haven't worked on any project to the extent that I will be working on Susitna. I worked for the Corps of Engineers and the Bureau of Reclamation for almost 44 years, being in the office of the Chief of Engineers in Washington, D.C., for 32 of those years. I had the opportunity to review projects being planned and designed in Alaska by the Corps' Alaska district.

One project in particular, having to do with a hydroelectric plant, was the Rampart Dam which only reached the survey report stage and was not authorized for design and construction. I never saw the Rampart site, nor did I sit in on any planning and design meetings. I reviewed reports on the project that came into the Chief's Office and I attended the Board of River and Harbor's review of those reports in Washington.

There is another project in the same category, the Snettisham dam, near Juneau. The Corps of Engineers constructed a tunnel from a lake to a powerhouse. That project had a very unique problem. A tunnel was driven to tap the lake well below the water level in the lake. I recall that there was a lot of debate among tunnel engineers on how the construction should be accomplished. Finally, a method which was developed and used previously in Sweden was adopted and proved to be successful.

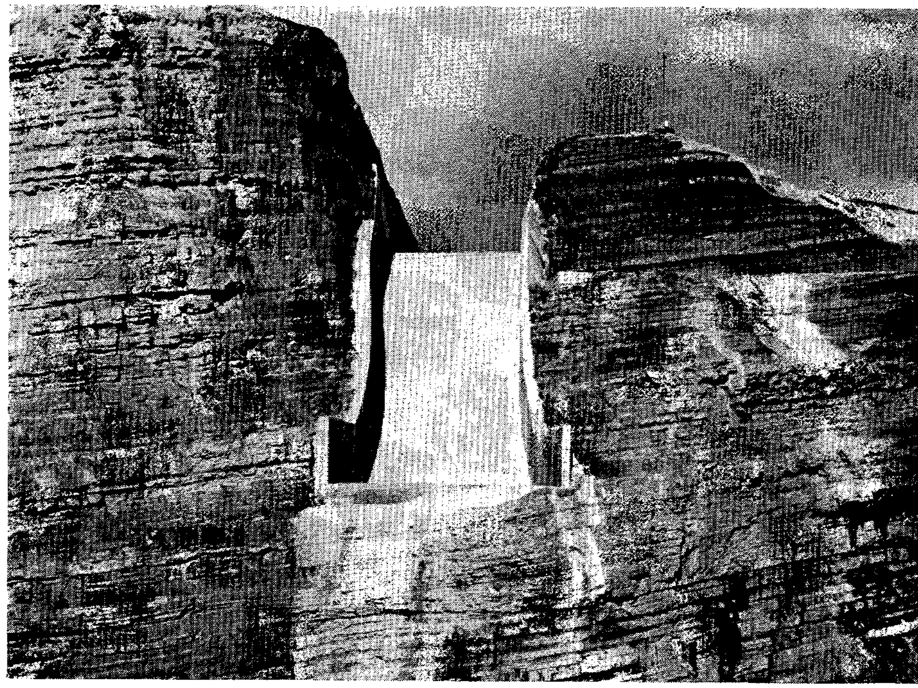
Another project with which I was involved in Alaska was a dam near Juneau on Gold Creek which was experiencing severe erosion of the outlet conduit invert. Recommendations were made on how to protect the invert against erosion. That is the extent of my participation in Alaskan projects.

Question: What other projects are you familiar with that resemble the Susitna project?

Douma: I think the projects that come the nearest to Susitna are the Mica and Revelstoke dams on the Columbia River in Canada. Mica Dam is not quite as high as Watana, but it is a rock and earthfill dam, as Watana is proposed to be. Revelstoke is about twenty miles or so downstream from Mica. It is an earthfill and rockfill dam, presently under construction. When completed (1983) it will be about 600 feet high, which is not too different from Devil Canyon.

Both of these projects are primarily for hydroelectric power, as are the two dams on the Susitna.

I suspect the hydraulic problems will be quite similar except for one major difference. Mica Dam has a low-level outlet that operates under very high head, consisting of two sets of gates located in a large diversion tunnel. The upstream set of gates discharges into what is known as an expansion chamber which dissipates about 250 feet of head. Downstream from this expansion chamber, another set of gates discharges into the downstream part of the tunnel. I don't think there will be anything like that at Susitna because, as I understand it, most of the water will discharge through the power plants and spillways.



The Engineering Journal, October 1969

A flip bucket spillway is much like a giant playground slide with the end curved upward. This dissipates the energy by dropping the water into a deep pool well clear of the end of the spillway.

"Fish live on air absorbed in water, but when there is an excess of nitrogen many do not survive. On the Columbia River, several ways were found to partially alleviate the problem. Unless precautions are taken in spillway design, this same problem may occur on the Susitna River after the dams are constructed."

Question: Did you work on the engineering for the Mica and the Revelstoke dams?

Douma: I worked on the engineering for Mica dam only. I was a special hydraulic consultant to CASECO, a consortium of three Canadian firms that did the design in Vancouver, B.C. I was involved for five or six years on the initial design, model testing, and construction.

Question: Was your role on that project similar to your role with the Susitna project?

Douma: Yes, I was involved with the hydraulic design and hydrologic aspects. CASECO was working for B.C. Hydro in the same capacity as Acres now works for the Alaska Power Authority on Susitna. I was a consultant to CASECO, the engineers who designed the project, not a consultant to the owner, B.C. Hydro. On the Alaska project, I am a consultant to the owner, the Alaska Power Authority, not the designer.

Question: So your function is the same, only the client is different?

Douma: Yes, that's right. My function is the same, which is to be involved primarily in the hydraulic design of the structures and the hydrologic aspects of the project.

Question: Have you had any experience with the kinds of conditions that you find in northern climates like Alaska? (Permafrost areas, glacial rivers)

Douma: As I recall, my only involvement with the design of projects that have had cold climates has been in Canada. The Mactaquac project in New Brunswick is one, and I am still on consulting boards for several dams on the Saskatchewan River in Saskatchewan Province. These projects are concerned with ice problems. I don't know whether ice problems on the Susitna will be more difficult than those on the Canadian Rivers. I assume they will be quite the same.

Question: What knotty problems have you encountered on hydroelectric projects?

Douma: I have jotted down four different knotty problem areas.

First, referring to Mica Dam, one of the major and most difficult problems was the question of reservoir slides. There are some active slides in the steep mountain slopes just upstream from the dam site and one question was whether filling the reservoir would cause large slides to come down into the reservoir.

An hydraulic model was constructed that could test what would happen if huge slides should occur. This model was built at the Western Canadian Hydraulic Laboratory in Vancouver. The model indicated that under the worst slide assumptions a large wave would be generated in the reservoir which would overtop the dam by 25 feet. We were very much concerned whether the top of the dam would erode so rapidly that it would cause the dam to fail and the reservoir to empty. Design precautions were taken by providing toe fills to control the slides and increasing the dam slopes in the upper part of the dam, both on the downstream and upstream sides. The crest width of the dam was increased to 110 feet instead of 50 feet so there would be less likelihood of dam failure in the event it should be overtopped by waves. Fortunately, after ten years the reservoir has been filled a number of times and there is no indication of any slides.

I don't think there will be a similar problem at Susitna because there does not seem to be any large, active slide zones in the reservoir areas similar to those on the Columbia River. That is one knotty problem which occurs on some hydroelectric projects.

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Another difficult problem is the design of cavitation-free, low-level outlets and spillways. I have already described the type of low-level outlet at Mica Dam which operates very well but there are a number of dams where difficult cavitation erosion problems have occurred. As low-level outlets at the Susitna dams will not operate frequently, cavitation erosion in them should not be a problem.

However, there will be spillway channels at Susitna in which water will flow at very high velocities as it drops from high reservoir levels to the downstream river bed. There will be serious problems with erosion of the concrete due to cavitation, if design and construction isn't handled correctly. This cavitation erosion of concrete is caused by high-velocity flow passing over a rough concrete surface which, in turn, causes pressures at localized areas to drop down to whât is called vapor pressure which produces cavitation erosion. That will be a problem of concern in designing the spillways for the Susitna dams.

A third knotty problem is erosion of the Susitna River channel downstream of the spillways. One alternative for the Watana Dam spillway is to provide two stilling basins for energy dissipation. These stilling basins will minimize downstream channel erosion, but they may have structural problems due to the high velocity and forces in the jump action within the stilling basin.

An alternative that was talked about at our first meeting was to use a flip bucket. The flip bucket would simply deflect the water out into the downstream river channel without any hydraulic jump action, eliminating the stilling basin structural problems. Sometimes flip bucket action causes deep and serious erosion in the downstream river channel. If flip buckets are considered for the Susitna dams, a careful analysis will need to be made of the potential for excessive erosion. Their use may not be feasible.

I have consulted on Tarbela Dam in Pakistan for five or six years where serious downstream channel erosion occurred due to operation of flip buckets. Spillway flows flipped out into a rock lined channel which was not as erosion resistant as engineers thought and a tremendous deep plunge pool, over 200 feet deep, was eroded. It was eroded in a lateral direction to one side which caused the erosion to approach the end of the flip bucket structure causing impending failure of the structure. Construction of remedial work over a period of two years at a cost of approximately $80 million was required to correct the problem.

A related spillway problem is the nitrogen supersaturation problem. On the Columbia River the flow of water through spillways into stilling basins resulted in excessive entrainment of air, causing an excess of absorbed nitrogen in the water. Fish live on air absorbed in water, but when there is an excess of nitrogen many do not survive. On the Columbia River, several ways were found to partially alleviate the problem.

Unless precautions are taken in spillway design, this same problem may occur on the Susitna River after the dams are constructed. If stilling basins are constructed there will be greater amounts of air absorbed in the water and there may be a nitrogen supersaturation problem with downstream fish.

If a flip bucket is used, as Acres has suggested, the water could be deflected horizontally into the downstream river channel and the nitrogen supersaturation problem would be minimized. However, if the flip bucket design results in formation of a deep plunge pool, then the same nitrogen supersaturation problem can occur because air entrained water plunges deeply into the plunge pool causing an excessive amount of nitrogen to be absorbed.

The fourth and last knotty problem I want to discuss is the environmental effect in the downstream channel. I have already mentioned nitrogen supersaturation which may be caused by spillway operation. Other environmental effects will result from the changed flow conditions in Susitna River downstream of the dams due to regulation of the flow by the dams. Channel configurations may change appreciably. Whether these changes have any environmental effect is being studied. Dr. Leopold thinks that it may change the erosion and deposition characteristics of the river in such a way that river areas where moose feed would be reduced. Under present natural conditions, large floods create new islands which provide moose browse.

"The proposed studies will most likely establish that reservoir-induced slides would not be a problem at the Susitna dams. "

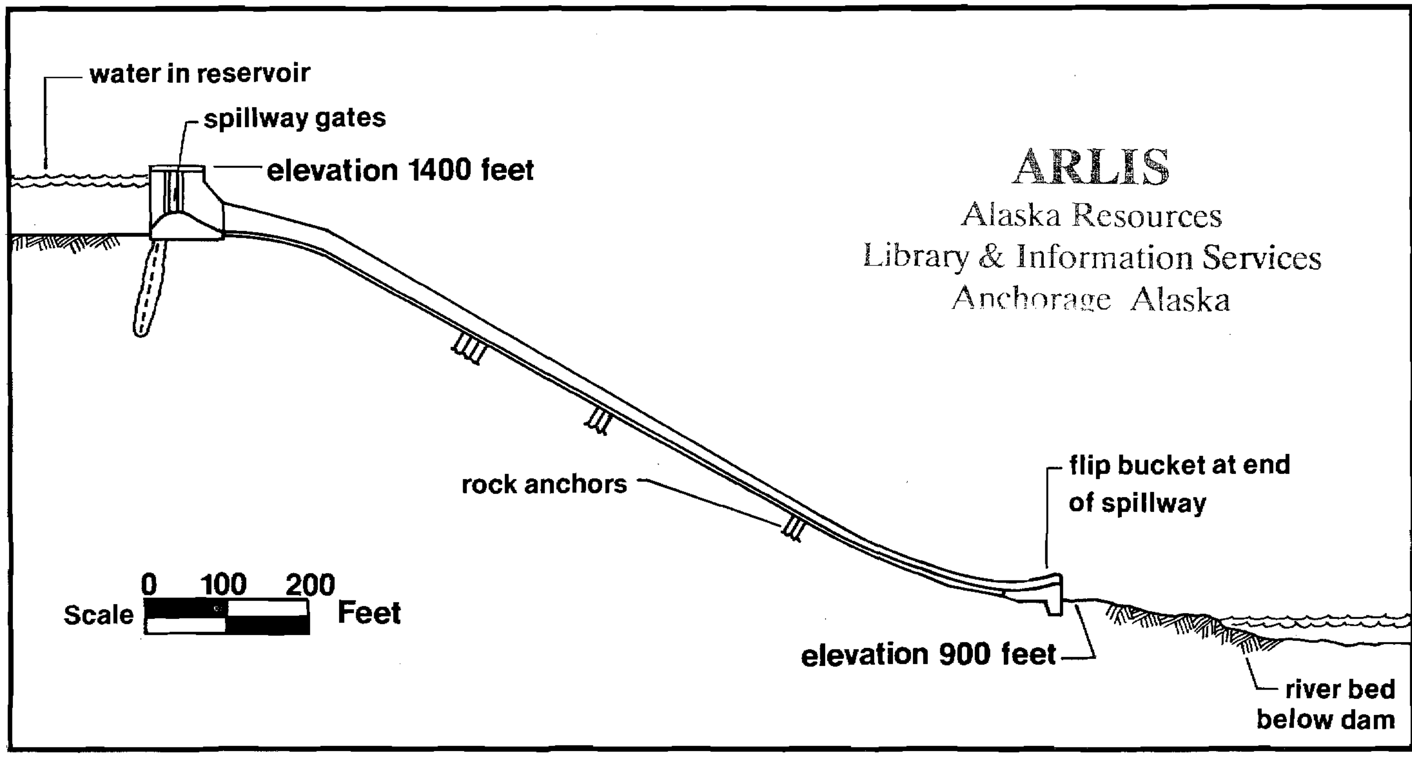
Question: Are those knotty problems unique to the Susitna situation, or are those the same problems that you face in other dam construction projects?

Douma: Those problems are not particularly unique to the Susitna project. Reservoir induced slides have occurred at many projects, but serious consequences due to dam overtopping by slide-generated waves have occurred at only a few dams. The proposed studies will most likely establish that reservoir-induced slides would not be a problem at the Susitna dams.

The problem of designing cavitation-free, low-level outlets occurs at every high dam which contains a low-level outlet that will operate for substantial lengths of time under high heads. This problem may not be serious at the Susitna dams because the low-level outlets would be operated infrequently.

All high dams with high-velocity chute spillways have the potential for cavitation erosion of the concrete chute and excessive erosion in the downstream river channel. Environmental effects due to nitrogen supersaturation may occur at any high dam which has a deep stilling basin, or plunge pool and a downstream fishery.

Finally, serious environmental effects may occur in the river channel downstream of any large dam and reservoir project due to major changes in natural river flows caused by regulated reservoir outflows.



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Cross-section of Devil Canyon spillway

Glossary of Terms

Spillways
Spillways are the structures that allow water to be discharged through, over, or around a dam to the river bed below. Their function is to pass flood flows without damage to the dam. They may or may not serve to dissipate some of the energy of the water.

Flip Bucket Spillways
The purpose of this type of spillway is to dissipate the energy by dropping the water into a deep pool well clear of the end of the spillway. It is much like a giant playground slide with the end curved upward. This throws the water a pre-determined distance before it falls into the pool.

Stilling Basins
Stilling Basins are usually used with gravity dams to help dissipate energy. They are depressed areas built deep enough into the river channel to reduce the velocity of the flow and prevent erosion below the dam.

Nitrogen Supersaturation
A typical Alaskan river is near 100% nitrogen saturation. When the amount of dissolved nitrogen exceeds this level, it is known as supersaturation and can potentially be detrimental to fish and other aquatic organisms.

The causes of supersaturation may be man-made or natural. Structures such as spillways on hydroelectric projects can cause supersaturation.

Natural examples of supersaturation occur below waterfalls and in rare cases, in large rapids.

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