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SCIENTIFIC PROGRAMS

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HEARING
BEFORE THE
COMMITTEE ON
INTERIOR AND INSULAR AFFAIRS
UNITED STATES SENATE
NINETIETH CONGRESS
FIRST SESSION
ON
SCIENTIFIC PROGRAMS IN THE
DEPARTMENT OF THE INTERIOR

MAY 18, 1967

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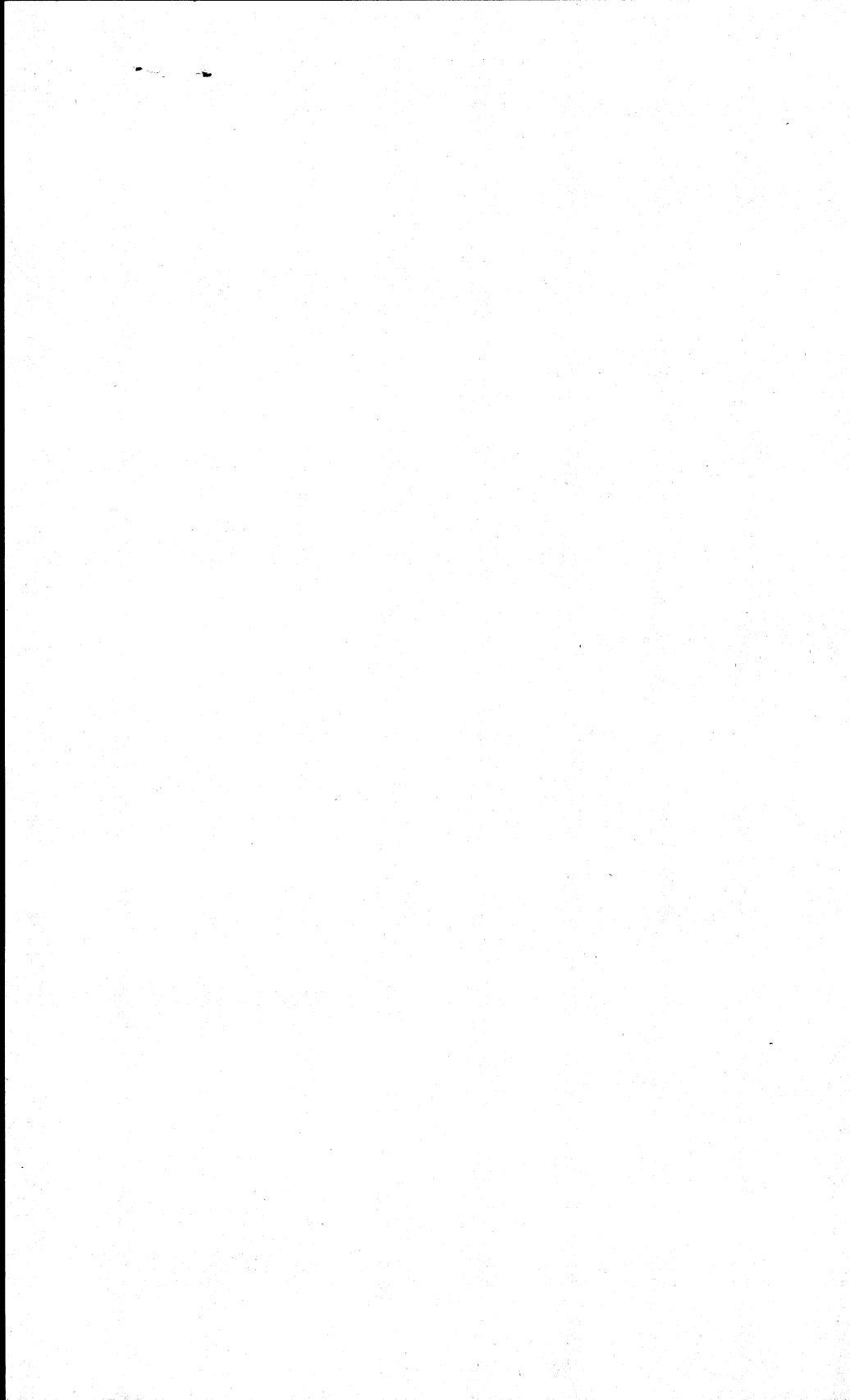
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SCIENTIFIC PROGRAMS IN THE DEPARTMENT OF THE INTERIOR

THURSDAY, MAY 18, 1967

U.S. SENATE,
COMMITTEE ON INTERIOR AND INSULAR AFFAIRS,
Washington, D.C.

The committee met, pursuant to notice, at 10:07 a.m., in room 3110, New Senate Office Building, Senator Henry M. Jackson (chairman) presiding.

Present: Senators Jackson, Anderson, Moss, and Hansen.

Also present: Jerry T. Verkler, staff director; Stewart French, chief counsel; William J. Van Ness, special counsel; and James H. Gamble, professional staff member.

The CHAIRMAN. The meeting will come to order.

The purpose of this morning's hearing is to review recent scientific and technological developments within the Department of the Interior.

The scope and scale of change resulting from advances in science and technology in the past few years is unprecedented. Ninety percent of all the scientists and skilled technicians who ever lived are living now. The amount of technical information doubles every 10 years.

Many of the changes caused by science and technology are fundamental. They influence our lives and influence the formulation of public policies. Some advances and developments will require new and amendatory legislation. We see examples of this in connection with recent advances in weather modification and in our ability to economically recover and process our vast reserves of oil shale.

The Congress has a duty to keep abreast of the implications and the impact of the Interior Department's and the Nation's rapidly expanding technological and scientific capabilities. I believe that today's hearing can serve this purpose.

We are pleased to commence our hearing this morning with an introductory statement by the distinguished Secretary of the Interior, Stewart L. Udall.

Mr. Secretary, will you come forward? We will be very pleased to have your statement.

He will be followed by Dr. Thomas F. Bates, the science adviser to the Secretary.

Mr. Secretary.

STATEMENT OF HON. STEWART L. UDALL, SECRETARY OF THE INTERIOR

Secretary UDALL. Thank you very much, Mr. Chairman.

I have a short prepared statement I will read in a moment. I should like to make some observations as well as summarize some of the highlights in it, if I may.

First, Mr. Chairman, I would like to commend you personally and the members of your committee for the interest and support you have given over the years to the scientific activities and endeavors of the Interior Department.

When I became Secretary, one of the things that I quickly realized was the importance of having a clear grasp of the scientific capabilities and opportunities of the Department. This was in a very real way one of the cutting edges of the Department. I was advised by wise people to get a science adviser. No previous Interior Secretary had ever had a science adviser. I said facetiously last night—because I am losing Dr. Bates in a few days—that I had worn out or used up three science advisers and three Under Secretaries. This has been one of the wisest decisions I have made. I have had three outstanding men.

The CHAIRMAN. You do not mean the using up of the science advisers and the Under Secretaries [laughter]. With that amendment, you may proceed.

Secretary UDALL. Thank you for helping me articulate.

Dr. BATES. Thank you for helping me.

The CHAIRMAN. You do not want to go into your new assignment all used up [laughter].

Secretary UDALL. I am the one that has been all used up from the pictures I see some mornings.

The opportunities there are to make science serve in the field of conservation and resource development, I think, will be shown the committee dramatically this morning. Some of the projects we are now working on were developed in the last few years. This is a growing field. The opportunity is growing where we can give the newest and best technology to the highest concepts of conservation. This is the real trick if we could do it.

I would like to say that you are going to see here this morning, in addition to my science adviser, some of the best scientific people in the Government. I could not be more pleased. I would like to say so publicly. I have had the opportunity of having Dr. Bates as my science adviser, Dr. Pecora as Director of the Geological Survey, and Dr. Hibbard as Director of the Bureau of Mines. You are also going to hear Dr. Weinberger and Dr. McHugh, two of our best scientists.

I think you will see we are increasing and enhancing our capabilities in the scientific field.

Today's world stands on the shoulders of yesterday's scientific achievements. We may quarrel with the manner in which our science and technology are being used, but we cannot deny the awesome power they place at our command.

Even if we would, it is far too late for us to shut the lid on Pandora's toolbox. Long ago, for better or for worse, we elected to grasp the mechanical extensions of our biceps and our prehensile thumbs, we chose to equip our feet with the wings of accelerated speed, we opted not to blink at the things beyond 20/20 vision that microscope and telescope would show our eyes.

From the earliest days of its history the Department of the Interior has been one of our Government's leading research agencies. Over the years Interior has invested more than 10 percent of its total program effort in scientific and engineering research on the Nation's natural resources. This has amounted to expenditures of several bil-

lion dollars since the Department was organized back in 1849. Its geologists and its mining and construction engineers were there to help pioneer the West.

This long-term investment in research has brought us the basic knowledge required to manage over 460 million acres of public lands, to administer mineral leasing on all federally owned lands, to provide water for 9 million acres of farmland, to protect 230 national parks, monuments, and historic sites, and to handle wisely our valuable fish and wildlife resources.

These are all direct departmental applications of our continuing research programs. But the benefits from this research reach far beyond the Department's boundaries. Interior furnishes vital information on the entire environment. It supplies our basic geologic and topographic maps, tells of earthquake hazards, predicts natural water supplies, and aids the minerals and fishing industries through its research and information services.

Few mineral deposits have been discovered and brought into production without the Geological Survey having played a role in some aspect of the exploration, or the Bureau of Mines having had a hand in the characterization and processing technology. The predictable catches of our U.S. fishing fleets today are the result of research performed many years ago by Interior and cooperating agency scientists.

This Nation has a dependable resource base. The fact that we are sure of this base is largely due to Interior's research efforts. We have shortages and we know that present supplies are far from inexhaustible. But we know where those shortages exist, we know how fast the depletion is taking place, and we are at work to find alternatives for resources that will some day no longer serve us. We need to continue, even to step up, our efforts in this direction.

We have concern, too, for how our resources have been developed. In the process of extraction we have been guilty of waste, of pollution, of landscape mayhem. Yet along the way we have found, through intelligently directed research, the means to match this ugly record with a creative one—discovery of additional resources, reuse of present resources, invention of new resources.

The scientific ability and determination of our past has established the dependability of our resource base. It is scientific ingenuity, honed by experience and tempered by concern, that will guarantee this dependable resource base into a future where the spoilage and pollution, which we also inherited from the past, are happily missing.

We already possess the kind of technology necessary to continue tearing away at our resources. If we choose to sit down at Nature's peace table and negotiate for her remaining treasures, then stepped-up research, mirroring our new environmental concern, is needed.

We are in, and have grown to accept, the nuclear age and the space age. Spectacular as these are, they leave us with the challenge of the next age, which is the age of environmental quality.

This will be an age in which man truly understands the earth and air and water that sustain him. He will try to operate in concert with these elements, rather than at their expense, for he will see clearly that the expense ultimately is his.

Many of our most pressing social problems have their roots in lack or misuse of our land and its resources. Development of a peaceful working relationship between man and Nature can do nothing to

harm man's relations with his fellow men, and might indeed do much to improve them. The need for continued environmental research is not merely a resource need—it is an increasingly urgent human, social need.

Every scientific achievement opens the door to several alternative avenues of advance. And as we make our choices, some of these doors swing shut—forever. We need to be surer than we have ever needed to be in the past that we see all the doors and that we choose the best possible route available.

Today's scientific and engineering efforts of the Department of the Interior are an investment in a brighter, healthier, more enjoyable America tomorrow. We welcome this opportunity to tell you briefly the nature of this investment—to show you how we intend to make it produce for the Nation not just dividends, but capital gains.

Mr. Chairman, we take considerable pride in the booklet that we have prepared for you. Many of the finest scientific people in the Department worked on it. I think it has been a very good effort for us in terms of summarizing for the Department what it is doing now and what our hopes are for the future.

We have testified recently before this committee on a subject, the important subject, of weather modification. We will be testifying soon again, I understand, on the oil shale.

We have selected this morning Dr. Pecora, who will make a presentation as the Department's top geologist.

But I thought it was most interesting for this committee to single out three or four of the most interesting and exciting projects and have the project managers present them to you in a brief fashion.

So Dr. Hibbard of the Bureau of Mines will make a presentation on Project Badger, which is a very exciting new project on underground excavation. It is amazing what we can do if we can adopt and use modern technology in underground excavation.

Dr. McHugh is the new Deputy Director of the Bureau of Commercial Fisheries and he will present a very exciting presentation on some of the latest developments in fishery forecasting.

Dr. Leon Weinberger of the Federal Water Pollution Control Administration will present a program on advance waste treatment or third-stage waste treatment. This is where we will clean up our water pollution and begin to regain our water. It is a tremendously significant development.

And then a subject that I spent some time on yesterday with Secretary Freeman, the EROS satellite project, will be presented by Dr. Pecora. Here is an example where we take space technology and look back to the earth and use this as a new resource management tool. It is a very exciting concept.

Mr. Chairman, we certainly welcome the opportunity to come before you this morning because it gives us an opportunity to summarize for ourselves and our own people and our own benefit just what we are doing now and to reexamine our opportunities for the future.

The CHAIRMAN. Mr. Secretary, may I compliment you on the way you have gone about this matter. I am impressed by the quality of the scientists you have brought in in key positions to endeavor to apply wisely the scientific tools and technological applications that flow from scientific research.

A while back there were many who were advocating a Department of Science which, to me, made no sense at all. They proposed to simplify the problem by putting all the scientists in one department so that they would somehow be a source of all scientific technology. As a layman, it just did not register with me, although it sounded good. There would then be one separate department with all the talent and information and technical knowledge needed. I think what you have here is a wise approach; have a science adviser who is in touch with the President's Science Advisory Commission, and in contact with other agencies. In this way you get the kind of exchange of information and free-flow studies which makes sense.

I do want to commend you for the good judgment you have used in selecting people. This is the key. There is no substitute for it.

Mediocre personnel will mean a mediocre department. We must have excellence; and I think you have done an outstanding job in choosing highly competent people. I want to commend you for the top leadership that you have selected and for the many new scientists in the department. You are involved in a broad-based effort and it certainly involves all key disciplines available to us today and the way in which you have gone about it, I think, has strengthened the Department. Of course, it acts as a great beneficiary to business, to the community, and to all America.

Senator Hansen.

Senator HANSEN. I have no comments.

The CHAIRMAN. Any questions, Senator Moss?

Senator Moss. I have no questions.

I would also like to commend the Secretary for the very great leadership he has shown in directing his Department in this area of science explorations and continuing to advance in the area of resources. Our resources, of course, have always been critical, but looking to the future, it is going to be even more critical to our Nation and mankind as a whole. So I believe you are on the right track and I was pleased to hear you today and I am looking forward to the other presentations.

Secretary UDALL. Mr. Chairman, in response to your question, I want to leave it to Dr. Bates to make the main response. I would like to say I agree wholeheartedly with the judgment you have expressed here in terms of how best to organize a scientific establishment. In a government as complex as ours and a world as complex as ours, I think we have come a long way in the last 10 years. I think the fact the President has the Science Adviser and that there is good communication is the answer. But to divorce a department and its day-to-day functioning from the closest scientific relationship, I think, would be a most serious mistake.

Dr. Bates has been with me 2 years and he is leaving in a few days.

I should like to say one final thing, therefore, because it is too seldom we think about these things or express them publicly, and that is that these five men, you are going to hear making presentations today, I am sure in every case if they wanted to, could step out into industry and command a much higher salary. They stay with their jobs, men of this type—and you have them throughout Government—because they feel they are making a contribution to the country. I think they are some of the finest people in Government and I want to say that.

The CHAIRMAN. I want to observe on that point we owe a great debt to what has been called "in-ers" and "outers." Those gentlemen come from industry, serve in Government, then return to industry. Those who come from the universities serve and return. I think this is one of the strengths of our system because of new factors that have come into play, particularly since the beginning of World War II. I am sure you would agree with me, Mr. Secretary, that this is something we need to push even harder because it is a great aid to the existing agencies to be able to bring in people, possibly only for a short tour, so that we may benefit from their fresh approach and ideas. It cannot help but invigorate the scientific community that is within the Government.

I hope Dr. Bates will be back with us again for another stint.

Secretary UDALL. I could not agree with you more. I think the more traffic on the bridge, the better. One of the things Dr. Bates did for me, in fact, was to spend many days in helping me select a new Director of the Bureau of Mines. I was fortunate to get Dr. Hibbard.

The CHAIRMAN. May we thank you for the cookies made of fish protein concentrate. I have not tried them yet. Have you tried them?

Secretary UDALL. Yes, I have tried them, Mr. Chairman, in the past. In fact, Jim Carr, my first Under Secretary, used to say there were scientists who believe this had something to do with enhancing a man's own welfare, particularly in terms of his potency and other factors. You should try them out.

The CHAIRMAN. But you did not answer the question. Why do you not try them on one of those hikes?

Secretary UDALL. I shall do so.

The CHAIRMAN. I am going to make use of them with my tea.

Thank you, Mr. Secretary.

Dr. Bates, we are delighted to have you here this morning. We want you to take over now and discuss these scientific operations and indicate how you want to proceed with the display of the models.

STATEMENT OF DR. THOMAS F. BATES, SCIENCE ADVISER TO THE SECRETARY OF THE INTERIOR

Dr. BATES. Thank you very much.

The CHAIRMAN. You are going to give an overview of the scientific development in the Department and then the various heads will supplement your statement.

Dr. BATES. That is correct.

The CHAIRMAN. All right.

Dr. BATES. Let me first say, in light of the very kind remarks of Secretary Udall and yourself, there could be no more stimulating job, as I see it, in Washington, than the one I have had with Secretary Udall. It has been a very real privilege to work closely with this man. I just wish when I get back to my university that I could write similar 2-year tickets for many of my colleagues to do the same thing. It works two ways. Those who come in and those who go out have a much better understanding of the effort and dedication of the people in the Government.

The CHAIRMAN. I have to leave for another meeting in a little bit and I want to ask you to what extent do you make use of consultants and what is your judgment of the benefit of the use of consultants?

Dr. BATES. We have been making increasing use of consultants in the Department of the Interior. My judgment is we should do a great deal more of this. As I will try to point out in these hearings, I think we are moving into an age where Interior is coming into its own. However, this age of environmental quality must involve not only the scientists and engineers in Interior but all the scientists and engineers in the country who can help in giving our people the right environment and properly managing natural resources.

As I will point out, we must not hesitate to put everybody on this team in any way we can. This means extended use of consultants.

The CHAIRMAN. Very good.

Dr. BATES. I would like to add to the Secretary's remarks my sincere appreciation for this invitation. It resulted in a very critical self-analysis of our program which is very good. I would like also to say in light of your remarks this has not been an easy job because in Interior the line of responsibility goes directly from the man at the top, the Secretary, down through the administrators, operators, and managers, to the engineers and research scientists. Thus, it is very difficult, for an operation like this, to pull out a particular cut because of the completeness of the spectrum. We have done it on a rather arbitrary basis but we think you will be interested.

I would like to say that in addition to the testimony and briefing book, we have, as you observed, various exhibits. I would like to make special mention at this time of the rather inconspicuous electric typewriter in your back room. This typewriter will be "on line" with a computer in Santa Monica, Calif. at the end of the hearing session. It is part of an experimental research program in the Department which will eventually permit any scientist or engineer to attach a portable acoustical device and electric typewriter to a telephone receiver, dial a certain number, and be on the line with a computer just as if he were sitting in front of it. We are just getting into this experiment. I hope if you have a moment you will stop and type out an appropriate question on the typewriter and get an answer from the computer in Santa Monica. We have a limited data base so we cannot answer all the questions.

The CHAIRMAN. We expect you to have that answer at the next meeting.

Dr. BATES. Yes, sir.

In these hearings we are purposely trying to take a forward look as if we were sitting in an automobile in our Department and looking out the windshield. As the Secretary mentioned there are tremendous challenges and opportunities on the horizon. However, there are no paved roads, no easy way we can see to get there. We have a small rear view mirror in front of us which we use to look back on the accomplishments of the past, not so much to cherish them but to take advantage of what we have learned.

As is the case in the business world, there must be a sound investment in order to ultimately realize any opportunity. I want to talk to you about the investment you and the Nation have made in the Department of the Interior. The most important part of this investment, as you have mentioned, is the people.

Let me turn to the first chart which shows the nature of the science and engineering manpower mix in the Department of the Interior.

You will find this chart on page 2 of your briefing book. Since there is some distance from you to this one I suggest you might want to refer to it there rather than here. This shows the distribution of the 7,500 scientists participating in our research and development program.

In the light of Interior's main mission, that is development and management of the Nation's natural resources, there are three important parts. The land resources, the water resources, and the living resources.

You will find the data on this in the background text.

With your permission I will simply summarize. As you can see, we have all types; physicists, biologists, geologists, geophysicists, hydrologists, oceanographers, and so forth. A quick point is that Interior has 70 percent of the federally employed geologists. It has also nearly 100 percent of the fish and wildlife biologists working in the Government.

However, it is not quantitative aspects that are important, but as you said, it is the qualitative aspects of the team that we are concerned with.

Let me mention one or two statistics. First of all, the 7,500 scientists we are talking about have published over 15,000 publications in the last 5 years. Seventeen of these people belong to the National Academy of Sciences or the National Academy of Engineering. Perhaps this is the top recognition that can be given to scientists and engineers anywhere. Thirteen of our national societies have Interior people as presidents and some 122 other Interior people serve in important offices.

I do not have the time to touch on all of the qualifications but this gives you an idea. We feel our team can compete on an equal basis with any other team that can be put together.

As any scientific and engineering group knows, however, it is not sufficient unto itself. As indicated to you previously, we are trying to build up our total program by using talent wherever we find it. The magnitude and complexity of the problems we face demand that the best people in the universities, industries, and nonprofit research organizations be brought into the total effort in a variety of ways. As one brief example, I suggest you refer to page 5 of your book, a table showing some aspects of the contract and grant program of the Office of Water Resources Research for fiscal year 1966. In this year, 35 different disciplines were represented by scientists and engineers working on the problems of water research under the sponsorship of this organization.

As a byproduct here I would like to mention that 1,300 students, largely graduate, participated in the research projects at the 81 universities involved. These are the people who are going to be appearing before you in a few years as we continue to face the water problems which I am sure we will have.

We work with outside groups not only through the contract and grant mechanisms, but as table 2 shows on page 7, through a wide variety of agreements of all types. These are cooperative arrangements, facility use programs and many others. Our people work with scientists and engineers in your States, your cities, your industries, your universities, wherever they may be in order to tackle all sorts of natural resource problems.

You will see from the column on the right in table 2, that we have our Interior scientists and engineers disbursed all over this country.

In fact, if I may say so, one benefit of this exercise was an analysis of some of this data we did not really appreciate. When we saw this table we thought it would be interesting to divide the number of agreements with States on a basis of the purely arbitrary line of the Mississippi River. Many people think of Interior as a western department but when you balance out our agreements with the State agencies east and west of the Mississippi, you come out almost even. Although there is no reason to relinquish the pride we have in relating Interior efforts to the development of western resources, it is evident that we are a truly national department. The dispersal of our scientists, engineers, and facilities is such that we can also think of Interior's program in the same light as a university extension service. One object is to put our facilities and engineers where the problems are. This is important for our people who then obtain firsthand knowledge of the problems to be solved.

I would also like to bring out one or two points here about Interior facilities that I think you will be interested in. Interior operates 18 high seas oceanographic vessels, 14 for the Bureau of Commercial Fisheries, three for the Bureau of Mines, and one for the U.S. Geological Survey. Additional ship space is obtained by charter. The Bureau of Sport Fisheries and Wildlife makes effective use of a two-man submersible and other small submarines have been used under charter.

We also have 12 mobile laboratories that measure everything from gold dust to fish and the characteristics of the environment for each.

The Geological Survey, by the way, is perfecting a 10-wheel lunar exploration vehicle called Trespasser which, when NASA can get it up there, will roll on the moon.

As you know, we have concentrations of snowmobiles, instrumented airplanes, trucks, and radar units converging on western mountain slopes to develop means of augmenting the natural snowfall to irrigate more of next summer's crop.

This, then, Mr. Chairman, is the nature of your investment in this particular team.

As the Secretary said, in the past we have been helping the American people live off the land. The challenge now is much greater because we must help our people live in harmony with the land. This is not going to be easy despite all of our science of the past. For example, even the basic ecological relations are not well understood. We live in ignorance of the details and sensitivity of the balances of nature that exist all around us. Until such basic knowledge is obtained we will not be able to measure accurately the effects of man's actions on his surroundings.

The clean river basin is an attainable goal providing we agree on how clean is clean as determined not only from the standpoint of potability of the drinking water but what kind of biota it should support—in what mix, over what distance, and in the presence of what human activity.

We are overflowing from our continents into the marine areas. How are the shippers, miners, oil drillers, fishermen, waste disposers, sportsmen, explorers, and the military going to work together on our Continental Shelves?

Another question which concerns me is whether we must soon zone the total United States in the same way we do municipalities: for

work here and play there, for highways and hedgerows, for asphalt and grass. We do not have the land use and land capability maps and knowledge to do this at the present time. We are building suburbs on top of the sand, gravel, limestone materials we should be using to build the houses. We are still paving aquifer recharge areas and drying up the ground water supply we plan to use in our cities.

We have a long way to go in these areas and we need all the support we can get from you and the American people.

The Secretary has already mentioned the people who will follow me. I will say no more about them.

I would like to show you the last chart to illustrate how the examples to follow represent the total matrix of Interior's scientific activities. You will find this chart in the book before you on the last page in my section following page 11. (See p. 44.)

The total Interior research and development effort can be represented on the one hand in terms of land resources, water resources, living resources, and on the other with respect to the way we must approach our problems: First in terms of discovery and exploration of the resource; then resource development followed by the addition of economic and social value, then resource use, followed finally by the reclamation and reuse—squeezing every drop out of that resource before we return it in good state to nature. We have cut this matrix several ways to try to give you a good cross section, thus Project Badger cuts across in this direction. The advanced waste treatment example emphasizes use and reuse. Eros represents the development of appropriate instruments and tools with which to make major advances. The Tuna forecasting example gives you a small sample of major efforts underway to enhance the development of food from the sea.

Any of us at any time will try to answer any questions you ask.

It has been a pleasure to appear here.

The CHAIRMAN. That is a very fine statement, Dr. Bates. It is quite apparent the second industrial revolution that has been referred to is creating problems and the Department of the Interior seems to be the recipient of a substantial part of that flow of trouble. The challenges certainly are almost unlimited. They will have to be faced up to and met.

Again, I want to express my appreciation for your very fine leadership.

Dr. BATES. Thank you.

The CHAIRMAN. Senator Hansen.

Senator HANSEN. I have no questions.

I, too, would like to commend you for a very excellent overview of the problems you have, Doctor.

Dr. BATES. Thank you very much, Senator.

The CHAIRMAN. Senator Moss.

Senator MOSS. A very lucid presentation, which makes me look forward to what is to follow, which I am sure will be of a high caliber, too.

The CHAIRMAN. Dr. Hibbard, we want to extend to you a warm welcome, and we are looking forward to your presentation.

You may proceed in your own way.

**STATEMENT OF DR. WALTER R. HIBBARD, JR., DIRECTOR, BUREAU
OF MINES, DEPARTMENT OF THE INTERIOR**

Dr. HIBBARD. If you do not mind, I would like to talk to these charts—that is—a chart talk.

It is a tradition at the universities.

The CHAIRMAN. It has become part of a Senate tradition, too. We serve on other committees such as the Atomic Energy Committee and over the years we have become acclimated to the tools the scientists use at colleges and now in government. We will try to be good pupils.

Dr. HIBBARD. I have a biographical sketch which may be put in the record, if you prefer.

The CHAIRMAN. Yes. It may be included at this point.

(The biographical sketch follows:)

**BIOGRAPHICAL SKETCH OF WALTER R. HIBBARD, JR., DIRECTOR, BUREAU OF MINES,
U.S. DEPARTMENT OF THE INTERIOR**

Dr. Walter R. Hibbard, Jr., internationally known metallurgical engineer, has been director of the Bureau of Mines since December 1, 1965, following his appointment by President Lyndon B. Johnson in October of that year.

Dr. Hibbard's selection to head the Government agency charged with the major responsibility for the conservation and development of the Nation's mineral resources came after notable successes in earlier careers in education and research and development, and in directing metallurgy and ceramics research for one of America's largest industrial concerns.

Born in Bridgeport, Conn., on January 20, 1918, Dr. Hibbard was graduated from Wesleyan University, Middletown, Conn., in 1939, and received a Doctor of Engineering degree from Yale University in 1942.

Following his military service in World War II as a naval officer attached to the Bureau of Ships, he joined the faculty at Yale as an Assistant Professor and later became Associate Professor.

Dr. Hibbard's growing reputation in the teaching and research fields attracted the attention of industry, and in 1951 he was recruited by the General Electric Company for its Research and Development Center in Schenectady, N.Y. There he progressed to the position of Manager of Metallurgy and Ceramics Research, directing a broad range of fundamental and applied research projects, a position he held when selected to become Director of the Bureau of Mines.

Dr. Hibbard's achievements in such fields as the plastic deformation of metals and the metallurgy of copper and its alloys have won him wide recognition from many professional societies. In 1950 he received the Raymond Award of the American Institute of Mining, Metallurgical, and Petroleum Engineers. From 1957 to 1961 he served as director of the Institute, and in 1967 he will serve as its President. He recently was named by AIME to receive the Institute's James Douglas Gold Medal, awarded for his notable career. For many years a registered professional engineer, Dr. Hibbard has served as President of the Metallurgical Society of the AIME, and is a past chairman of the Society's committees on the metallurgical profession and on engineering management. In January 1963, he was one of ten eminent metallurgists elected to the newly created grade of Fellow of the Metallurgical Society. In addition, Dr. Hibbard belongs to the British Institute of Metals and the New York Academy of Sciences, and is a fellow of both the American Academy of Arts and Sciences and the American Association for the Advancement of Science. He also is a member of the Materials Advisory Board of the National Academy of Science, and was recently its Chairman. In 1966 he was elected to the newly organized National Academy of Engineering.

Dr. Hibbard is the author of more than 70 scientific papers and has been widely recognized as a major contributor to the science of metallurgy. In 1957, he was a member of the exchange delegation of United States metallurgists visiting the Soviet Union.

He has been elected to many honorary and professional fraternities including Phi Beta Kappa, Sigma Xi, Alpha Chi Sigma, and Gamma Alpha. He also holds

an honorary Doctor of Laws degree from the Michigan Technological University, Houghton, Michigan.

Dr. and Mrs. Hibbard have three children and reside in Rockville, Md.

Dr. HIBBARD. I would like to say I am happy to have the opportunity to explain Project Badger.

There are three very important ingredients. First of all, there is a technological challenge which I think is an extremely important challenge—where you see a way of accomplishing something that you know will make a breakthrough in excavation technology.

Secondly, it involves interagency cooperation. There are nine agencies in the Federal Government interested in this and we are all working together as a team, with a lead agency. In this case it is the Bureau of Mines.

Thirdly, this is a chance to serve society. The mining industry has been for many years scolded for its air pollution, water pollution, land pollution, for being robber barons of natural resources. Here is an opportunity for the mining industry to develop the technology to be used to serve society.

The name of the project is Project Badger. It is a project in rapid subsurface excavation technology. The increasing application of this boring machine, a 20-foot in diameter machine, which can bore a hole in soft rocks represents the beginning of a breakthrough which may be as important to this country as the discovery of dynamite and its use in mining 100 years ago. The usefulness of this machine will go far beyond mining. Indeed, its broad applicability to the many and varied problems of a technological society is a consideration that makes the effort to advance it very rewarding.

The nine agencies working together on this are the Army, Air Force, Atomic Energy Commission, Geological Survey, Bureau of Reclamation, Housing and Urban Development, high-speed transportation, Bureau of Public Roads, water and power agencies and Bureau of Mines.

The geophysical distribution of the kind of problems that the program can be responsive to is shown in this chart. This chart is also in your text following page 14. It affects all areas of the country. It can be used for highways and parking. For example, today we are going into the high-rise development. If you go to Chicago and see the marina, it is a circular cylinder going up in the air where parking is on the first 13 floors and apartments on the next 13 floors. I think the trends in the future will be to go underground. We have used up much of our urban upper space so we will have to tunnel highways, parking areas and living space underneath the earth. We are going to have urban rapid transit underground. We are going to have urban utilities: we are going to have high speed intercity transportation, water tunnels, sewage tunnels, power tunnels, oil and gas pipelines, defense, atomic energy installations; and, of course, the continuation of mining underground. So the tunneling, in fact, is going to have a large impact. It is going to be in a sense a renewal of Jules Verne.

Two examples I would like to mention very quickly. There has been a study of the commuter problem in Los Angeles. Everyone who has commuted there in the morning knows it is really rugged. The thought is they could build 1,000 lane-miles of commuter roads underground as tunnels, saving surface space, solving the pollution prob-

lem and, in addition, developing parking space underground: From the standpoint of getting to work you would come up to the surface and work in an office building and have a view of reviving natural beauty rather than the concrete landscapes many of these highways have produced.

A similar situation exists in Chicago. There they would need an estimated 1,300 miles of tunneling. Chicago is talking about putting their airport 5 miles out in Lake Michigan and having a commuter system back and forth to this platform from the shore. These are the kind of things which will be involved.

All in all, we can identify at this stage of the development potentially 13,000 miles of tunnels to be driven for these various purposes. And here on this chart (p. 47) is the estimated growth in need for subsurface excavation during the next 15 years for urban highways; mass transit, and others; including water, sewage, power. These are annual figures estimated over 15 years from now to the \$21½ billion spent annually in 1982 for this purpose. Incidentally, the figures are derived from the 9-agency study so the input is across the board.

The estimated cumulative cost of subsurface excavation during the next 15 years is shown here on this chart (p. 48). It is shown with research and development to total \$11 to \$12 billion and without research and development totaling \$20 billion.

In other words, if we continue with the evolutionary kind of technological development which is occurring now in this field, the cost of this tunneling will be about \$20 billion on a cumulative basis.

We believe that with a properly focused enthusiastic research and development program, we can cut as much as \$8 to \$9 billion from the cost of these tunnels. Most of these tunnels will be paid for by the public, by public utilities. Therefore, this advantage of \$8 billion could accrue to the public, to the taxpayer. Therefore, it is an appropriate kind of research and development program for the Government to undertake.

In actual fact the experience with the development of this technology, I think, illustrates the point here. On this chart (p. 14) is the historical and projected development of tunneling technology over the years. Starting in 1850, the initial mining efforts, I think if I may just show you this picture—there were a group of men who had hammers and chisels and were single jacking. Then we devel-



oped piston drills and the ordinate is the rate advanced in feet per week shown. As we developed slowly, about 1860 when drills and dynamite first came in, 1867, specifically, we could advance about 20 feet of mining a week on a three-shift basis. Then we developed the locomotive for carrying away the muck, and developed hammer drills, mechanical loaders, and multiple hole drilling. We developed the tungsten carbide bits and at the same time we could drill faster. We learned the fact that if you drill a particular pattern of drill holes, explosives were much more effective. Until today, 1967, by this technique, drilling and blasting, we can progress about 250 feet per week, a factor of more than 10 over this period of roughly 125 years.

Now, with this tunneling machine, with the appropriate kind of soft rock, can go about 375 feet a week, which is up in here. If we permit this technology to evolve in the way it has in the past, we could expect to attain something like 750 feet per week by 1982. For example, the boring machine was developed for a specific job in New Mexico. I saw the manufacturer's representative in Pittsburgh last week. I asked them what improvements had been made in the last 6 months. They said none. I said why. They said because we have not had any contracts for purchasing advanced equipment. You do have to have contracts for development. Their research and development is very small otherwise and the development will be only as fast as they have contracts to stimulate them.

For example, in the 25 miles of subway scheduled for the District, no consideration is being given to this type tunneling device. The

equipment has not been advanced far enough to be certain it will work in the geological structures underground in the District and therefore it is not being considered.

The CHAIRMAN. Dr. Hibbard, I do not wish to interrupt your train of thought, but as you have been discussing this, I have thought of the enormous amount of money we are spending in connection with our nuclear testing program underground. Maybe you can relate, to the extent you can in open session, what contribution has occurred from the work that has been done in this area? Certainly there has been a substantial amount of research and coordination that takes place between the Interior Department and the Atomic Energy Commission.

Dr. HIBBARD. There has been major fallout from these. We work very closely with the Atomic Energy Commission. In fact, the Atomic Energy Commission is one of the nine agencies we are working together with on this matter.

The CHAIRMAN. I hope you will explain it at the proper time. I think it is a very important point. If you want to elaborate on it now, it will be fine.

Dr. HIBBARD. As part of our program, we hope to get access to one of their large boring machines in Nevada. This is one of the ways we believe we can speed our development because certainly this equipment has been built as the result of Atomic Energy Commission contract, Bureau of Reclamation contract. We think this is a starting point of our research program. We are working very closely together.

To continue, we believe, with appropriate research and development program as mentioned, instead of ending up in the range of 750 feet per week, we can probably develop equipment that will permit speeds in the range of 1,750 per week. This will make a tremendous difference in the cost of tunneling and thus the use of the tunnels. Either we can do the same amount of tunneling with less money or, in my opinion, I think tunneling will be much more accepted and we can spend the same amount of money for much greater amount of tunneling.

I think one of the most exciting areas today is Montreal where they have put in a new subway, where they have an underground complex which illustrates this trend away from moving skyward toward moving underground. In Montreal you not only drive underground and park to take the subway but there are stores, restaurants and hotels.

To summarize briefly, the concept of advanced tunneling systems, the equipment we have today is simply the borer or cutter. I say simply because when a tunnel is bored with a 36-foot diameter machine, it goes forward 1 foot and produces 36 cubic yards of muck to dispose of. This is about 90 tons. When the equipment is advancing 10 to 20 feet an hour there is a tremendous requirement for removing material, and a brand new system is required. Here it is in concept on this next chart (p. 46). It looks like a vacuum cleaner, but it is continuous removal.

Secondly, when the equipment moves this fast a whole new concept of ground stability is required. Here again, in concept a liner slides in place as the machine moves forward and maintains the cut.

Thirdly, you must be able to cut whatever rock, whatever material is in the path. There are mountains with both soft and hard rock. The borer must be able to cut both so we believe there will be new designs of cutting tools. In addition, when we move this fast under-

ground the whole environment problem is intensified. Air must be supplied to the working people. So here we have a sealed capsule with people driving the machine. At this speed and this size they must be sure they are driving accurately. When you are going 25 miles at 1,750 feet a week, a few degree off will cause intolerable inaccuracies. So a system of laser beams is set up to control and direct the guidance of the machine accurately.

Most importantly, we must design the tunnel using the geology of the terrain to our advantage. The rock formations must be considered in relation to the path of the tunnel. Selection must be based on geological considerations.

Well, to sum it up, we think this is a very exciting program. We think we can make real headway with the tunneling system operating, to a point where we can not only advance the technique of mining—incidentally, a machine of this type is being considered for oil shale—but we can also advance the concept for subsurface utilities for use in every day society. Thus not only making a contribution to our own special industry but a contribution to society as a whole.

Thank you very much.

The CHAIRMAN. Thank you, Dr. Hibbard, for a very fine presentation.

Senator Hansen.

Senator HANSEN. I am quite impressed with it. Especially when I think we might be drilling at 1,750 feet a week.

The CHAIRMAN. Senator Anderson.

Senator ANDERSON. I have one question of Dr. Bates.

You mentioned some relationship of atomic energy to space groups for work on the moon.

Dr. BATES. Yes.

Senator ANDERSON. What was that again?

Dr. BATES. The Geological Survey is now developing a 10-wheel mobile unit which they call the Trespasser which will, hopefully, be flown someday to the moon. It will be able to move over the surface, carrying its own atmosphere with it, in order to better analyze the nature of the lunar surface. I am sure Dr. Pecora would be glad to give you more detail.

Senator ANDERSON. Is this in connection with the space program?

Dr. BATES. That is right. I am sure you already know the Geological Survey has been very much involved with NASA's study of the moon on the basis of exploration we have had so far.

Senator ANDERSON. Well, there is a device they are now working with on the moon that was put there by the Space Administration. What is this particular experiment you are having?

Dr. BATES. This is Dr. Fischer, who is Research Coordinator of the EROS program.

Dr. FISCHER. I do not believe, sir, the one operating is capable of carrying men. The one the Geological Survey is developing is a manned vehicle. It is being developed only in cooperation with NASA. They are testing a prototype with NASA in the field leading to development of a suitable vehicle.

Senator ANDERSON. We are ready to start appropriations and I was wondering if this was a duplication.

Dr. BATES. I think not, Senator Anderson. We must work very far ahead in the development of devices which may not be on the

moon for some time to come. Some of the work being done now will undoubtedly not come to fruition for a good many years. But someday we will be able to move a man and analyze the surface just as they do on earth.

The CHAIRMAN. Do you have any questions of Dr. Hibbard?

Senator ANDERSON. No.

The CHAIRMAN. Senator Moss.

Senator MOSS. Dr. Hibbard, I enjoyed your presentation very much. This is a fascinating project you were talking about. Would this tunneling machine be able to go up and go down as well as across?

Dr. HIBBARD. Yes. It will go straight down and bore a hole at any angle.

Senator MOSS. Do they use anything like this in all those extension tunnels in Montreal? I have been through them, too.

Dr. HIBBARD. There are some cutting machines used today. I was up in the Coeur d'Alene area and there they have a reamer which will drill a hole 6 feet in diameter. They just finished a ventilation rise 500 feet long which they did at a rate of 30 feet per shift. It is just amazing when you see these things. They did have problems of muck disposal. They let the muck fall into the bottom of the hole and it took them about 2 weeks to remove it.

Senator MOSS. After they moved ahead?

Dr. HIBBARD. Yes, after they moved ahead. There was so much muck as they moved ahead that they could not handle it. This is why it would take a whole new system to remove this much muck as it is generated.

Senator MOSS. I was impressed. We encounter big trucks every morning taking the fill out of the cut in the Mall and the trucks are moving the fill every morning. I think there ought to be some better way to get rid of it instead of running all around all the time.

Dr. HIBBARD. Oh, there is. We could do that with a rapid underground excavation or tunneling system.

Senator MOSS. If they had a boring machine working there maybe it would do better.

One other question. You said you deal with soft rock. I just wondered, is that in the current machines you are talking about?

Dr. HIBBARD. Yes, sir.

Senator MOSS. What is soft, what kind of rock?

Dr. HIBBARD. Soft is sandstone. Let me put it another way. One of these machines was tried on one of the recent tunnels on Long Island and could not cut it. The rock was too hard. We believe we can advance the cutter design to a point where we will have a boring machine to cut through any rock we are likely to encounter. This is one of the new advances that must follow from this program.

Senator MOSS. The drilling bit used for drilling oil wells and shafts like that are diamond bits. Could they be fitted into the face of this so they would cut hard rock?

Dr. HIBBARD. The cone-shaped bits like those used for oil wells can be used. Part of the problem is the design of the carbide inserts, the location of these cutters on the rotating members and sequence of the cutters. But this, I think, is well within the grasp of today's science and technology.

Senator MOSS. We have been talking, of course, in this committee about the central Arizona project where the water will have to be taken a long distance across a very arid State.

The CHAIRMAN. Are you confining your tunnels to Arizona?

Senator MOSS. Just Arizona only. Is the state of the art far enough advanced now to be considered putting a tunnel underground?

Dr. HIBBARD. This type equipment has been used for underground tunnels by the Bureau of Reclamation, I think, in New Mexico. One of their tunnels in New Mexico was bored.

Senator MOSS. As the chairman suggests, I have other ideas for it, too.

Senator ANDERSON. Who pays for this work? From where is the appropriation?

Dr. HIBBARD. I believe that the research and development to stimulate this type program is properly the responsibility of the Government.

Senator ANDERSON. I want it broken down a little bit. What is this function?

The CHAIRMAN. Who is participating in Project Badger?

Dr. HIBBARD. At the moment there are nine Federal agencies. At the moment Project Badger consists of a study which is being carried out in the National Academy of Science National Research Council to outline for us the most effective, the most needed kinds of research and development which will bring this program forward. They are to report back from study within the next year.

Senator ANDERSON. I was trying to find out how this project is being financed. It is my understanding the Interior Committee knocked it out and you are making quite a play for it.

Dr. HIBBARD. There are funds proposed for appropriations in our 1968 budget. And in the House markup, these funds were largely allowed. In the Senate markup these funds were not allowed. I hesitate to answer your question because I am not sure what our funds will be. But I certainly hope that we can get these funds.

The CHAIRMAN. What amount have you requested in the budget for fiscal 1968?

Dr. HIBBARD. \$2.7 million.

The CHAIRMAN. Is that the total amount the Federal Government would be spending in connection with this program?

Dr. HIBBARD. This is the specific amount for this development. There are other Federal expenditures specifically concerned with the particular projects, but this would be the total amount for this development; yes, sir.

Senator ANDERSON. I think one of the things that concerns me is the fact that industry would be primarily the beneficiary in the sense industry would be engaged in the manufacture of this equipment. What sort of contribution does industry make? Obviously, we all will benefit by reduced costs and improved technology, but how is this handled from that standpoint?

Dr. HIBBARD. Industry contributed to the budget about \$500,000 a year, which is largely associated with construction contracts. This is not a research-oriented industry. They are responsive only to competition and need.

Senator ANDERSON. You mean bidding on equipment?

Dr. HIBBARD. Yes.

Senator ANDERSON. Is all the basic research being done by the Federal Government?

Dr. HIBBARD. It is largely being done by the Federal Government.

Senator ANDERSON. Then you contract out certain portions of the project, that is mainly equipment, then you get your bids and make awards; is that right?

Dr. HIBBARD. Yes, sir.

Senator ANDERSON. But all the research is being done by the Federal Government?

Dr. HIBBARD. Yes, sir.

Senator ANDERSON. Why should industry not be more involved in this? This was the question, I understand, that was raised in connection with the turndown by the Senate Appropriations Committee. While we are on it, I think it would be useful just to have that.

Dr. HIBBARD. First of all, I think it is important to know, equipment manufacturers are not the kind of people to undertake research necessary to produce the kind of advancement we are talking about here. In other words, in my chart there are three curves. I think the kind of evolutionary development occurring if the Government undertakes no additional research is shown by the green line. This is the kind of development that has been going on, the kind of development which has been satisfying industry, so to speak. Now, the substantial part of this \$20 million we foresee being spent in the next 15 years will, in fact, be spent by public agencies, people who will need tunnels or subways. For example, for building highways, for transporting water. Therefore, the major benefits of this advanced technology, tunneling technology, will be a decrease in costs to the taxpayer.

Senator ANDERSON. Yes. But how about the fellow who is manufacturing this equipment. He is not going to starve.

Dr. HIBBARD. No.

Senator ANDERSON. I mean the benefits flow ultimately like any improvement in science and technology to the people as a rule, but it seems to me industry, and I refer to it in the plural, the industry has a tremendous opportunity. If they are looking for growth, if you are looking ahead and take a careful look at the requirements during the period you outlined there, if we find this approach happens to be feasible, I would think the equipment industry would move into this area and say to their board of directors, "This is a neglected area and I think we ought to get on the stick and get with it." Is that not what business is looking for?

Senator MOSS. Is this not the key to the SST development? They decided industry would not do it, so the Federal Government moved in.

Dr. HIBBARD. It is going to be extremely expensive. Something industry is not going to do alone. Today they can sell everything they can make because the mining industry is booming. To be perfectly honest, if I were—I am speaking for myself now—a chief executive or officer in one of these corporations I am not sure I would do research because the cost would squeeze my market from \$20 million to \$12 million.

Senator ANDERSON. Except that you open up new markets. This is the key point, Doctor, that is being missed. You know, years ago Ford

discovered by reducing the price of automobiles he sold more automobiles and made more money. This is way back in 1914. I am talking about mass production techniques but I do not think that follows.

Dr. HIBBARD. I completely agree with your line of reasoning.

The CHAIRMAN. Or to use another expression, when the breakthrough comes.

Dr. HIBBARD. Yes. Once the breakthrough comes everybody will be in there with their own money. But I think what you need for this kind of research and development program is to establish a feasible way of doing this work. I know that is not the kind industry is going to do.

Senator ANDERSON. Just to pursue it a little further, what has happened with the tremendous demand created by use of underground subways? Is industry doing this?

Dr. HIBBARD. Yes, sir. This has largely been done in response to contract.

Senator ANDERSON. I mean, they have improved the State of New York as a result of this great demand for a number of underground tunnels each year.

Dr. HIBBARD. Through Federal funding.

Senator ANDERSON. What happens to the patent? What I am talking about is the expenditure of Federal funds with no participation by industry. Who is going to get the patent rights?

Dr. HIBBARD. I think the U.S. Government should have the patent rights.

Dr. BATES. I see no difficulty there with regard to our policy in Interior.

The CHAIRMAN. I think this is important. I am surprised industry has not come forward with a joint venture approach in which industry could make available its talent and facilities working in cooperation with the Federal Government.

Dr. BATES. If I might add my point, Senator, a good deal of the work that needs to be done is pretty basic knowledge as well as applied knowledge for this whole area. Rock mechanics, for example. We must know how a rock is put together, in order to take it apart.

Dr. HIBBARD. One other very important point, we do not have the people for this program. We are stimulating the universities to produce people in this field. As of now we do not have enough technical engineering talent.

The CHAIRMAN. Do not misunderstand. I am saying it is a very important program.

Senator Anderson.

Senator ANDERSON. I am still curious about it. Two large tunnels were built in the Navaho project in New Mexico. Who paid for that? The Department of Interior offered the contract but the industry has not—

Dr. BATES. Mr. Mermel, of the Bureau of Reclamation, can answer that question.

Mr. MERMEL. The Hughes Manufacturing Co. makes a boring machine. Few manufacturers are in this business because of the tremendous—

Dr. BATES. Who actually paid for the tunnels?

Mr. MERMEL. I would like to comment on this and say so far as the contractor's bids on the tunnel, he gets paid by the cubic yard regard-

less of how it is excavated. If he has incentive and imagination to buy one of these machines and make a profit, then he will make a profit. This is motivation. Not very many contractors are willing to invest money in a machine of unknown character. Therefore, they continue excavating under conventional method because the man is paid and he gets paid and is not losing anything. To venture into a new device is a risk not very many want to undertake except the imaginative ones in the Navaho tunnels and those cases.

Senator ANDERSON. That is right. But what I am trying to say is that industry is interested enough to go out and bid on these contracts and the Government has not a penny in them. Does the Government need to invest in this?

Mr. MERMEL. The Government is not investing anything in the machine. It is purely a deal between the contractor and the Hughes Manufacturing Co.

Dr. HIBBARD. This is where the green line goes——

Senator ANDERSON. The big tunnel machine does not know whether it is red or green. It just digs a hole.

Dr. HIBBARD. However, the machine would not have been built if it had not been a Federal contract.

Mr. MERRILL. The contractor's own initiative brought about the use of this machine.

Senator ANDERSON. Exactly.

Dr. HIBBARD. Because he was trying to make a profit and find faster excavating methods. None of the savings from the machine development went to the taxpayer. If the Government does the research in this field to develop new techniques of excavation therefore they will make it more efficient and more economical to bore tunnels, the savings will accrue to the taxpayer in the contract price—not to the contractor in lower cost and high profits.

Senator ANDERSON. This tunnel was bored and built without Government incentive for a new machine.

Dr. BATES. Senator, if I may make a statement. If we rely on what companies have been doing by their own initiative we will progress by 1982—according to Dr. Hibbard's chart—from a rate of 400 feet per week without continuous boring machines to about 750 a week with such machines. However, if the Federal Government is willing to put in additional research and development, we can jump this rate to about 1,750 feet per week.

Senator ANDERSON. The water supply eventually carried in this tunnel will be, what, about 110 acre-feet? Would that not be big enough? Will not the tunnel they now have carry all that water? Why should it be bigger?

Dr. BATES. I think the truth of the matter and the point Dr. Hibbard was trying to make was that in terms of the total amount of tunneling done, all of the uses we have for tunneling, we have to do it more effectively and more rapidly.

Senator ANDERSON. But you would not have to in the case of the San Juan Tunnel. Why would it be necessary to have the Federal Government do it?

Dr. BATES. I think we are talking about relative progress, moving much faster if we are willing to put in a certain amount of Federal money to stimulate industrial activities.

Senator ANDERSON. It was fast enough before, was it not?

Dr. BATES. Dr. Hibbard has pointed out that in the case here in the District of Columbia we could probably show that it would be possible to move forward more rapidly with regard to moving the excavated material if we could use boring machines; and we could get those trucks out of Senator Moss' way.

Dr. HIBBARD. The reason the nine agencies got together to discuss this problem was that this technology is not developing fast enough and the savings from such technology are not reflected in contract prices. In our opinion there must be a response to these needs, a meeting of these requirements. The plan for the District of Columbia subway is to drill and blast. But it would be much faster and more efficient if it could be bored. We do not have the equipment to bore it. No contractor is coming forward willing to take a risk to do it. I think all these agencies feel a certain amount of stimulation by the Federal Government will be a good investment and will pay back many times this amount to the taxpayers.

The CHAIRMAN. Senator Hansen.

Senator HANSEN. I would like to add a word in support of Senator Anderson's statement here today. I know very little about mining. I have been down in a few of the tungsten mines in Wyoming. I suspect, though I do not know, that the development of that machinery there would be largely through the efforts of private industry. I would venture the opinion that some of the important discoveries that are going to be hit upon in the days ahead and weeks and years ahead will be innovation by practical people down there who are concerned with lessening costs and increasing profits, that sort of thing. I would suggest also they are having considerable experience. I would expect in the order of hardness that would be soft rock, would it not? Yet this provides an easy and fruitful area, in my judgment, Senator Anderson, to gain some valuable experience in the ways a man can propel a machine into the face of a rock wall and to bring the material back. I know this part of the operation down there. I raise this point because I think it lends credence to the point you are trying to make.

Dr. BATES. It is the role of the Bureau of Mines to work with industry in cooperative ventures. I do not think it is an either/or situation. We need some of both.

The CHAIRMAN. I do not think there is any question but what there is great opportunity here. The metropolitan areas are just one part of it. Obviously the applications go beyond that. I think we can all agree we need to exploit the opportunities. I think the problem, in part, is whether industry could not do a little more. Maybe if they are more effectively exposed to the opportunities that lie ahead they would show a little more initiative. I understood, Dr. Hibbard, you have done this by meeting with large equipment manufacturers to discuss this whole program.

Dr. HIBBARD. Yes. In fact, part of this program is specifically to go to them on a joint venture or cost-sharing basis to stimulate them to do research, develop research.

The CHAIRMAN. Senator Moss.

Senator MOSS. No questions.

The CHAIRMAN. Thank you, Dr. Hibbard. We appreciate having your very fine presentation.

Dr. Leon Weinberger, who is the Assistant Commissioner for Research and Development of the Federal Water Pollution Control Administration.

Dr. Weinberger, you may proceed in your own way with whatever approach you feel is most convenient.

STATEMENT OF DR. LEON WEINBERGER, ASSISTANT COMMISSIONER FOR RESEARCH AND DEVELOPMENT, FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

Dr. WEINBERGER. Mr. Chairman, members of the committee, I would like to abstract some of the remarks in the publication that you have before you.

The Nation and the world are beginning to realize that natural resources must be used and used again many times to sustain our increasing rate of population growth and industrial and economic development. It is not fully recognized that our waters are reusable resources and are being used, reused, and used again.

The purpose of this presentation is to indicate that a more deliberate reuse of our water is not only possible but also practical and that it will be one of the best ways of meeting our water needs.

We have been relying, at least in part, on nature to modify our waste discharges by natural forces, but remedial measures are being overwhelmed by increased waste loads.

Fortunately, science and technology can be expected to meet the challenge. What is this challenge? The challenge is to conserve rather than to destroy our water resources.

Gentlemen, I will try to cover a few points very briefly.

What is the pollution relationship between water quality and water quantity? What is the relationship between water pollution control and water quality—water quantity? The relation revolves around the reuse of water.

I will present some examples of water use and reuse facilities and additionally, I will perform for you an actual demonstration of the redemption of water purification and reuse.

What is water pollution? Well, it is the introduction of bacteria, carbon or any impurity that interferes with a water use.

On the chart are some of the classifications we can use to define water, but the uses I am referring to include, of course, all uses: by cities, municipalities, and industries; uses for agriculture and irrigation, plus for propagation of fish and other aquatic life and wildlife.

What is the relationship between water quality and water quantity? A question frequently asked is: Are we running out of water? The correct answer is: We may be running out of water.

I will concentrate the next few moments on the question of our fresh water resources.

There are increased demands for water—for example due to our industrial growth, our population growth, and water requirements for agriculture and recreation. Increased demands are associated with all water uses, even the increase in the amount of waste that must be disposed of. One of the most common ways of disposing of these wastes is into these waters. To meet the increased demands for fresh

water we must either: (1) increase the amount of fresh water, (2) discover new sources of fresh water, or (3) reuse our available fresh water sources.

One may look at pollution control as a program dedicated to permit the multiple use of our water. For example, so that water used by municipalities, can be reused for propagation of aquatic life. Our fish-and-aquatic-life water might be reused by industries and further reused for irrigation. Water used for irrigation, to be reused for recreation. Indeed, water used by one municipality, to be reused by another municipality.

Wastewater treatment is the most common method for removing manmade impurities so that our environment is protected. We must remove enough of the impurities so that their presence cannot be overwhelming. Obviously, since the amount of fresh water is relatively fixed and since the amount of pollution we generate increases steadily, more impurities have to be removed.

To illustrate this, I have some bottles here, one of which includes raw waste water. As the waste loads increased, we had to introduce treatment which we refer to frequently as primary treatment to remove some impurities and then we discharge the waste water. With further treatment we are able to remove more impurities; as pollution continues to grow we will have to remove more and more of the impurities. Many locations in the United States today are providing this degree of treatment.

The degree of waste water purification required is determined by the specific purpose for which the treated water will be used.

Gentlemen, this is a plant for the treatment of polluted water. I am going through the illustration. First is primary treatment, followed by secondary treatment; one often hears about it. The third treatment is advanced waste treatment which now adds all known processes. One of the interesting things in our approaches has been that it enables us to build on existing facilities.

It becomes apparent that, as we remove more and more of these impurities, we end up with water that certainly looks pretty good. As a matter of fact, it is too good to throw away. We find many places throughout the United States—the West, East, North, and South—where people are looking at this way of augmenting certain waters which they may need.

This is an illustration of a 2½ million gallon per day plant at Lake Tahoe where this degree of treatment is provided today.

Here is a plant at Santee, Calif., where waste water is being treated for reuse in recreational lakes. People swim in that water; they are fully aware that it is treated waste water. It was because of the demand by the public, that it was finally opened for swimming.

This represents a waste water treatment plant at Whittier Narrows, Calif.; the treated waste water is used to recharge the ground water so as to augment the municipal water supply.

Gentlemen, it is possible that we can solve two major problems by applying existing improved and new technology. One of the major problems being total water pollution control from known sources and the removal of all impurities I have indicated. There is a possibility that we can reduce the low-flow augmentation requirements needed to enhance the quality of our streams. And, this actually rep-

resents almost as much pollution protection, gentlemen, as ways of augmenting our supplies of water. This is not a "blue sky," long-range program; instead, it represents systems which are in use today and which are being placed in use every day.

Gentlemen, while I have been talking to you I have been conducting that experiment because the water I have been drinking is treated waste water. This is purified waste water.

Gentlemen, this water—no sleight-of-hand—this water is safe and meets or exceeds the highest drinking water quality standard anywhere. I might say my staff has indicated it is safe. This is in part a tribute to the staff. It also represents my faith in my staff.

Gentlemen, in conclusion, I might say I will show the other bottle to Senator Jackson. What this other bottle represents, sir, is drinking water of the common variety. This is treated waste water by some advanced techniques.

Gentlemen, I have tried to illustrate, perhaps by a dramatic example, what, I think, indicates what can be done and what is being done. We do have a limited amount of water. We have some glasses. We will be pleased to pass them around to the group and to anybody who would like to participate.

The CHAIRMAN. You are extending this doctrine of faith quite far.

Dr. WEINBERGER. Gentlemen, I thank you. If there are any questions at this point.

The CHAIRMAN. Doctor, how much water are we wasting at the present time by failure to utilize this process of reuse for various purposes, either for agricultural use or for human consumption. Do you have any figures on that or can you estimate it?

Dr. WEINBERGER. Sir, I do not because one of the assignments given to us by the committee last year was to come up with a specific figure. Every stream in the country which is polluted, if you will, is an example of us not using that stream to the fullest. By this particular experiment, which is perhaps the ultimate, I am not suggesting this is what we need every place.

The CHAIRMAN. Now, to follow up on that point, what is happening on the cost factor? You are involved in research to achieve these reuse objectives. What can you tell us about costs?

Dr. WEINBERGER. Let me come back to one of the bottles—if one looks at this from a pollution control point of view, the cost of providing this degree of treatment—the primary and secondary treatment—will be somewhere between \$50 and \$200 per 1 million gallons.

The CHAIRMAN. Which is a relatively low cost?

Dr. WEINBERGER. Yes, sir. Now, we have cut the cost by approximately 50 percent more. In other words, we actually have plants in operation today, where to cut the pollutant level by using carbon adsorption, all the way to here, costs about another 10 cents per 1,000 gallons. I might say this (primary and secondary) treatment plus carbon adsorption, plus chlorination would remove most of the pollution and would take care of bacterial pollution. This is actually demonstrated in a rather large pilot plant.

Further treatment, using an electrodialysis or reverse osmosis process, would remove the salt content. Reverse osmosis is based very much on the treatment being developed by the Office of Saline Water. The current project we are talking about here may very well be building heavily on their technology.

The CHAIRMAN. Through research the cost figures can go down?

Dr. WEINBERGER. Yes. We have been able to reduce the past cost figures by 50 percent. There is a very good indication of following up on the previous presentation. Industry is very much in this thing.

The CHAIRMAN. Is industry becoming increasingly more active in advancing research to improve techniques?

Dr. WEINBERGER. Senator, they are now.

The CHAIRMAN. I meant in the last couple of years.

Dr. WEINBERGER. Yes. And I would say, in large measure, that part of it results from some stimulation provided by Federal funds.

The CHAIRMAN. European countries have been involved in the reuse factors of water for many years, have they not?

Dr. WEINBERGER. No, sir. Not as a rule. Europeans at the present time lag behind our technology. I should not be talking about that so generally.

The CHAIRMAN. I did not qualify it, but I meant the percentage of their use of water. Has there been a substantial recycling program going on?

Dr. WEINBERGER. In some places. Some parts of Europe have been doing this. This is a very important point. We are going to have to do this in the United States.

The CHAIRMAN. Senator Hansen.

Senator HANSEN. I do not have any questions. I am certainly very much interested in the presentation you make here, Doctor. Coming from the West, I appreciate the importance of these developments. We have already felt the pinch of inadequate water supply. We look forward to the further development and refining of these techniques you described this morning, not only as a means of providing a more nearly adequate supply to some of the coastal regions, but also to make additional water available to the upper reaches of the Basin States and to augment the supply generally.

The CHAIRMAN. Senator Anderson.

Senator ANDERSON. You do not try to get absolutely all the pollution out of the water, do you?

Dr. WEINBERGER. No, sir. This is one of the things that makes my job a little easier. You do not have to remove all of the pollution because the drinking water we have has a certain amount of impurities. There is a certain amount of salt in it. It is not harmful. In fact, without it you would not want to drink the water. So, you do not have to remove all the impurities. In some cases we have to remove more than others.

Sir, if I may indicate here, each one of these steps should be looked at as removing a different kind of pollution. In certain situations we might end over here and not require more removal. But in some places we would remove it over to here in order to get back to the original quality.

But, certainly, we do not have to remove all of the minerals in the water.

Senator ANDERSON. I think the slight pollutants make a better taste in the water. I have had some samples.

Dr. WEINBERGER. Exactly the point, sir. One would not want to take out all the minerals found in the water.

The CHAIRMAN. We do not want to get into the fluoride question, do we?

Senator ANDERSON. The point of my question was that I have two wells. One is about 10 percent polluted and the other is free of pollution. I found out my family wants to drink a little dirty water.

Dr. WEINBERGER. I was going to point out that samples of water may be of different quality and better quality but, as the Senator points out, pure water is supposed to be tasteless and odorless. You can appreciate that this may not have a nice pleasant taste.

The CHAIRMAN. Senator Moss.

Senator MOSS. Your second chart, Dr. Weinberger, where you show distillation and then the water is united with water that has not been through this process, is that to upgrade the quality of the part that goes through distillation?

Dr. WEINBERGER. Senator, this is, again, partly in response to Senator Anderson. What I am indicating is that there is the possibility of splitting a stream of water so one can take water, somewhat higher in mineral content, and blend it with a distilled water so you do not need very high removals. The advantage is attained when you are able to combine two processes and come up with a blended water of good quality. One process is very expensive, and the other is very inexpensive.

Senator MOSS. It is treated to remove pollutants and then blended with stream water to upgrade the natural water?

Dr. WEINBERGER. That is the purpose. The distillation process upgrades the water, with blending back to a potable quality.

Senator MOSS. Thank you.

The CHAIRMAN. Thank you, Dr. Weinberger, for a very interesting presentation. You have your work cut out for you.

Dr. WEINBERGER. Thank you.

The CHAIRMAN. Off the record.

(Discussion off the record.)

The CHAIRMAN. Our next witness is Dr. William T. Pecora, Director of the Geological Survey.

Dr. Pecora, we are delighted once again to welcome you back to the committee. You may proceed in your own way.

STATEMENT OF DR. WILLIAM T. PECORA, DIRECTOR, GEOLOGICAL SURVEY, DEPARTMENT OF THE INTERIOR

Dr. PECORA. Thank you, sir.

I recall being here a year and a half ago and appearing before this same committee. Sometimes I wish you had advised and consented negatively because we have so many things to do, so many programs, and we have, of course, to do this with limited funds and facilities at our disposal that the life of a bureau chief is a harried one.

I should like to talk to the committee today, sir, about EROS. E for earth; R for resources; O for observation; S for satellite. This program has brought the Department of the Interior together in a major enterprise, more so, I think, than any other single effort because the intent of the program is to use every available science technique which we are developing through our national space program to use on earth for man and his resources.

I have some illustrations I would like to present to you briefly and go through them but the first one will make the basic point.

The EROS program has made a number of experiments with aircraft-carrying instruments so to determine their feasibility for certain purposes and then judging whether these techniques can be used successfully in orbiting vehicles. So the EROS program, per se, is a combination of both aircraft and spacecraft. One of the remote sensors used in this program is the infrared sensor. This determines the thermal conditions of terrain, and the distribution of water as free water and as moisture. This and other sensors will provide information on the distribution of vegetation, the vigor of vegetation, the distribution of alien fluids within water, the coloration of rocks and soils, and the relative differences in temperature.

This exhibit shows an experiment which was conducted in the Hawaiian Islands. It was known to the natives there was fresh water under the sea off the Hawaiian Islands. In aircraft mounted with an infrared sensor we flew and located more than 200 offshore springs where fresh water from the land was being lost but is coming out of the ocean bottom. I happen to have here a jug of water taken from the bottom of the ocean near station 2. Two springs are located there. This is a most important scientific discovery because we can apply this technique not only to Hawaii, which is relatively short of water on the west and south side, but to other coastal areas. If we can locate such lost water springs we can then recover the water for use on land. You can see many applications in recovering this undersea water before it is lost to the sea.

Since this infrared sensor measures relative temperature it is the cold fresh water coming up through warm sea water that has been detected.

Relating to our aircraft experiment again we wanted to see if we could in some way observe the distribution of pollutants. This is a photograph of the mouth of the Maumee River as it enters Lake Erie; a polluted lake. The photograph depicts the course of the pollutants issuing from a sewage treatment plant and shows that the breakwater is effectively impounding the sewage and preventing its dispersal into Lake Erie. We have only one station located on shore which analyzes the quality of this water, obviously this meter is not giving the whole answer. This same illustration is given in black and white in your booklet. The job here is to determine what is happening to the general flow of these polluted waters in such areas. Such experiments will give us an overview immediately rather than requiring a great number of quality measuring stations or a great number of vessels at the mouth of the river to determine what is happening.

The next illustration shows results of an infrared sensor experiment that determined the temperature differences between salt water and fresh water at the mouth of the Merrimack River in Massachusetts. The fresh water is on the left and the salt water is on the right. They have a different color because their temperature is different.

The CHAIRMAN. What is the temperature difference between fresh and salt water? How do you know it is really not fresh water temperaturewise?

Dr. PECORA. The Atlantic Gulf Stream shows a 5° to 10° difference in temperature from the bordering ocean. We can measure down to a degree or better, depending on the nature of the instrument.

This infrared sensor can detect the interface of the fresh and salt water during movements of the tides and floods. This exhibit shows

a major city located right at the interface. One would have to investigate other situations like this in hundreds or thousands of estuaries throughout the world to best locate fresh water supply intakes. It becomes rather important also in relation to fishing to identify the contact of fresh and salt water. I know in some European waters it is important to know ocean water temperatures to determine how the fishing is going to be today or tomorrow.

The next illustration is also contained in the briefing book. One of the major responsibilities of the Federal Government is to acquire a great deal of scientific information about the crust of the earth so we may indicate a mineral resource target which the private sector may then pursue. The private sector will risk large sums of money if there are ideas for them to work on. The target area is in bright color and it is our principal aim. The block below it, exploration, development, production, consumption, is entirely the area of the private sector. However, in order for us to lead to the target point, we need to throw in all the information which we can get. Now, here is a case where data from space, if it can be provided, gives another input. Because our feet cannot cover all the ground at the same time, the Eros Program can give us clues as to the structure and determination of the crust which will lead us to the target areas for resources.

We have mentioned the measurement of difference of heat. Here is a simple application—Mount Rainier taken from an airplane. The photo on the left shows snow as white and rock as black. On the right we have measured the different heat, again with the infrared system, from an aircraft. We can outline the areas of abnormally high temperature material. This has a real significance. Mount Rainier may still be a geologic hazard or it may not be. It is, also, possible that it could serve as a source of geothermal energy—in any event it bears watching, and we can watch it from aircraft or space.

The Taal volcano eruption in the Philippines a few years ago was a major catastrophe. We immediately put in a system of temperature measurement periodically with an aircraft to determine the point of later temperature buildup. Another eruption took place a couple of months later at this point. We think this kind of warning device and the attempt to locate geological hazards, if we can get this kind of coverage worldwide, would be a great service to mankind.

This system can point out other hot spots on the crust of the earth such as forest fires or geothermal regions. But if we can locate the hot spots which are warming up to erupt again it will be of real benefit to man.

Our scientists are applying both infrared and radar techniques to their study of geologic hazards associated with the San Andreas Fault in California. This effort is an adjunct to other Geological Survey studies that are predicated on the proposition that earthquakes are predictable. Readings with these new tools are adding to our understanding of the history of movement along the San Andreas Fault, and hopefully we will soon be able to interpret them in terms of the dynamics of earthquake regions.

The radar image shown in this exhibit is an example of the kind of small-scale imagery that is becoming a valuable aid in studying potential geologic hazards to obtain guidelines for safe urban development. The San Andreas fault is more than 600 miles long and goes

from the southern part of California through the San Francisco area out to the ocean. It has been the source of earthquakes many times, the most disastrous being 1906. Population has increased in the meantime. It is our intent to locate as many earthquake faults as we can and we do better by a broad coverage rather than individual piece-by-piece coverage.

For the past 3 or 4 years we have been working as partners with NASA and with transfer of funds from NASA. This year the transfer was in the order of \$1½ million. Added to this are resources from our own organization. This partnership enables us to get the best possible results from our studies of test sites in the United States.

Also the illustration shown in your booklet locates test areas that have been used in various kinds of experiments in order to determine the feasibility of making resource observations from manned or unmanned satellites. This means we have, we think, obtained a kind of experience which makes us ready now to look ahead for other possibilities.

We have organized within the Department of the Interior on a broad base. As I said, for the last 3 or 4 years we have been building up this kind of experience. Now we are assembling a program involving many bureaus and missions within the Department looking toward such an approach. Secretary Udall in his earlier remarks referred to this broad program. You can see also in your booklet eventual help with mapping requirements, making engineering map surveys, marine resource, and oceanography, commercial fishing, geological surveys, human resource activities, including parks, recreation, fish and wildlife; and, finally water resources, not only for discovery of new supply but also for their conservation, for example a means by which pollution control can be achieved.

In this program, as it is set up, the Secretary has designated a central office—a central clearinghouse. At the National Academy of Sciences we have had special advisory committees in these areas. We are hoping to continue our joint enterprise with NASA.

Secretary Udall has mentioned we have had many conversations with Agriculture. We are ready to consider now what might be done in the future, reaching out to apply science and technology to our joint needs in land management and total resources.

Mr. Chairman, I believe that is a very quick review. I merely wanted to touch on the highlights because time is moving along.

The CHAIRMAN. That is an excellent presentation, Dr. Pecora.

In connection with the discovery of fresh water in the ocean areas, have you been doing any testing off the east coast or west coast or the gulf?

Dr. PECORA. Only in a limited sense, we did image one spring off the coast of Florida; but this is an ideal application, particularly to the coast of southern California.

The CHAIRMAN. I was thinking of southern California.

Dr. PECORA. In southern California we can try to locate the areas of fresh water along the coast. This is one of the main applications of that procedure; yes, sir.

The CHAIRMAN. Certainly, worldwide, the opportunity is tremendous.

Dr. PECORA. Yes, sir. In many areas, Mr. Chairman, the country is dry not because of shortage of rainfall but because the water sinks

into the ground and becomes "lost" water. If we can apply techniques like this we see a great application in this one area alone.

The CHAIRMAN. Senator Hansen.

Senator HANSEN. In that connection, Dr. Pecora, let me ask: Has your technique been perfected to the degree you might be able to locate underground active reserves or is this difficult?

Dr. PECORA. No, sir. It is related, Senator, the temperature of the surface of the ground is affected by the proximity of ground water to the surface. Soils on one side of a fault can have a different temperature because the level of ground water is different on one side than on the other. Reservoir structure can be delineated for many resources in addition to water-bearing formations.

Senator HANSEN. It is a very exciting realm of research. I compliment you for a very fine presentation.

Dr. PECORA. We would like to show you and your colleagues on the committee when you have more time together some of the benefits that have already been determined by this. We see many applications for the future. We are in this stage now, groping, reaching out and foreseeing great benefits to mankind. With your continued support, interest, and sympathy we hope to succeed.

The CHAIRMAN. We want to commend you and compliment you on all you are doing. You have our support.

Dr. PECORA. While I am here, I am going to show you—

The CHAIRMAN. Another act of faith.

Dr. PECORA. This water was collected off the shore of the Hawaiian Islands.

Off the record.

(Statement off the record.)

Dr. PECORA. It is not as chemically pure as that offered by Dr. Weinberger, but it has a healthy mineral content. It is a sample of "lost" fresh water.

The CHAIRMAN. Thank you very much.

Our next and last witness is Dr. J. L. McHugh, Deputy Director of the Bureau of Commercial Fisheries.

Dr. McHugh, we are pleased to welcome you to the committee and, as in the case of the previous witnesses, you may proceed in your own way.

STATEMENT OF DR. J. L. McHUGH, DEPUTY DIRECTOR, BUREAU OF COMMERCIAL FISHERIES, DEPARTMENT OF THE INTERIOR

Dr. McHUGH. Thank you, Mr. Chairman.

I will try to be brief, but I will hit the highlights, at least.

The Bureau of Commercial Fisheries has a very broad responsibility for research on living resources of the ocean, and for freshwater studies not only for purposes of conservation but also to get the product to the consumer in prime condition.

The CHAIRMAN. We want to thank you for the cookies.

Dr. McHUGH. You are welcome, sir.

The CHAIRMAN. Also, I was very much interested in the global food situation. These cookies are one of the examples due to help feed some of our less fortunate neighbors in other parts of the world.

Dr. McHUGH. I would like you to consider the problems of the tuna fisherman. Incidentally, I am confining my remarks to tuna because it is impossible to cover our entire program and I thought tuna was particularly applicable worldwide. It illustrates practically all the problems of the fisheries.

Consider the problems of a tuna fisherman based in San Diego. As I will indicate on the first chart, he must decide whether to fish off Washington and Oregon for albacore, off Baja California for bluefin, off Mexico or South America, or perhaps the Marquesas Islands for yellowfin or skipjack, in the Hawaiian Islands region for skipjack, in the Atlantic, off our eastern seaboard for skipjack or bluefin, or off the west coast of Africa. Up until recently, our tuna fisherman had to make his decision pretty much by rule of thumb. Sometimes he would simply go out and seek the fish at random or sometimes simply by long experience from learning where the best fishing grounds are.

A modern purse seiner may cost \$1.5 million and require a crew of about 15 to operate it. Investment is high and risks are great in the highly competitive world of high-seas tuna fishing. The uncertainty of supply of raw materials also creates a serious problem for processors. They cannot be certain from one month to the next how much fish will be available.

The second figure gives us an example of what happens under certain conditions. This is the history of the albacore tuna, which is the white meat tuna and the most valuable one.

There was quite an important fishery off our west coast which began shortly after the turn of the century. After about 10 years the catch dropped off to a low point and for a period of 10 years there was hardly any catch at all. Then the fish began to show up again and there has been a substantial catch in the last 25 years with rather large variations. There have been tuna off our coast every year since the late 1930's. This is an example of the kind of problems the tuna fisherman faces. In the period from 1925 to 1935 they did not do very well. The industry was in rather bad shape economically.

Let us go on to the next chart. This gives some ideas on the general reasons why the variations occur. This chart of the North Pacific Ocean represents the water conditions in 1957. The area outlined in red was much warmer than average over a period of years before this, and the blue area off the western side of the Pacific extending out from Japan represents an area several degrees colder than normal at this time of year. We call the years 1957 to 1959 the warm years, for on our side of the Pacific the water temperatures were as much as eight degrees higher than normal. The whole circulation had changed.

To understand the fluctuations in the tuna fisheries, it is helpful to know something of the circulation of the North Pacific Ocean. This circulation is characterized by a large clockwise gyre, essentially similar to the atmospheric circulation. The North Pacific drift to the eastward splits off the Oregon-Washington coast into a northward flowing current which forms the Alaska gyre and a southeastward flowing cold California current which turns to the westward off Baja California. The current flows past Hawaii as California current extension waters, becomes part of the north equatorial current, passes northward as the warm Kuroshio current and mixes with the cold southward Oyashio to complete the clockwise pattern.

We are able to identify those currents and water masses by their temperature and salinity characteristics.

For instance, the California current, since it originates in northern latitudes, is a cold current. High rainfall and reduced evaporation in north latitudes also keep its salinity relatively low. By monitoring the temperature and salinity characteristics of the ocean waters, we are able to detect changes in current patterns and forecast distribution of the fish associated with these current systems.

For example, the Coast Guard provides monthly flights along the Pacific coast from Seattle to southern California, to enable the Bureau of Sport Fisheries and Wildlife to make aerial infrared measurements of surface temperature patterns. This information is distributed promptly to commercial and sports fishermen.

Albacore distribution in the eastern Pacific was affected by these changes in ocean conditions. Albacore are known to make transpacific migrations. At some stage of life the same fish may be sought by Japanese live-bait fishermen off Japan, Japan long-line fishermen in the west central North Pacific, and sport and commercial fishermen off the west coast of North America. In May and June each year the albacore move from central North Pacific waters into North American coastal waters. When spring warming occurs early in coastal waters, the albacore arrive early. If the coastal waters are warmer than usual, the fish appear farther north. The area of best catches during typical years is off northern California, Oregon, and Washington.

The CHAIRMAN. You say warm year; you are talking about the temperature of the water?

Dr. McHUGH. Yes, sir. I am talking about the years in which the water is warmer along our coast than it normally is.

The CHAIRMAN. It may not go hand in hand then, it may be cold on land and the water may be warm?

Dr. McHUGH. Yes, sir.

The CHAIRMAN. The relationship to the fact that the Japanese current plays a part in this case is why you get tuna fishermen off Alaska as well?

Dr. McHUGH. That is right. Downstream from the California current, variations in the California current extension waters affect the Hawaiian skipjack fishery. We know a little bit more about the causes there. We have discovered that tuna always live in the shaded area labeled California current extension. The boundary between the California current extension, with relatively low salinity, and the North Pacific central water, with relatively high salinity, is well defined by a salinity gradient which usually lies just south of the islands during late autumn and early winter. During February or March it begins a northward movement, passing the islands in spring and reaching its northern position just north of the islands in July or August. The movement of the boundary is reflected in changes of surface salinity which are monitored by regular sampling near Koko Head, Oahu. We can determine pretty accurately when the tuna will be coming. In fact, for the coming year we are forecasting a very poor catch because the salinity started high and it did not look as if the waters would move as far north as it does in most years. Our forecasts have not always been completely accurate but we are looking into the future on how to improve our forecasts and to determine the causes and effects.

The CHAIRMAN. You are getting a lot more data now, I take it, regarding the quality of the water from a temperature standpoint, and so forth, than you were heretofore?

Dr. McHUGH. Yes, we are conducting many more oceanographic surveys in these areas.

The CHAIRMAN. But the application of this knowledge goes beyond fisheries and gets into the problems of undersea warfare, does it not?

Dr. McHUGH. Yes, indeed.

The CHAIRMAN. So it is this tremendous interest in oceanography and ocean temperatures that you feel are particularly important to many other areas besides resources in the sea.

Dr. McHUGH. Yes, we are working very closely with the Navy and a number of other Government agencies and State agencies, too. We have a very close relationship with the Navy in the Pacific to get information on ocean characteristics from the tuna boats, from our own research vessels, and merchant ships. These are sent in by radio. They are then transmitted back to the Navy and are run into a computer and produced on charts which can then be relayed back. This has helped the Navy also because they are getting information and we are both benefiting.

The CHAIRMAN. Therefore you have a good exchange program with other agencies in the Government.

Dr. McHUGH. We feel we do. And it is very much to their advantage and ours, too.

One other thing I wanted to mention, another rule of thumb, is by fishing around the sea mounts which are so abundant off the coasts of California and Central and South America. Fishermen have known for years that tuna will congregate at times near islands or reefs. Later it was discovered that they also like to gather around sea mounts, which do not reach the surface. The regular navigational charts were not adequate to locate these features on the fishing grounds, so the Bureau developed its own set of charts. These are in great demand by tuna fishermen. Using information gathered by the Navy, too, we have found that some of the differences in tuna abundance are related to the topography of the ocean bottom. These charts have been very helpful and the fishermen say they catch them more easily.

I would like to come back to chart No. 1 which shows the entire ocean. We are now beginning to realize the changes in tuna abundance are not only related to changes taking place in the ocean conditions but also we have to look farther and farther over the horizon, sometimes many thousands of miles away, to try to explain why the ocean changes.

For example, scientific studies recently carried out by the Inter-American Tropical Tuna Commission have shown that the strength and position of the Azores high-pressure cell over the Atlantic Ocean affects precipitation and winds in the eastern tropical Pacific Ocean, which in turn affect ocean circulation and distribution of tuna in the Eastern Pacific. The strength and position of the Azores high also affects upwelling and increases biological productivity off the coast of Africa, with profound effects, no doubt, upon fisheries there also.

In another study it was suggested that the severe flow of warm surface water into coastal Peru where normally cold water was found is related to meteorological and oceanographic processes thousands of

miles to the westward in the Pacific Ocean. It is also known that the severe storms that roar into the Pacific in the winter through Mexico affect the biological productivity of ocean waters and movements of tuna in the eastern Pacific. Events that push cold air southward over the United States into the Gulf of Mexico frequently have their origin in the north central Pacific or even over northeast Asia. The same atmospheric conditions over northeast Asia that may ultimately produce winds in the Gulf of Mexico also cause winter monsoons in the northern Indian Ocean. Northeast winds bring dry continental air over the Indian Ocean, causing surface water flow to the westward. Low rainfall and high evaporation cause a rise in salinity. The process reverses in the summer monsoon from May to December. Undoubtedly, but in a way still little understood, the monsoons have a profound effect on abundance and availability of Indian Ocean resources.

So, just these two high pressure areas have a tremendous effect.

Senator HANSEN. Dr. McHugh, do I infer from your testimony that there is a rather significant fluctuation in the degree of salinity in certain currents in the ocean at different times of the year or comparing one year with another?

Dr. McHUGH. Well, the currents each have their own characteristics of temperature and salinity. The California current, for example, has a low temperature. And it has a fairly low salinity, too, because a great many rivers run into the north Pacific. It is characterized by its low temperature and low salinity. We can tell simply by that and we can watch the movements of these currents. They do not always flow in the exact place and change with atmospheric circulation, too.

Senator HANSEN. Dr. McHugh, I think you have presented a very interesting story here this morning and I can appreciate the applicability that it has. It goes far beyond simply the concern we all have in fisheries and takes in other areas as well.

I do not think I have any further questions. I would like to commend you for a very interesting discussion here.

Dr. McHUGH. Thank you, sir.

I would like to make one other comment. Dr. Pecora mentioned briefly our interest in Eros satellite. We also have been working with manned satellites, working very closely with the Gemini astronauts. In fact, on their last flight we had them take pictures so that we could follow the currents. Unfortunately, we were working over the mouth of the Mississippi River, all covered with clouds at the time. But we have all their photographs and we have learned a great deal. It looks to us it will be very significant and will be very useful in the future.

The CHAIRMAN. Dr. McHugh, this has been very helpful. I am sorry I had to step out just a minute. I hope at another time we will be able to have you back as well as your predecessors who made their presentation. Obviously we have not been able in this limited time to get into all the facets of your work and the work of the other departments within the Department of Interior.

Your testimony has been extremely helpful and enlightening. I am sure I speak for my colleagues when I say how much I am impressed by the display. I think Stan Olsen has been responsible for arranging that, Dr. Bates.

Dr. BATES. That is correct.

The CHAIRMAN. Mr. Olsen was here but has left the room. We have had a number of compliments and the press have particularly mentioned how helpful and useful the displays have been.

Many times we get displays that are really so complicated they do not tell a story to the layman. The displays you have presented here today have been extremely helpful in that respect and I want to thank each of the witnesses and you, Dr. Bates, for the wonderful job you have done in putting this together. Especially to you, Dr. Bates.

I want to wish you well in your new assignment. We hope you will become an "in-er-out-er"—be out for awhile, but we hope you will be back in.

Really, the way we run our Government today the public does not always appreciate the role played by private citizens who serve a short time but are not career employees of the Government. When they are in they are very able and distinguished career people. But I think more and more we need to have the support of those individuals who are willing to give a portion of their professional career to public service and then go back to their calling, whether it is in an institution of higher learning or private business or any other sector within our society. And I want to thank each and all for this very fine presentation.

Dr. BATES. I would just like to thank you for your words and say in parting that my feeling about the future of the Department of the Interior is illustrated by the story of the lady tourist who said to the cab driver as they passed a building, "What do those words mean, 'the past is prologue'?" He said, "Lady, that means 'You ain't seen nothing yet.'"

The CHAIRMAN. The entire written portion of your report, of course, which could not be fully presented in the limited time, will be in the record.

I think the presentation which you put together is certainly an excellent one. I am going to take it home and in spare moments I will be able to complete my reading in this area and probably come up with some more questions later to ask all of you.

Again, many thanks. We are in your debt for a very excellent morning.

Dr. BATES. Thank you, Senator.

(The report referred to follows:)

THE INVESTMENT IN NATURAL RESOURCE SCIENCE AND TECHNOLOGY—A SPECIAL REPORT ON SCIENCE AND TECHNOLOGY AND THE MISSION OF THE DEPARTMENT OF THE INTERIOR—PREPARED FOR THE SENATE INTERIOR AND INSULAR AFFAIRS COMMITTEE, MAY 18, 1967.

INTRODUCTION

U.S. DEPARTMENT OF THE INTERIOR,
OFFICE OF THE SECRETARY,
Washington, D.C.

Hon. HENRY M. JACKSON,
U.S. Senate, Washington, D.C.

DEAR SENATOR JACKSON: I have the honor to transmit to you herewith a special report on science and technology and the mission of the Department of the Interior.

Today's world stands on the shoulders of yesterday's scientific achievements. We may quarrel with the manner in which our science and technology are being used, but we cannot deny the awesome power they place at our command.

Even if we would, it is far too late for us to shut the lid on Pandora's toolbox. Long ago, for better or for worse, we elected to grasp the mechanical extensions of our biceps and our prehensile thumbs—we chose to equip our feet with the wings of accelerated speed—we opted not to blink at the things beyond 20-20 vision that microscope and telescope would show our eyes.

From the earliest days of its history the Department of the Interior has been one of our Government's leading research agencies. Over the years Interior has invested more than 10 percent of its total program effort in scientific and engineering research on the nation's natural resources. This has amounted to expenditures of several billion dollars since the Department was organized back in 1849. Its geologists and its mining and construction engineers were there to help pioneer the West.

This long-term investment in research has brought us the basic knowledge required to manage over 460 million acres of public lands, to administer mineral leasing on all federally-owned lands, to provide water for nine million acres of farm land, to protect 230 national parks, monuments and historic sites, and to handle wisely our valuable fish and wildlife resources.

These are all direct Departmental applications of our continuing research programs. But the benefits from this research reach far beyond the Department's boundaries. Interior furnishes vital information on the entire environment. It supplies our basic geologic and topographic maps, tells of earthquake hazards, predicts natural water supplies and aids the minerals and fishing industries through its research and information services.

Few mineral deposits have been discovered and brought into production without the Geological Surveys having played a role in some aspect of the exploration, or the Bureau of Mines having had a hand in the characterization and processing technology. The predictable catches of our U.S. fishing fleets today are the result of research performed many years ago by Interior and cooperating agency scientists.

This nation has a dependable resource base. The fact that we are sure of this base is largely due to Interior research efforts. We have shortages and we know that present supplies are far from inexhaustible. But we know where those shortages exist, we know how fast the depletion is taking place, and we are at work to find alternatives for resources that will someday no longer serve us. We need to continue, even to step up, our efforts in this direction.

We have concern too for how our resources have been developed. In the process of extraction we have been guilty of waste, of pollution, of landscape mayhem. Yet along the way we have found, through intelligently directed research, the means to match this ugly record with a creative one—discovery of additional resources, reuse of present resources, invention of new resources.

The scientific ability and determination of our past has established the dependability of our resource base. It is scientific ingenuity, honed by experience and tempered by concern, that will guarantee this dependable resource base into a future where the spoilage and pollution, which we also inherited from the past, are happily missing.

We already possess the kind of technology necessary to continue tearing away at our resources. If we choose to sit down at Nature's peace table and negotiate for her remaining treasures, then stepped-up research, mirroring our new environmental concern, is needed.

We are in, and have grown to accept, the Nuclear Age and the Space Age. Spectacular as these are, they leave us with the challenge of the next Age, which is the Age of Environmental Quality.

This will be an Age in which man truly understands the earth and air and water that sustain him. He will try to operate in concert with these elements, rather than at their expense, for he will see clearly that the expense ultimately is his.

Many of our most pressing social problems have their roots in lack or misuse of our land and its resources. Development of a peaceful working relationship between man and Nature can do nothing to harm man's relations with his fellow men, and might indeed do much to improve them. The need for continued environmental research is not merely a resource need—it is an increasingly urgent human, social need.

Every scientific achievement opens the door to several alternative avenues of advance. And as we make our choices, some of these doors swing shut—forever. We need to be surer than we have ever needed to be in the past that we see all the doors and that we choose the best possible route available.

Today's scientific and engineering efforts of the Department of the Interior are an investment in a brighter, healthier, more enjoyable American tomorrow. We welcome this opportunity to tell you briefly the nature of this investment—to show you how we intend to make it produce for the nation not just dividends, but capital gains.

Sincerely yours,

STEWART L. UDALL,
Secretary of the Interior.

THE INVESTMENT

In his letter of transmittal Secretary Udall has stated the challenge facing his Department as it shares with the Congress and the President the formidable task of using properly America's natural resources to attain an Age of Environmental Quality. The Department he has directed so effectively for six years consists of 68,500 men and women. These people are grouped in various bureaus and offices, and possess a tremendous variety of talents and interests. They have unity in that each has a contribution to make in helping to meet this challenge. 7,500 of these men and women are scientists and engineers. They have similar capability, knowledge, and prestige in the scientific community to that of their colleagues in industry and the universities. They differ only in that they have chosen to apply their skills to help in the accomplishment of Interior's missions. Their primary role is to serve the Secretary and his management team by providing the research results, the data, and the engineering know-how which are essential to the utilization of our resources and the attainment of a high quality environment.

This role is not a new one. During the past century the Department of the Interior has established a position of leadership both in solving immediate problems and in the long range research necessary to produce solutions in natural resources conservation and development. This has been accomplished by the accumulation of an outstanding work force of scientists and engineers, by providing them with the facilities and equipment essential to their task, by encouraging them to participate fully in the activities of the scientific community, and by placing them in strategic locations where their work could be made more meaningful and effective through cooperative endeavors with municipal, state and other government agencies, with the universities, and with industry.

These three components—top quality personnel, good facilities with specialized equipment, and excellent cooperative arrangements with other responsible groups—constitute the investment that you and this nation have made in anticipating the challenge of more effective use of our resources and environment.

From the time of the Department's creation, effort has been concentrated on developing a scientific and engineering staff eminently respected by colleagues and dedicated to close cooperation with the academic community. As a result the Department today has a professional cadre sufficiently outstanding in quality to attract other top-flight scientists and engineers thereby continually renewing and improving the caliber of the research and development team.

In a department with as many and as diverse responsibilities as Interior, this team must consist of experts from almost every scientific and engineering discipline. Figure 1 illustrates the interdisciplinary character of the Department's attack on the problems of our land, water and living resources. The mix of talents and experience penetrates through the bureaus and other organization groups to the laboratories and experimental sites where the problems are faced and solved. The generalized relationships portrayed in the figure are detailed on the rosters of the Department's various agencies. The following examples are illustrative:

According to the latest figures of the Civil Service Commission, 1374 of the Government's 1965 geologists—or 70%—are in the Department of the Interior. They are largely in the Geological Survey, but we also find them on the payroll of the Water Pollution Control Administration, the Bureau of Mines, the Bureau of Indian Affairs, the Bureau of Land Management, the National Park Service, and the Bureau of Reclamation. At the same time the Geological Survey does not depend on geologists alone to get its job done. It employs 108 physicists and geophysicists, 229 chemists, 141 cartographers and geographers, 436 hydrologists, 2 oceanographers and 1096 engineers of all types. As might be expected an astrophysicist is included among the experts on the astrogeology program.

The Department has the largest group of aquatic and fishery biologists of any agency in the government, or, for that matter, anywhere else.

The Bureau of Mines leads all other organizations in the number of mining engineers, mineral beneficiation experts, mineral economists, and metallurgists. Ceramists, mathematicians, and statisticians are also important members of the total team devoted to the evaluation, mining, processing and use of our mineral and fuel supplies.

THE MANPOWER MIX

Interior Scientists & Engineers Engaged in Research & Development

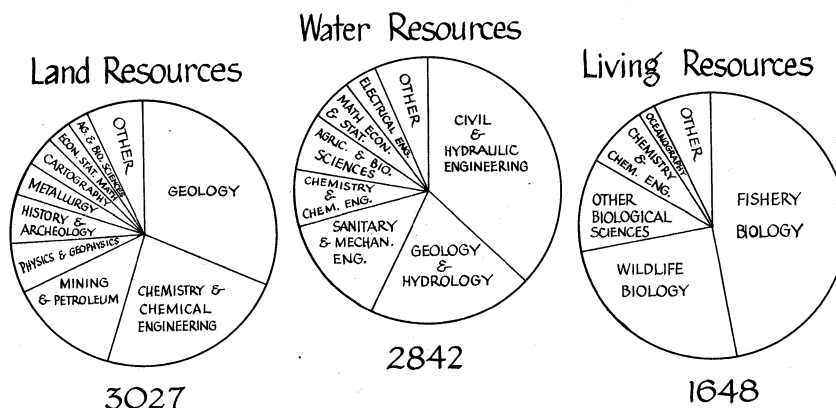


FIGURE 1

In the "living resources" area the range is just as great. Wildlife biologists look to the Bureau of Sport Fisheries and Wildlife for some of the best employment opportunities open to them. Oceanographers, pathologists, physiologists, zoologists, biometricians, bacteriologists, geneticists, parasitologists, animal husbandry experts, foresters, botanists, food technologists, and even home economists are on the roles of the bureaus responsible for the health of American animal and bird populations and for the quality and development of fisheries products.

Archaeologists and historians perform the research that is vital to proper management and use of the nation's many national parks, monuments, and historic sites. Lawyers and economists are engaged in social science research activities in a wide variety of programs throughout the Department.

The proportion of scientists and engineers in the various disciplines is far from static within the Department. Significant shifts may be the result of a number of factors such as changes in the nature of the missions, accession of new responsibilities, and reorientation of effort because of scientific and technologic developments. Thus, the new knowledge and engineering know-how that makes weather modification an essential part of our total water system, justifies—indeed requires—additions to the Interior staff of outstanding meteorologists and atmospheric physicists to manage and participate in the expanding Atmospheric Water Resources program. Of the 2400 scientists and engineers added to the Department's personnel roster in the past six years, 1326 or 55% are specialists trained in the numerous disciplines important in the solution of the nation's water resource programs. An important reason for part of this significant increase was the transfer in May 1966 of the Federal Water Control Administration to the Department of the Interior.

The soundness of an investment depends more on qualitative than quantitative factors. Training, experience, imagination, enthusiasm and leadership are all required. In an evaluation of the caliber of science and engineering talent on Interior's 7500 man research and development team, the record of the past five years speaks for itself.

During that time Interior specialists published 15,050 technical papers in national and international scientific journals.

279 people served as members of advisory panels.

Interior scientists and engineers served as presidents of 13 national scientific societies; and 122 held other offices in such societies.

Professional societies made 113 awards to Interior specialists; and 26 special awards were made by other national, state and local groups.

Seventeen individuals are members of the National Academy of Sciences or the National Academy of Engineering, and 37 are members of the National Research Council.

Despite the strength of Interior's in-house science and engineering groups, the magnitude and complexity of the problems they face demand that the best people in the universities, industries, and non-profit research organizations be brought into the total effort in a variety of ways. As an example, table one shows the disciplines and degrees held by the principal and co-principal investigators directing research on some of the projects supported by the Office of Water Resources Research in fiscal year 1966. The truly interdisciplinary nature of the effort required to solve the nation's water problems is strikingly demonstrated by the spread of these 629 scientists and engineers over 35 disciplines, including seven social science areas, history and law. Over 1300 students, largely graduate, participated in the 603 research projects at the 81 universities involved. Similar contract and grant programs are sponsored by all of Interior's bureaus in varying degree depending on their need for extramural expertise and facilities in order to perform the mission in the most effective manner. During fiscal year 1966 an estimated 1300 man-years of top-level talent was added to the in-house effort through the expenditure of \$52,200,000 in contracts and grants. This significant part of the total Interior science and engineering investment not only helps to provide for the interchange of knowledge so vital to technological progress, but works effectively toward the ultimate solution of the increasingly formidable problems of the future by aiding in the training and direction of the scientists and engineers who will have to face and solve them.

TABLE 1.—DEGREES HELD BY PRINCIPAL AND COPRINCIPAL INVESTIGATORS, OFFICE OF WATER RESOURCES RESEARCH PROJECTS, 1966

Discipline of investigator	Degrees held by investigators of—								Total number of degrees by discipline
	Allotment projects				Matching grant projects				
	Doc-toral	Mas-ter's	Bach-elor's	Other	Doc-toral	Mas-ter's	Bach-elor's	Other	
Agronomy	9	1			2				12
Atmospheric science	1								1
Biology	30	2	1		2				35
Botany	12	1							13
Chemistry	22		1		3				26
Climatology	2	1			1				4
Conservation					1				1
Ecology	9		1						10
Economics	25	4			12	4			45
Engineering	130	75	7		18	11	1		242
Fish and wildlife	12				5				17
Food science	2								2
Forestry	5	3	1		4				13
Geography	8	1							9
Geology	54	8	2		4	4			72
History	1								1
Horticulture	3	1							4
Hydrology	10	2			2				14
Law	5	5		3	1			1	15
Limnology	3				1				4
Meteorology	5	4			1				10
Mineralogy	2								2
Oceanography	1								1
Physics	12	1			1				14
Planning						2			2
Political science	2				3				5
Psychology	2								2
Radiology	1								1
Recreation and parks		2							2
Seismology	1								1
Sociology	4								4
Soil science	10	2			5				17
Veterinary science	1								1
Water resources	2	1							3
Zoology	21	1			1	1			24
Total	407	115	13	3	67	22	1	1	629
Percent	75.6	21.4	2.4	.6	73.6	24.2	1.1	1.1	

¹ Bachelor of laws.

In addition to contracts of all types, numerous other mechanisms exist by which the Department makes use of experts not on its regular payrolls. As one example the use of both specialists and students on a "While Actually Employed" (WAE) basis not only furthers the goals of the agency by the employment of the best talent available outside the organization itself, but has proved to be a sound way of interesting talented students in government programs and problems, and ultimately recruiting some of them for more permanent employment. Of the over 400 Ph.Ds now employed by the Geological Survey, for example, it is estimated that nearly one-third worked for the organization as students in the "WAE" capacity. A break-down by states of the total extramural effort that constitutes a formal part of Interior's research and development program is shown in Table 2. The listing effectively demonstrates both the national scope of the Department's responsibility and the widespread dispersal of its funds as it seeks nationwide support in the attainment of the nation's goals for which it is responsible. The formal agreements with state agencies are of a variety of types, such as:

- Cooperative Project research
- Contractual arrangements
- Matching fund agreements
- Data and information exchanges
- Sharing of facilities

Problems of coordination are met through the use of field coordinators, by liaison with municipal, county and state planning commissions, and through a multitude of informal communication channels.

The column in Table 2 giving the number of Interior scientists and engineers working in each of the fifty states is illustrative of the Department's effort to keep its experts face to face with the problems at their source. This "extension service" aspect of the Department's research and development program provides an essential awareness of the character and changing nature of the job to be done, and enables the scientist and engineer to evaluate his efforts in the light of the present and potential needs of the community he is trying to serve.

TABLE II.—NUMBER OF AGREEMENTS ENTERED INTO BY THE DEPARTMENT OF THE INTERIOR AND NUMBER OF RESEARCH AND DEVELOPMENT EMPLOYEES AT DUTY STATIONS BY STATES, FISCAL YEAR 1967

State	State	Universities	Industry	Total	Number of Interior personnel
Alabama	17	5	0	22	50
Alaska	33	4	2	39	152
Arizona	14	16	0	30	130
Arkansas	10	3	1	14	31
California	35	88	18	141	494
Colorado	18	34	4	56	1,330
Connecticut	12	2	4	18	12
Delaware	12	2	1	15	0
Florida	17	18	2	37	93
Georgia	21	11	0	32	147
Hawaii	14	4	0	18	43
Idaho	10	6	0	16	6
Illinois	15	24	3	42	79
Indiana	14	8	2	24	44
Iowa	12	16	1	29	4
Kansas	16	13	0	29	3
Kentucky	11	2	1	14	56
Louisiana	18	4	0	22	23
Maine	20	4	1	25	25
Maryland	22	14	0	36	366
Massachusetts	12	30	5	47	151
Michigan	10	29	1	40	100
Minnesota	16	8	0	24	166
Mississippi	16	2	0	18	22
Missouri	19	10	1	30	77
Montana	20	10	0	30	17
Nebraska	12	1	0	13	4
Nevada	18	13	0	31	92
New Hampshire	10	3	0	13	0
New Jersey	19	11	7	37	82
New Mexico	14	12	0	26	248
New York	23	60	22	105	36
North Carolina	18	15	1	34	58
North Dakota	20	4	0	24	57
Ohio	10	19	4	33	295
Oklahoma	16	19	3	38	172
Oregon	21	36	0	57	382
Pennsylvania	18	18	25	61	405
Rhode Island	15	6	0	21	32
South Carolina	13	13	0	26	4
South Dakota	12	15	0	27	26
Tennessee	13	10	0	23	12
Texas	19	23	4	46	155
Utah	21	23	2	46	106
Vermont	8	6	0	14	0
Virginia	13	6	4	23	196
Washington	29	32	2	63	610
West Virginia	12	6	3	21	169
Wisconsin	17	29	1	47	28
Wyoming	12	7	0	19	86
District of Columbia	7	1	5	13	709
Puerto Rico	2	1	0	3	5
Virgin Islands	2	0	0	2	0
American Samoa	2	0	0	2	0
Guam	1	0	0	1	0
Total	831	752	130	1,713	7,517

Note: In addition, the Department has entered into 25 agreements with 19 different foreign nations.

Since the talents and training of scientific personnel are wasted if appropriate facilities and specialized equipment are not available, the far-flung groups of experts require that support functions be provided throughout the country. Natural resources being extremely varied in character, appropriate research facilities are similarly so:

The Department owns and operates 18 high seas oceanographic vessels—fourteen for the Bureau of Commercial Fisheries, three for the Bureau of Mines, and one for the U.S. Geological Survey. Additional ship space is obtained by charter. The Bureau of Sport Fisheries and Wildlife makes effective use of a two-man submersible and other small submarines have been used under charter.

Twenty-six mobile laboratories measure everything from gold dust to fish and the characteristics of the environment for each. A 10-wheel lunar exploration vehicle called "Trespasser" is being readied by Geological Survey to roll on the moon.

Research observatories range from the famous, 55 year old laboratory perched on the rim of Kilauea volcano in Hawaii to portable blinds used for studies of bird—and hunter—behavior on remote duck marshes.

Pilot plants explore advanced waste treatment methods for sewage, liquification of coal, salvage of junk car metal, desalting of sea water and a host of other processes designed to reclaim and reuse water, air, and solid wastes.

Yellowstone and other natural parks, as well as wildlife refuges, national monuments, estuarine oyster beds, Alaskan glaciers, and the high seas and ocean bottoms are but few of the research sites that hold the secrets pertaining to effective utilization of present and future resources.

A four and a half mile direct-current test line (the longest in existence) is tied into test transformers which can step up voltages to as high as 1,100,000 volts in order to further our knowledge on power transmission.

Snowmobiles, instrumented airplanes, trucks, and radar units converge on western mountain slopes to develop means of augmenting the natural snow fall to irrigate more of the next summer's crops.

The land resources, the water resources, and the living resources are all about us, but Atlantic and Pacific fish differ, Utah copper and Pennsylvania coal have little in common, and pollution problems vary from river to river. The network of Department of Interior laboratories has been designed to place groups of specialists in the best places to solve present problems and conduct the basic research that is necessary to meet presently unseen future needs. University campuses are the sites for 36 of the Department's major laboratory installations; and have long provided a natural mechanism for strengthening both the institution and the agency in common efforts to produce trained specialists and research results. In line with the President's directive of September 1965 on "Strengthening Academic Capability for Science Throughout the Country," the Department is moving to increase the effectiveness of the relations that have long existed.

Taken in total—the 7500 people, the far-flung facilities, the innumerable supporting arrangements—the investment represented by Interior's research and development program is significant, but nonetheless modest in relation to the size of the needs. The Department's science and engineering team has played a vital role over the years in making America great. Vast mineral developments can be traced directly to Geological Survey research. Entire industries have been born in processes developed by the Bureau of Mines. Major new U.S. fisheries have been started in recent years because of fisheries research begun 15 years ago. We have Hawaiian geese today because of the efforts of avian biologists 20 years ago. Nucleus flocks of the Aleutian Canada geese and other endangered bird species with restricted ranges are being held in captivity today as insurance against catastrophic changes in the wild. The adequate handling of water supplies in the Eastern drought was predicated on the research and records of Interior hydrologists working much earlier in times of plenty.

The Interior research and development team that has helped America live off the land, now faces the much greater challenge of leading the nation into an Age of Environmental Quality in which the people must live in harmony with the land. It will not be easy. Despite all of our science of the past, the ecological relations are not well understood. We live in ignorance of the details and sensitivity of the balances of nature that exist all around us. Until such basic knowledge is obtained we will not be able to measure accurately the effects of man's actions on his surroundings. The "clean" river basin is an attainable goal

providing we agree on how clean is "clean" as determined not only by potability of the drinking water but what kind of biota it should support—in what "mix," over what distance, and in the presence of what human activity.

As our civilization overflows more and more from the land into the marine area, how are the shippers, miners, oil drillers, fishermen, waste disposers, sportsmen, explorers and the military going to work together on the continental shelves and in the coastal bays and estuaries?

Must we soon zone whole regions for work and play, for resource recovery and wilderness, for asphalt and grass, highway and hedgerow? We don't now have all the maps and knowledge to do it wisely. We build suburbs over the gravel and construction materials we should be using in the houses. We pave aquifer recharge areas and dry up the ground water supplies we plan to use in our cities.

Whatever the management problem, it is solved best from a sound base of knowledge and know-how. 7500 scientists and engineers in the Department of Interior are engaged in a wide range of projects—of both basic and applied research nature—that are pertinent to the challenge. These activities are described in the following pages under one of three categories. Four have been selected for special treatment as examples of the major subject-matter areas of research in the Department: 1) the development of appropriate instruments and tools with which to make major advances (Project Eros); 2) a program for increasing the speed and efficiency of underground excavation and tunneling (Project Badger); 3) the effort dedicated to the recovery of food from the sea with emphasis on forecasting the movements and habits of Pacific tuna; and 4) the problem of resource reclamation using advanced waste water treatment as a specific example. Figure 2 shows how these 4 illustrative topics cut across the matrix of problems that can be classified on the basis of land, water and living resources on the one hand, and transformation processes on the other.

Natural Resource Science and Technology

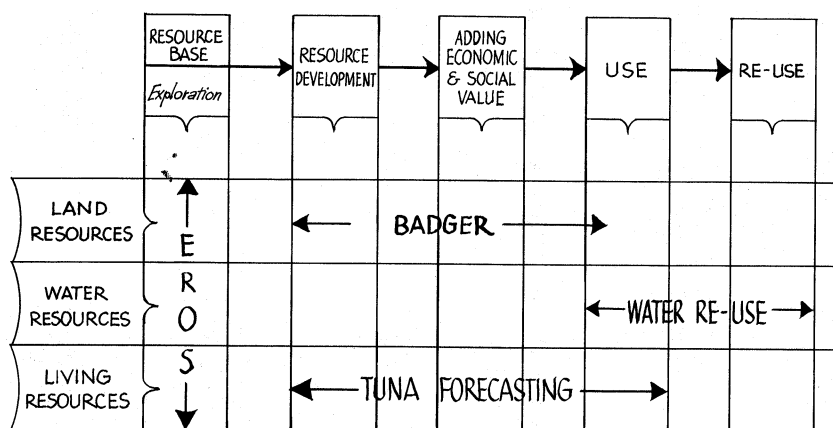


FIGURE 2

In addition to these, eighteen other science and engineering activities deemed to be of particular interest are used to illustrate in slightly lesser detail the wide range of programs underway in the Department's research and development effort.

Finally, 45 other programs are very briefly described to provide information on the breadth of Interior's involvement and investment in science and technology. It is important to point out here that the amount of space given to a particular activity results from constraints determined by the amount of material that could be included rather than the importance attached to the activity.

PROJECT BADGER

Never before has the mining community been faced with such exciting challenges and opportunities as those confronting it today. The primary technology with which it is concerned i.e., the assemblage of machines that are used to ex-

tract mineral raw materials from their place in the earth's crust, is on the threshold of a revolutionary advance. The increasingly successful application of rock-tunnel boring machines, such as the one shown in figure 3, represents the beginning of a breakthrough in excavation technology as important as the introduction of explosives to replace human toil in tunneling for minerals during the middle ages. We can look forward to an era of rapid change in mining as new science, new machines, and new engineering techniques are developed that will permit economic production of the increasing amounts of minerals the Nation must obtain from deposits that are becoming harder to find, deeper in the earth and lower in quality.

The usefulness of this new rapid-excavation technology will, of course, go far beyond mining. Indeed, its broad applicability to the many and varied problems of a technological society is a consideration that makes the effort to improve it potentially so rewarding. Increasing population, attended by profligate use of the land surface in the past and by growing congestion in the present, is resulting in a demand to go underground with the utilities and facilities vital to a complex society, wherever it is economically feasible to do so. Figure 4 shows the nature and geographical distribution of some of the problem areas in the United States that are causing increasing national concern. Some of the major problems are water supply, sewage, mining, urban mass transportation, mass intercity high-speed ground transportation, and highways through mountainous and urban areas. Only very limited use is being made of the earth's subsurface to alleviate these problems, because current technology is inadequate. An improved technology that would permit faster, cheaper, more efficient development of the earth's subsurface would be a significant contribution.

Almost all of the service functions shown in figure 4 now require at least some subsurface excavation. As the population of the United States grows and becomes increasingly urbanized, this requirement obviously will accelerate. An estimate of the current and the projected annual rate of expenditure over a 15-year period for subsurface excavation is illustrated in figure 5. In 1967, an estimated \$1½ billion will be spent for tunneling, and by 1982 the annual rate will increase five-fold to \$2.5 billion. These estimates are probably conservative, because they are based solely on projected needs in these problem areas derived from space considerations alone. In other words, if present population and urbanization trends continue, this is the amount of subsurface excavation that will have to be done, regardless of the cost. Obviously, if the cost could be reduced sufficiently, the amount that would be done would increase because more of the smaller cities could afford subway transit systems. Furthermore some of the bold new concepts for utilization of the subsurface would then become feasible. An example is the dramatic plan proposed by the North American Water and Power Alliance to reverse the flow of several sub-arctic rivers and redistribute their waters in the western United States, Canada, and Mexico. This project, which would make extensive use of tunnels, would bring new life through irrigation to 90,000 square miles of arid land, help flush pollution from the continent's waterways, and generate enormous amounts of electric power. Other ambitious plans have been proposed to solve vehicular traffic and parking in some large cities. For example, a Rand Corporation study showed that an efficient private vehicular commuter system for Los Angeles would require 1,000 lane-miles of tunneling exclusive of parking facilities. Chicago would require 1,300 lane-miles.

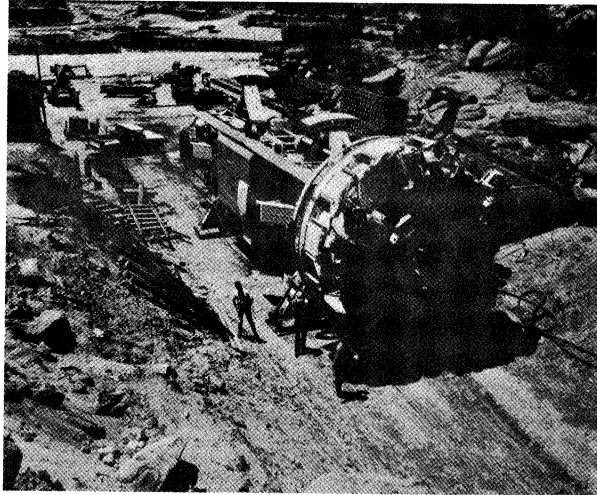
The minimum amount of subsurface excavation that will be required will represent a sizable public investment. As shown in figure 6, it is estimated that during the next 15 years the tunneling required for all purposes, excluding defense needs, will cost at least \$20 billion. This will be the cost if the technology advances only at the normal rate that can be expected without Government action. However, by an aggressive, well structured research and development program, it is confidently believed that the cost can be reduced substantially, probably by as much as 50 percent within the next ten years. Halving the cost of underground construction then would result in a saving to the taxpayer of between \$8 and 12 billion in the cost of construction of just these minimum facilities.

The benefit to the public would, of course, go much further than the monetary savings. Increasingly valuable land surface would be saved for other purposes. The quality of our environment would be improved. Needed public utilities could be put into service much more quickly.

The need for subsurface excavation technology is not new. Since prehistoric times, man has gone underground for minerals. The caveman probably did some

tunneling to improve his shelter. And throughout history, one of the usual developments of an advancing society has been an increased use of tunnels and other subsurface structures as a consequence of increasing urbanization. The Romans and Egyptians, and even earlier civilizations, were tunnel builders. The need is much more urgent now than ever before, simply because of the constantly increasing size of our population and the magnitude and complexity of the services it demands.

A ROCK TUNNEL BORING MACHINE



**BORES A 20 FOOT DIAMETER TUNNEL
IN SOFT ROCKS**

FIGURE 3

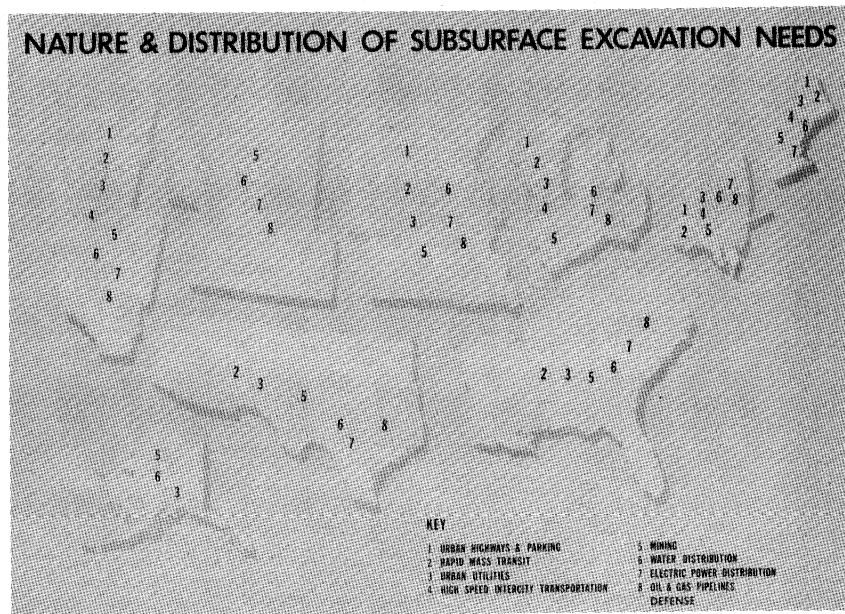


FIGURE 4

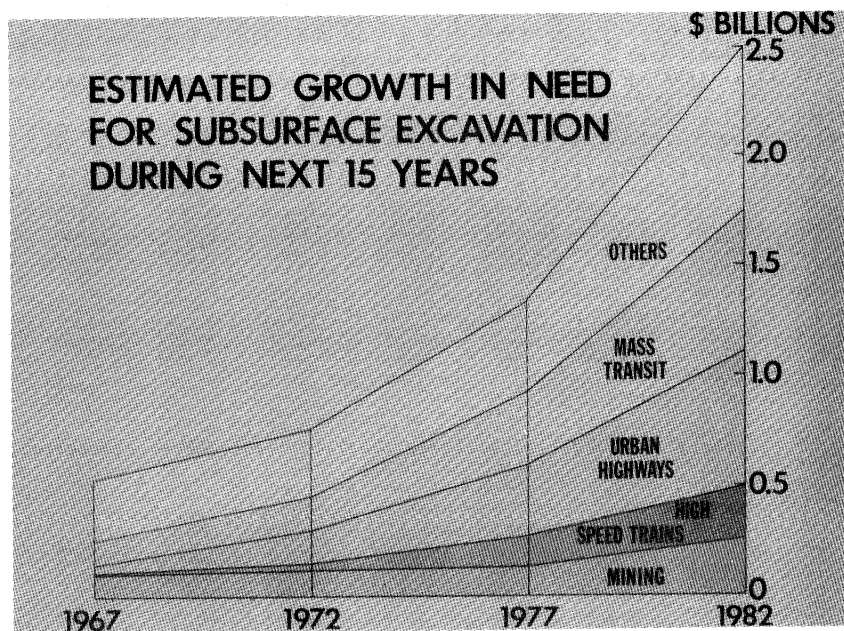


FIGURE 5

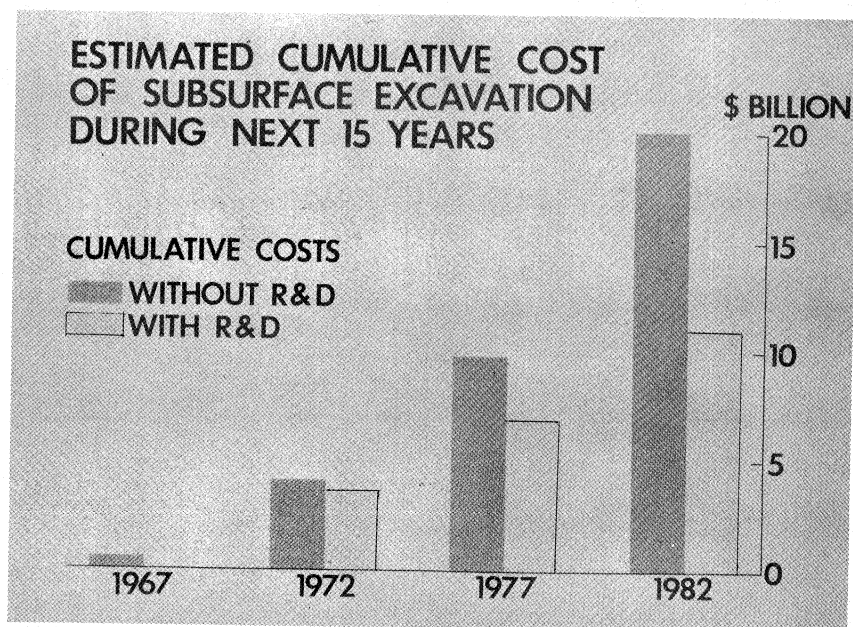


FIGURE 6

The United States is fortunate in having available today resources which, if brought to bear properly, can produce the advanced rapid-excavation technology required to meet this need. Mining research done by the Bureau of Mines and at a few of the universities is developing basic scientific knowledge, experimental procedures, and engineering techniques that will provide the springboard for accelerated progress. The strong national scientific and engineering community developed since World War II as a result of research in atomic energy, aerospace, and defense, can make major contributions to advancing excavation technology, a field to which its talents have not yet been applied. The long experience and the engineering and production know-how of the mining, construction, and equipment industries form the final element in a capability for advancement of tunneling technology far beyond anything that has ever before been available.

Among the most important of the advanced techniques available to us now, as a result of the rapid progress in science and engineering during the past 20 years, is the systems approach developed by the military to produce advanced weapons systems quickly. This approach is based on the simple and rather obvious truth that the quickest way to improve any technologic system designed to accomplish a specific task is to work toward improving all of the elements of the system simultaneously. In practice, this is not quite so simple as it sounds. The elements, or series of acts, that make up a system are usually interrelated and interdependent. Any change in one element usually affects the performance of one or more other elements of the system. The systems approach only became feasible, therefore, with the development of the high-speed digital computer, which makes possible the rapid evaluation of alternative hypothetical solutions to the problems involved in the many elements of a complex system.

The success of this approach has been amply demonstrated in the weapons systems and the aerospace technology that we now take for granted. It can do as much for us in excavation technology.

The tunneling technology we have today has evolved slowly, one step at a time, in the normal evolutionary manner. Some brilliant man with a mineral deposit to mine or a tunnel to drive had an idea that he thought would save him some effort or make him some money, and so he built a new machine. If it proved successful, others adopted it and improved it until it became a standard item of the technology. Then some later genius recognized another opportunity, perhaps made possible or even necessary by the earlier innovation, and he built

another new machine. And so it went, as shown in figure 7 until our present bag of tools evolved.

The change in rate of improvement that can be expected with the systems approach is illustrated by the slope of the curve at the right side of figure 5. The current average rate of tunneling with mechanical boring machines is 375 feet per week. With an intensive research and development program, it is expected that the rate could be increased to 1500 feet per week in ten years. In 15 years the projected rate is 1750 feet per week. Without an accelerated research and development program, i.e. at the current low effort, the tunneling rate as shown in figure 5 is expected to be only about 800 feet per week in 15 years.

Any excavation system, whether for construction of a subway or for mining coal, involves a complex series of actions which can be grouped, according to their purposes, into four principal sub-systems—rock disintegration, materials handling, ground control and support, and environmental control. First, the rock, soil, or mineral must be broken, i.e., it must be separated from its original place in the crust of the earth. Second, it must be loaded and transported to some other location. Third, the ground around the opening must be stabilized, or supported, to prevent or control its movement. And fourth, the environment must be controlled, i.e., the influx of water and noxious or explosive gas must be prevented, and a safe livable atmosphere maintained for the workmen.

Therefore, a logical approach to the effective advancement of tunneling technology would be to conduct research on each of the subsystems according to the needs of the total system. Because of this logic, the Bureau of Mines has established its excavation research organization on a subsystem basis. During the past few years, the Bureau has been developing an in-house capability for each subsystem. It is, in fact, the only research organization in the United States that encompasses all functions of the excavation process. The professional staff comprises a diversity of disciplines including mining, civil, mechanical, electrical, electronic, hydraulic, and general engineers, physicists, geophysicists, geologists, chemists, mathematicians, computer programmers, metallurgists, and statistical theorists. These professionals, numbering approximately 300, are located at four research centers: in Denver, Colorado, Spokane, Washington, Minneapolis, Minnesota, and Pittsburgh, Pennsylvania. Their objective is to improve present technology and to provide new technology through scientific and engineering research. It was because of this capability that the Department of the Interior was selected by President Johnson to coordinate a government-wide subsurface excavation research and development that would benefit, not only mining, but any activity involving subsurface excavation.

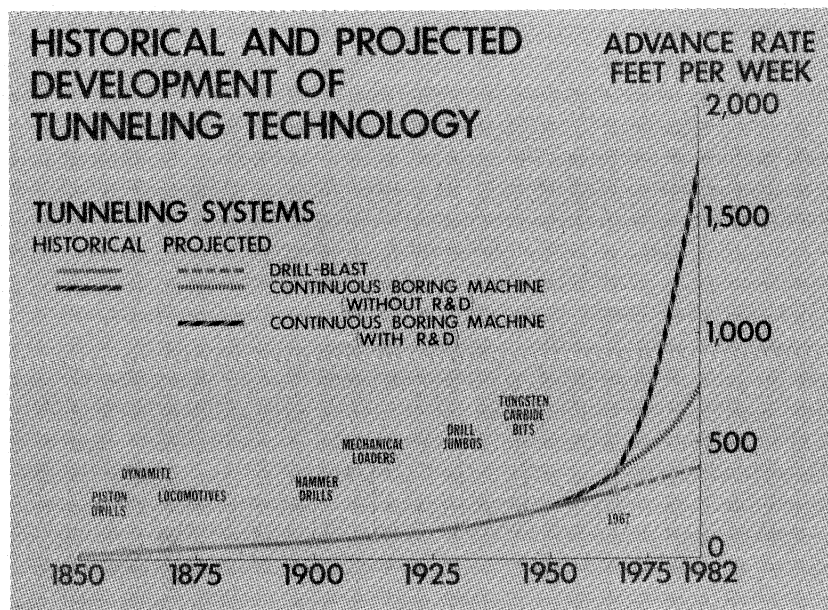


FIGURE 7

An initial and historically significant breakthrough has been made just recently in the first and probably the most critical of the underground excavation subsystems—rock disintegration with a continuous-mining machine. This does not imply that, prior to this breakthrough, rock was particularly hard to break. Egyptian slaves were able to break rock in a tunnel many centuries ago by driving wooden wedges into cracks of the rock face and wetting them so they would swell and dislodge fragments. But the manner and rate of breaking the rock is generally the governing factor in determining the performance of the total excavation system. Drilling and blasting, the rock-breaking method generally used for tunneling in the harder rocks, is a cyclic, essentially manual operation, in which one act must be completed before the next is started, thus establishing limits on the performance of the other subsystems and of the total excavation system.

Because of the built-in cyclic nature of the drill-blast method, a truly rapid and continuous excavation system could never be developed around this method. Nevertheless, even with these severe limitations, the drill-blast method can be used to illustrate what can be accomplished in time through refinement and development of the crude model existing at the brink of an important breakthrough. In the 1860's, when mechanical drilling and high-explosive dynamite were introduced for tunneling, the rate of advance was about 20 feet per week. This was about twice as fast as the era's conventional method of manual drilling and blasting with low-explosive black powder. But even though the tunneling speed was doubled, the cost of drilling with the first generation of mechanical drills was three times that of manual drilling. Now, after 100 years of haphazard and unsystematic development of this method, tunnels can be advanced about 250 feet per week which is more than a 12-fold increase. This improvement is attributed primarily to semiautomation of the drills, better material for the drill unit and rock bits, more efficient transfer of energy to the rock bit, upgrading the explosives, and improving the other elements of the system built around and supporting the drill-blast rock-disintegration subsystem.

The recent introduction of the mechanical boring machine is considered just as significant as the introduction of mechanical drilling and high explosives. It provides an entirely new concept around which a rapid tunneling system can be developed. The attractive feature of this method is that it breaks and loads the rock continuously and simultaneously, thereby eliminating the slow and costly periodic interruptions of the cycle. With continuous breaking, work can now begin toward making continuous and concurrent the other three subsystems. This opens the way to spectacular increases in speed and reductions in cost. In addition, serious consideration can be given to remote control and guidance, which are essentially precluded at present by the cyclic nature of drill-blast methods.

Today's mechanical boring machines, although impressive, are still in an early stage of development, perhaps at the same crude stage of the first mechanical drills a century ago. Until now, they have not been successful in very hard rock. Even so, in rock where they are applicable, they are already outperforming the conventional drill-blast method. An important point to remember is that these boring machines have been incorporated into a system built around the cyclic drill-blast method of breaking rock. Both the materials handling and the ground support subsystems used with the continuous-boring machines are the same cyclic methods developed for the cyclic drill-blast method. Obviously continuous materials handling and ground support must be developed. Based upon experience to date, if a method could be developed to continuously transport the rock broken by current boring machines, their efficiency would probably be increased 50 percent without any other improvement in the system. Actually, higher-capacity continuous materials handling systems must be developed to match the output of the future boring machines. It can be stated confidently that both the machine performance and the range of effectiveness of the mechanical boring can be improved substantially by the application of new scientific and engineering knowledge developed in the rapidly advancing fields of materials science and applied mechanics. For example, current machines apply static thrust and a rotating head with fixed or rolling cutting bits to bore through earth or the softer rocks. With better materials and mechanical design, a machine could probably be designed using dynamic thrust to bore through the hardest rocks. The latter principle has proved to be one of the best methods for drilling small-diameter holes in hard rock.

Also, many other attractive possibilities exist for accomplishing continuously and rapidly this first key step in the excavation process. The Bureau of Mines and others are experimenting in an exploratory way with unconventional energy

sources for breaking rock, such as the flame jet, plasma jet, dielectric heating, hydraulic jet, laser, chemical softening, ultrasonics and electrolinking. A few have already been successful for special applications, such as the jet-piercer for drilling blast holes in the hard taconite ore, but none has approached the stage of development where it can be seriously considered for incorporation in a tunneling machine in the near future. Nevertheless, these avenues are well worth exploring, because one or a combination of these new rock-breaking methods could provide another revolution in tunneling technology. Before any of these methods can be considered for further development, a considerable amount of fundamental research on properties, failure mechanisms, and other aspects of rock behavior must be done.

Some of the remote guidance-and-control technology developed in the fields of atomic energy and aerospace is sure to find use in reducing the cost and improving the performance of continuous-tunneling systems. But the earth medium in which excavation technology functions is much more complex and variable than the atmosphere or outer space. Indeed, less is known about it. A beginning has been made in such concepts as the sensing devices used for the remote direction of coal mining machines and the laser guidance system developed by Hughes Tool Company for the tunnel borer shown in figure 3. This beginning, together with a national geophysics capability that has reduced the problems of nuclear blast detection to reasonable proportions, makes us confident the goal of an almost completely automated tunneling system is not beyond reach.

Another area worthy of intensive research is remote measurement and characterization of the subsurface prior to excavation. Significant savings would result if superior techniques could be developed to analyze underground conditions from the surface and through a relatively small number of strategically placed drill holes. The most favorable sites or routes could be selected, where alternatives exist, resulting in lower costs for excavating and supporting the opening. Contractors could submit bids with low risk yet closely approximating actual costs, rather than high bids based upon the most unfavorable subsurface conditions.

A method using statistical correlation and computers for delineating mineral deposits is being developed by the Bureau of Mines. It has good possibilities for meeting part of the needs in characterizing the earth's subsurface for general-purpose tunneling. These techniques have already demonstrated the capability, not only to provide more accurate interpretations of some exploratory drill-hole data than conventional graphic methods, but also to provide them faster.

The development of continuous methods of ground support and control has not yet been given serious attention. However, we anticipate that the fund of knowledge and the basic technology already available will permit rapid advancement of this subsystem. The science of rock mechanics, a field pioneered by the Bureau of Mines, is advancing rapidly. Consequently, safe and efficient design of the underground structures required for some of the more daring concepts advanced by urban planners is just a matter of increased research effort. New materials, not yet considered for tunnel linings, are available. Although continuous placement of these materials will present some problems, they appear to be amenable to good imaginative engineering.

The materials-handling subsystem is probably the one that will require the most effort and imagination. Except for some research on hydraulic pipeline transportation and development of complex belt-conveyor systems, essentially no research in materials handling, applicable to high-speed tunneling, has been done. Substantial innovation will be required to obtain maximum effectiveness of the present generation of tunneling machines.

The Bureau has recently started some research on broken rock particles and aggregates with respect to the behavioral properties and flow mechanisms involved in their loading and transport. Also some exploratory experimentation is being done with a novel type of conveyor which may be useful in tunnels. But this work must be expanded and other capabilities brought to bear on the problem to develop materials-handling equipment that will meet the performance requirements dictated by the projected speeds of future tunneling systems.

The principal problems to be solved in the area of environmental control, i.e. coping with inflows of water and gas, are related to the discovery of their presence before they are encountered. Bureau research on definition of the areal scope and control of methane and water problems in mining will provide a nucleus for a sound national effort in this area. Life-support already developed

in the fields of aerospace and oceanography will furnish a good foundation for development of the technology required to provide a good working environment for the operators of the rapid excavation systems of the future.

To sum up, we are confident that the resources are available to develop a rapid-excavation technology that will not only save the public money, but that will make available additional space that is vitally needed. The problems have been defined and, by using the systems approach to tackle all of them simultaneously, rapid progress can be made. An artist's conception of the future tunneling equipment and techniques is shown in figure 8. Note that all sub-systems are compatible and continuous and can be controlled with minimum resources. The remotely-guided boring machine has a streamlined design. Both the temporary and permanent lining are being applied automatically and continuously. And the materials-handling concept not only provides for loading and transporting the broken rock continuously but also removes any dust generated and all of the water and gasses that may be encountered. This drawing illustrates the 15 year technological objective of Project Badger.

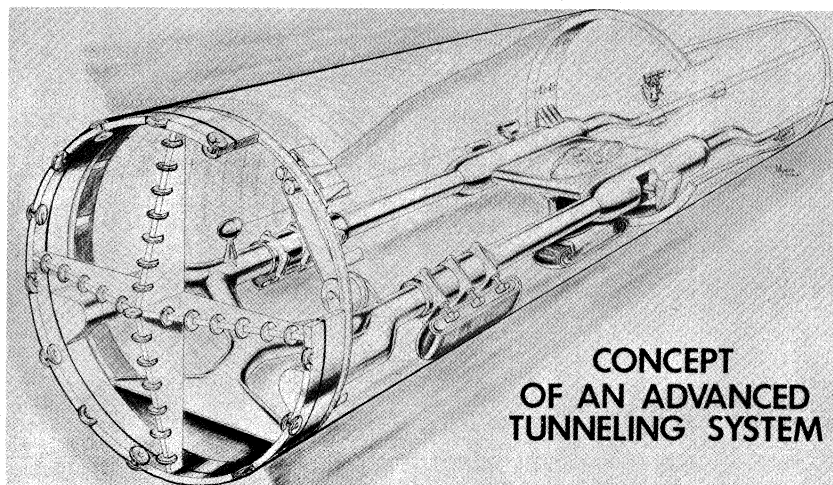


FIGURE 8

TUNA FORECASTING

The Bureau of Commercial Fisheries has very broad responsibilities, which cover all aspects of the fishing industry. We study the living resources in their natural environment to gather information necessary for conservation. We study the technology of fishing, fish preservation, and fish processing to reduce the cost of catching fish and to get them to the consumer in prime condition. To these ends we provide a variety of services to industry and the public.

It is not commonly recognized how large a scientific program the Bureau of Commercial Fisheries supports. We employ more oceanographers, limnologists, and marine biologists than any other agency, Federal, State, or private. Over 120 of these scientists hold a doctor's degree. We operate some 30 scientific laboratories on the ocean and the Great Lakes, and 12 research vessels longer than 100 feet. Many of our scientists and laboratories have worldwide reputations for their competence and special skills in radiobiology, shellfish farming, pesticides, air-sea interaction, plankton, and many other important fields of research.

In a short presentation it would be impossible to describe even the highlights of our scientific accomplishments and plans for the future. I do not intend to try. We have selected some aspects of tuna research, because the resource and its fisheries generally illustrate the problems and objectives of all fishery research.

Worldwide resource

Tunas are worldwide in distribution. They support one of our most valuable fisheries. Some species make long migrations, and some are capable of supporting much larger catches. On the other hand, some tunas are restricted in distribution and movements; some are already producing the maximum possible yield or are overfished; and some fluctuate widely in distribution and abundance.

Research on the living resource provides a basis for forecasting. Sometimes it is difficult for the layman to understand how a particular piece of research can be useful for forecasting or prediction, especially when it is described in the jargon of the scientists. But prediction is essentially the goal of all our scientific programs on the living resources. To reduce to a minimum the cost of catching fish and to maintain the resource of its maximum productive capacity it is essential that we learn how to say in advance where, when, and in what numbers the fish will be and how many can safely be caught. I will show you how we propose to answer these questions for tuna, and this will give you a general idea how we can accomplish the same objectives for salmon in the Pacific Northwest and Alaska, sardines and anchovies off California, fresh water fisheries in our lakes and streams, a variety of fishery resources in the Atlantic and Gulf of Mexico, and sport fisheries generally.

It is said that our tuna fisheries in the Pacific Ocean began in 1903 because the run of sardines off southern California failed that year. The following quarter century saw a gradual increase in the size of the fleet, the size of vessels, and the extent of the fishing grounds. By 1930, the day of the large bait boat, or tuna clipper, as it is commonly called, had arrived. Vessels from southern California were fishing as far south as the Equator, and when brine refrigeration was developed in the late 1930's the working time and range of the fleet were further increased. When World War II broke out a number of large tuna vessels were under construction and many new vessels were entering the fleet. The U.S. Navy took these and sent them with crews intact to the South Pacific where they provided invaluable logistic support.

For several years after World War II the economic climate was favorable for expansion of the U.S. tuna fleet. Imports were not yet available. Profits were good and were used to build new vessels. Later, however, competition from foreign fishing fleets, especially the developing Japanese high-seas tuna fleet, cut into the profits of the U.S. fishermen. United States fishermen have remained competitive by increasing their efficiency through assistance from Federal and State Governments and by their own ingenuity.

The Pacific coast fleet is composed of approximately 140 large vessels capable of extended voyages at sea. Most of these operate from southern California ports. About 1,000 small coastal vessels fish for albacore seasonally along the U.S. Pacific coast. Over the past two decades, landings of Pacific-caught tuna by U.S. fishermen have consistently been among the most valuable catches of the United States, along with shrimp and salmon. The tuna fisheries are worth about \$50 million annually to U.S. fishermen, about \$150 million at retail value.

The fisherman's dilemma

One of the most difficult problems facing a sport or commercial fisherman is to decide where and when to go to make the best catch. Consider the decisions that a purse seine captain from southern California has to make. He must decide whether to fish off Washington and Oregon for albacore, off Baja California for bluefin, off Mexico or South America or perhaps the Marquesas Islands for yellowfin or skipjack, in the Hawaiian Islands region for skipjack, in the Atlantic off our eastern seaboard for skipjack or bluefin, or off the west coast of Africa. A modern purse seiner may cost \$1.5 million and requires a crew of about 15 to operate it. Investment is high and risks are great in the highly competitive world of high-seas tuna fishing. The uncertainty of supply of raw materials also creates serious problems for processors. They cannot be certain from one month to the next how much fish will be available.

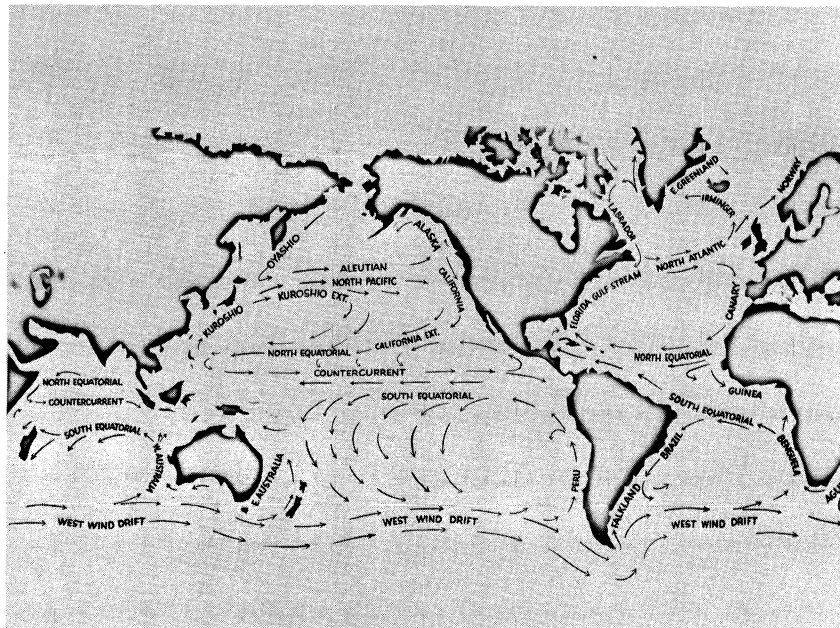


FIGURE 9

Changes in absolute abundance of tuna are obviously a problem to fishermen, but so are the movements of tuna as they range the oceans to feed and spawn. Over the years, fishermen have accumulated a vast amount of experience which usually tells them where to go to find fish. In many years and seasons, however, to the dismay of the fisherman, his "rule of thumb" breaks down and he is left literally with an empty bag. Fishery oceanographers in post-mortems of these fluctuations in availability have been able to explain in part, on the basis of a changing ocean environment, why the changes in distribution of tuna occurred. However interesting this may be to the oceanographer, it is not much help to the fisherman to know why he failed last year. The trend now is toward increased emphasis by fishery oceanographers in understanding the ocean, ultimately to predict these changes in tuna distribution in space and time. The benefit to fishermen will be enormous if precision can be reached in forecasting, so that San Pedro purse seiners can be told several months in advance that the probability for good catches is better, say, off northern California than off the U.S. east coast.

In any fishery, fluctuations in landings are caused by changes in absolute abundance of a species or its distribution in the ocean, and changes in intensity of fishing. Catch of albacore off the U.S. west coast varied widely from almost nothing in the late 1920's and 1930's to over 60 million pounds in 1950 (Fig. 10). Bureau of Commercial Fisheries scientists in cooperation with their colleagues of the State of California have been studying possible causes of these fluctuations. They have concluded that these fluctuations are caused mainly by changing ocean conditions. Thus, it is probable that if we had known as much in the late 20's and early 30's as we know now, the fishery would not have failed. Similarly, fluctuations in skipjack landings in Hawaii appear to be the result of changes in ocean conditions in that area. Enough has been learned of the relationship between these tuna resources and environmental conditions that forecasts

can be made several weeks in advance of fisheries. Forecasts by Bureau laboratories in Hawaii and California usually are successful.

Ocean current systems

To understand fluctuations in the tuna fisheries, it is helpful to know something of the circulation of the North Pacific Ocean. This circulation is characterized by a large clockwise gyre, essentially similar to the atmospheric circulation. The North Pacific drift to the eastward splits off the Oregon-Washington coast into a northward flowing current which forms the Alaska gyre, and a south-eastward flowing cold California current which turns to the westward off Baja California. The current flows past Hawaii as California Current Extension waters, becomes part of the North Equatorial Current, passes northward as the warm Kuroshio Current and mixes with the cold southward flowing Oyashio to complete the clockwise pattern.

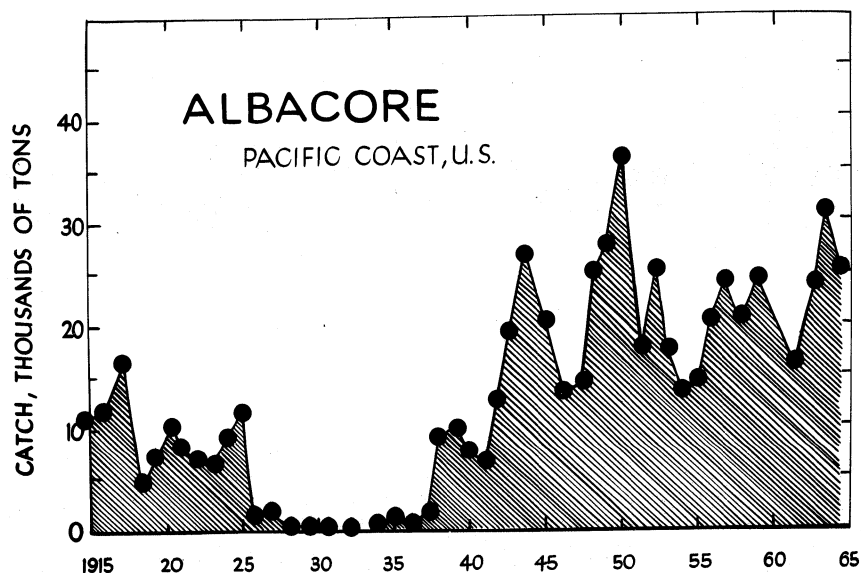


FIGURE 10

We are able to identify these currents and water masses by their temperature and salinity characteristics. For instance, the California Current, since it originates in northern latitudes, is a cold current. High rainfall and reduced evaporation in north latitudes also keep its salinity relatively low. By monitoring the temperature and salinity characteristics of the ocean waters, we are able to detect changes in current patterns and forecast distribution of the fish associated with these current systems. For example, the Coast Guard provides monthly flights along the Pacific Coast from Seattle to Southern California, to enable the Bureau of Sport Fisheries and Wildlife to make aerial infra-red measurements of surface temperature patterns. This information is distributed promptly to commercial and sport fishermen.

Our laboratory at Stanford University has been studying broad-scale changes in the Pacific Ocean temperatures by month over the years 1949-1962 to discover what changes have occurred (Fig. 11). In the early years of the period the eastern Pacific Ocean temperatures were lower than average, but between 1956 and 1957 a major change occurred: the eastern Pacific became much warmer and the western Pacific colder and remained so for several years.

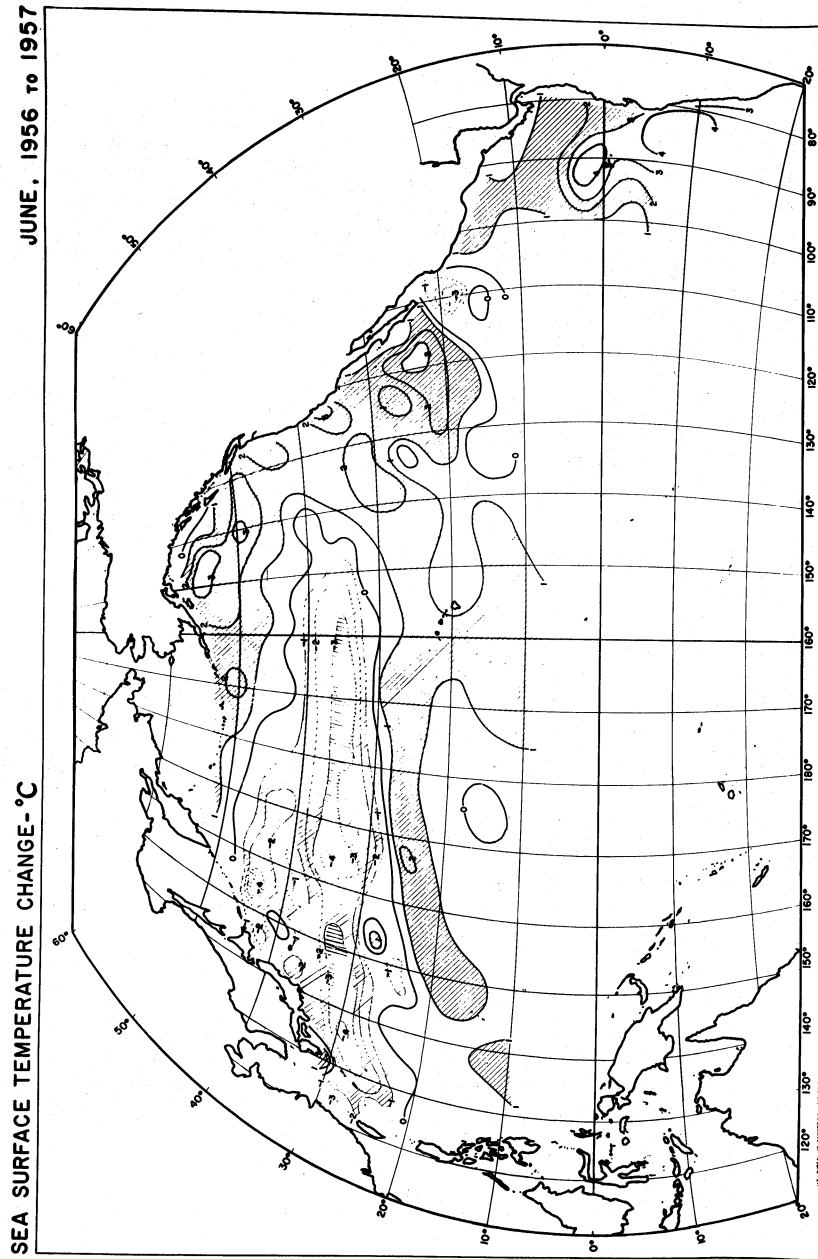


Figure 11

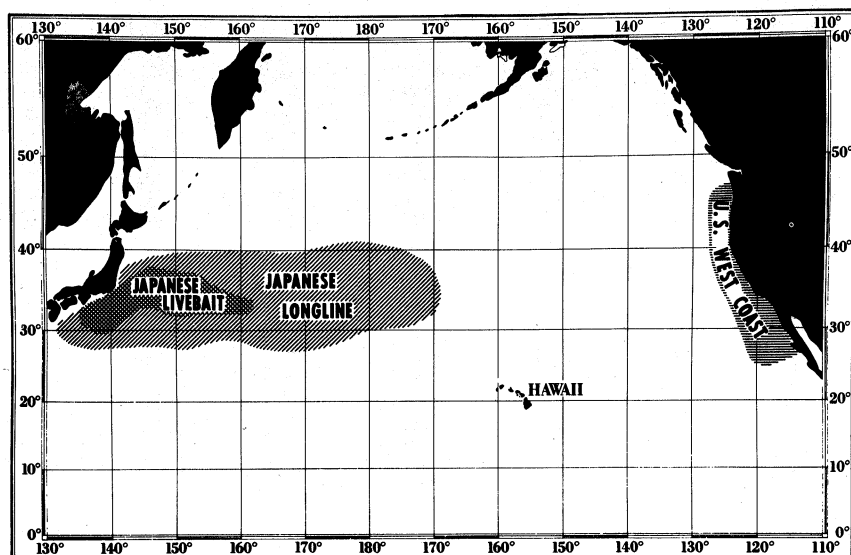


FIGURE 12

Albacore distribution in the eastern Pacific was affected by these changes in ocean conditions. Albacore are known to make transpacific migrations (Fig. 12). At some stage of life the same fish may be sought by Japanese live bait fishermen off Japan. Japanese longline fishermen in the west central North Pacific and sport and commercial fishermen off the west coast of North America. In May and June each year the albacore move from central North Pacific waters into North American coastal waters. When spring warming occurs early in coastal waters, the albacore arrive early. If the coastal waters are warmer than usual, the fish appear farther north. The area of best catches during typical warm years is off Northern California, Oregon and Washington. In cold years most of the fish remain off Baja California and California (Fig. 13).

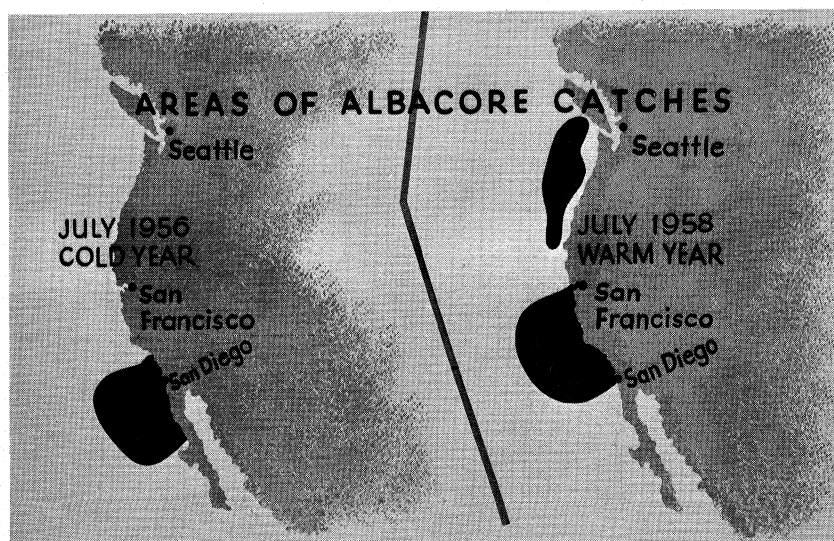


FIGURE 13

The temperature changes are a reflection of changes in the California Current system. Once these conditions develop, they persist for several months and sometimes for several years, which is why we can forecast where the fish may appear off our coast. But sometimes we have made forecasts only to be contradicted by radical ocean changes between time of forecast and onset of fishing. We must understand causes behind these broad-scale ocean changes if we are to increase our precision in forecasting.

Downstream from the California Current, variations in the California Current Extension waters affect the Hawaiian skipjack fishery. Of importance in Hawaii are the North Pacific central and the North Pacific equatorial water types of the transition zone between these, the California Current Extension (Fig. 14). The boundary between the California Current Extension, with rela-

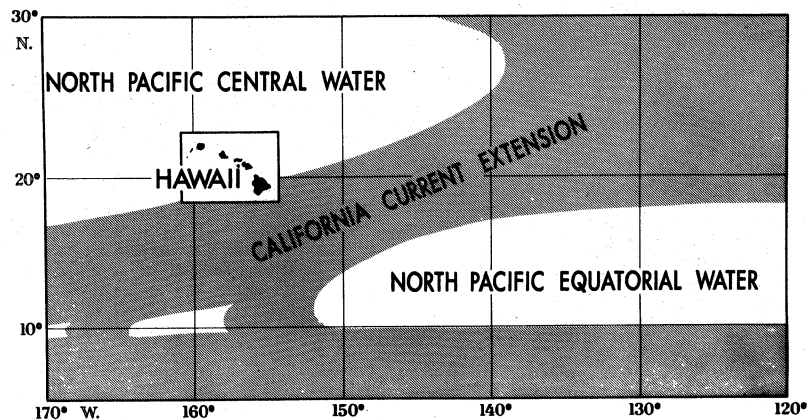
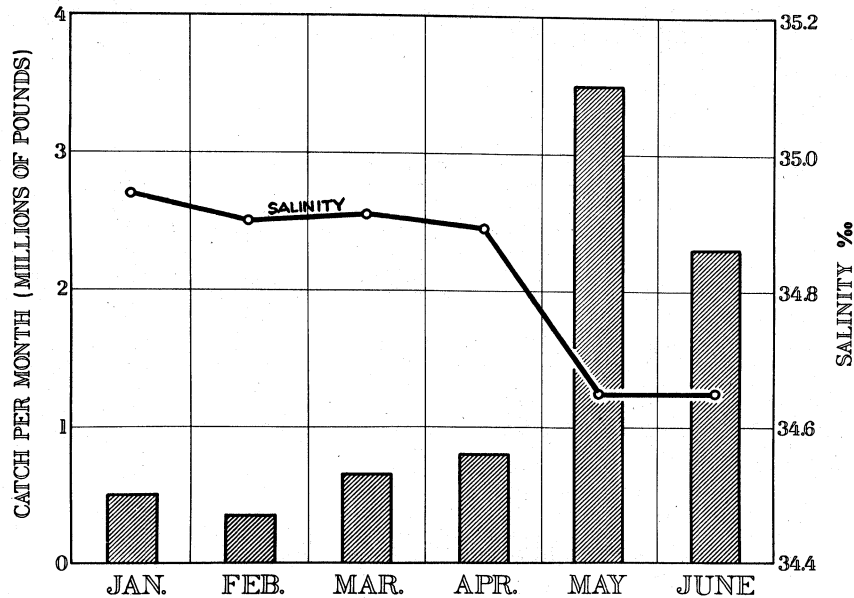


FIGURE 14

tively low salinity, and the North Pacific central water, with relatively high salinity, is well defined by a salinity gradient which usually lies just south of the islands during late autumn and early winter. During February or March it begins a northward movement, passing the islands in spring and reaching its northern position just north of the islands in July or August. The movement of the boundary is reflected in changes of surface salinity which are monitored by regular sampling near Koko Head, Oahu. It has been found that when the California Current Extension bathed the islands in summer skipjack landings were above average, whereas when North Pacific central water prevailed landings were below average. From these findings and additional information on water temperatures, we are able to predict whether skipjack landings will be above or below average for the season.

Other factors

We have found that some of the differences in tuna abundance are related to the topography of the ocean bottom. Fishermen have known for years that tuna will congregate at times near islands or reefs. Later it was discovered that they also like to gather around seamounts, which do not reach the surface. The regular navigational charts were not adequate to locate these features on the fishing grounds, so the Bureau developed its own set of charts. These are in great demand by tuna fishermen.

Tuna also gather around floating objects in the sea. This characteristic also has possibilities for aiding the fishing fleet. We are studying phenomenon from a floating raft with underwater viewing ports. Preliminary results have been spectacular. In a relatively short period the raft accumulates a following of oceanic fishes, from small forage fish to large dolphins, tunas, and sharks.

Although we can explain causes for local variations in abundance and distribution of fish stocks on the basis of changing ocean conditions, we have had to look farther and farther over the horizon, as much as many thousands of miles away, to try to explain why the ocean changes.

The answers lie in understanding interactions between global atmospheric and ocean circulation. Scientific studies recently carried out by the Inter-American Tropical Tuna Commission have shown that strength and position of the Azores high pressure cell over the Atlantic Ocean affects precipitation and winds in the eastern tropical Pacific Ocean, which in turn affect ocean circulation and distribution of tunas in the eastern Pacific. The strength and position of the Azores high also affects upwelling and increases biological productivity off the coast of Africa, with profound effects, no doubt, upon fisheries there also.

Another study by the Tuna Commission suggests that the severe 1957-58 "El Nino"—a flow of warm surface water into coastal Peru where normally cold water is found—was related to meteorological and oceanographic processes thousands of miles to the westward in the Pacific Ocean. It is known also that the severe Tehuantepec storms that roar into the Pacific in the winter through the Isthmus of Tehuantepec, Mexico, affect the biological productivity of ocean waters and movements of tuna in the eastern tropical Pacific. Events that push cold air southward over the United States into the Gulf of Mexico, producing Tehuantepec winds frequently have their origin in the North Central Pacific or even over northeast Asia. The same atmospheric conditions over northeast Asia that may ultimately produce Tehuantepec conditions also cause winter monsoons in the northern Indian Ocean. Northeast winds bring dry continental air over the Indian Ocean, causing surface water flow to the westward. Low rainfall and high evaporation cause a rise in salinity. The process reverses in the summer monsoon from May to September. Undoubtedly, but in a way still little understood, the monsoons have a profound effect on abundance and availability of Indian Ocean resources.

We are convinced that we must pay more attention to global atmospheric and oceanic circulation. In this respect we are now studying possible application of earth orbiting satellites, which will give us this global look, to assist in marine resource development. Problems in marine resource development and management will intensify in the future, and we must use the best of the newly developing technologies to solve these complex problems.

WATER USE+REUSE=FORMULA FOR PROGRESS

This Nation and the world are beginning to realize that natural resources must be used and used again many times to sustain our increasing rate of population growth and industrial and economic development.

The principle of use-reuse applied directly to many of our most common natural resources. As examples, steel used in automobiles is salvaged and re-used again, even in automobiles; the oil drained from crankcases is often refined and reused. Wood products are refinished and reused, perhaps occasionally as an antique but more often as a raw material for cardboard or pressed wood manufacture or, at least, as a fuel in some domestic or industrial furnace. Wool and cotton are reprocessed and rewoven into cloth. The air we breathe, even now, has been inhaled and exhaled by others and used previously in manufacturing, combustion, or cooling processes. Soil and minerals are re-used—the whole concept of crop rotation is built upon this principle and building materials, brick, stone, concrete, are frequently re-used, if not directly in construction then in landfill or breakwaters. Even the fashion world has jumped on the reuse bandwagon—hair cuts provide the source material for toupees and wigs. And on it goes—the examples are almost endless.

If we did not purposefully reuse our natural resources, it would be as if we traded in the family car every time it got dirty. We cannot afford that luxury or, rather, that needless extravagance. So it is with water—along with air, our most basic and most essential natural resources. We wash our cars when they get dirty; likewise, we must “wash” our water when it becomes dirty.

The hydrologic cycle

The volume of water on this earth is fixed. This volume has served the needs of this planet over and over again through a natural use-purification-reuse process called the hydrologic cycle. Briefly, water evaporates from the ocean into the atmosphere, it condenses to rain and falls on the land, it is “used” by man, by animals, by nature, and then it flows into our rivers to the ocean where it evaporates again, and the cycle continues. But water is used and re-used much more directly when we consider the withdrawal of water from streams by cities and by industries to be used and then returned to the very same streams as wastewater.

Many people have heard the old adage that a stream is purified every seven miles. This natural renovation of used water is what we call “stream self-purification” and there is some validity to the concept. In simpler times stream self-purification was often able to accomplish satisfactory results. Unfortunately, by today's standards and with today's waste burdens, natural purification can cope with only a small fraction of our wastes and with only the simpler, non-persistent types.

Giving nature a hand

What pollution control scientists of the Department of the Interior are trying to do, in essence, is to supplement the natural treatment involved in stream self-purification and in the hydrologic cycle. Research and development in water pollution is aimed at obliterating the pollution burden which man is placing on the natural water purification cycle and simultaneously at supplementing the earth's natural supply of fresh water by providing man-made purification systems allowing the purposeful and direct recycling and reuse of water. In other words, we are trying to find ways to renovate wastewaters so that they are no longer detrimental to the environment and so that they, effectively, become “new” supplies of clean, fresh water.

Because man's and industry's wastes are complex and are becoming increasingly more complex, the new purification methods being developed are quite sophisticated and advanced technologically. These methods to combat water pollution are among the highest examples of the scientist's and engineer's art. They are being developed by the Department of the Interior's Federal Water Pollution Control Administration, and in a sense may be looked upon as analogous to a scientific formula. Like a formula, advanced waste-treatment systems are composed of numerous factors which may be fitted together and interchanged to solve particular pollution problems or to produce reusable water of a desired quality. The more difficult the pollution problem is, the greater the number of factors in the formula.

The degree of purification required is determined by the specific purpose for which the treated water will be used. At some locations the irrigation water used for non-edible crops, for golf courses, and for parks is municipal waste effluent that has been conventionally treated and then chlorinated; many of the organic and all of the inorganic impurities are not removed. To produce water for industrial reuse, the treatment sequence might have to remove scale-forming and corrosive components. To reuse wastewaters recreationally, treatment must include steps to disinfect, remove algae nutrients, and to eliminate distasteful conditions such as color, odor, and foaming. To renovate a wastewater so that

it could be deliberately reused for municipal purposes, that is, for drinking, cooking, and bathing, a treatment sequence would be needed to *completely* purify the water of suspended and dissolved organic and inorganic impurities. As can be seen, a number of purification processes must be available to remove the various types and quantities of contaminants. These various processes are the variables in the advanced waste-treatment formula.

Types of treatment

There are two general types of treatment sequences. They represent the concerted efforts of research and development over the last six years by scientists and engineers in the Federal water pollution control program. In the series-type system (Fig. 15), the total flow passes through all processes or steps in sequence. In the parallel sequence (Fig. 16), the flow is divided into two parts; each part passes through different treatment steps and then the flows are recombined.

SERIAL FLOW RENOVATION SYSTEM

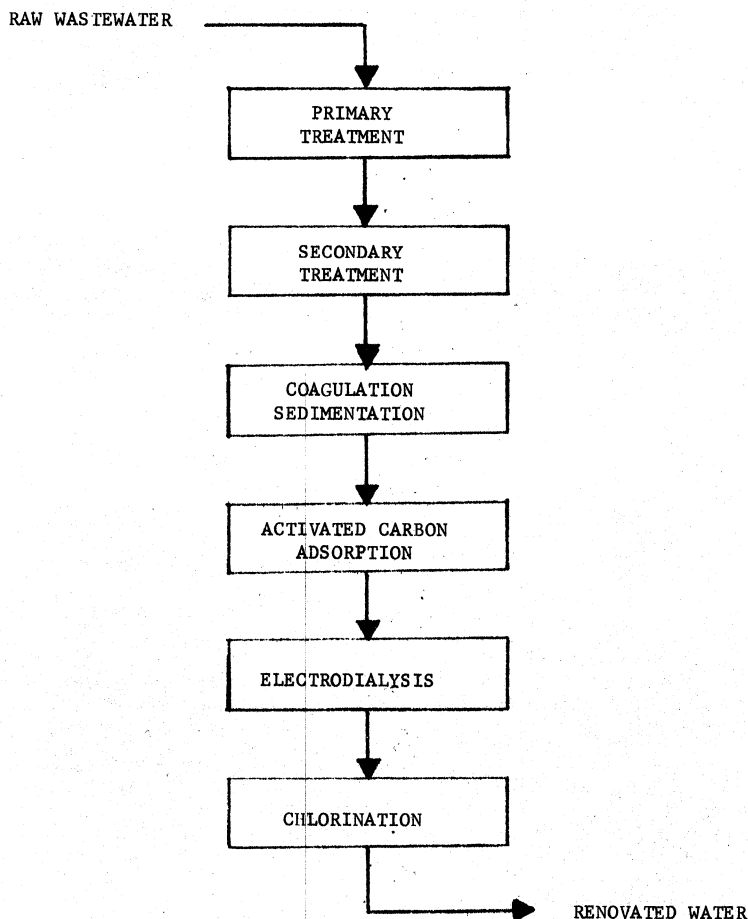


FIGURE 15

PARALLEL FLOW RENOVATION SYSTEM

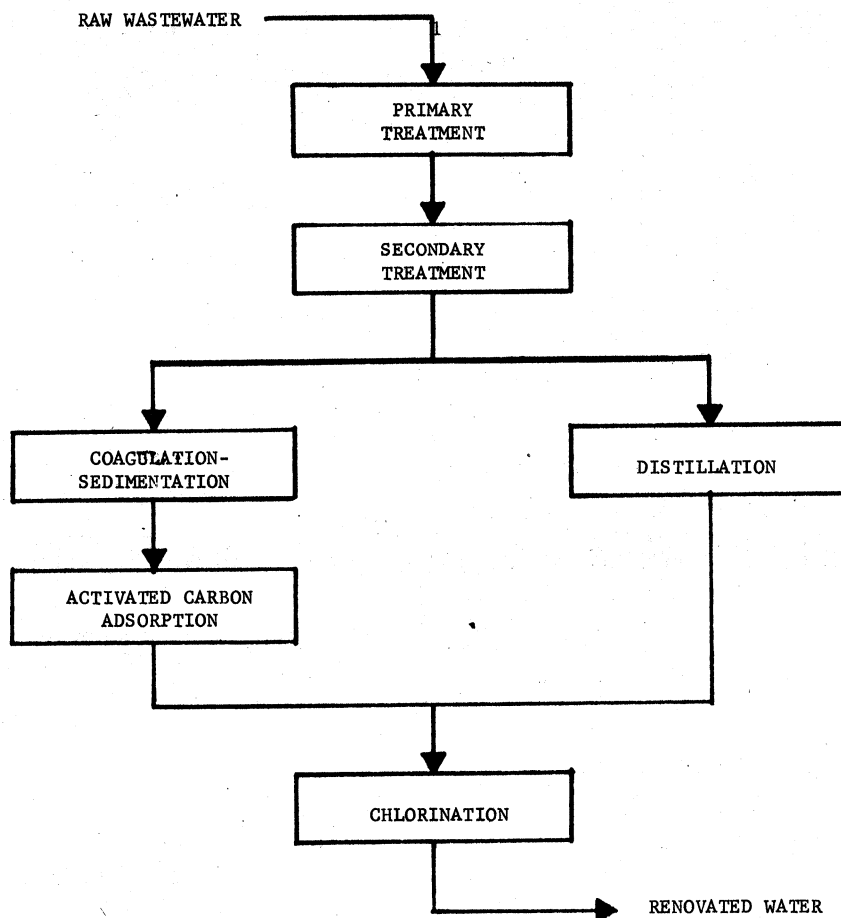


FIGURE 16

Advanced waste-treatment now generally involves the treatment of wastewaters after they have passed through conventional primary and secondary treatment. Primary treatment removes materials that easily settle or float; in general, these are the impurities that can be easily seen with the naked eye. Secondary treatment involves the use of bacteria to break down impurities—called biologically degradable contaminants—under controlled conditions. These degradable contaminants are primarily organic compounds of natural origin. After secondary treatment, the waste may be purified by such processes as filtration, coagulation-sedimentation, activated carbon adsorption, chemical precipitation, electrodialysis, distillation, reverse osmosis, or ion exchange. A possible advanced waste-treatment plant is shown in figure 17 and changes in water quality through such a plant are given in figure 18.

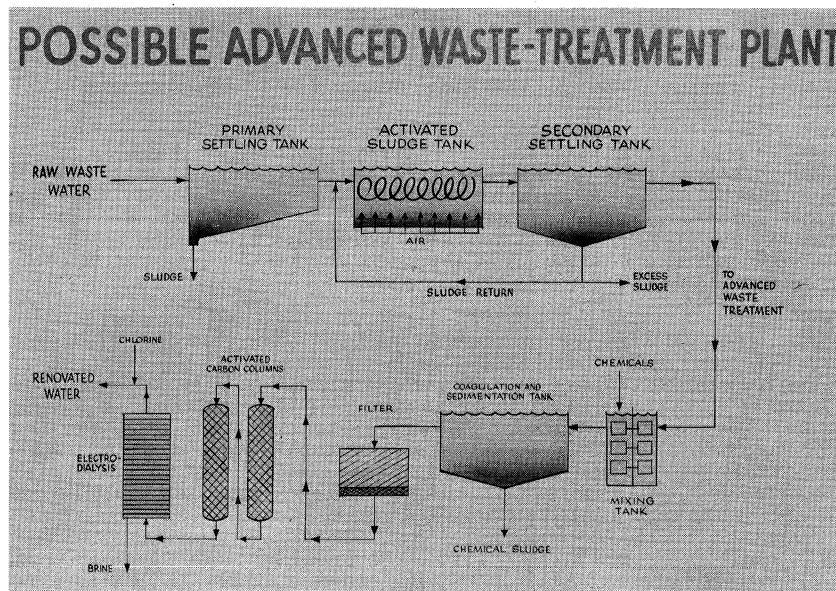


FIGURE 17

NOMINAL WATER AND WASTEWATER COMPOSITIONS

		TAP WATER	RAW SEWAGE	PRIMARY EFFLUENT	SECONDARY EFFLUENT	RENOVATED WATER
SUSPENDED SOLIDS,		LESS THAN				LESS THAN
ppm		0.1	300	200	30	0.1
BOD (BIOCHEMICAL OXYGEN DEMAND),						
ppm		0	300	200	30	0
TOTAL ORGANIC MATTER (TOC),						
ppm		2	100	75	15	1
TOTAL DISSOLVED SOLIDS,						
ppm		400	800	800	750	400
MICROORGANISMS, No. 100 ml						
a) TOTAL COUNT AT 57°C.		500	1×10^9	1×10^7	1×10^6	100
b) COLIFORMS		0	1×10^7	1×10^5	1×10^4	0

FIGURE 18

For removal of suspended and colloidal solids and for precipitation of phosphate nutrients, several coagulating substances can be added to wastewater. Alum, lime, or both can remove solids quite efficiently, and, with proper modification and control of the operation, over 90% of the phosphates can be removed.

Soluble organics including synthetics, petrochemicals, pesticides, etc., may then be removed very effectively by passing the wastewater through a bed of activated carbon granules. As the carbon granules become saturated or "spent," they are passed through a high temperature furnace where the carbon is "reactivated" and the adsorbed contaminants are incinerated to harmless carbon dioxide and water. Adsorption, using granular activated carbon, is perhaps the furthest developed of the advanced waste-treatment processes.

A municipal wastewater treated with the two preceding processes in series will, with one exception, have been restored to a chemical quality generally comparable to that of the city's tap water before it was used. The exception is the dissolved inorganic salts which are added during each use of a water but which are not removed by these two processes. A single municipal use of water adds about 300-400 mg/1 of dissolved salts. Since many water supplies contain dissolved salts at approximately this same concentration, one municipal use of the water roughly doubles the dissolved solids or mineral content of the water. Fortunately, a single pass through a treatment process called electrodialysis can reduce the concentration of dissolved minerals by about half; the removal achieved, therefore, is roughly equal to the salts added to the water during use. Electrodialysis is one of the most promising methods for removing these inorganic pollutants from water.

Other processes

Other potential advanced processes are on the drawing boards or in various stages of development. Bio-denitrification is a process in which microorganisms reduce harmful nitrates to elemental nitrogen under certain process conditions. The use of finely powdered activated carbon instead of granular carbon is being studied. The adsorption rates for powdered carbon are much higher than for granular carbon. The foam separation process makes beneficial use of the unwanted foam so common in many municipal and industrial wastewaters. Organic contaminants may be removed from waste by deliberately generating a foam and then physically separating the foam from the liquid.

Chemical oxidation can selectively destroy the refractory or highly resistant organic materials which are only partially degraded by conventional biological treatment. Oxidants such as ozone, chlorine, and even oxygen from the air itself are under investigation. Chemical oxidation has the advantages of removing organic contaminants without producing a residual waste concentrate and of simultaneously destroying all microorganisms, bacteria and viruses.

Experimental work on distillation of wastewaters is in an early stage of development. From studies to date it has been established that volatile contaminants will carry over into the distillate. Fortunately, it appears that these materials may be removed by activated carbon treatment or by ion exchange, but considerably more research and development is needed to assess the applicability of distillation as an advanced waste-treatment process.

Reverse osmosis, in which highly pure water is actually squeezed through specially made plastic membranes, is one of the more intriguing processes now under study. Laboratory and small-scale pilot plant tests to date have produced product water containing less than 50 mg. per liter of dissolved solids.

Finally, the ion exchange process, which was earlier given low priority because available ion exchange resins tended to become fouled by organic materials commonly found in wastewaters, is being given new emphasis. As a result of new developments in resin technology, this process shows considerable promise for removal not only of dissolved minerals in general but potentially of specific impurities also both organic and inorganic.

Using processes already developed and now being operated in pilot-scale installations, it is possible to achieve any degree of waste treatment desired and, in fact, to purify wastewater to drinking water quality. The water in this container was wastewater from the City of Lebanon, Ohio, near Cincinnati. At Lebanon we are operating an advanced waste-treatment pilot plant incorporating coagulation-sedimentation, filtration, activated carbon adsorption, electrodialysis, and disinfection. This water is potable. In fact, it exceeds in quality the tap waters of a great many communities in the United States at the present time.

Our present research is aimed at bringing these processes to full-scale embodiment and confirming through full-scale demonstrations their cost, performance, and operating reliability. It is also our aim to explore and develop new and improved systems capable of achieving these treatment goals at even lower costs and with even greater efficiency.

Pilot projects

The FWPCA is operating pilot plants at Pomona (fig. 19) and Lancaster (fig. 20), Calif., as well as at Lebanon, Ohio (fig. 21). Additional pilot plants are being designed or constructed at Piscataway, Md., and Manassas, Va., as well as right here in Washington, D.C. Advanced waste-treatment projects now being supported by research and development grants include those at Santee, Irvine, and San Jose, Calif.; Lake Tahoe on the Nevada-California border; Dallas, Tex.;

Fort Collins, Colo.; and Green Bay, Wis. Full-scale water re-use for irrigation and industrial processes is becoming more widespread in Texas, New Mexico, Arizona, Nevada, and California. Serious consideration is being given to installing a complete water renovation facility at Grand Canyon.

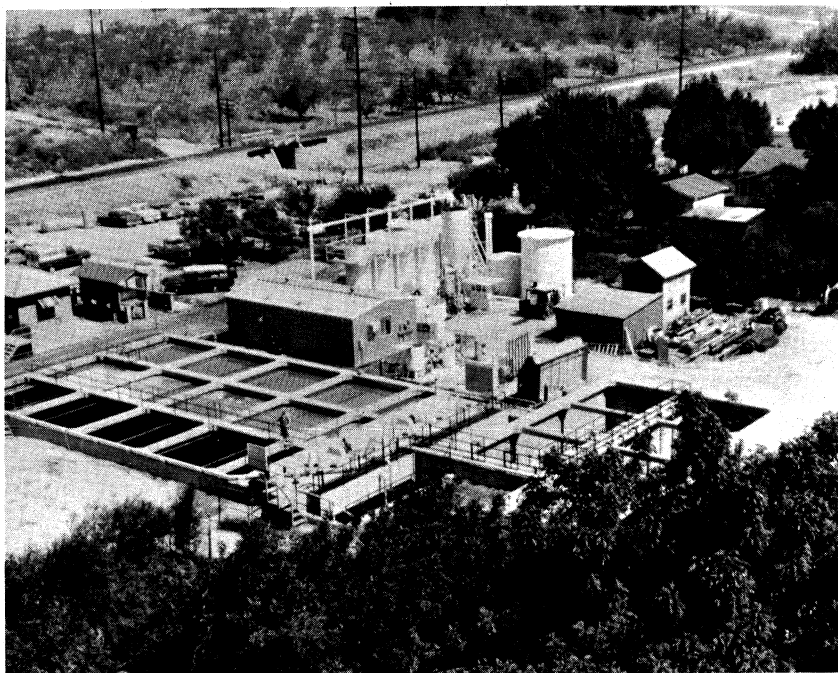


FIGURE 19

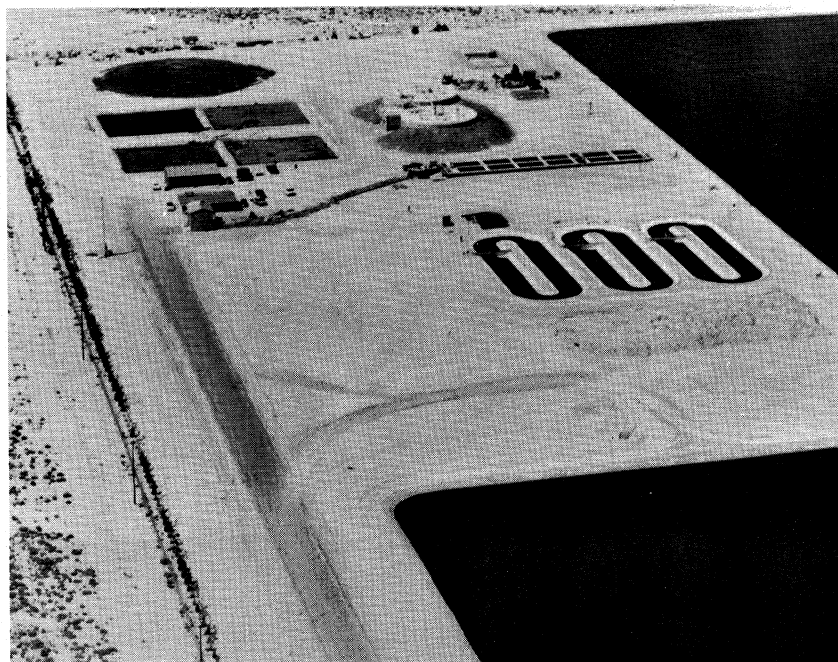


FIGURE 20

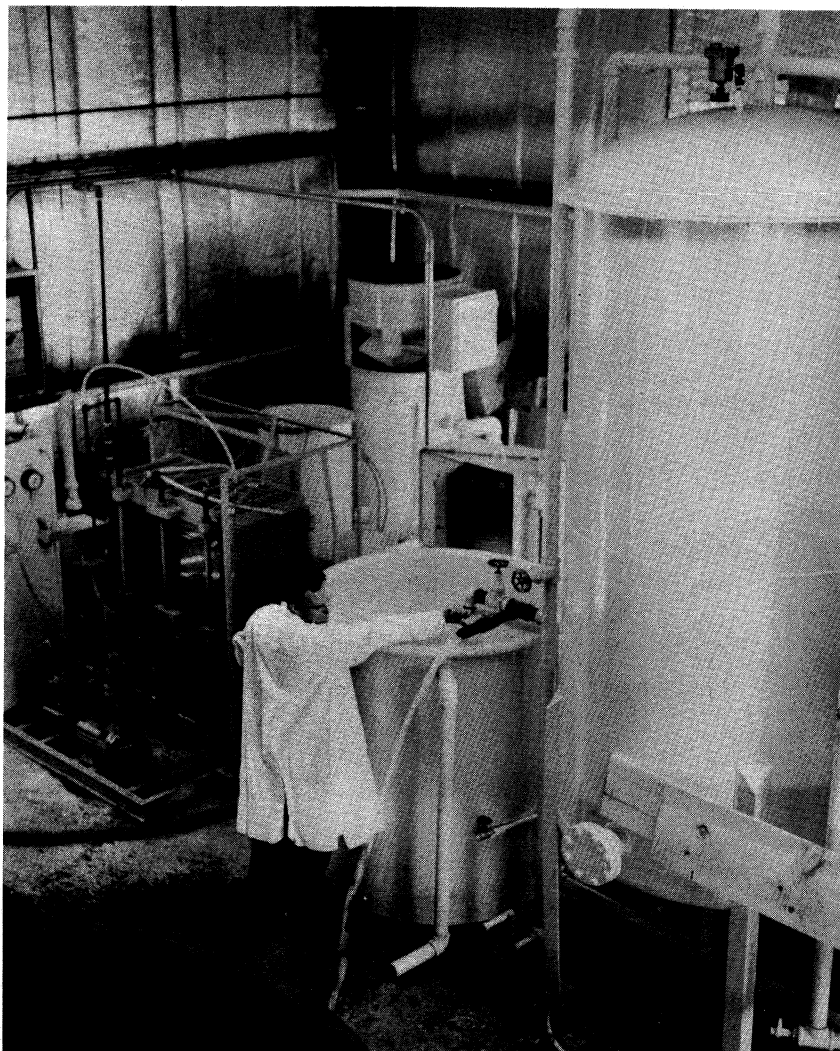


FIGURE 21

The project at Santee, Calif., near San Diego, is particularly noteworthy. Here, wastewater is purified to the extent that it can be used without dilution in a series of man-made lakes for recreational purposes—boating, fishing, and even swimming (fig. 22). The public acceptance of renovated wastewater at Santee is a real milestone in wastewater re-use. The public is completely aware of the source of the water and has accepted it enthusiastically. A similar project is being planned at Lancaster, north of Los Angeles. In this community, adjacent to the arid Mojave Desert, renovated wastewater will be used to develop an inland aquatic park. Overflow from the recreational lakes will then be used industrially and finally, will serve as irrigation water for adjacent lawns, parks, and golf courses.

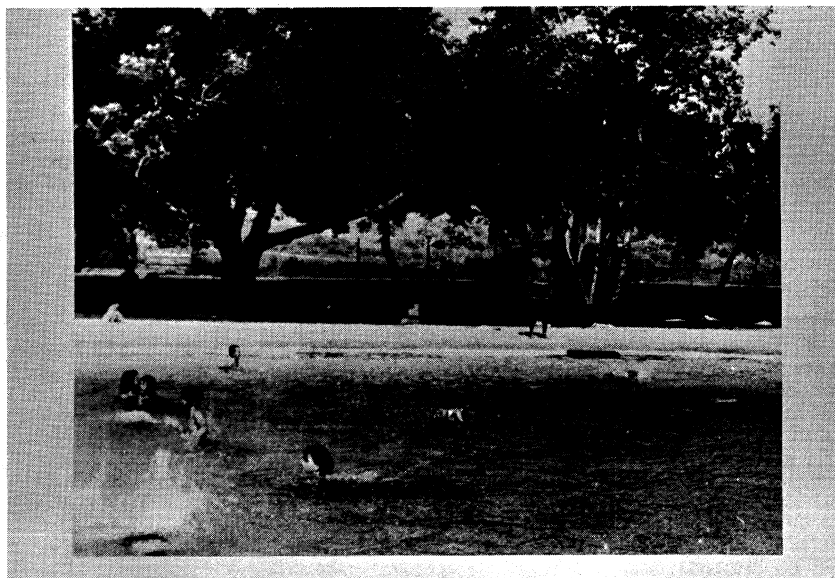


FIGURE 22.—Use of renovated waste water for swimming at Lake Santee, Santee, California.

Several advanced waste-treatment processes are being tested for treatment of irrigation return flow waters. Potentially, such waters could be recycled and reused thereby eliminating the pollution load on streams and simultaneously augmenting the irrigation water supply.

In the industrial area, the project at Fort Collins, Colo., involves studies to develop high efficiency treatment for sugar beet factory wastes. The objective is to concentrate the wastes by chemical precipitation and to re-use the purified effluent in a closed in-plant recirculation system. Can you imagine such an industrial plant without a waste outfall? Such is the ultimate objective of this research. Another research project at Richland, Wash., is aimed at developing selective ion-exchange materials which could remove ammonia from industrial or domestic wastewaters as well as from agricultural run-off. At Green Bay, Wisc., a research study is just getting under way to evaluate various advanced processes for treating combined municipal and industrial wastewaters.

In summary, research and development on advanced waste-treatment and wastewater renovation technology has been under way since late 1960. Its objective has been the development of an arsenal of treatment tools capable of achieving any goal in waste water purification. Approximately 30 advanced waste-treatment processes have been or are now being screened to assess their technical and economic feasibility. About one-third of these have been rejected from consideration, and several have been developed into the large pilot-scale stage. In the last few months a number of research and development grants have been awarded by the Department of the Interior to various communities to initiate design and construction of full-scale demonstrations, large-scale field evaluations, and pilot plant investigations of these processes. Other processes now undergoing feasibility evaluation or in the engineering development stage would allow purification of wastewaters from either municipalities or industries to such a degree that pollution from these sources could be completely eliminated.

In advanced waste-treatment lies the final answer to many of our water resource problems. With this technology we believe we can come close to fulfilling President Johnson's recent pledge to "doom water pollution in this century."

EROS

What is EROS?

Recent aerospace activities have shown that data acquired from spacecraft can provide much important information on the earth's natural resources. EROS is the acronym from Earth Resources Observation Satellite, the Department of the Interior's program for applying all types of space data to the natural resources problems it faces. A satellite designed especially for sensing and transmitting information on natural resources is envisioned and would be of tremendous value to the program. EROS is being carried out cooperatively with NASA, the Department of Agriculture, and other agencies of Government, and is designed to blend the resources expertise of Interior with the space flight engineering expertise of NASA into a meaningful and economical earth resources survey program.

Where do we stand technically?

The Geological Survey and other Bureaus of the Department of the Interior have been applying remote sensors to resources problems for more than a quarter of a century. This experience, supported by the fund of resources information and resources associations developed through more than a century of study, enables the Department to define its data needs and to apply the data toward the solution of national resources problems.

During the past four years, we have been working intensively with NASA in aircraft sensor surveys of selected sites in the United States (Fig. 23). These recent surveys have improved our ability to apply well known sensors, such as cameras, in an optimum manner and have developed a greater understanding of the resources applications of the newer sensors, such as radar.

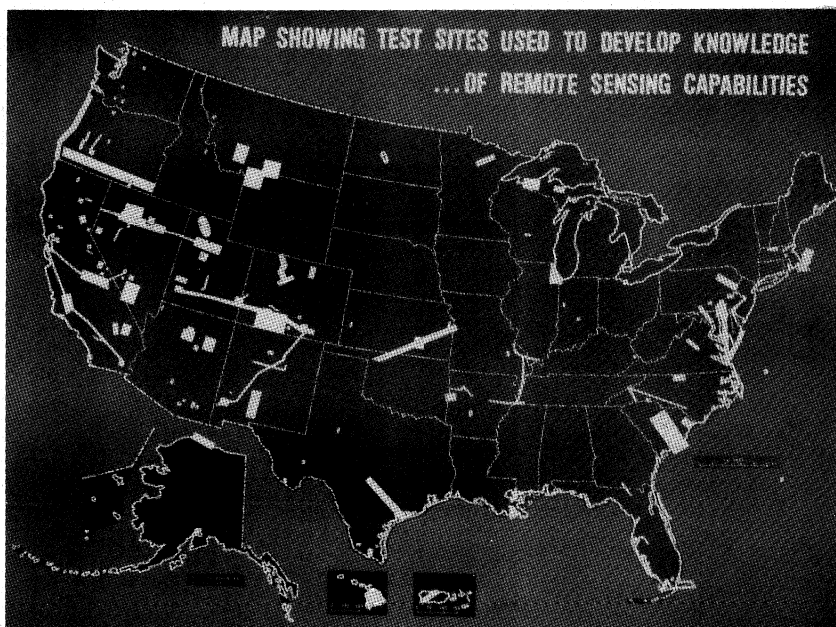


FIGURE 23

Studies of data acquired from Gemini and other spacecraft have demonstrated the validity of our theoretical conclusion that data acquired from space have unique qualities that recommend their use for analysis of changing conditions on the earth's surface and for the design of regional developments. These data also fill a role in the logical process of "zeroing in" on a resources target (Fig. 24).

NEW INPUT TO SYSTEM

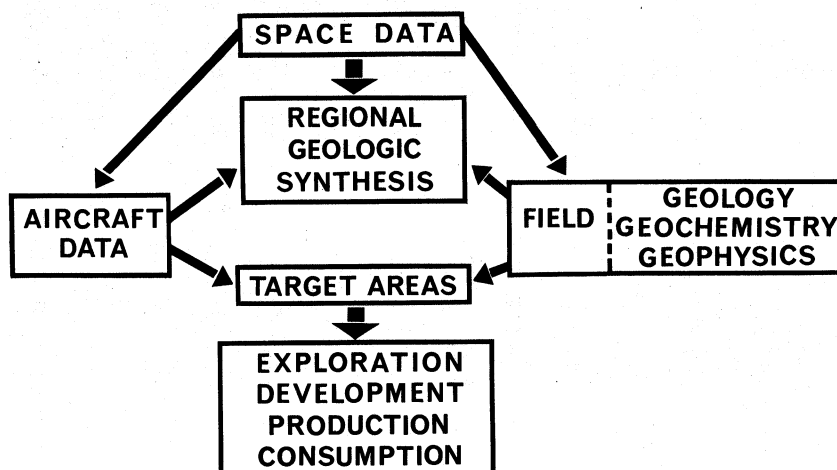


FIGURE 24

Our experience has enabled us to develop a simple set of performance specifications for a general purpose, resources satellite. We believe that these specifications can be met with equipment already in existence or with equipment that could easily be built. We also believe that there will be a continuing need for a satellite of the type we envision and that the results of a survey of the earth with this satellite will amply justify a continuing, cooperative program of research utilizing increasingly sophisticated sensor systems.

Our performance specifications have been transmitted to NASA; they are currently being equated against available satellite and sensor systems by the Goddard Space Flight Center, and we have offered to help fund an experiment, provided the recommended system fulfills our requirements and can be expected to lead toward an operational system.

Where do we stand administratively?

Secretary Udall has asked the Geological Survey to act as the lead agency in developing a unified EROS Program that will meet the data needs of the largest possible number of Bureaus and Agencies. We have organized this effort on a Departmental basis (Fig. 25). Dr. William T. Pecora, Director of the Geological Survey, is serving as the Director of the EROS Program.

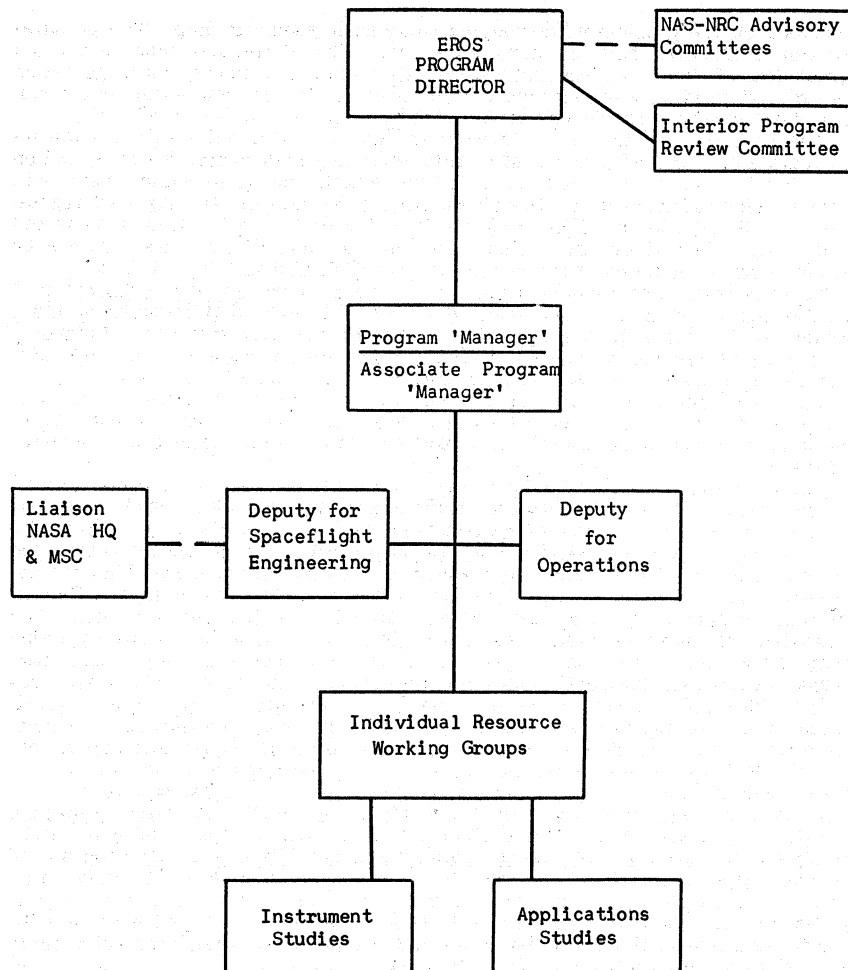


FIGURE 25.—EROS Program Organization.

Various Bureaus of the Department have appointed liaison personnel who meet regularly with the EROS Program staff to review progress and to develop data requirements. As shown in figure 3, an Advisory Committee has been organized in the National Academy of Sciences; this committee meets approximately four times a year to review overall progress toward objectives and to recommend additional studies to provide proper program balance.

A contract has been awarded to the Westinghouse Corp. to conduct an applications and cost-benefit analysis for the Department. We expect that the analysis will be complete by early fall. This effort, complementary to cost-benefit studies being undertaken by the Department of Agriculture and NASA is funded by Interior Bureaus from their own resources.

What are we doing now?

At the present time, we are completing work on a rationale for an initial, general purpose, earth resources observation satellite. This satellite is specifically

focussed on the problem of developing small-scale thematic maps. The preparation of small-scale thematic maps is our most difficult resource task; it takes a great deal of time to collect and reduce data from many places in a large region in order to produce a map giving a broad overview. These small-scale maps cannot, with present methods, effectively portray features of a dynamic quality.

The sensors that have been selected for the initial satellite will provide information on the configuration of terrain, including underwater features, and on the distribution of water as free water and as moisture. These same sensors will also provide information on the distribution of vegetation, the vigor of vegetation, the distribution of alien fluids within water, and the coloration of rocks and soils. We believe these observations are the most meaningful ones that can be made to serve the needs of the largest number of disciplines.

These sensors have a common geometry so that the results of the observations may easily be compared. The selected sensors and orbital parameters produce images that contain the least possible number of variables so that the data may be usefully applied to resource purposes by scientists having a minimum of training and experience. Also, the data are amenable to automatic analysis.

We are planning on a long-life vehicle so that we may determine the rates at which land use and other changes are taking place and so that we may obtain resource information from seasonal variations in the appearance or character of the terrain.

One of the initial objectives of the program is to produce a photo-image map of the world. The desirability and practicality of undertaking such a task is demonstrated by the mosaic of space photographs of Peru, recently compiled by the Geological Survey. Secretary Udall, in describing this mosaic before the recent meeting of the American Society of Oceanography, said "This mosaic covers roughly a third of a million square miles. In just one pass, the Gemini astronauts photographed almost 80% of Peru; it took just three minutes. The scientists who have seen this mosaic consider it to be superior to any available map of the region, in terms of information conveyed. One can see the gross patterns of land use, distribution of snow, the levels of the lakes, geologic features of possible economic significance—all at a single glance . . . the value of such mosaics in planning the development and use of lands is so great that I believe we ought to do more of this kind of work." Because of the inherent orthographic quality of space photography, this mosaic is in essence a map; the cost of compiling this mosaic was approximately one-tenth of one cent per square mile.

In addition to applying available space data to our current resources problems, and looking ahead toward the development of an initial program of space flight for resource purposes, we are participating in NASA's continuing program of remote sensor research. This research has the dual purpose of (1) developing new and increasingly sophisticated instruments for resource observation purposes and (2) evaluating instruments that have been developed elsewhere in the Government (principally in the military establishment) with respect to their potential use for resource purposes.

The Geological Survey is actively investigating the design and development of aircraft and spacecraft instruments to detect and measure reflected ultraviolet energy, ultraviolet stimulated luminescence, emitted infrared radiation, reflected radar energy, and the magnetic field of the earth. We are also working cooperatively with the Department of Commerce in defining camera systems which, when flown in orbit, will make possible timely revision of our national topographic maps. A recently completed cost-benefit study suggests an annual benefit of \$155 million per year from domestic map revision alone.

What are the potential benefits of our continuing research?

They Can Help in Our Studies of Geologic Hazards and Our Search for Sources of Geothermal Energy

Figure 26 compares an aerial photograph and an infrared image of Mt. Rainier, Washington. Bright areas on the infrared image are areas of abnormal warmth. The presence of thermal anomalies suggests that Mt. Rainier may still be a hazard; however, these anomalies also suggest that the mountain contains sources of thermal energy that might be harnessed for the benefit of man. The Geological Survey, the Government of Iceland, and the Air Force recently completed a cooperative infrared survey of known geothermal power sources in Iceland. These surveys demonstrated that modern infrared systems could be used to map potential geothermal power sources; all known thermal anomalies were successfully imaged, and a few previously unknown anomalies were found.

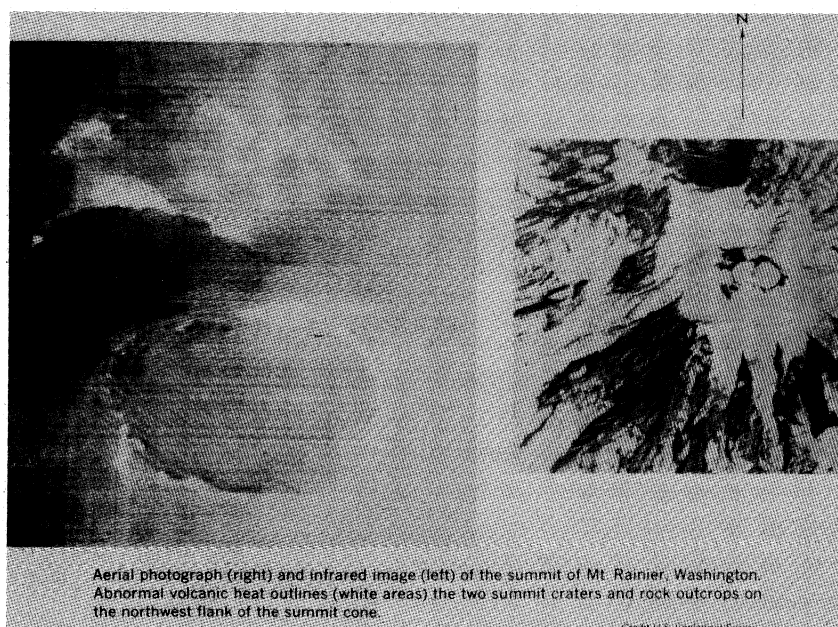


FIGURE 26

Infrared techniques have also been used to survey the Kilauea volcano in Hawaii, Taal volcano in the Philippines, and Irazu volcano in Costa Rica. The aerial inspections of Kilauea and Taal suggest that detectable changes in thermal emission precede some eruptions by as much as eight months.

Our scientists are applying both infrared and radar techniques to their study of geologic hazards associated with the San Andreas fault in California. This effort is an adjunct to other Geological Survey studies that are predicated on the proposition that earthquakes are predictable. Readings with these new tools are adding to our understanding of the history of movement along the San Andreas fault, and hopefully, we will soon be able to interpret them in terms of the dynamics of earthquake regions. The radar image, shown in figure 27 is an example of the kind of small-scale imagery that is becoming a valuable aid in studying potential geologic hazards to obtain guidelines for safe urban development.

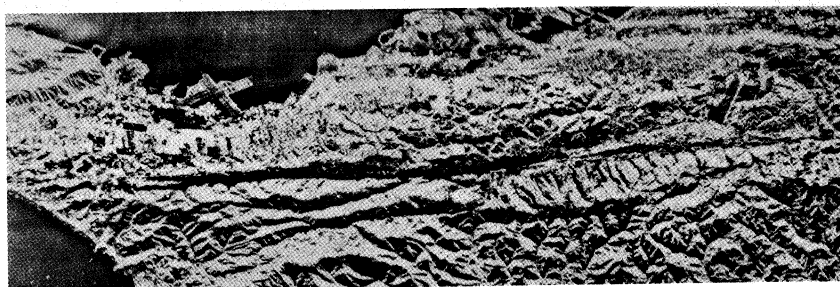
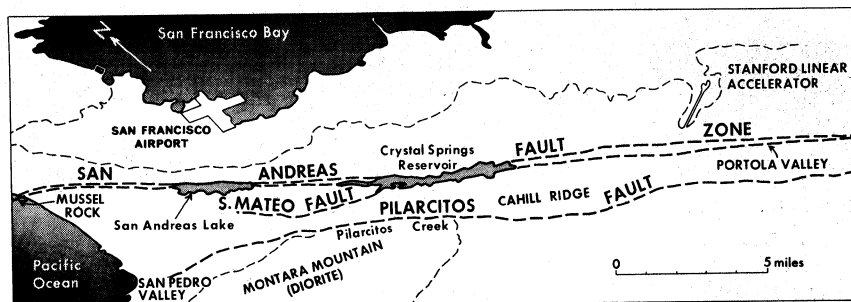


FIGURE 27

They Can Help in Our Search for Mineral Resources

Radar images of the Carlin, Nevada, area have revealed surface expressions of a number of faults, and they show that the recently discovered Carlin mine (the largest new gold mine in the United States) is associated with a previously unrecognized fault structure. These images suggest that other areas nearby are worthy of intensive exploration. It is almost certain that small-scale images acquired from space will add greatly to our knowledge of the tectonic framework of the United States and will be of immeasurable assistance in guiding our exploration programs.

They Can Aid Greatly in Achieving an Understanding of Dynamic Phenomena

Figure 28 is an infrared photograph and a topographic map of the Maumee River as it enters Lake Erie. The photograph depicts the course of the pollutants issuing from a sewage treatment plant and shows that the breakwater, constructed since the last topographic map was revised, is effectively impounding the sewage and preventing its dispersal into Lake Erie. This photograph strikingly illustrates our need for understanding the distribution of pollutants as well as their character and concentration. The following facts are particularly significant in pollution research: water quality meters give us precise data from pinpoint locations; the Geological Survey operates a water quality meter at the end of the quay on the east side of the river; the readings from this meter do not measure the quality of the water in the full cross-section of the river.

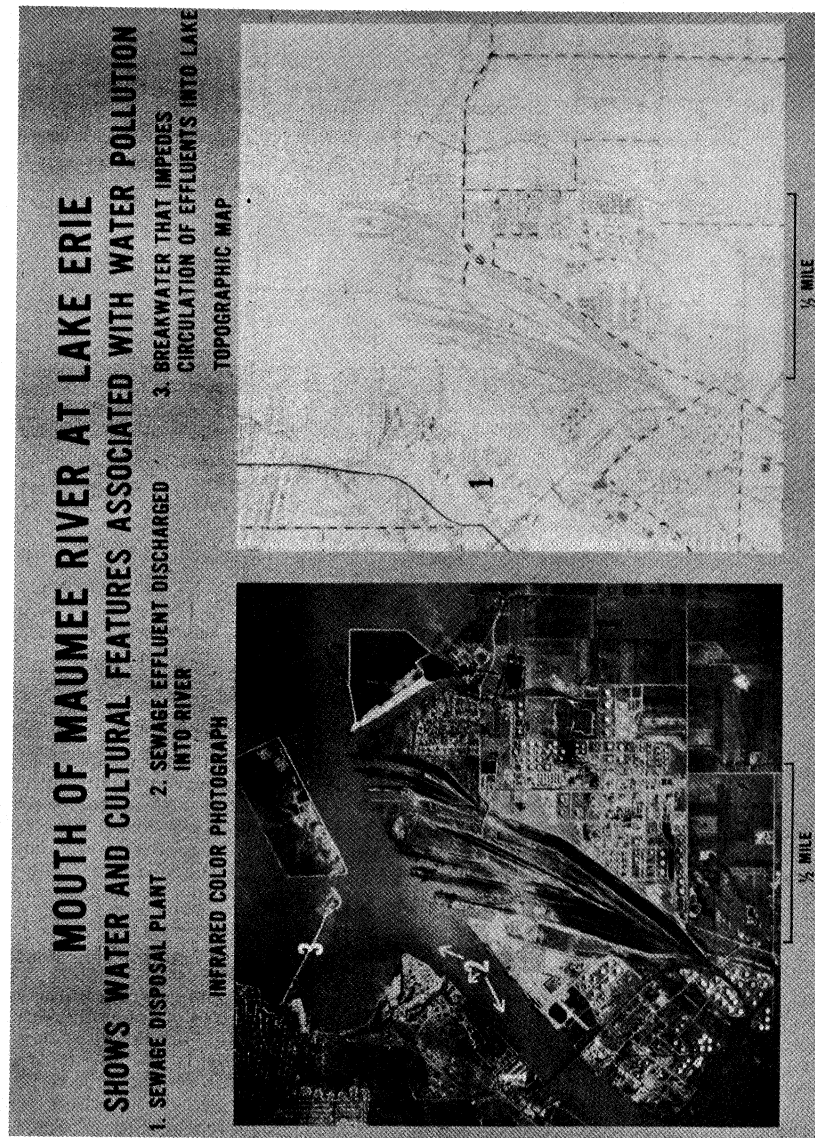


FIGURE 28



FIGURE 29.—Infrared imagery shows edge of salt water intrusion in estuary.

Figure 29 is an infrared image showing the interface between salt water and fresh water at the mouth of the Merrimack River in Massachusetts. Cooperative studies recently undertaken by the Geological Survey and the State of Massachusetts have demonstrated that we can use infrared techniques not only to locate interface, but to observe movement of the interface with time. We are now extending these observations to other estuaries, and we look forward eagerly to repetitive viewings of the dynamics of estuaries from space and to studying the relationship between these dynamics and the food resources of estuaries.

They Can Help Us Make Effective Use of the Sea as a Source of Food and Minerals

One can see further beneath the water from space than from any other vantage point. Improved knowledge of the configuration of the bottom in near-shore areas could help us significantly in our search for mineral deposits beneath the sea. Interior's Bureau of Commercial Fisheries, working cooperatively with the Navy Oceanographic Office, has demonstrated the feasibility of observing relative ocean temperatures from aircraft or space. Knowledge of water temperatures plays an important role in guiding our fishing fleets to their resource targets. Through the techniques of absorption spectroscopy, it now appears possible to identify the species in a school of fish by analyzing the light reflected from minute traces of oil that fish release to the surface of the ocean. It also appears possible that our ultraviolet investigations may lead to a system whereby we may observe bioluminescence directly from space platforms.

They Can Help Us in the Management of Our Nation's Lands

Recent Gemini photographs have shown that relative conditions of range lands in the United States may be assessed from space, and we plan to employ data from the initial EROS satellite for this purpose. We believe that this observational capability can be refined through the use of multispectral imaging systems so we can make a rapid determination of range condition—this would help in adjusting grazing densities to achieve greater food production from our national lands. Observations from space will, of course, help us in assessing the use of our recreational facilities, in monitoring changes in our national seashore areas, and in conserving our national parks and wilderness areas.

What Else Can They Do?

The resources potential of observations from space can be the subject of lengthy speculations, but in all probability some of the largest benefits will come from applications as yet undefined, and perhaps unimagined. We expect the unexpected, and we are prepared to adjust our programs to take advantage of these unforeseen uses.

What is our philosophy?

Our philosophy is very simple: We wish to take the best available tools, apply them directly toward solution of resource problems, and make the results available to the public for their use and benefit, as rapidly as possible. Our philosophy is perhaps best exemplified by our recent infrared survey of the periphery of the island of Hawaii. Because the temperature of fresh, ground water differs from the temperature of the ocean, we were able to map the distribution of approximately 250 large, unknown springs issuing into the ocean from the island. In effect, we were mapping the distribution of lost water. The presence of a number of these springs has been confirmed; their total flow is hundreds of millions of gallons per day. Maps have been prepared and released so that the public can use them to guide their search for water. Unquestionably, this survey will speed development of the island of Hawaii, and it has stirred world-wide interest.

SELECTED PROGRAMS—INFORMATION SYSTEMS TECHNOLOGY

NEW APPROACHES TO INFORMATION HANDLING

The most important input to all research, and especially that carried out in Interior, is the intellectual prowess and creative talent of the scientists and en-

gineers who carry it out. Each area of inquiry and each project has its own peculiarities and complexities and calls into play an individual combination of technical disciplines and facilities. Vocabularies, techniques, and perspectives differ—as they ought to—but some common problems can be discerned in virtually all research. Important progress is being made within Interior to ensure that emerging methodological innovations are applied as widely as possible, consistent with goals and priorities.

Among the problems shared by nearly all researchers are those of information sensing and recording, handling, and retrieval. Here electronic communications techniques offer exciting opportunities. These techniques have been given extensive applications in the major scientific spheres in which Interior scientists are engaged.

Observing and recording

The first of these is the observation of natural phenomena. In Interior this problem is often acute, because the research is concerned with phenomena that occur on a vast scale and cannot be transferred to or duplicated in the laboratory. Simultaneous observation and recording of widely dispersed data is now feasible with electronic monitoring systems.

The Federal Water Pollution Control Administration has some 29 complexes of recording and monitoring devices installed along various rivers and estuaries. The most sophisticated of these complexes is found along the lower Potomac where four devices have been installed which automatically collect water samples and make eight chemical, physical, and visual analyses every hour. The data are transmitted over telephone cables to central logging equipment at FWPCA headquarters in Washington. Continuous visual display of daily variations in pollution indicators will permit rapid response whenever water quality standards are violated. The equipment also prepares input tapes for digital computers. Data from all recording and monitoring systems are now stored in a PHS computer installation in Cincinnati, Ohio, from which Federal scientists, contractors, and grantees can retrieve information regarding the pollution behavior of any of the rivers being monitored.

In the North Pacific, the Bureau of Commercial Fisheries has made a successful start on a project that will eventually result in the dispersal of up to 50 submersible monitoring buoys over a vast area of the ocean. Suspended at varying depths, these buoys send temperature and salinity measurements via radio signal to small shipboard computers which process the data in a manner similar to the FWPCA installation. A major objective of this system is to identify the boundaries of large water masses which are known to be controlling factors in fish migrations. An instantaneous picture of water mass locations will greatly enhance our ability to predict where large schools of tuna are most likely to be.

The Geological Survey has installed 31 seismograph telemetry stations in five "clusters" along earthquake fault lines in California. Each station consists of a small electronic package buried in a shallow hole and connected by cable to the nearest telephone line. The telemetry network permits monitoring of minute but highly significant earth movements throughout the area. The data are placed on 16-mm film and processed continuously, making it possible to locate hypocenters of seismic events for display on a three-dimensional plot.

Handling Floods of Data

The second major problem area stems from the "data explosion." Increasingly we are learning that research must deal with staggeringly complex interactions and with data in such volume that historic approaches to analysis and evaluation are totally inadequate.

In a few cases Interior scientists have found that the interactions of relevant factors fall into patterns which can be expressed as mathematical models. It then becomes possible to predict with great accuracy how, for example, a river system or mining operation will be affected by variations in any factor.

The FWPCA has developed a complex general model for simulating the behavior of river basin systems. The model accommodates variations in water and land use, institutional arrangements, and changes in water management. It permits analysis of the effects of differing rainfall patterns, waste inputs, dams and reservoirs, and differing water control measures. Using the model, scientists at FWPCA can get answers to questions such as: How do current management practices in a particular basin influence water quality? What changes in management would provide what quality at what cost? And will the flow in a wild river be sufficient to maintain a required wetted perimeter for fish spawning?

The model has been or will be used on 14 river basins, including the Patuxent, Chehalis, Merrimack, Red River of the North, and the James. Other models of river/estuary complexes are in operation and proving successful.

In a similar way, Bureau of Mines scientists and engineers are approaching the point where computer-operated models can be used to project the operation of complex mineral recovery and processing systems. Beginning with the ore body itself, the interlocking system models will reflect the total surface and subsurface conditions, including distribution of mineral values, rock types, rock stresses and strength, and faulty joints and fractures. Also Socio-economic constraints such as the national need for certain minerals, social policies of the Government, worker safety and comfort, etc., can be imposed on the models. The objective is to enable the Bureau to identify optimum approaches to utilization of the country's diminishing mineral resources.

Keeping up to date

The third information problem area is that of communication among scientists. As the Department's scientific missions expand and become more complex, it is critical to ensure that researchers be aware of what other scientists are doing and have done in the same and related areas. We can safely say that the technological revolution going on throughout the world is so vast that the scientist can rely no longer on his personal sources and contacts to gain the awareness and understanding he needs to do his work.

Publications in the fields where Interior is doing research have been estimated at more than 100,000 annually. Within the federal establishment alone there are nearly 100,000 on-going research projects, each a potential source of useful information to one or more Interior scientists. Ways must be found to alert the individual researcher to who is doing what in his field of interest and in related fields. In many cases this can be done by the development of large stores of bibliographic data which can be rapidly screened, retrieved and disseminated on a selective basis. In other cases, the scientist needs to have immediate access to specific technical information.

To deal with this problem the Secretary of the Interior has established the concept of a Natural Resources Science Information System. During Fiscal Year 1968 the Department will undertake to implement a Water Resources Scientific Information Center. This center will screen the world's literature dealing with water resources and, utilizing computer procedures, match the bibliographic input with the interest profiles of some 10,000 researchers employed by Interior, other Federal Agencies, and contractors and grantees engaged in water resources research. Each user will then receive notices of the current literature which the computer has found to be pertinent to his interests. The system will also afford users a retrospective search capability permitting them to look back over a period of time for pertinent information.

Similar systems are already operational at Bonneville Power Administration and the Bureau of Reclamation serving smaller groups of users in electrical, civil, and hydraulic engineering.

The Bureau of Sport Fisheries and Wildlife at the Patuxent Wildlife Research Center has developed and is expanding a data retrieval system of remarkable speed and flexibility. Through a combination of computer and microfilm procedures, a Bureau scientist may obtain, in about three minutes, detailed data on the testing experience of virtually any pesticide. Expansion plans call for storage of a wide array of data on organic substances, so that the scientist can enter his query on the basis of a coded expression of the compound's composition and structure. Through such an approach there exists a strong potential for the elimination of lengthy, duplicating test procedures.

Meeting the challenge

These descriptions merely illustrate that in all the major research areas the challenge of the information explosion is being met through ingenious use of modern technology. In the past, both financial and technical barriers limited the rate of progress in this area. Systems and devices for handling information by electronic means are difficult to design and expensive to implement. The current thrust is toward overcoming these barriers through the use of integrated general purpose "software" made possible by the new generation of computer hardware. If successful, these efforts will substantially reduce the cost and time lag now associated with design and implementation of specially tailored systems.

The Interior scientist can now look forward to a time when he can rapidly create and interact with a series of interlocking information systems which parallel and assist the flow of information from the observation of phenomena to the communication of research results to the ultimate users.

WATER RESEARCH

WEATHER MODIFICATION IN WATER RESOURCES

Reclamation's role

Scientific knowledge of the atmosphere and understanding how man can influence it have advanced sufficiently during the past two decades to warrant the design and operation of large-scale experiments in one aspect of weather modification—precipitation control. Through major field experiments and continued scientific research, practical techniques can be developed to augment water supplies for the Nation's continued economic and social growth. This is the role of the Bureau of Reclamation's Atmospheric Water Resources Program.

Water supplies are now critically short in several regions. Future requirements, as projected by the 1960 Senate Select Committee on National Water Resources, will soon begin outpacing supplies in many other regions. Northeastern droughts and pressing water quality problems clearly verify these projections and indicate the massive effort required to provide the comprehensive water resource development essential for adequate water supplies. In addition to weather modification, such new techniques as desalination, evaporation control, and watershed management must be developed to supplement the more conventional methods in water management.

The broad spectrum of public economic benefits with widespread ecological and social enhancements from the application of precipitation modification techniques and the expanded research effort required for their development call for continued Government leadership, involvement, and support.

Achievable goals

Best estimates of precipitation increase range from 10 to 20%. Continued research and development may revise these estimates upward. Weather modification techniques for increasing precipitation in mountainous portions of the West can become a reality in five years. In 20 years, a comprehensive technology can be developed for modifying precipitation throughout the Nation. This is the present goal of the Atmospheric Water Resources Program.

Not only can the specific techniques for increasing precipitation be developed through research, but methods for applying them most effectively to augment water supplies. Scientific research in numerous disciplines must be integrated into a comprehensive program to accomplish these goals.

As the Government's department of natural resources, with many and varied responsibilities in the field of water, it is logical that an expanded national effort in atmospheric water resources should be the responsibility of the Department of the Interior through its Bureau of Reclamation. Weather modification for increasing water supply is completely harmonious with the basic mission of the Department and the Bureau.

The research and development program

The Atmospheric Water Resources Program is outlined in the Department of the Interior's report, "Plan to Develop Technology for Increasing Water Yield from Atmospheric Sources." This plan is the outgrowth of a six-year research program which clearly indicates the possibilities and the nature of the effort required to develop practical techniques. A nationwide research program undertaken by the Bureau would develop regional capabilities to modify precipitation, each tailored to the climatological, physical, and social-economic conditions of the region, concentrating first in regions of most critical water need.

A practical technology provides for four functional considerations: (1) deciding if precipitation modification is feasible, (2) recognizing suitable opportunities for application, (3) correctly applying the required techniques, and (4) monitoring and evaluating the results. These considerations require inclusion of broad regional studies to identify and resolve the social, legal, economic, hydrological and ecological problems to accompany the more basic scientific research activities and field experimental operations. Detailed research is required in cloud physics and dynamics and cloud development processes, where detailed knowledge is insufficient for devising modification techniques. Needed are re-

search on condensation and ice nuclei climatology, mechanisms of heterogeneous nucleation, cloud system characteristics, diffusion, and effects of particle charges and charge distribution on precipitation. Intensified research and development is required on seeding agents and delivery systems; on specialized instrumentation such as airborne rain gages, nuclei counters, vapor density indicators, doppler radars for vertical velocity measurement, and precipitation rate sensors; on data collection systems; and on real-time analysis and display systems.

Because of past and current research programs, orographic cloud seeding techniques for augmenting the winter snowpack in the western mountains have been developed to where pilot-type operations are now warranted. Techniques for increasing precipitation from convective- and stratus-type clouds and from frontal storms are still in the development stages and additional years of intensive effort will be required before major application can be tested through pilot operations.

The important last phase is the establishment of large experimental field operations or pilot projects for testing feasibility and solving the problems of widespread application. Comprehensive monitoring and evaluation will be included in these projects.

Most program activity will be performed by university and private firms, with Government agencies generally furnishing the specialized support and management. Research conducted through universities will be administered not only with a view toward producing specific results, but also for strengthening academic research and educational capabilities in general, especially in smaller colleges.

As a result of the Atmospheric Water Resources Program, additional fresh water is anticipated to be producible for \$1 to \$1.50 an acre-foot in the Upper Colorado River Basin. In a society and economy highly dependent on water for continued growth, the benefit of this water will be far reaching. Support necessary for this program must expand from the current \$3.8 million to \$50 million by 1972 with continuing support thereafter.

BASIC AND APPLIED RESEARCH IN DESALINATION

How does water dissolve a salt crystal?

What is a water molecule? What is a salt ion? What occurs at the interface between a water molecule and a salt ion? These may sound like rather simple questions in an era of sophisticated research, but they are but a few of the many questions scientists still must answer and these answers will be of utmost importance to our search for low-cost desalting processes.

In discussing the desalting of the ocean and other natural saline waters, it is appropriate first to outline what is meant by these terms. Sea water is a homogeneous mixture of water molecules and salt particles, predominantly rock salt (sodium chloride) with smaller amounts of more than 40 other minerals. These minerals can remain in a dissolved state only because the pulling forces between the charge-bearing salt particles (ions) and water molecules are not very different from the forces between water molecules themselves, yet there are distinct differences in behavior between the saline and aqueous components. We must take advantage of these differences in order to separate them.

Fortunately, though we cannot explain fully, the aqueous component is sensitive to both the addition and withdrawal of heat, while salt is not. The application of voltage will move the salt, but have no direct effect on the water. These and other observable differences have been known for many years and used in various desalting methods. It is certain, however, that subtle molecular-scale events cause and control observed differences. It is reasonable to assume that there are molecular-scale events that are not yet recognized and practical to expect that basic research into these fundamental phenomena will provide more efficient means for exploiting distinctions between salts and water.

The more we know about aqueous solutions and saline solutions in particular, the better we can manipulate them to effect a separation between the salts and the water. Known desalination processes have reduced the cost of conversion, but they are not presently efficient enough to produce fresh water at very low cost. Thus, we have no more reason to be satisfied with known desalting technology than Shockley had to be satisfied with vacuum tubes, or Salk with iron lungs or Fleming with salvarsan.

Why are saline solutions so complicated? That question may be answered as follows: The particles comprising these solutions are so tiny that if each salt

particle and water molecule in a gallon of sea water were enlarged to the size of a sand grain having the diameter of a typed period (.), the resulting mass of sand would cover the entire surface of the earth to a depth of more than 800 feet! Items this small are extremely difficult to handle, yet it turns out that scientific techniques can furnish a surprising amount of information about this submicroscopic situation, and research currently under way is continually giving rise to a deeper understanding of actions and interactions which is so needed to generate new ideas.

One example of a desalting method initiated and developed through research activity to the pilot plant phase of development is reverse osmosis. The first discovery was that by applying pressure on a saline solution in contact with a relatively simple polymeric plastic (cellulose acetate), fresh water would pass through the membrane and salt would not. Even though the flux (water flow rate) was approximately a fluid ounce per square foot per day, it was a major scientific achievement. Many detailed studies followed in a search to discover exactly what occurred inside that thin sheet of cellulose acetate to accomplish this separation. As scientists developed a better understanding of this phenomenon, they were able to design and prepare new membranes which provided improved water flow while retaining the salt rejection properties. Membranes are now available with flow rates of 30 gallons per square foot per day and pilot plants to field test this new process are now nearing completion.

One of the many basic problems scientists faced in the development of the reverse osmosis membrane was to determine why or how the membrane permitted the water to pass while rejecting the salt. It could not be simple filtration because the saline and aqueous component particles are too near the same size. It was necessary to study the chemical natures of the membrane polymer, water molecules, and salt ions. From these studies a reasonable qualitative description of how the process works has been evolved and is guiding further investigation as the search for more efficient membranes is continued.

A great many questions about this process remain unanswered: Why does pressure affect water so much more than salt? What is the exact way in which the chemistry and geometry of the polymer determine paths of flow? How can the procedure of preparation and/or the syntheses of new polymeric materials produce more durable membranes? Why is it that some natural membranes can desalinate? What can be done about the membrane-adjacent buildup of salt which interferes with flow? Answers to these and other questions can be expected to come from the perceptive application of modern scientific approaches, and each new answer can improve the potential of the process.

It is readily apparent that saline water conversion, although a technology having operational and historical ties to engineering development, has its roots in basic science.

Freezing processes provide another example of basic research studies being conducted by the Office of Saline Water. It has long been known that when salt water freezes, the ice crystals contain no salt. The freezing temperature is lowered by the salt, and both the temperature change and the amount of heat involved have been understood for many years in terms of classical thermodynamics. Based on this information, engineers have successfully designed freeze-demineralization processes, but inefficiencies still exist which must be reduced in order to decrease the cost of product water. One area in which more fundamental knowledge is needed and is being obtained is to accurately determine what takes place at and near the surfaces of growing ice crystals. We also must understand better how the size and shape of ice crystals are related to nucleation, to rates of cooling, and to the composition of the solution. This is important because a critical step in the process is washing the brine away from the ice, a step which depends strongly on the nature and form of the ice crystals. We also are obtaining new data and information on the mechanisms and kinetics by which heat, water molecules, and ions are transported to and across the boundaries between ice and solution so that these transfer steps can be made fast and efficient. Careful scrutiny of these research areas leads back to still more fundamental questions.

Similar examples could be offered in other research areas and basic research is being sponsored to extend the frontiers of knowledge. In each case, there are good clues to the fundamental questions. The existing evidence is sufficient to provide ample justification for continued effort by experienced scientists and engineers to pursue basic research studies in desalination. Indeed, desalting is a particularly opportune field of research for the very reason that present proc-

esses do not approach theoretical efficiency. Whereas one could only hope to increase the efficiency of an electric motor by a few percent through additional research, there is a very real opportunity to increase the efficiency of water desalting processes by a factor of five or more. The best method of attaining major improvements in product water costs is through research on the principal sources of irreversibilities (inefficiencies). For most desalting processes, these irreversibilities arise largely from transport of energy or matter at phase boundaries. Nearly all of the present processes require more than 30 times the work energy needed for reversible separation. Several processes can use the work available from low-temperature energy, which is seldom useful for other purposes. Existing methods employ semipermeable membranes or interfaces between phases (liquid-vapor, liquid-solid, or liquid-liquid). Most of these are rapid but thermodynamically quite inefficient; others are more efficient but slow. Basic research will provide a better understanding of both the transport processes and the thermodynamic losses. Thus, research has an opportunity and potential of truly unusual dimensions for achieving dramatic reductions in the cost of desalting water. Additionally, this information will find application in separation processes used in areas other than desalination.

Commercial saline water conversion is already a fact, and industry has assessed it as a basis for profitable expansion and diversification. As new technology drives down the cost of product water, desalination will find increasing application as the cheapest or only alternative means of obtaining a supplemental source of supply in an ever greater number of areas.

The work sponsored by the Office of Saline Water has stimulated research and development activities throughout the world, and this, in turn, has led to the accelerated development of new or improved desalting processes. The Office of Saline Water is recognized as the world center of desalting technology, and this information is made available to all who wish it. By utilizing the scientific capabilities of OSW in a continuing program of basic and applied research, the Department of the Interior will maintain its position of leadership in this new area of water supply.

ESTUARINE ECOLOGICAL SYSTEMS AND POLLUTION CONTROL

The great coastal zone of the United States in which the land and river systems join to become the oceans is one of our great natural resources. This unique geological region is the entrance to the river systems for immensely valuable anadromous fish, such as the salmon and the shad, the nursery ground for one stage in the life cycle of the shrimp, and the permanent home for crabs, oysters, and clams and the temporary home for millions of migratory waterfowl. Approximately half of the Nation's population lives within easy driving range of the estuaries and the coast—a favored location which is exploited to the fullest degree during the summer months when the seemingly endless coastal resources are subjected to great multiple-use pressures. Twenty-four States, the District of Columbia, Virgin Islands, Puerto Rico, and Guam enjoy the ownership and control of this unique area. Congress has also recognized the great national interest in these resources and, in the Clean Water Restoration Act of 1966, directed that a national study be made to provide a technical and administrative base for development of future management policy.

Science and technology necessarily have an important role in understanding the complex relationships among estuarine biological populations and the responses of these populations to changed environmental conditions induced by man's actions. Cataloged in broad terms, these relationships include the problems of eutrophication, in which undesirable aquatic growths are overstimulated by nutrients from industrial, agricultural or municipal wastes; sediments from agriculture, construction, industry and channel maintenance which change bottom characteristics and smother desirable plants and animals; biologically active chemicals, such as pesticides, sulfite waste liquors, and detergents which interfere with the most fundamental of the life processes of reproduction and normal growth; the availability of oxygen—necessary for the life of most desirable organisms—which is directly related to the oxygen depletion characteristics of industrial and municipal wastes; heated water from industry and power stations and its perhaps subtle effects on biological populations accustomed over centuries to a narrow range of temperatures; and oil along with its devastating effects on both beaches and biological populations as so dramatically brought to our attention in recent weeks. Each of these problems must be understood and resolved both as an entity, and in relationship to each other, within the broad

range of climatic and oceanographic conditions which prevail in our vast estuarine systems reaching from the arctic seas of Alaska to the tropic seas of Hawaii and Puerto Rico.

The demands of this task far outrun the availability of scientific knowledge although considerable progress has been made in many areas in recent years. There are many recent examples in which the research programs of the Department of the Interior have contributed to the understanding of the estuarine ecological systems and in which the expertise of Interior's scientists has been applied in programs for pollution prevention and water quality enhancement. These examples have ranged through such diverse fields as 1) oceanographic engineering studies which permitted the accurate forecasting of the rate of salt water movement up the Delaware River during the recent period of great drought in the Northeast and which pinpointed the scheduling of upstream reservoir releases thereby protecting the Philadelphia water supply while minimizing water loss to other upstream users; 2) documentation of the toxic effects of sulfite mill wastes on shellfish and fish in Puget Sound; 3) contributions to the understanding of problems resulting from the discharges of warm water into estuarine systems to assist in powerplant site selection; 4) the development of methods for the detection of pesticides at "parts per billion" levels and establishment of the cause-effect relationship of these minute levels to the recent extensive destruction of fish life in the Mississippi River; 5) the determination by the Bureau of Commercial Fisheries of the growth-inhibiting effects of pesticides on oysters; and 6) the determination by the Geological Survey of minute quantities of metals such as zinc or copper in streams which discharge into estuaries. However, the knowledge bank which is available to the engineer and scientist is as yet inadequate for real understanding of the ecological systems in estuaries necessary for effective water pollution control and water quality enhancement.

The technical problems associated with the protection of estuarine resources are vastly different from those which are encountered in the study of fresh water streams and lakes. Whereas a river consistently flows in one direction, the estuary presents a dynamic situation constantly reacting to the forces of wind and tide. Flow is sometimes in one direction, sometimes in another, and sometimes not at all. This complex situation is made even worse by the difference in weights of fresh and salt water which permits the lighter fresh water to ride over the salt water below. Thus, an estuary frequently has dissimilar top and bottom flow patterns which is reflected in differences in water quality in the top and bottom layers of water. Consequently, almost any major study of dispersion, retention, or distribution of a pollutant in an estuary presents problems which tax the abilities of the most skilled mathematicians, and the capabilities of space age computers. Mathematical models have, however, been applied to complex estuarine situations by Interior specialists to determine ecological impacts of proposed water resource development. Two outstanding examples are the San Joaquin Master Drain Study in California and the Delaware Estuary Study in New Jersey, Pennsylvania, and Delaware. Similar models are currently being applied to the Potomac River-Chesapeake Bay system to develop methodology which will upgrade water quality in the most effective manner.

The variations in water masses within a given estuary also present many problems in the collection and examination of water samples for pollution. In general, many more samples are required; the cost of collection is higher; and, the difficulties of laboratory examination are magnified. To meet these challenges the technician must find ways to obtain adequate data at reasonable cost and to develop methods for identification of pollutants in water in which ocean salts are present in varying degree. Progress is being made, and more progress is likely. Automatic devices are being developed for the sensing of pollutants and for transmission of flow and quality data to a central point; such a system has already been installed in the Potomac River below Washington. The Federal Water Pollution Control Administration is now developing a research project for use of infrared imagery for the rapid aerial mapping of thermal pollution sources (fig. 30). The atomic absorption spectrophotometer has been adapted for the detection of minute quantities of metallic contaminants.

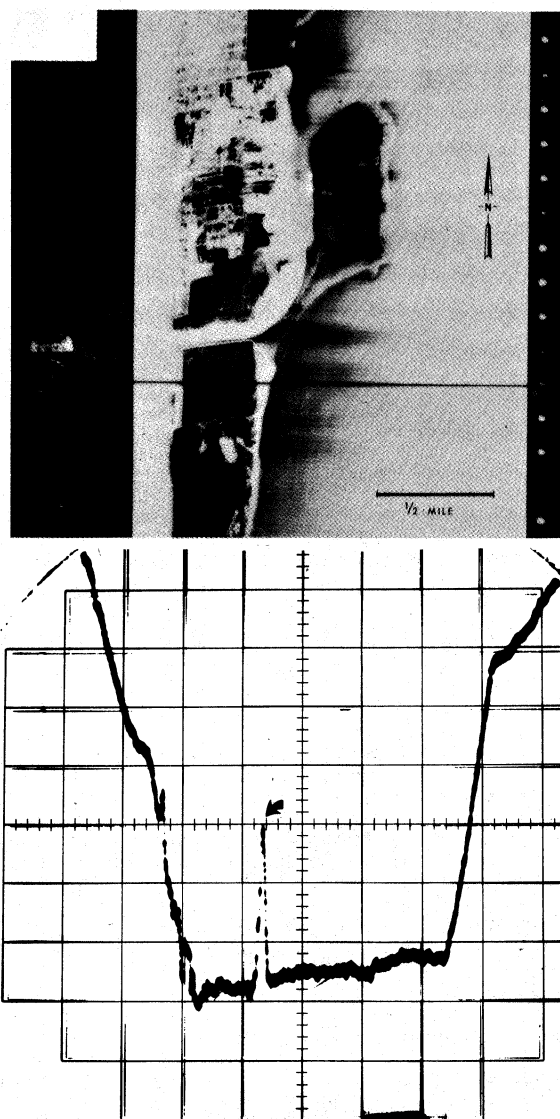


FIGURE 30.—Infrared imagery of a portion of Texas City showing thermal effluents.

Upper : Part of aerial infrared photograph showing two thermal effluents (white).

Black line shows location where temperature profile in lower picture was made.

Lower : Typical temperature profile obtained from infrared photograph. Black line represents temperature across the picture above. Note sharp spike at location of thermal effluent.

The establishment of water quality standards for estuarial waters also places great demands upon the marine biologist. Again, the information now available to the estuarine scientist is inadequate. For example, a recent water pollution control bibliography on nutrients lists only 8 out of 137 references applicable to the problems of eutrophication in the estuaries. Advanced research of the highest caliber must meet this inadequacy and, to fill the gap, the National Marine Water Quality Laboratory has been established in Rhode Island. Initially this laboratory is undertaking studies of the elusive factors which regulate the growth of food organisms in estuaries. As part of this effort, complementary studies are being undertaken at other Federal Water Pollution Control Administration laboratories located on the Yaquina Bay at Newport, Oregon.

The effects of many forms of pollution are difficult to evaluate. The spectacular results of an adult fish kill are easily understood and appreciated. But there are many biological disturbances which are just as catastrophic, but which are not so easily observed. Waste heat discharged to an estuary may destroy the food supply of waterfowl. Pesticides in trace quantities may slow the growth rate of oysters so that they may never reach marketable size. Thermal or low-oxygen-level barriers may prevent anadromous fish from reaching spawning grounds. Common industrial wastes, such as those from sulfite pulp mills, may interfere with the natural reproductive processes of both shellfish and fish (Figs. 31 and 32). Efforts of Federal Water Pollution Control Administration and the Bureau of Commercial Fisheries have been instrumental in the development of highly sensitive bioassay techniques which measure the responses of critical organisms to these adverse combinations of toxic materials.

Even man is not exempt from the hazards of waste discharge into estuaries. Some species of fish and shellfish have a demonstrated ability to concentrate bacteria or viruses from sewage—to concentrate insecticides by a factor of up to 70,000 and to concentrate industrial wastes to levels thousands of times greater than in the water itself.

Ultimately, the prevention of pollution and enhancement of water quality rests in the hands of the engineer-scientist who must design the treatment plants and water quality control methods which have both the capability and the reliability necessary for the protection of our marine resources. Scientists of the Department are in the forefront of this effort to develop new methods and to better apply old methods. Advanced research programs are making use of highly sophisticated laboratory and field projects to explore how nutrients can be best removed from municipal and industrial wastes. Such processes as ion exchange, electrodialysis, and reverse osmosis, processes on the very forefront of knowledge, are under investigation even now. Computers, electronic instrumentation, remote sensing devices—in short, the most advanced tools of science—are being brought to bear on the problem.

The role of the social scientist must also be recognized, for he may well have the task of interpreting and analyzing public opinion. It is vitally important that there be an adequate understanding of the economic and social values of the estuaries, and that these values be utilized in benefit-cost analysis. This need is being considered in comprehensive river basin studies and in pollution abatement research and studies to help better define these elements as a step toward better management of the Nation's resources are being developed.

In summary, the Nation appears to have recognized that the estuaries are a valuable national resource which must be preserved and managed for the public good. In many cases the control of pollution will be the key to the success of this effort. In turn, effective control of pollution requires the acquisition of a great deal of additional knowledge about the effects of thousands of different water quality factors on a complex biological system of plants and animals. Many of the programs of the Department of the Interior are oriented toward the generation of this information and its translation into effective means for protection and preservation of one of our great natural resources—the estuary.

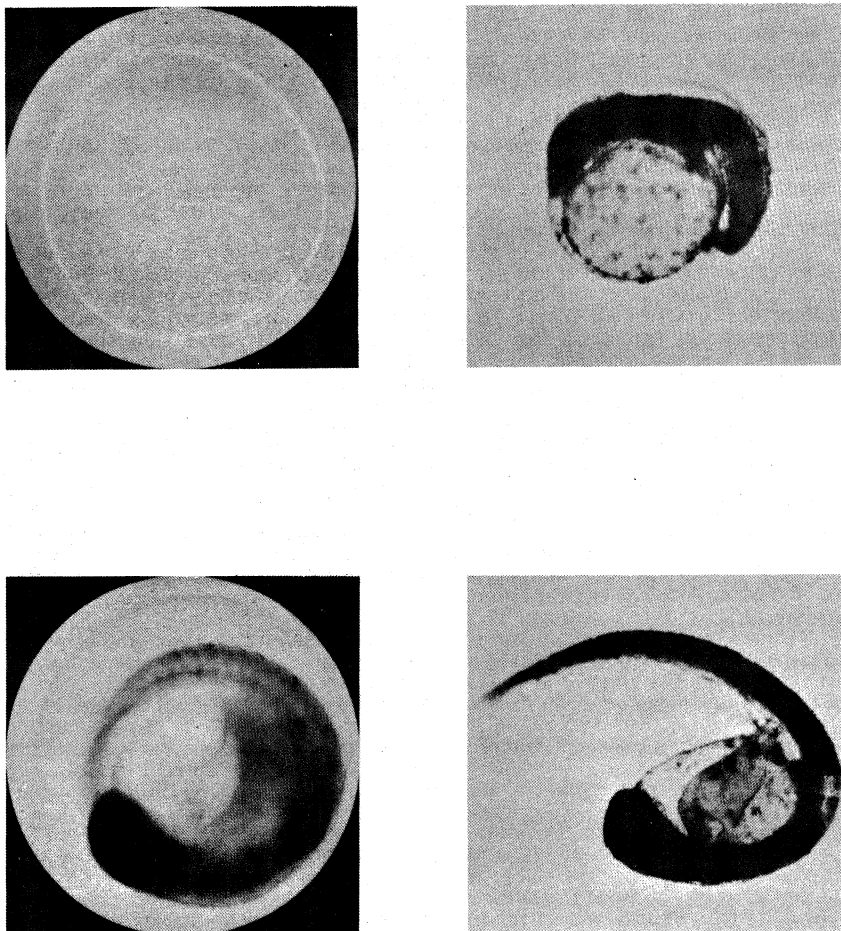


FIGURE 31.—Four observed stages of development of English sole eggs after about seven days' incubation in test and control solutions. Upper left: Dead egg. No apparent embryonic development. Upper right: Developing egg. Limited embryonic development. Lower left: Developing egg. Embryonic development nearly complete. Lower right: Transitional fry. Just after hatching. Organism has not yet straightened.

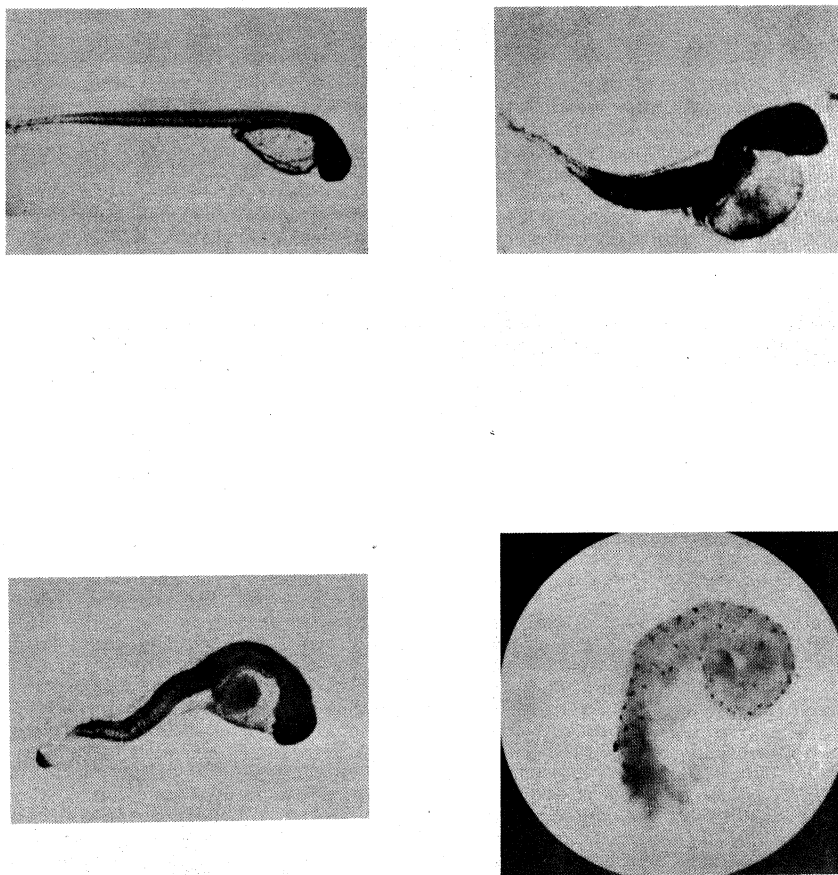


FIGURE 32.—Four observed stages of development of English sole eggs after about seven days' incubation in test and control solutions. Upper left: Normal fry. Upper right: Abnormal fry—most frequent type of deformity. Lower left. Abnormal fry. Lower right: Abnormal fry—note great amount of tissue disorganization.

BRIEF DESCRIPTIONS OF ADDITIONAL PROGRAMS IN WATER RESEARCH

WATER QUALITY REQUIREMENTS RESEARCH

The development of water quality requirements for all uses must be based on the appropriate quality criteria for each use. The uses of water vary from water to sustain life, to water used for industrial purposes, to water used recreationally and esthetically. While some of the quality requirements for the various uses are now known, others are not. The establishment of quantitative quality requirements for the range of human uses and for use by aquatic life and wildlife in both marine and freshwater environments is the research problem now being faced by Interior's scientists studying "effects of pollution." This challenge involves research in identifying, measuring, and characterizing a myriad of pollutants and then relating levels of pollution to the various effects on water quality.

Determination of water quality requirements for fish and aquatic life is now underway for both freshwaters and coastal waters. At the National Water Quality Laboratory in Duluth, Minn., and the National Marine Water Quality Laboratory in Narragansett, R.I., the Federal Water Pollution Control Administration has initiated programs on the water requirements of diverse species and studies of their sensitivity to pollutants and toxicants. This necessitates rearing and maintenance of plankton organisms, invertebrates, aquatic insects, including their instars, and fishes. Bioassays are not being overlooked.

The Bureau of Sport Fisheries and Wildlife has an extensive Reservoir Fishery Research project concerned with the effect of water quality on fish production.

Among the Geological Survey's concerns are thermal stratification processes and biological influences as related to water quality.

The Office of Water Resources Research supports research in the field of water quality requirements at some 86 universities throughout the country.

Investigations underway and anticipated will produce essential information which can be applied in solving problems of control of pollution.

WATER QUALITY CONTROL: POLLUTION FROM MUNICIPAL SOURCES

Polluting discharges from municipalities are of two principal types: (1) municipal sewage and (2) urban storm runoff (discharges from storm and combined sewer systems).

Historically, little concern has been paid to urban runoff and pollution from municipal sewage has been partly controlled through application of waste treatment processes largely developed about the turn of the century. These waste treatment processes, however, were not designed to cope with the water pollution problems now emerging. The character of municipal sewage is being altered by our increasing use of synthetic products and also by the increasing introduction of industrial wastes directly into municipal sewerage systems.

Pollution from urban runoff is a matter of growing concern. The problem of discharges from storm and combined sewers has received recent attention and a sizable attack on this problem is already underway. The heart of the problem is, of course, that during storms the large volume of urban runoff water, which can itself be highly polluted, must be bypassed around conventional treatment facilities because these facilities were not designed to handle such large peak loads. This results in the discharge of sizable quantities of polluting materials directly to receiving waters without benefit of any treatment. This bypass water contains not only the runoff pollution but also contains in the case of combined sewer systems, much of the sanitary sewage which would normally have received treatment by the municipal facility. A variety of possible solutions to this problem are now being explored. For example, studies are underway of most of the more conventional storage techniques, including the use of tanks with pump-back to the interceptor, surface storage ponds, and treatment lagoons. More unique applications of storage principals such as localized "upstream" storage to prevent overloading of "downstream" sewers need further development. The use of chlorine to disinfect storm and combined sewer discharges is included in several projects; new disinfection techniques suitable for application to high volume—short duration flows need exploration as do entirely new concepts in peak-load treatment devices and in-sewer flow controls.

WATER QUALITY CONTROL: POLLUTION FROM INDUSTRIAL SOURCES

The quantity of industrial wastes discharged annually into the Nation's rivers is, in the most conservative estimates, equal in its pollutorial effect to municipal wastes. In all probability, it is significantly greater. The determination and development of economical methods of treatment of industrial wastes to prevent these damages to rivers is a challenge of major significance. These damaging effects run the entire gamut from unsightliness to toxicity; for example, oil slicks, tastes and odors, fish kills, floating solids, and even dissolved compounds poisonous to man.

The economic aspect of industrial waste control requires that both conventional and completely new approaches must be made to this problem. Present waste treatment methods, although satisfactory in many cases, do not provide solutions to the problem today and offer little hope that they will provide the type and degree of treatment which will be needed in the future.

An effective attack on this problem requires the development of a cooperative industry-government effort to determine, develop, and install treatment processes, process modifications, water conservation programs, etc.

One specific technique is the evaluation and separation of industrial wastes into broad categories requiring similar treatment. These categories would then be characterized to form the foundation for subsequent bench-scale, pilot-scale and full-scale studies of new methods of control.

Work on waste reduction at the source would be coordinated with treatment studies such that treatment would be pointed toward the processing of an irreducible minimum of waste.

HYDROLOGIC SYSTEMS

Hydrologic systems are parts of the earth's water cycle isolated for particular attention. A single stream, a river basin, or the entire global water supply may be involved. All are natural states involving inputs by precipitation; storage as soil moisture, ground water, or surface supply; and outputs by evaporation, product development, or flow to the sea. All are subject to the orderly but poorly understood variations of nature and to the random influences of man. Man must understand these complex systems if he is to adapt his operations to their behavior or to modify their behavior to meet his needs.

Situation and outlook

Thus far much piecemeal information has been collected on precipitation patterns, behavior of surface waters, occurrence and movement of ground waters, sources and fates of water contaminants, and the engineering, legal, and economic factors involved in management of specific water supplies. However, little competence has been developed in integrating these various factors for thorough understanding, or effective manipulation of even the smallest hydrologic system. Limited progress has been made in identifying the kinds of water data most needed for proper understanding of systems and little skill has been developed in selecting management alternatives to provide best adjustment to, or best modification of, the particular hydrologic system involved.

Looking to the future we must learn to make these integrations with complex models so that all of the elements which influence the behavior of hydrologic systems, including the constraints of nature and the economic, sociological, and legal complexities created by man will be taken into account.

Needs

Better understanding and management will require new information and technology. Relatively little is known about the behavior of water as it passes from the land surface to underground storage. Thus, artificial recharge and effective manipulation of ground-water supplies is impracticable. Management of surface waters for improvement of quality, as by artificial reaeration, still is in the experimental stage. Biological influences on water systems are poorly understood. Better methods are needed for collecting and handling data.

Courses of action

A concerted effort must be made to develop systems analysis techniques for assessing the value of data now being collected and for identifying new data needs and management sensitivities to various kinds of data. A great variety of quantitative and qualitative water monitors must be devised for generating real time information and effective systems must be devised for transmitting and storing the data they generate. Better remote sensing methods must be developed for probing underground systems and for sensing surface water phenomena which are either too large or too complex to be analyzed effectively with ground equipment. We must develop the understanding necessary to perfect artificial recharge of ground water and quantity and quality control of surface water on a grand scale.

Expected benefits of the program

A proper program will provide for continuing program analysis and redirection of work toward the most baffling elements of hydrologic systems. It will concentrate data collection and research on those factors of greatest importance in water management and will provide sufficient understanding of natural behavior to permit some control of processes such as recharge and reaeration. It will provide a basis for optimum management of water resources by indicating the best mix of water supply and water use alternatives for each situation.

WATER SUPPLY AUGMENTATION AND CONSERVATION

The research and development program is devoted to improving the water supply situation by either increasing available supplies or conserving existing ones. Activities include research in reservoir evaporation reduction and research involving control of phreatophytes and aquatic weeds. Reducing evaporation loss is vital for water supply conservation—average annual evaporation from large lakes and reservoirs in the 17 Western States alone is estimated at over 14 million acre-feet. Also, control of water-wasting weeds and obnoxious aquatic plant growth by mechanical, chemical, and biological means can significantly increase water yield.

In the Bureau of Reclamation, where evaporation reduction research is largely performed, the program objectives are to find the most suitable materials for evaporation retardants, to develop practical methods for applying these materials to large water surfaces, and to develop reliable techniques for determining evaporation savings. Reclamation believes that these savings can well mean the extension of irrigation to new areas, reevaluation to a feasible status of some projects deficient in water, and increased power revenues. A recent development in the Reclamation program involved the testing of a device using a laser-beam light source for measuring evaporation rates from reservoirs.

Weed control research, also conducted largely by Reclamation, consists of laboratory and field studies of aquatic weeds, phreatophytes, herbicides, algacides, soil sterilants, pesticides, and emulsifiers. Included are field-scale applications of herbicides and field trials of mechanical eradication devices. A recently developed atomic measuring method is used as an aid in regulating dosage rates of certain algacides used to control weeds in canals and waterways.

HYDRAULICS AND ENGINEERING WORKS

This program encompasses research and development activities in hydraulics, concrete, materials technology, open and closed conduits, soils engineering, and structural and rock mechanics. Research is focused on design of water control structures, on materials used in these structures, and on improved methods of construction, operation, and maintenance. Since water resource structures are growing rapidly in number, size, complexity, and cost, the research is directed toward improved economy, efficiency, and safety of these works.

Research is performed to solve structural problems; to make best use of concrete and its constituents; to investigate hydraulics problems by studies of dams, spillways, outlet works, canals, pipelines, gates, valves, water measurement devices, and flow in aquifers; to investigate soil embankments and foundations; to develop protective coatings and bituminous materials; to solve corrosion problems and develop techniques for cathodic protection of metals; and to develop special techniques for chemical and physical analyses of materials and for application of radioisotopes.

The Bureau of Reclamation, which conducts most of these activities, defines several areas of technology offering great promise: Location of underground cavities by a new seismic method; performance of rock mechanic tests in remote areas utilizing lightweight portable equipment; incorporation of earthquake and high-pressure forces in soils testing; development of a mobile nuclear laboratory for field studies of flow rates in underground aquifers and through turbines; design of a dual-purpose salmon spawning and water conveyance portion of the Tehama-Colusa Canal; use of "instant X-ray" to detect breaks in transmission lines; and development of an "earthquake simulator" for more realistic design of structures subject to earthquake forces.

GRANTS FOR TRAINING PROFESSIONAL MANPOWER IN NATURAL RESOURCES

The research and training grant programs of the Department of the Interior assist institutions and individuals in specialized training relating to water resources management and water pollution control. The objective of these programs is to increase the Nation's resource of professionally trained manpower for scientific, technical, and management positions.

There is a shortage of information needed to solve many varied and complex problems in water quality and quantity. The support of professional and technical training in educational institutions is necessary to assure the professional personnel required.

The benefit of these programs is to strengthen the academic capabilities of educational institutions for specialized training in the field of water resources

management and water pollution control, and to increase the number of institutions providing such training.

These grant programs develop new technical information and broaden the base of scientific participation in water research. This broad participation provides practical training for professional personnel in specialized fields of natural resources. The Department's training grant and research fellowship programs award direct support to institutions and individuals for specialized training in water pollution control.

ENERGY

GASIFICATION AND LIQUEFACTION OF COAL

The Department of the Interior's program in this area consists of in-house scientific and engineering development work by the Bureau of Mines and research contracted for by the Office of Coal Research. The objective of both agencies is the production of petroleum-type fuels and natural gas substitutes from coal by processes that are economically competitive with the natural products. At the same time, however, the total program is carefully coordinated to avoid any duplication of effort.

Conversion of coal to liquid and gaseous fuels is being investigated in the development stage by five routes, namely, carbonization, solvation, hydrogenation, gasification, and catalytic synthesis. The processes thus far evolved employ two or more of these five methods. Gasification is required to produce the hydrogen for hydrogenation, as well as the synthesis gas for catalytic synthesis. Carbonization yields a liquid product suitable for hydrogenation into a petroleum-type liquid. Solvation provides a means of separating the hydrogen-rich fractions of the coal from its recalcitrant high-carbon content and the mineral matter. In this way a product suitable for hydrogenation into a liquid petroleum-type oil is obtained.

Four projects aimed at production of liquid fuels from coal are being conducted under contract to the Office of Coal Research. They are: (1) Solvation followed by hydrogenation, (2) Fluidized carbonization followed by hydrogenation, (3) Hydrogenation of the whole coal and (4) Carbonization of coal as slurry in petroleum-type residues. The in-house projects being performed by the Bureau of Mines are: (1) Novel methods for hydrogenation of coal and tars, (2) Entrained flash carbonization and vapor phase hydrogenation, and (3) Catalytic synthesis of gasoline.

Work directed toward production of gaseous fuels from coal involves a number of projects designed to eliminate or reduce the oxygen requirement for production of hydrogen and synthesis gas. Contract projects under the Office of Coal Research are: (1) Superpressure gasification, (2) Use of molten salts, and (3) Dolomite, to furnish the required reaction heat. In-house projects of the Bureau of Mines are concerned with: (1) Fluidized gasification of caking coals, (2) Two-zone gasification with air to produce synthesis gas or a rich producer gas, and (3) Fixed bed gasification of caking coals to produce an industrial gas.

Two processes are also under development—one by contract, the other in-house—for the hydrogenation of coal at high temperature into a natural gas substitute. One process would convert pretreated coal to gas suitable for upgrading by catalytic synthesis and would generate a portion of the hydrogen required in the hydrogasifier by the injection of steam which would serve also to control the temperature. The other process would use a raw bituminous coal to produce a high-Btu gas directly and would produce the hydrogen needed externally or by reaction internally of steam with iron. Catalytic synthesis of high-Btu gas is also being investigated.

Bureau of Mines programs in basic research are directed toward study of corona and high-frequency electrical discharges and laser beams in reactions with coal. These are supplemented by studies directed toward determining acid catalysis mechanisms, production of hydrogen catalytically from coal and to the electrochemical hydrogenation of coal; the latter two, at low temperatures and atmospheric pressure. Projects under contract involve processes that react coal at extreme temperatures in electrically generated plasmas.

POWER DEVELOPMENT AND TRANSMISSION

The role of science and technology in the management, conservation and development of natural resources is clearly demonstrated in four very important activities of the Office of the Assistant Secretary-Water and Power Development. These are:

1. The third powerhouse at Grand Coulee Dam on the Columbia River in the State of Washington.
2. The proposed direct-current transmission lines in the Pacific Northwest-Pacific Southwest Intertie.
3. "Super-voltage" Power Transmission.
4. Improvement in the technology of placing electric power transmission lines underground.

Careful scientific study, aided by modern computer technology, has made it possible to accurately predict the streamflow at various locations on the Columbia River. This has enabled the planning of a large capacity powerhouse—9 million kilowatts—at the Grand Coulee site.

These studies demonstrated that generators of 600,000 KW capacity can be efficiently and effectively utilized. This will result in lower unit cost for the generators and lower cost for the third powerhouse. No generators of this size are in existence today, so considerable design and development must be accomplished. This can be done only through the fullest utilization of the scientific resources available.

The procurement of such generators will naturally involve certain modern model studies and other considerations along very advanced scientific lines. It will be necessary also to provide high-voltage cables and circuit breakers with very high short-circuit duty, both involving advanced scientific capabilities.

After much study and careful investigation of the use of direct-current transmission in other sections of the world, sufficient scientific data were available to warrant the consideration of two 750,000 volt 835-mile direct-current transmission lines as part of the Pacific Northwest-Pacific Southwest Intertie. No such transmission lines exist today in the United States. Again, advanced scientific principles and know-how will be involved in building, operating, and maintaining these lines.

The expected use of "super-voltage" power transmission in the 750,000 to 1,000,000 volt range will require extensive developmental studies and research to determine design criteria. Serious doubt exists in the possibility of extrapolating present design parameters to these higher voltages. Possibly entire new design concepts will be involved. Investigations are currently in progress to define the transient voltages created when switching high tension transmission lines. Improved understanding of electrical system behaviour and of equipment capabilities would assist materially in extending the limits of high voltage power transmission techniques, both for overhead lines and for underground cables.

In the area of underground transmission, stemming from President Johnson's 1965 White House Conference on Natural Beauty, a research and development program for advancing the technology of underground high-voltage lines has been developed by the Department of the Interior. This program has been submitted to the President, and initial funds are being sought in the Department's budget for F.Y. 1968. President Johnson has directed the initiation of this program. The technical problems are formidable and can only be solved by the free and extensive use of scientific know-how and research.

This program will utilize the scientific talents of not only the Department of the Interior, but the entire industry. We will be working with all segments of the electric power industry and with the Electric Research Council of which the Department is a member. Examples of the types of research needed include:

1. Development of new and different cable insulating materials which are not only applicable for high voltage but less costly to supply and simple to splice and terminate.
2. Development of forced cooling methods for increasing current carrying capacity without a proportionate increase in cost.
3. Development of new and improved methods of trenching and placing cables. This would involve new boring or excavation techniques. In this we would expect to draw heavily on the expertise of the Bureau of Mines.
4. Optimization and systems studies to determine the characteristics required for harmonious integration and utilization in existing power systems.
5. Determination of the characteristics of underground cable for direct-

current lines and automatic controls required to allow a parallel operation with alternating-current systems.

6. Development and application of alternating-current and direct-current conversion equipment and cable installations which will permit wider use of the inherently lower cost direct-current cable systems.

7. Transmission of electric power by use of superconductivity. This is accomplished by using a refrigerant to reduce the conductor temperature nearly to absolute zero (-459° F.), which practically eliminates electrical losses and heating problems.

8. Transmission of power by microwaves through wave guides. This concept involves converting the energy to be transmitted to very high frequency radio waves which are beamed through a hollow pipe to the receiving end where the energy must be reconverted to a form suitable for normal use.

9. Study of the opportunities of synthesizing a molecular structure having superconducting properties at temperatures well above those of present materials. Such a conductor would permit loss-free underground transmission at reduced cost over long distances.

BRIEF DESCRIPTIONS OF ADDITIONAL PROGRAMS IN ENERGY

COAL AS A SOURCE OF ELECTRIC POWER

By far the largest use of coal today is for generating electricity in central station power plants. This use of coal is increasing but, because of developments in nuclear energy, there is some uncertainty as to how long this increase will continue, and whether there may be a large decline in the use of coal for power generation in 20 to 25 years. The Office of Coal Research (OCR) has a statutory responsibility to develop projects beneficial to the coal industry. Consequently, OCR is supporting a number of projects designed to both increase the efficiency of coal-fired thermal power plants and reduce their capital costs. If these projects are successful, the position of coal in the face of increasing competition would be considerably enhanced. A side benefit, inherent in some of these projects, is the reduction of thermal and atmospheric pollution. Both of these forms of pollution are becoming of increasing concern, and are an increasing additional cost factor in the location of coal-fired power plants.

OCR's oldest power project is the fuel cell, being developed under contract with Westinghouse. Technical feasibility of a high-temperature, solid-electrolyte, coal-energized, fuel-cell system has been demonstrated. A great deal of work has been done in developing a low-cost method of fabricating the large number of fuel cell elements that would be needed in a plant of practical scale. Indications are that the desired goals can be achieved. Plans are underway for the design, construction, and operation of a 100-kilowatt demonstration unit.

Feasibility studies have indicated that the coal energizing, fuel-cell system may be able to operate with thermal efficiencies approaching 60 percent, with capital costs below those of conventional central stations. Additionally, such a system would discharge no sulfur or nitrogen oxides to the atmosphere, and would require practically no cooling water. Thus, this system has a potential for greatly enhancing the competitive position of coal in power generation and, at the same time, achieving the conservation goals of reduced thermal and atmospheric pollution.

OCR also has had a study of magnetohydrodynamic (MHD) coal-fired electrical power generation performed under contract by Westinghouse, and is considering the support of a 30,000-kilowatt demonstration plant. This would be two-thirds financed by organizations outside of the Government. MHD has reached a relatively advanced scale of development in relation to other exotic power systems, and it appears the time has come to proceed to large-scale demonstration in order that its potential for increasing thermal efficiency can be shown.

OCR is preparing to contract for development of a thermionic topper as an auxiliary to coal-fired steam power plants. This device, which has the advantage that it may be used to modernize existing older power plants, appears to be capable of increasing over-all thermal efficiency by as much as 10 to 12 percent, at low capital cost, thus also enhancing coal's competitive position and helping to assure continued development and use of abundant domestic coal resources.

Work has just started on development of the electrogasdynamic (EGD) system of coal-fired power generation. One development contract is about a year old, and several interesting proposals are being evaluated. EGD, somewhat analogous to a Van de Graaff generator, uses a stream of gas containing charged

particles to generate high voltage direct current. Present efforts are to generate ± 375 kv. electricity to match the Department's western high voltage d.c. lines now under construction.

For coal firing, the EGD system has the attraction that fly-ash acting as the necessary charged particles, is beneficial, rather than the usual nuisance. EGD generators have no moving parts, and, if suitable materials of construction can be found, it has the promise of being relatively low in capital cost. Reasonably high efficiencies appear to be attainable and cooling water is required. Thus, if it can be successfully developed, EGD has many attractions for the coal industry. It would be particularly useful in the West, where large deposits of coal are located in arid areas at considerable distances from the centers of power consumption. EGD, without a cooling water requirement, could be installed at any mine-mouth and, because of its direct current capability, could produce power for transmission to consumers at reasonable rates.

NONENERGY USES FOR COAL

In pursuing additional non-energy uses for coal, the Office of Coal Research has a process under development, by Melpar Inc., for the production of acetylene from anthracite by means of a sodium reaction. If successful, this could provide the basis for a new chemical and plastics industry in the anthracite producing regions. After considerable early experimental difficulties, recent indications are encouraging and process development is now being scaled upward.

Three other projects are underway to develop processes for the electro-treating of coal which could enhance its potential as a source of useful chemicals, including hydrogen and acetylene. Encouraging progress is being made in all three projects, although they are in early stages with much more work to be done. The three processes are:

1. Electrical resistance heating of coal in a fluidized bed, being investigated at Iowa State University.
2. Electric arc processing of coal, the coal forming a consumable electrode, being developed by AVCO Corporation.
3. High-frequency induction heating of coal which is being investigated by Stanford Research Institute.

WASTE DISPOSAL

Coal also offers promise as an aid to more efficient disposal of Solid Wastes. Rand Development Corporation, under contract to OCR, is constructing a pilot plant in Cleveland, Ohio, to treat 10,000 gallons per hour of sewage, using coal as a filter and as an adsorbent. After use, the coal and sewage mixture will be tested as a fuel for steam and power generation.

It already has been demonstrated, on a small scale, that coal will effectively remove the common contaminants from sewage; also that it will remove phosphates and hard detergents to a degree far exceeding that of conventional sewage treatment methods. On paper, the economics are favorable. Now the hardware must be developed and the economics proved. Certain problems must be overcome. For example, some coals are considerably more effective than others. Also, the costs and problems of grinding and sizing coal to the most desired 50 x 150 mesh size are greater than anticipated. Recent tests with small quantities of polyelectrolyte or ferric chloride have greatly improved the effectiveness of the process. The pilot plant is scheduled for operation in late July.

GEOHERMAL SOURCES OF ENERGY

The earth is a tremendous reservoir of heat, most of which is too deeply buried or too diffuse to consider as economically recoverable energy; but large areas, particularly in regions of volcanic and tectonic activity, have higher than normal concentrations of stored heat that might be economically harnessed as an important new source of energy.

About one million acres of Federal lands in five western States have already been determined as having current potential value for geothermal resources and an additional 86.3 million acres in thirteen western States have been classified as prospectively valuable for geothermal resources.

Current interest in areas of abnormally high geothermal resources is for the electric power which can be generated in these areas by releasing steam from naturally hot spots through drill holes and channelling the steam into turbine

generators. One such plant at The Geysers in northern California is now producing over 56,000 kilowatts and the developers say that this site has a potential of producing over one million kilowatts.

The Geological Survey estimates that 5 to 10 percent of the world's geothermal energy resources are in the United States and that there is enough heat stored in rocks in the upper six miles of the crust beneath the U.S. to equal the heat content of 900 trillion tons of coal.

The Departmental program is aimed at providing the basic geologic, geophysical, and geochemical knowledge necessary for effective exploration and development of geothermal energy and at locating areas of potential geothermal energy. Information will be developed to provide the background knowledge necessary for the efficient administration of the geothermal resources on Federal lands.

The Department has also received a proposal to participate in the development of an electric power generating unit that utilizes ocean thermal gradients to drive a propane gas generator. Such a unit is known to be theoretically operable, but its need, practicality, and economic feasibility are unknown. The proposal has received mixed reactions by Departmental specialists.

OIL SHALE

Demand for liquid fuels in the U.S. for the period 1969 to 1980 is expected to be equal to the total consumption of these products since the discovery of oil in the U.S. Oil-shale deposits in the U.S. contain one of the largest potential sources of energy available from fossil fuels and will inevitably be a future source of hydrocarbons. Production of petroleum products from oil shale is approaching commercial feasibility. R and D on reduced mining costs, in situ combustion, improved methods of retorting, and processing of products could significantly advance the development of a full-scale industry. Although petroleum refining practices can be used to upgrade shale oil, lower cost methods to treat a high nitrogen content shale oil must be found.

The expected increase in crude oil reserves from now through 1980 will show a deficit of 6 billion barrels if the rate of adding reserves is not increased. One way to meet this need is to develop an economical capacity for shale oil production from the 50 billion barrels equivalent of known oil shale resources that are amenable to conventional methods of mining, retorting, and refining. The program includes research that could lower production costs and that could allow industry to develop a shale oil production capacity of 1 million barrels of shale oil per day by 1980.

A 10-year program has been proposed by the Department to perform both basic and applied engineering research on: (1) The physical and chemical properties of oil shale and kerogen (the solid organic material in oil shale from which shale oil is derived by heat treatment) as related to occurrence in the deposit and how the properties vary with geologic conditions; (2) composition of shale oil, shale-oil components, and shale-oil fractions with particular reference to heavy hydrocarbon fractions; (3) application of basic data on the properties of oil shale to improve processing methods; (4) fundamentals of catalytic, thermal, and chemical treatment of shale oil; (5) effects of retorting temperature variables; (6) effect of physical properties of oil shale on efficiency of crushing; (7) methods for retorting oil-shale fines; (8) techniques for utilizing spent (retorted) shale; and (9) spent-shale disposal problems.

MINERALS

HEAVY METALS

Situation and outlook

Gold and certain other heavy metals including silver, platinum metals, mercury, tin, antimony, bismuth, nickel, and tantalum are being consumed at a rate far exceeding domestic production. To satisfy our needs we are relying heavily on imports and, for gold and silver, on sales from Treasury stocks. The situation for gold is particularly critical because, in addition to the monetary demands for this metal, consumption by industry and the arts has risen markedly in the past few years while domestic production has remained relatively constant. As a result, we now use more than three times the volume of gold we obtain from domestic mines. Unless the net gold balance is altered favorably, Treasury stocks are expected to reach a critical point by 1977.

Needs

It is necessary to (1) effect an increase in domestic production of gold at least to the level of industrial consumption, thereby reducing the drain of U. S. gold stocks, and (2) demonstrate a capability to produce significant additional amounts of gold from domestic sources in the near future, thereby providing a psychological advantage to the U. S. in international economic diplomacy. New deposits of gold that can be developed profitably by industry with current techniques, as well as economically marginal or submarginal deposits, must be identified and delineated. New mining and metallurgical techniques must be developed to make many of the marginal and submarginal deposits profitable to operate.

Alternatives

The supply of gold could be increased by raising the price above the \$35/ounce figure set in 1934 or by paying subsidies to gold producers. Both of these alternatives are vigorously opposed by the Treasury Department.

Criteria (for Government involvement)

The combination of fixed price and increasing production costs has caused mining of gold to decline. As a result, little research in support of gold production has been done either by Government or by private industry in the United States. The Heavy Metals program of the Department of the Interior—being conducted jointly by the Department's Geological Survey and Bureau of Mines—is designed to rekindle interest in gold.

Preferred course of action

Under the Heavy Metals program, basic geologic, geochemical, geophysical, and technological information is being gathered and disseminated to stimulate increased efforts by private industry in searching for new deposits and in developing new ore bodies. In recent years, for example, most of the effort devoted to gold has remained in the context of traditional sources (namely gold veins, conventional placers, and byproduct recovery) and of traditional treatment methods. But if gold output is to be increased significantly, new sources in new kinds of geologic environments must be found and new sampling, mining, and metallurgical techniques must be developed. Primary emphasis at present is directed toward finding and stimulating the production of gold, but concomitant discoveries are expected in the other heavy metals.

Technical objectives

In scope, the Heavy Metals program is designed to include any subject that has a bearing on the occurrence and geological-geochemical behavior of gold and the other heavy metals, or on improvements in methods of mining and recovery. The objectives of the program are:

- (1) Delineation of exploration targets that private industry can develop.
- (2) Identification of large-scale, low-grade resources that might be made into productive deposits through improvements in technology.
- (3) Development of mining systems and processing methods to make low-grade resources minable at acceptable costs.
- (4) Development or improvement of sampling and analytical techniques and detection devices that will enhance the capability of both Government and industry to locate and delineate deposits.
- (5) Expansion of knowledge of the processes that control the occurrence and behavior of gold and other heavy metals in nature.
- (6) Improvement in the methods to appraise and classify the potential of new deposits.

Application of science and technology

To attain the objectives of the Heavy Metals program, a wide variety of scientific and technologic methods are being utilized or are under development. Some examples are:

- (1) Basic geologic mapping.
- (2) Improved extremely sensitive and rapid analytical techniques.
- (3) Mobile chemical laboratories and spectrographs.
- (4) Highly sophisticated analytical instruments based on neutron activation principles.
- (5) New equipment for sampling such as the experimental resonant vibratory drill which will be tested both in the continental shelf waters and on

land. Portable X-ray analyzers are also being developed for use in boreholes to determine presence of gold and silver.

(6) Statistical methods using computers for analyzing sample data and preparing mathematical models of ore bodies, which will be essential in developing optimum mining plans.

(7) Laboratory and in-place testing of properties and character of rock mass that will govern design of open pits, selection of equipment and disposal measures.

(8) Laboratory leaching tests on actual gold placer (alluvial) samples to develop in-place mining methods and a new extractant for leaching gold that was recently discovered through Bureau research.

(9) Economic study of a hypothetical open-pit operation which has been programed on a computer to examine varying conditions to determine optimum return.

Geologic mapping has been carried on by the Geological Survey for nearly a century, and this time-tested tool continues to be the backbone of studies of known deposits and of the search for new ore deposits. To understand fully the occurrence and origin of ore deposits, it is necessary to determine their structural and stratigraphic setting, and this can be accomplished only through careful geologic mapping. Once the setting of a known group of deposits has been determined, well-prepared geologic maps are invaluable in choosing favorable structural and stratigraphic sites in which to concentrate the search for new deposits.

Even before inception of the Heavy Metals program, basic geologic mapping paid off handsomely with the discovery of the Carlin gold mine in north-central Nevada. In 1960, R. J. Roberts of the Geological Survey published a report entitled "Alinement of mining districts in north-central Nevada" which was based on several years of geologic mapping in that area. Roberts noted a relationship between ore deposits and the Roberts Mountain thrust fault and suggested that carbonate units in "windows" in this thrust fault would be favorable places to explore for new deposits. Geologists with the Newmont Mining Company studied Roberts report and decided to explore in the Carlin window. Newmont began a drilling program there in 1962 and ultimately discovered an ore body having estimated reserves of 11 million tons averaging 0.32 ounces of gold per ton. Production from this ore body began in 1965.

Analytical methods far more rapid and sensitive than the old slow and costly fire-assay techniques have been developed and several new methods are under investigation. These more sensitive methods are essential to the program because gold is a material of high value and thus low concentrations constitute ore even by standards of the past. "One-ounce" gold ore, the ambition of many a prospector and mine operator, is a concentration of only 34 parts per million and much gold ore containing only one-third this amount is being mined today. Geochemical anomalies of gold, which are essential clues to new deposits, may be in the parts-per-billion range, as might also be the gold ore of the future.

In order to study adequately the gold-bearing conglomerates of northwestern Wyoming, J. C. Antweiler of the Geological Survey developed a technique based on atomic absorption principles that will measure gold in concentrations as low as 10 parts per billion.

Certain "pathfinder" elements, such as mercury and tellurium often accompany gold in ore deposits, and since these elements are more mobile than gold, they often migrate from a deposit into seemingly barren rock and soil above or adjacent to the ore. Thus, detection of anomalous amounts of these elements may be used as a guide in the search for concealed deposits of gold. A sensitive, wet-chemical method for determining tellurium was developed in Geological Survey Laboratories four years ago and more recently there was developed an instrument, based on the principle of atomic absorption, that can detect mercury in concentrations as low as five parts per billion. The instrument can be mounted in a station wagon and is capable of making 60 to 100 analyses per day.

Mobile chemical labs able to operate in remote and rugged areas have revolutionized the search for new ore deposits. The old-time prospector had to rely on slow and costly assays. If he couldn't see it, he couldn't find it. Not so with the modern exploration geologist who can have with him in the field a fully equipped, self-contained mobile chemical laboratory. These labs, developed by the Field Services section, Exploration Research Branch of the Geological Survey, generate their own electricity and contain crushing and grinding equip-

ment as well as sleeping and cooking facilities for the chemist. They can be stocked with chemical supplies and equipment with which rocks and/or soils can be analyzed for as many as 41 elements. Instead of shipping his samples to a central lab and waiting weeks or even months for results, the geologist can get his samples analyzed in a mobile lab within hours after he has collected them, thereby enabling him to carry out his work more effectively—abandoning areas in which the analyses are low and concentrating his efforts in areas of promise.

Neutron activation methods have been used for several years to analyze rocks and soils in the laboratory. Recently, F. E. Senftle of the Geological Survey developed a truck mounted instrument, which makes it possible to use neutron activation for analyzing rocks and soils in place. Consequently, it is no longer necessary even to collect a sample, as long as a truck can be driven over the spot that one wants analyzed. The rock or soil under the truck is irradiated and the activities of the induced products are determined. The nature and concentration of the induced radioactivity indicate the amounts of certain elements present in the area being tested. An instrument for performing in situ analyses for silver is now operational and one capable of detecting gold is being developed.

New sampling equipment and methods are essential to the success of the Heavy Metals program since accurate sampling is the vital link between finding targets and developing an actual resource. In recent years one of the most interesting and novel developments in drilling has been that of vibratory-resonant drilling. This concept, which consists of vibrating the drill rod rather than pounding it, has increased the speed of drilling considerably in soft and unconsolidated materials. This type of drilling was developed by a totally owned subsidiary of the Shell Oil Company and is being used commercially in driving piles. Experimental units have been developed for drilling smaller diameter holes. The Bureau of Mines has cooperative agreements to test this concept of drilling and recovering cores during an Alaskan cruise this summer by its marine mining research vessel the R/V VIRGINIA CITY (fig. 33). Another unit has also been purchased to test in-land deposits.



FIGURE 33.—Bureau of Mines marine mining research vessel,
the R/V *Virginia City*

An interesting new sampling device that is being developed by the Bureau is a portable X-ray probe that can be lowered into small diameter drill holes to determine the presence of gold or silver. Such a device would be invaluable as a means of improving efficiency in sampling techniques.

The Bureau of Mines has pioneered statistical sampling techniques over the past few decades and is presently further refining these methods for the heavy metals program. Extensive sampling experiments and subsequent analysis at the Homestake gold mine, the Nation's leading gold producer, have indicated that very significant reductions in the amount of exploration drilling may be achieved using these techniques. The Bureau will be applying these methods in its sampling at the Cripple Creek area of Colorado and northwestern Wyoming where the Geological Survey has identified potential resources and requested sampling programs.

One of the major premises on which the Heavy Metals program is based is that large, low-grade deposits will be identified which may be mined using surface methods. This will require high-tonnage (ranging from 25,000-100,000 tons per day) production systems not presently in use for heavy metals output. (The largest open-pit gold mine at Carlin, Nevada, has a daily production of 2,500 tons.) The Bureau's mining research centers are all doing research that will provide the best methods of fragmentation, ground control, materials handling and waste disposal. These will be integrated through a systems engineering approach to provide the optimum mining method for any given set of conditions. This will be particularly essential when you are mining large, low-grade ores where minimal unit costs are required.

The Bureau of Mines is also devoting a significant effort to developing new techniques of recovering heavy metals. One interesting aspect of this work by the metallurgical research groups is that of in situ leaching, or solution mining, as it is sometimes called. This technique consists of passing a leaching agent through an alluvial deposit which will bring the heavy metal into solution. This metal-bearing solution must then be collected and treated to recover the gold or other heavy metals. The obvious advantage of such a system is that it could totally eliminate the mining costs (including disposal). There are potential disadvantages, principally that of water pollution if toxic leaching agents such as cyanide are used. The Bureau's metallurgy research center at Reno has developed a new leaching agent of minimal toxicity which is presently undergoing comprehensive testing.

The Bureau of Mines also is presently involved in a two-pronged economic analysis of the possibilities of increasing gold production at a price of \$35 an ounce from known mining properties through research resulting in mining cost reductions. One part of the study is concerned with developing an economic model of the gold industry which will make it possible to simulate the effect on total U.S. gold production and reserves of a given percentage reduction in a certain general category of mining cost. This national model will point to the general type of cost category, for either lode or placer mines, which will give the greatest increase in U.S. gold production from a given percentage cost reduction, as well as point to the geographic area of the country that can provide such production increases. The second part of the study is concerned with developing detailed engineering and economic models for each type of mining system (i.e. open pit, placer dredging, underground methods, etc.). These models are designed to simulate, in detail, the effect of a reduction in specific types of costs upon the rate of return of a mining property. Depending upon the specific type of mining system applicable to the particular properties in the geographic areas pointed out by the national model, the detailed information concerning these properties can be derived and used in the relevant micro-economic and engineering model. This model will then point to the specific mining costs, which if they are reduced by a certain percentage will increase the rate of return of the properties enough to make them profitable at a \$35-an-ounce price for gold. The cost data indicated in the model will serve as a guide to the areas in which research efforts should be concentrated.

Expected benefits

The Heavy Metals program is relatively new and its ultimate benefits cannot yet be predicted with any certainty. To date, however, work under the program has led to the discovery of an ore deposit at Cortez, Nev., which contains at least 660,000 ounces of gold; to identification of substantial marginal resources in the Cripple Creek district of Colorado; and to recognition of large sub-marginal resources in conglomerates of northwestern Wyoming.

USE OF NUCLEAR EXPLOSIVES IN MINERAL EXTRACTION

Situation and outlook and technical objectives

The depletion of high-grade mineral reserves and the growth of our population have made necessary the utilization of increasingly lower grade mineral deposits to sustain an expanding economy. So far, improvements in technology have met these demands admirably. However, the economic limits of existing technology are rapidly being reached in many areas of mineral extraction and processing, and further marked advances are necessary if we are to continue to have available the variety and quantities of mineral products that we require.

Utilization of nuclear explosives offers a key to an assured future supply. Moreover, while such utilization may make possible economic extraction of

mineral resources not now available by any known production techniques, obviously, there is a strong possibility that the development of a successful nuclear explosive technology will also permit lower cost production of mineral resources already being utilized.

National significance

The gradual development of explosives over the years has made possible new and more efficient blasting applications in the modern minerals industry. Since the discovery of black powder, the entire field of explosives technology has steadily improved. Each significant advance has made possible cost reductions that have permitted the economic mining of increasingly lower-grade mineral deposits. The atomic age, now more than two decades old, offers the promise of using the world's most powerful explosive to achieve further substantial economies in producing the mineral raw materials needed by man.

The Interior Department's Bureau of Mines, in cooperation with the U. S. Atomic Energy Commission and private industry, is now engaged in a program of research aimed at utilizing the energy of nuclear explosives to expand our domestic mineral resources base. The success of these cooperative efforts in one or more of the fields of mineral development could add significantly to the reserves of metals, nonmetals, and fuels that can be made available at reasonable real costs.

Criteria for government involvement

Government participation is essential in developing the technology that will permit use of nuclear explosives in the mineral industries primarily because at present, and for many years in the future, the control of nuclear explosives can be expected to remain a government responsibility. Moreover all existing technology, whether for military or peaceful uses of nuclear explosives, has been developed by the government or under close government supervision. Therefore, only the government can furnish the explosive and the technical knowledge for its safe industrial application. Until the government, with the cooperation of industry, has demonstrated that nuclear explosives can be used safely in the minerals industry, the industry will be reluctant to assume the major costs and the responsibility for public safety that are inherent in the use of nuclear explosives.

Nevertheless, it is also clear that any demonstration of the effectiveness of nuclear explosives in industrial application should be jointly undertaken by government and industry, and that each should share a proportional part of the necessary costs of the projects authorized. The government must determine the overall safety aspects of any proposed experiment, and must provide the nuclear explosive and supervise all safety. The technology available should be provided by the government. Once a particular minerals application has been demonstrated to be feasible and safe, the government should withdraw to the extent possible and all similar applications in the future should become the responsibility of the using industry, with the government acting only to insure security and safety.

Preferred course of action

The efficient use of nuclear explosives in the mineral industries depends on: (1) continued research and development in the production and design of nuclear explosives, (2) continued cooperation between government and industry in solving the many problems of industrial application, (3) availability of nuclear explosives for industrial use at reasonable costs, and (4) international acceptance of the Plowshare concept for peaceful use of nuclear explosives; that is, the nations of the world must reach agreement not to prohibit by test-ban treaty, the beneficial use of nuclear devices.

Expected benefits

A brief description of possibilities for nuclear explosives in the mineral industries will point out some of the potentials for this energy source.

Deep underground nuclear explosions usually create large "chimneys" of broken rock, and several potentially valuable industrial applications for this effect can be identified. For example, a nuclear chimney and related fracture zone in underground natural gas bearing rock formations of low permeability could act as a highly effective well bore, which may make it possible to recover natural gas from such formations with far greater efficiency and economy than is now possible. In an oil-shale deposit or a low-grade copper orebody, a nuclear chimney might make possible in-place retorting or leaching operations through which the fuel or metal values could be recovered without incurring the costs inherent in mining and disposal of waste rock. Created in an area regionally near, but

locally remote from, major population centers, such a chimney could be used to store natural gas near the consumer-end of gas transmission lines. In this way it could help gas companies provide better service to consumers during periods of peak demand.

It has been estimated that if nuclear stimulation of natural gas reservoirs is successful, the economically recoverable gas reserves of the United States could be more than doubled from less than 300 trillion cubic feet to about 600 trillion cubic feet. If in-place retorting of domestic oil shale in nuclear chimneys proves feasible, as much as 160 million barrels of oil might be recovered. Similarly, nuclear chimneys might lead to the recovery of millions of tons of copper that are not economically within reach at present and such chimneys also could provide space needed for storing billions of cubic feet of natural gas.

The costs of determining the feasibility of these, and perhaps other, applications for nuclear explosives can, of course, only be estimated, but it is believed that the government's share could range from \$10 million to \$20 million a year for several years.

BRIEF DESCRIPTIONS OF ADDITIONAL PROGRAMS IN MINERALS

TECHNOLOGICAL AND RESEARCH CORE

For fulfilling its obligations as the focal point of the United States Government effort to assure an adequate supply and dependable flow of minerals, the Department of the Interior deems it essential to maintain a technical and scientific competency in all major phases of mineral supply, resource base appraisal, extraction, processing, and utilization. Such competency allows the Department to furnish accurate and timely advice as the basis for policy decisions and to discharge its advisory function for management of the mineral resources on public lands. In addition, the core activities, involving basic and exploratory research, provide the capability to identify and meet needs and opportunities in the minerals field. A cadre of competent and knowledgeable earth scientists and minerals technologists identifies emerging needs and problems and formulates effective measures to meet them.

These responsibilities necessitate intimate knowledge of diverse sciences and complex technologies. Interdisciplinary staffing is essential. As an example, the core research personnel of the Department represent about 50 different disciplines and possess an intimate working knowledge of the practices employed for the discovery, production, preparation, and use of at least 60 different mineral commodities.

The foundations of the core programs are (1) basic studies of scientific concepts and principles and (2) fundamental measurements and phenomena to produce accurate data of a lasting nature upon which applied research and technology can build.

Special development programs directed toward specific, measurable goals and exploratory research aimed at adaptation and application of scientific knowledge require the stimulation and support of a concurrent program of imaginative basic research in promising scientific areas. Continuous aggressive pursuit of knowledge in the physical sciences and allied disciplines is mandatory for advances in technology for recovery, reclamation, and effective use of mineral materials. Equally important, basic scientific investigation is necessary to assure that Department personnel maintain broad technical competency in their component disciplines; such competency will provide a monitoring window to the rapid advances taking place in basic science throughout the world.

MINERALS EXTRACTION RESEARCH

Projections show that unless we find more domestic deposits that can be worked economically with present technology, or develop the technology that will enable us to process new marginal or deeper lying deposits our dependence on imports will increase or the price of mineral products will rise substantially.

The most acceptable solution to our mineral resources problems is continuous and accelerated technological advance. This requires a better understanding of the mechanics involved in each of the elements of mining (ground control, rock breaking, materials handling, and environmental control and management). Such an understanding of fundamentals is essential to the development, engineering, and design of improved mining systems.

The intimate knowledge of diverse sciences and complex technologies that must be acquired will involve interdisciplinary efforts directed to basic and applied studies of scientific concepts and principles. These studies can produce the accurate data which can be applied immediately to the advancement of mining technologies and ultimately to the development of whole new mining systems. New systems are, inescapably, a "must" if we are to produce a continuing adequate supply of minerals from lower grade and less accessible deposits and, at the same time, minimize mining-related damage to the environment.

The value of the research and development effort can be measured largely in the public benefits it can be expected to yield. These include the assurance of a continuing supply of minerals (on which 80-85% of our industrial economy depends), improved conservation and expansion of domestic minerals resources, and preservation of environmental quality.

MARINE MINERAL MINING

The need to develop the technology of marine mining is born of the accelerating demand for minerals, the projected potential of the marine environment as a supplier of minerals, and the embryonic level of present marine mining technology. A primary purpose of the Department program is to accurately define the resource potential of the marine environment. Initial attention is directed to the continental shelf because of ready accessibility to land-based processing facilities and because of the probability for discovery of heavy, high-unit-value materials, such as gold and platinum.

A major element of the program deals with development of sampling and deposit delineation equipment and of techniques for the characterization of marine mineral deposits. An integral part of this effort is definition of deposit characteristics and of the environmental conditions essential to quantifying the mining problem and establishing mining system requirements.

A second element of the program encompasses the design, development, and testing of equipment and systems that will enable economic recovery of minerals from the ocean environment. Initially, emphasis is being placed on engineering research studies to determine the adaptability of existing dredging systems for marine mining.

MARINE MINING EQUIPMENT

The technology of marine mining is still in a primitive stage, struggling to develop adequate equipment and techniques for exploration. Only now are we beginning to recognize and define the problems to be overcome in developing a domestic marine mining industry. Nevertheless, with Federal encouragement in the form of an adequate research effort, a domestic industry probably can be established within five years.

U.S. population is increasing and so is per capita consumption of minerals. Depletion of known mineral reserves will be accelerated as other nations step up their industrial expansion. The ability of our last frontier, the sea, to help satisfy future mineral needs must be determined now, and such an assessment requires a whole new technology.

Instruments and techniques must be developed to permit accurate identification of all distinguishing features of marine mineral deposits. Once this can be done, production methods can be developed on a systems basis. Only then can the significance of marine minerals be determined.

To augment USGS exploration techniques, the Bureau of Mines is developing both geophysical and direct methods for delineation studies. Development of production-systems technology will involve research and engineering studies in materials handling, in situ fragmentation and beneficiation, mining platform design, mineral processing, waste disposal, and problems of environmental disturbance.

Quantitative data on marine mineral resources are nearly non-existent. Nonetheless, production of metal and non-metal minerals in the U.S. totaled \$7.4 billion in 1965, about \$2,049 per square mile of land area. If this ratio is projected to the continental borderlands within 125 miles of the coast, an eventual level of mineral production of \$3.2 billion can be projected. Such extrapolation is the best guess that can be made until more reliable data becomes available.

METHANE CONTROL

Rapid depletion of shallow coal deposits that are relatively free of explosive methane gas is forcing us to extract an ever-increasing quantity of coal from deeper, generally much gassier, deposits. Hazardous conditions created by methane in these deeper mines have increasingly hampered productivity and coal recovery and adversely affected production costs.

To combat this undesirable trend, we must acquire a better understanding of (1) the conditions controlling methane's occurrence and volume, and the rate at which it moves through coal beds, (2) the manner in which beds may be degasified before and during mining operations, and (3) ways in which the gas might be collected and used instead of being wasted to the atmosphere. To gain the requisite knowledge, expansion of current studies in methane drainage is planned.

Techniques that show promise are: the interpretation of geologic structures as a basis for predicting occurrence of excessive amounts of methane, injection of water into coal beds to help force methane out of them, and drainage of methane through holes drilled into the coal seam. These and other, as yet unexplored, methane-control techniques are to be further developed and their economic practicality demonstrated.

Through such research and development efforts, effective methods can be devised to reduce hazards to those working in deep coal mines. In addition, it should be possible to reduce methane-caused work stoppages by 50 percent, and to permit a good part of the methane now wasted to the atmosphere to be collected and used either as a fuel or for producing a high-quality lamp black. Aside from reducing workman hazards, dollar benefits realized through application of the knowledge in research could be expected to start accruing significantly in 1972. By 1982 these benefits could reach an estimated \$220 million per year.

ALUMINUM

The versatility of aluminum and its alloys has led to extremely rapid growth in production and consumption of aluminum in recent years. Growth is projected to continue, at least through 1980, at a rate of 6 to 8 percent per year.

Nearly 90 percent of the aluminum produced in the United States is made from imported bauxite. Avoidance of constraints that may be imposed on the production and use of aluminum, due to expected increased cost of bauxite or possible periods of national emergency, requires development of methods for recovery of aluminum from alternate source materials.

The producing industry has examined the question of alternate source materials to the limit allowed by corporate decisions based on immediacy of return on research dollars invested. The long-range value of an aluminum industry based on domestic feed, however, is of such wide national importance that a supplemental Government research effort is clearly justified.

The Department of the Interior's Bureau of Mines is continuing a program to develop economic processes for recovery of alumina (the intermediate, oxide, material used for producing aluminum by standard technology) from either clay or anorthosite. Both of these materials are in ample domestic supply. Concurrently, new and scientific approaches are being investigated to determine the feasibility of producing aluminum either directly from ore or from intermediate materials other than the oxide.

COPPER

An adequate domestic copper supply is essential in the national interest to offset drains from a growing economy and from interruption of foreign supply, as typified by reduction of imports from the Congo during the recent political strife there.

The effects of wild fluctuations in world copper price, between 31 and 90 cents during the last 3 years, was minimized by the stability of domestically produced copper, which held a relatively uniform price between 32 and 36 cents. To serve as a basis for continued stability, the domestic copper producing industry will require advances in technology to enable economic mining and extraction from ever-decreasing grades of ore. Needed are improvements in mass-mining and materials-handling techniques and in traditional concentration and reduction methods, or the evolution of entirely new processing systems.

Department of the Interior research, which is designed to complement industrial efforts, is aimed: at devising efficient concentration methods to significantly reduce the 114,000 tons of copper annually discarded as mill tailings; at developing thermodynamic and reaction kinetics data on which to base new reduction and smelting processes; at gaining the technology for improving leaching and recovery practices; and at developing new mining systems that will enable faster, safer, and less expensive extraction of ore.

FERTILIZER MINERALS

An urgent demand for food and fertilizer is being felt around the world. Rapid population growth and rising standards of living in emerging nations is expected to compound the demand.

The United States now exports \$325 million worth of fertilizer annually, and it probably will raise this figure to \$1 billion by 1970. Fertilizer exports have considerably more leverage than food exports in averting mass famine. Food worth \$1 million will feed only 70,000 people while fertilizer worth \$1 million will help provide food for 200,000 people. It is evident that expansion of the fertilizer industries can be expected at an accelerated rate and that problems associated with the efficient development and exploitation of phosphate and potash should be given high priority.

With current practice, more than one-third of the phosphate rock mineral is lost before conversion to fertilizer. Department of the Interior research is directed toward development of beneficiation methods to avoid processing losses and to allow economic mining of lower-grade deposits.

Potash presents Interior research scientists with a different type of problem. The domestic potash industry faces a competitive disadvantage in relation to the rapidly growing Canadian industry. Canadian reserves, second largest in the world, are exploited at lower costs than are U.S. deposits. Only the development of more efficient techniques to recover potash from low-grade ores and brines will prolong the existence of the domestic potash industry.

IRON

Domestic and international developments in iron ore production during the last 15 years have been characterized by rising demand, by a shift of production from the United States to foreign suppliers, and by an increase in beneficiated iron ore in proportion to total output.

U.S. consumption of iron ore is expected to increase by 34 percent between 1965 and 1980. Iron and steel manufacturers need the assurance of a high-quality, minimum-cost feed material. The ore producers need an advanced technology which will permit them to exploit domestic iron ore resources at a cost competitive with foreign ores. For meeting these needs, the Department of the Interior is conducting research to devise a technology capable (1) of recovering iron efficiently from the vast resources of domestic iron ores and (2) of making higher quality concentrates and stronger agglomerates than are currently obtained. The improved beneficiation procedures should make the domestic ores competitive with foreign imports; this would tend to stabilize the price and supply situation for American industry. The higher-grade, stronger agglomerates will further improve the efficiency of iron making because they will increase blast furnace throughput and reduce coke and flux requirements.

SULFUR

Sulfur consumption rose 44 percent in 5 years to 8 million long tons in 1965, primarily due to increased production of phosphatic fertilizers. Since 1963, demand has exceeded production; withdrawals from producer stocks have met the deficit. The drop in stocks has resulted in recent price increases. Sulfur is now at its highest price since 1919.

Nearly 65 percent of the sulfur produced in the United States is obtained by Frasch mining of domes in the Gulf Coast area. While apparently sufficient to support the present level of production, this source will not be adequate to satisfy the expected growth in sulfur demand. About one-quarter of U.S. sulfur is recovered from sour natural gas and sulfur containing refinery gases; however, a major future increase in sulfur from this source cannot be expected.

To meet projected demands for sulfur, Department of the Interior research centers on recovery from alternate sources. An economic treatment for flue gases

could provide sulfur while reducing air pollution. Bureau of Mines scientists have recently applied hydrometallurgy and ion-exchange technology to devise a new method of recovering sulfur from almost unlimited supplies of gypsum and anhydrite. This process promises to be economically competitive over a broad range of conditions.

IMPROVED MINERAL MATERIALS

Many industrial-type processes have been shown to be more efficient than those now operating but they cannot presently be utilized because the required materials of construction have yet to be developed. This is true in such common categories as steam power generation, metallurgical and chemical processes, and in engines for high-speed transport where higher temperature operation would result in higher output per unit of fuel.

To meet such requirements, the Department of the Interior is engaged in development of new and improved metals, alloys, ceramics, and composites which have the ability to resist highly unfavorable operating environments and also, whenever possible, combine great strength and light weight. Often, the attainment of these goals contributes to the specialized needs of the Department of Defense, the National Aeronautics and Space Administration, and the Atomic Energy Commission, but the principal activities of the Department of the Interior are directed toward materials for use in the industrial economy and toward provision for an expanded mineral resources base. Additional objectives include improvements in methods of fabricating materials and extending their service life, and the synthesis of minerals to replace natural substances which are in short supply and high in cost.

INDUSTRIAL MINERALS

Nonmetal, nonfuel minerals are essential components of the Nation's construction, chemical, and transportation industries. The annual mine output value of the raw materials (sand, gravel, crushed stone, clay, lime, crushed mica, salt, gypsum, fluorspar, spodumene, etc.) approaches \$5 billion.

Industrial minerals, in general, command low prices and, therefore, are subject to limited shipping distances. Many of them must be concentrated to meet stringent grade and impurity limitations. High-grade deposits of some of these minerals are being depleted, and economic exploitation of lower grade ores necessitates development and improvement of methods for beneficiation.

The Department's research is aimed at improving industrial recovery of those nonmetallic minerals (excluding phosphate, potash, and sulfur) that fill needs essential to the national economy, but it is restricted to areas where identified need is greatest and chances for improvement are highest. Such research is diversified and demands specific talents. Current projects include: devising methods for improving grade and recovery of kyanite, sillimanite, and feldspar from disseminated ores; development of design parameters for attrition-grinding equipment; conversion of heavy-liquid separation from batch to continuous operation; development of a new process to prepare zirconia from zircon.

HELIUM

In its helium program, the Bureau of Mines produces and sells helium for current beneficial use, acquires and stores helium for beneficial use in the future, and does research to provide new knowledge of the properties of helium as a means of extending its usefulness.

Most of the current uses for helium are in our Nation's space and missile programs, atomic energy program, undersea activities, and research. Possible future uses for helium include underground power transmission and more efficient generation of electrical power through the use of materials which are superconductors at the temperature of liquid helium.

The Bureau's helium research is for the purpose of improving processes for the extraction, purification, liquefaction, transportation, storage, and use of helium by developing more accurate thermodynamic and phase-equilibrium data for helium, and by obtaining information on various properties of helium, such as absolute viscosity, dielectric constant, solubility, and diffusion. The work is done by reviewing previous research from all known sources, evaluating and identifying errors and omissions in previous work, and by performing experiments and making measurements to fill gaps where there are no data. In addi-

tion, the helium research effort provides technical support to the production and sales and the acquisition and storage functions by solving non-routine problems in physical analysis and measurement of helium-gas mixtures.

FISH AND FISHERY PRODUCTS

AQUICULTURE

Aquatic farming or aquaculture is not a new idea. Roman oyster farms in the first century B.C. used methods similar to those used today. It is strange that private interest in commercial aquaculture has developed only recently on a large scale. Our fisheries bureaus receive inquiries for information and advice almost daily. The requests are from large companies with abundant capital and from individuals seeking ways to increase their income, and a few are from persons hunting methods of supplementing retirement income. About 20 companies are engaged in marine aquaculture.

Less than 10 years ago, farming of freshwater food and game fish was a burst bubble. Rice and soybean farmers of the Mississippi delta states, encouraged by a few scattered successes, had converted surplus acres to great pond and reservoir complexes. They built a processing plant, planted some young catfish, buffalo fish, black bass and other sunfish, and usually awaited a harvest in vain.

Rearing trout and salmon in Government-owned hatcheries for replenishing public fishing waters has a hundred years of history in this country. But large-scale privately owned fish farming (except for a few trout farmers) began when an Arkansas rice grower found that his rice-watering reservoir contained wild sunfish, buffalo fish, and catfish that were marketable for food or sport. The idea caught on quickly as a means of supplementing farm income and using surplus lands. Fish farmers' associations were organized, Arkansas law was changed to allow sale of farm-reared fish of any species, but the husbandry aspect of fish rearing was largely unrecognized.

Now in 1967, all the evidence points to fish as a profitable crop (catfish is the best) to diversify the farming practices of Arkansas, Alabama, Kansas, Louisiana, Mississippi, and Texas. A science of large-scale fish husbandry is developing and in 5 years has turned freshwater fish farming from a long-shot gamble to an enterprise with as much opportunity for success as other crop raising.

The Nation's coastal areas also have potential in aquaculture—the magnitude of which is yet to be fully realized. At about the same time the Arkansas rice grower was discovering his new cash crop, the Bureau of Commercial Fisheries was getting its aquacultural research started, emphasizing artificial spawning, feeding, and culture of oysters and clams. Results are already in use by oyster companies in operating hatcheries to produce seed oysters. In 1965 and 1966, three of these commercial hatcheries produced 40,000 bushels of seed oysters. In 3 years this seed could produce 120,000 bushels of market oysters valued at \$1,900,000—a value approximately equal to all Bureau funds spent on oyster aquaculture research in the past 9 years.

The Bureau of Commercial Fisheries conducts research on oyster, clam, pompano, and shrimp aquaculture at laboratories at Milford, Connecticut; Oxford, Maryland; St. Petersburg Beach, Florida; and Galveston, Texas. Life history, physiological, and behavior studies at other Bureau laboratories contribute to the development of aquaculture of lobsters, crabs, and other fish. The Bureau of Commercial Fisheries projected 5-year plan increases emphasis on aquacultural studies, particularly of genetics and selective breeding, foods, diseases, and development of culture methods from larvae to adults.

After enactment of the Fish Farming Act, P.L. 85-342, the Bureau of Sport Fisheries and Wildlife in 1961 established a Fish Farming Experimental Station at Stuttgart, Arkansas, and a demonstration area at Kelso, Arkansas; the latter awaits full development. The Bureau of Commercial Fisheries participates in the fish farming development program with gear development, technology of processing, and marketing promotional activities. Fish farming research is solidly based on the older warmwater fish-cultural research for the hatchery program of the Bureau of Sport Fisheries and Wildlife.

In the lower Mississippi River valley freshwater fish farming is now well enough established that it must be regarded as a basic part of its agriculture. Fish is the only crop developed in the past generation that offers an opportunity to diversify the agriculture of the area. While embodying principles of water and soil conservation as basic parts of the practice, fish farming produces a crop

for which there is no surplus and no acreage restriction, and which actually improves the land for arable crops. Even in its present state of development, fish farming can be profitable, yielding in some instances gross income and net profits exceeding that of rice. In addition, it is a natural addition to the cultural practices used in rice-soybean farming, introducing a rice-fish-soybean rotation program.

Interesting and possibly far-reaching tests are in progress at the Bureau of Sport Fisheries and Wildlife station in Arkansas, in cooperation with the agricultural experiment stations of the University of Arkansas—Department of Agriculture. The tests, which already look promising, involve fish-rice rotations. When rice is planted following a fish harvest, the ground already is leveled, is weedless without application of herbicides, and has been nitrogen-enriched by the fish. New varieties of short, strong-stemmed rice should give considerably larger yields per acre, perhaps as much as 120 bushels compared with a usual 80 or 90.

A conservative estimate of production of channel catfish is 15 million pounds, worth more than \$6 million, plus an additional \$1 million worth of fingerling catfish. Gross income from bait minnow production in Arkansas has not been studied in detail, but we know it exceeds returns from catfish several fold. In Lonoke County, Arkansas, the income from 10,000 acres of fish in 1965 was estimated at \$4 million while the income from 110,000 acres of soybeans grossed only \$6 million. In Arkansas alone there are 3.5 million acres of land that could be used for fish farming. If about 10,000 acres of catfish brought a return of \$6 million last year, the potential income from 3.5 million acres is staggering. Production of channel catfish in 1965 was reported to average 1,600 pounds per acre and to gross between 35 and 50 cents per pound. Production costs were 25 to 30 cents per pound.

Although present production is only a fraction of potential pond fish acreage, it is increasing at a rate of only 10% annually. Producers and new investors add catfish acreage because of relatively high prices obtained for this species from *live fish markets*. Most future production increases, however, must be sold as conventional food fishery products at far less than live fish prices. To assure adequate profits under these conditions, close attention must be paid to quality and efficiency through all phases of production: culture, harvesting, handling, processing, storage, transportation, and marketing.

The natural habitat and man-made impoundments over 1,000 acres in size which produce commercial species of fish in the Missouri River basin total only 2,267,000 acres and yield less than 3 million pounds of fish (that is, 1 pound per acre) with a value well under \$1 million. The possibility of increasing the natural fishery is limited, owing in part to pollution, siltation, and destruction of habitat. The prospect for farm ponds in the south-central states is limited only by technological development and the enterprise of the farmer.

Knowledge in the field of fish husbandry has progressed to a point where desirable fishes can be produced at a favorable profit margin. Research at the Stuttgart and Marion stations has successfully surmounted many of the problems that faced the pioneer fish farmer. Research on spawning, care, and rearing of fry and fingerlings; disease control; supplemental feeds; feeding methods; stocking rates; water management; and general fish-cultural procedures is sufficiently advanced that a beginning fish farmer can enter the field and find a ready source of information to help him learn the techniques that are needed in fish farming. This is not to say that knowledge needed is complete; rather, it is intended to show that research has paid off handsomely in the 5 years that directed studies have been underway on the problems of fish farming.

In one county in Arkansas, the farmer-owned Production Credit Association made \$2 million in loans for fish farming in 1967. This is 25% of the amount loaned for rice farming and 10% of the Association's total business. The fish farming loans are made without security because in that county the *average* fish farmer is realizing a *net* return of \$300 per acre.

Needs (and problem areas)

Catfish farming is growing. In areas needing new industry and employment, expansion of fish farming will create job opportunities. While Mississippi and Arkansas are the present center of production, other states are expected to benefit from the introduction of fish farming. The unskilled, the semiskilled, and those dependent on seasonal agricultural employment—a high percentage of which are minority group members—will be particularly assisted by the

opportunities offered in expansion of this new industry. In areas where conventional farming is an important source of income, fish farming can be incorporated into the agricultural structure and, in many areas, can be introduced into the crop rotation patterns.

Farm and pond fish operators are mostly uninformed and inexperienced about fisheries commerce. Unless technical assistance is available, large investments could be wasted and the resulting confusion could set the industry back many years.

One of the biggest obstacles in pond fishing management is the lack of efficient practical harvesting and handling systems. Most farms do not yield enough fish to warrant individual investment of the \$7,000 to \$10,000 for required equipment. Without equipment, farmers resort to the most primitive methods of netting and removing fish from ponds. With poor methods, labor costs are higher, the time needed creates difficulties in taking advantage of market opportunities and shipping schedules, and the fish are subjected to undesirable conditions in shallow muddy waters. Manual harvesting methods often increase costs and reduce profits of otherwise sound business enterprises.

Many farm-raised catfish in the project area are sold alive, either as fingerling stock or as adult fish for fee-fishing recreational ponds. By contrast, catfish from river fisheries enter human food markets as processed products—primarily eviscerated fish on ice. This results from the widely scattered nature of the river fishery, serving only local markets. Because of the lack of centralized production and marketing, a sophisticated handling system did not develop. If farm-raised fish production continues to increase as projected, however, vast quantities of catfish have to move directly into human food markets. More modern products, such as frozen, convenience-type items, will have to be developed to attract new markets and meet existing competition.

Under current production methods, the industry is likely to suffer gluts during fall and winter. New concepts for the handling of fish during hot weather, and better processing techniques, should be considered. Promotional needs for the future should not be overlooked. Here, the Bureau of Commercial Fisheries, with its specialists in gear technology and market development, can complement and supplement the fish husbandry research of the Bureau of Sport Fisheries and Wildlife. Provisions for this kind of teamwork are included in development plans.

The immediate need for development is at the Kelso, Arkansas, demonstration area. Here is a unique opportunity for a joint effort by the Bureau of Sport Fisheries and Wildlife and the Bureau of Commercial Fisheries. Large ponds of about 40 acres, when constructed, could be used to demonstrate production methods and to test new findings from the Stuttgart and Marion laboratories; at the same time the ponds can be used for gear research, fish handling research, and fish behavior studies.

A number of smaller reservoirs of varying sizes are also needed. These ponds should have uniform bottoms with only enough fall to assure drainage and should be free of borrow ditches on the inside. Construction of this nature has several advantages:

1. Shallow areas which encourage the growth of noxious plants are eliminated.
2. Usefulness for gear research is greatly enhanced.
3. Such ponds serve equally well for the purposes of both the Bureau of Sport Fisheries and Wildlife and the Bureau of Commercial Fisheries.
4. The ponds can be farmed for rice or soybeans; this will allow research on crop rotation and its economics, soil improvement and enrichment, and water conservation methods.
5. Ponds of uniform-depth are most suitable for the chemical and temperature stability needed in intensive production.

Research is also underway to acquire data necessary to license for aquatic use certain drugs and chemicals needed in fish farming. These include antibiotics and sulfas for disease control; herbicides for weed removal; chemicals for external parasite treatment; anesthetics to facilitate handling, spawning, and transport of large live fish; and hormones to stimulate spawning. None of the most effective and desirable chemicals is licensed for use on food fish. The ponds at Stuttgart are insufficient for this needed research.

Until more ponds are available, it is not possible to pursue research on catfish hybrids with any degree of success. So far, 18 different catfish hybrids have been produced, and some of these promise to be valuable in fish farming and fish

management. It has already been demonstrated that one hybrid will grow 30% faster than either parent species. Such growth is of immediate concern to the fish farmer since this could possibly mean a 30% greater dollar yield. The potential of the hybrids cannot be fully realized without adequate research, and this will require numerous small ponds so that each group of hybrids under test can be kept separate for extensive periods of time.

By 1973, nearly 100 companies are expected to be engaged in marine agriculture. Some oysters or clams probably will be raised for market on well-regulated farms. Basic research programs for effective industry development of agriculture must be begun now.

FISH PROTEIN CONCENTRATE

Situation and outlook

The human body can function properly only within a narrow range of physiological limitations, reflecting what it needs in terms of nutrients it can derive or synthesize from the food it consumes. Nutritionists recognize that sufficient food is neither an adequate remedy for hunger nor a guarantee of adequate nutrition. An overabundance of any single food ingredient in the diet of peoples suffering from malnutrition may even aggravate the conditions and speed the onset of sickness or death. In short, a satisfactory diet must contain—in addition to carbohydrates, vitamins, minerals, and water—not only an adequate supply of proteins which the body can synthesize for repair or replacement of body tissues, but also an adequate supply of those other highly specific protein elements which the body needs but cannot synthesize.

Proteins are composed of chains of amino acids, some of which—the so-called “nonessential” amino acids—the human body can synthesize from other forms of ingested food materials. Other amino acids, however, are called “essential” inasmuch as the body unconditionally requires them to insure its normal health and growth but cannot synthesize them itself. These essential amino acids must, therefore, be contained in the food eaten. The absence of essential amino acids from many diets is responsible for certain widespread, malignant deficiency diseases, and for the most general type of malnutrition. Facing this problem, the newly formed National Council on Marine Resources and Engineering Development proposed that the United States embark on a major long-range program to exploit the oceans as a source of animal protein to help feed the undernourished people of the world. Convinced that the manufacture of fish protein concentrate (FPC) provides an expedient method of acquiring an unused source of animal protein from the sea, the Council has placed the FPC program among the top eight programs that should receive priority attention.

Fish protein concentrate, produced by the Bureau of Commercial Fisheries solvent extraction method using isopropanol, is a dry, almost odorless, tasteless powder. It is bacteriologically and biochemically safe. It is stable without refrigeration or other special preservation techniques, making it particularly useful because much of the need is in areas where preservation methods are unavailable or not well developed.

The total protein content of the finished product is about 80%, much higher than most protein sources now available for human consumption. FPC also contains a high level of valuable minerals and vitamins. It is a valuable dietary supplement when used in such food products as noodles, prepared cereals, milk shakes, gravies, soups, etc.

National significance

Realizing the need to develop a highly nutritious protein concentrate, the Bureau of Commercial Fisheries embarked on a comprehensive research program for the manufacture of FPC. Its purposes were twofold: (1) to provide new market outlets for underutilized species of fish off our coasts and thus assist the depressed segments of the commercial fishing industry, and (2) to develop an inexpensive, high-quality animal protein supplement to help alleviate malnutrition in many developing areas of the world.

Needs

There is a lack of clinical information indicating any clear-cut protein deficiencies in the United States today, compared with many of the less developed nations. However, it is becoming more fully recognized that even small protein deficiencies result in listlessness and general lack of ambition even though the cases are not advanced enough to result in death or high susceptibility to disease. The need for FPC in the United States is not so demonstrable in correcting wide-

spread and easily recognizable deficiencies as it is in the more subtle effects of borderline inadequacies.

The single most important potential benefit of FPC in the United States is providing a low-cost animal protein source for low income groups, to free more income for purchasing other needed goods and services.

Much more serious protein deficiencies exist in many countries of the world, particularly in the less developed areas.

It has been estimated that each of the more than three billion people alive today requires about 70 grams of protein per day to remain healthy. A growing child requires 2 grams of protein per kilo of body weight, and that an adult requires 0.35 grams per kilo of body weight. Of the required 70 grams, nutritionists agree that about 40% or 28 grams should be protein of animal origin. According to the United Nations Food and Agriculture Organization, two billion of the world's population receive less than half of this required amount. About 30 million additional tons of animal protein, or about 180 million tons of animal flesh meat, are required to satisfy fully the animal protein requirements of the present world population.

The FAO document, *Third World Food Survey*, states that, if the world population were to increase according to the "medium" United Nations projection for 1975, world food supplies must be increased by over 35% merely to sustain the population at its present unsatisfactory level of diet. If a reasonable improvement in the general level of nutrition is to be achieved, world food supplies must be increased by over 50% and food supplies containing animal protein increased by 60%. By the year 2000, using the same world population growth projections, food supplies must be trebled and animal protein supplies must be increased approximately 4.5 times.

Assumptions and constraints

We must assume that with the increasing world population all sources of protein must be utilized. To two billion people in the world, hunger is a stark reality of chronic malnutrition, resulting not only from a lack of food but also, and most especially, from a lack of food of sufficiently good quality. By and large, the nutrient factor most lacking in deficient diets is good-quality protein. Accordingly, a great search has developed all over the world for protein sources that can be processed into concentrated and convenient products. These protein products must be inexpensive and, most important, must be suitable for use as food supplements that will not change the taste and other characteristics of the products to which they are added.

For these reasons it has been concluded that it is vital to investigate methods of harvesting the vast food resources of the oceans and inland waters. The objective was to develop processes that would make the protein from fish available to those who need it in an acceptable form at a price they could afford. It was realized that fish, available in vastly larger volumes than currently harvested, is a food of the highest nutritional value but underutilized for human nutrition, because of its tendency to spoil rapidly and because no satisfactory and inexpensive methods of preserving the raw material in a palatable form had been developed.

The idea to produce a fish protein concentrate as an inexpensive protein food supplement is by no means new, since private industry, government, and international organizations have sought to develop satisfactory methods of production.

Much valuable information had been developed but could not be translated into action programs for a number of reasons: technical failures delayed practical development on some occasions; at other times the protein concentrate proved to be unstable or unacceptable to the ethnic groups for which it had been intended. Sizable markets that might stimulate industry action were not anticipated. One of the most important obstacles was, however, the attitude of the U.S. Food and Drug Administration, which required proof that fish protein concentrate made from whole fish was safe, nutritious, and wholesome. Until the use of whole fish was approved by the Food and Drug Administration, no fish protein concentrate produced from this raw material could officially be sent overseas, and no foreign manufacturers would produce fish protein concentrate for fear of criticism that a food not good enough for Americans could be deemed suitable for people in developing nations.

The interest shown by the industry in FPC accelerated rapidly with the enactment of the Fish Protein Concentrate Act and approval by the FDA. The interest ranged from that of becoming a primary processor to becoming a contractor for

the plants authorized. The domestic industry has further expressed interest in FPC plants in other countries.

In spite of this increased interest, there continue to be plausible reasons why industry is not ready to develop the process and product. These are: (1) the potential advantages of products manufactured by improved extraction methods or methods not yet approved, such as the enzymatic digestion method; (it is possible that such products may serve as foodstuffs in their own right as opposed to use only as protein supplements); (2) the high capital cost combined with lack of information concerning acceptance and demand for the product; and (3) the need for further research on species not covered in the FDA regulation.

Alternatives

Many of the inexpensive bulk foods available in developing countries contain almost no protein. This applies to cassava, sago, polished rice, bananas, etc. In many countries, such foods may contribute up to 70% of the caloric intake. Other vegetable foods such as soy beans, peanuts, sunflower seed, cotton seed, etc., while containing fairly substantial proportions of protein, are almost always deficient in certain essential amino acids and cannot fulfill all the dietary needs for protein. Dry milk, while a good protein source, is produced only as a residual product, after milk needed for higher valued uses has been met. Thus, a significant increase in dry milk production is unlikely. Production in the United States in recent years has only kept abreast of population increases. Yet world needs for low cost animal protein continue to expand rapidly. Thus, the question is not how well FPC competes with dry milk, but how products supplemented with FPC or dry milk compare in price and nutrient adequacy with other types of foods.

Application of science and technology

Methods have been developed to manufacture FPC by utilizing three different processes: (1) solvent extraction procedures to remove water and fat and fat-like substances from the raw material; (2) enzymes, micro-organisms, or specific biological agents to break down the protein of the raw material, render them water-soluble, and separate the fish protein product from the raw material; (3) physical methods to effect separation of protein from nonprotein material of the raw fish.

In the development of FPC much has been done in the area of chemical extraction methods for which 20 or 30 different approaches have been made available. Products produced by the chemical extraction procedures are essentially insoluble in water and have either bland tastes or are almost odorless and tasteless. The chemical methods which have been studied use a variety of solvents. However, the most promising of these solvents are alcohols, because these substances do not require as high a temperature for dissolving and for distillation. These chemicals are more stable and less toxic than other solvents. Among the alcohols that have been used, ethyl alcohol and isopropanol are the most popular because their toxicity levels are relatively low and supplies are ample.

Biological processes offer considerable promise and are of great interest because they result in water-soluble products which can have distinct and desirable characteristics of color, odor and taste. These processes yield end products in greater variety than those obtained by the solvent method. There are a number of different biological procedures, none of which has yet received significant attention.

Objectives

The objectives of the long-range program are: (1) to alleviate human hunger by a plan carefully designed to extract more usable food from the sea, (2) to strengthen the international posture and leadership of the Nation by policies that look to peaceful, cooperative uses of the sea and that make new and improved technology available to the developing nations, (3) to upgrade and assist domestic fishing and fish processing industries through development of markets for species not now caught, new fishery products, and expanded knowledge of the oceans.

The overall program concept is broad and comprehensive: it considers all facets of a total system for providing ocean resources to consumers; it anticipates multiplying the presently used food resources of the ocean by a factor of perhaps five, processing and distributing these resources effectively in many forms suitable to the particular needs abroad and even in this country; it contemplates active participation of United States and foreign governments as well as private enterprise, using technology, capital, and promotion to establish a self-sustaining industry.

Public Law 89-701, known as the Fish Protein Concentrate Act, was enacted by the 89th Congress in 1966. It authorizes construction of one FPC experimental and demonstration plant and leasing of another.

The objective of the legislation is to develop the best and most economical processes and methods of manufacturing for human food a nutritious, wholesome, and stable fish protein concentrate, and to conduct food technology and feasibility studies on such products.

Funds for construction of the federally-owned plant were included in the appropriation request for Fiscal Year 1968. The sum of \$1,000,000 was requested for construction of the plant and \$700,000 was requested for its operation, maintenance and associated research for the first year.

Construction of the federally-owned plant followed by leasing an improved plant will provide adequate means to refine the isopropyl alcohol extraction technique; develop new and better techniques, using both lean and fatty fish; and learn specifics in regard to cost, capacities, byproducts, and economics. In operating these plants, the capability of the key personnel will be developed, and will provide the nucleus for the "export" of knowledge for the planned United States-sponsored plants abroad.

BRIEF DESCRIPTIONS OF ADDITIONAL PROGRAMS IN FISH AND FISHERY PRODUCTS

HABITAT INVESTIGATIONS FOR COMMERCIAL FISHERIES

Fisheries resources management requires extensive information on aquatic environments, such as:

1. Habitat factors determining abundance and availability of stocks
2. Productive capacity of ecological complexes
3. Expected production of fish from given brood years
4. Control of conditions required to maintain or to enhance production

This information is obtained from basic research programs on resource-related variables in the freshwater, estuarine, and marine habitats. Bureau of Commercial Fisheries environmental programs attack the above problems in all three habitats in or near the Atlantic and Pacific Oceans, the Gulfs of Mexico and Alaska, the Bering and Caribbean Seas, the Great Lakes, and inland reservoirs. Research is underway not only for the existing profitable salmon, tuna, crabs, oysters, alewives, and menhaden fisheries, but also for developing and latent fisheries, including ocean perch, hake, herring, and groundfish, that are becoming increasingly important to the United States.

Because the habitats are increasingly jeopardized by industrialization and land developments, the problems of maintaining fisheries resources require continuing research concerning the relationship of resources to environment.

MARINE FINFISH

United States fishermen need forecasts on the abundance and distribution of fish. Marine finfish programs of the Bureau of Commercial Fisheries provide data for predictions of abundance and distribution, for maintenance of maximum sustained yield, and for preparation for international negotiations. Proper protection of fish stocks and U.S. fishing rights on the high seas can be achieved only through international agreements.

During the five-year planning period beginning in 1969, emphasis will be devoted to studies of underutilized and unutilized species. These include the hake, anchovy, and groundfish resources of the eastern Pacific and the tuna resources of the tropical Atlantic, on all of which new fisheries are developing. Research on menhaden, Atlantic herring, and New England groundfishes will continue, to determine the causes of the marked fluctuations in catch that are characteristic of these well-established fisheries. The battle to maintain valuable salmon runs despite changed river conditions will continue. Emphasis will be placed on reducing the losses of downstream migrants, on improving the accuracy of predictions, and on increasing knowledge of the environmental requirements for maximum salmon production.

With support from Federal Aid Programs (PL 88-309 and PL 89-304), State fishery research and development activities will be greatly strengthened. On a matching-fund basis, and supplementary to Bureau programs, work will be conducted in fish tagging, food studies, fish culture, inventories of local fish stocks, and life history studies.

INLAND FISH FOR COMMERCE

The 1964 production of freshwater fish in the United States was approximately 150 million pounds, worth about \$23 million to the fisherman. This represents a small catch in relation to potential production. Japan, a country $\frac{1}{25}$ the size of the United States, produces only 30% less freshwater fish than does the United States.

Expansion of inland commercial fisheries is expected to be evidenced in propagation of catfish and trout in farm ponds, in greater utilization of the fishery resources in reservoirs, and in development of the underutilized fisheries of the Great Lakes.

The Bureau of Commercial Fisheries research program will emphasize the underexploited Great Lakes fisheries. An effort will be made to develop methods for predicting abundance of major commercial species and to formulate recommendations on attaining a maximum sustainable yield.

Research concerning reservoirs will involve developing methods for predicting the size of commercial fish stocks, the influence of the environment on fish populations, and the effect of commercial fishing operations on recruitment.

Federal research on warmwater pondfish and trout culture is underway at eight field stations. In addition, Federal Aid programs will augment these studies by contract with the States under the Commercial Fisheries Research and Development Act.

COMMERCIAL SHELLFISH

Shellfish are nearly five times more valuable in terms of price per pound than are all other fish marketed. Demand frequently exceeds supply for major shellfish species. The development of marine farming by using methods similar to modern agriculture is of great interest in the industry.

Research on oyster and shrimp agriculture is increasing. Future studies will involve artificial spawning, selective breeding, nutrition, hatcheries, and pond culture on oysters, shrimp, lobsters, crabs, and some fish.

King crab and west coast shrimp fisheries have developed recently. Research will increase knowledge of crab and shrimp life histories and population characteristics and will provide data essential for better management of the fisheries and for international negotiations.

Research on Gulf of Mexico shrimp, surf clams, and lobsters will continue. The activities of the Shellfish Advisory Service will be increased to provide more frequent contacts with industry.

OTHER COMMERCIAL MARINE-LIVING RESOURCES

The other commercial marine-living resources element includes seals, whales, and other marine plant and animal resources, such as algae, marine bait worms, and mussels.

The fur seal annual harvest is expected to reach 70,000 animals by 1973—an increase of 8,000 to 10,000 yearly over the average of the previous decade. The goal is attainment of a maximum sustainable yield. Since 1956, the herd population density has been varied in efforts to determine the most suitable herd size.

The collection of biological data on and the marking of whales is underway as the basis for setting quotas and developing management plans for the principal species in the North Pacific Ocean. Slight increases in the whole catch can be expected by 1973. Scientific management, however, will permit a large increase in whale harvest by the year 2000, if international cooperation is achieved soon.

The total national fishery program is enhanced by the Federal Aid program. As administered by the Bureau and carried out by the States, the Aid program has been mutually beneficial to the agencies concerned with other marine plant and animal resources.

HARVESTING

Limited economic and technological resources preclude commercial fishermen from systematically improving conventional harvesting methods. Consequently, a major segment of the American fishing industry exhibits low technological ability. Assistance is required in two major areas: vessel design and modification (to reduce operating costs) and development of more versatile harvesting techniques (to improve fishing efficiency). In addition, knowledge must be expanded on resources of potential commercial significance.

Efforts will be directed toward developing a variety of fishing techniques that are tailored to the behavioral patterns of specific fishes and toward studies in

mechanization and development of techniques that will increase yields in the farm-pond fish industry.

Modern engineering and technological knowledge will be utilized to improve vessel gear mechanization, to improve fleet-fishing tactics, and to determine optimum vessel design, size, and gear combination.

Contractual arrangement will be made with private-sector organizations engaged in advanced technology. Fishing explorations for assessment, evaluation, and prediction of unidentified and underutilized resources will continue.

PROCESSING

Processing enables fish to be converted from raw materials to products desired by consumers. Processors are concerned with quality, costs, and consumer preference.

The processing research of the Bureau of Commercial Fisheries is intended to provide standards, methods, and procedures that will assist the fishing industry in improving product quality and processing and in developing new products.

The Bureau of Commercial Fisheries efforts will include:

- (1) Development of additional standards for fishery products.
 - (2) Inspection of fishery products.
 - (3) Technological research to improve fishery products.
 - (4) Development of new preservation techniques using irradiation pasteurization, controlled atmospheres, and chemical inhibitors.
 - (5) Research to develop uses for fishery product fractions, such as fish oil.
 - (6) Research on microbiological spoilage problems associated with specific fishery products, such as smoked fish.
 - (7) Development of methods and machines to improve operational efficiency of selected segments of the industry through systems engineering.
- Processing contracts will be made with private organizations.

RECREATION

HISTORY AND ARCHEOLOGICAL STUDIES

National Park Service programs in historical and archeological fields involve investigations with two major orientations: studies needed for development, interpretation, and administration of units of the National Park System; and studies aimed at identifying, recording, and encouraging the preservation of significant elements of the prehistoric, historic, and architectural heritage of the United States. These study programs are essential to the successful implementation, on the Federal, State and local levels, and in the private sector of the national historic preservation policy enunciated in the Historic Sites Act of 1935, and reaffirmed and broadened in the National Historic Preservation Act and related legislation of 1966.

Park historical and architectural studies

The National Park System contains 148 units established for historic or prehistoric values. In addition, many of the scenic and recreational parks contain secondary historic, prehistoric, or architectural features meriting preservation and interpretation. It is the responsibility of the National Park Service to insure that all such values are identified, that significant sites and buildings are preserved and restored in the most authentic manner possible, that development programs do not impair features of historical or architectural interest, and that accurate information is available for interpreting the history and meaning of such features to the visiting public. Research is essential to all these purposes.

Historical studies are conducted principally in libraries and archives, supplemented, as necessary, with field investigations. Architectural studies frequently require, in addition, investigation of the fabric of a building. Both kinds of studies culminate in reports that serve as a basis for action programs such as restoration, preparation of museum exhibits or audiovisual presentations, new-area justifications and development proposals, and master planning.

Examples of the kinds of information developed in historical and architectural studies can be found in comprehensive research reports on the newly established Nez Perce National Historical Park, Idaho, and St. Gaudens National Historic Site, New Hampshire, which will guide all aspects of development and interpretation at these new parks. Similar data are incorporated in a series of historic-

structures reports, supporting the restoration of about twenty historic buildings at Fort Davis National Historic Site, Texas; in voluminous and detailed studies, produced by a continuing program dating from 1950, that have served as the principal tool for the authentic restoration of Independence Hall in Philadelphia; and in historical base maps for Harpers Ferry National Historical Park, West Virginia, the Lincoln Boyhood Home National Historic Site, Indiana, and the Lava Beds National Monument, California, that will guide important interpretive and development programs at these areas.

Nationwide survey and preservation programs

Under authority of the Historic Sites Act of 1935, the National Park Service conducts the National Survey of Historic Sites and Buildings and the Historic American Buildings Survey. The former identifies historic sites and buildings of national historical significance; the latter records by photograph, measured drawing, and other techniques significant examples of the Nation's architectural heritage. Both have proved major forces in stimulating and guiding historic preservation efforts in both the public and private sectors.

Over the past decade, the National Survey of Historic Sites and Buildings has included studies of about 3,000 historic sites and buildings in 22 broad themes. These have led to the identification of nearly 800 properties as possessing national significance. The findings are made available to the public by means of a publication program, and by designating, as Registered National Historic Landmarks, all sites whose owners make application. (The Park Service does not administer any.) National Landmarks are recognized by the award of a certificate and bronze plaque.

In a little over three decades, the Historic American Buildings Survey has recorded by photograph or measured drawing about 12,000 significant examples of American architecture throughout the Nation. HABS records are deposited in the Library of Congress where they are among the most frequently consulted of the Library's many collections. Through a publication program, HABS also makes available to the general public catalogs of its accomplishments.

These two programs provide preservation and planning groups, as well as concerned citizens everywhere, with authoritative guides to a large segment of the Nation's heritage that should be preserved for posterity. By focusing public attention on sites and buildings so recognized, the National Survey and the HABS have significantly aided local preservation groups in protecting important symbols of the Nation's heritage. In some instances, this Federal recognition has been a decisive factor in saving a threatened site or building.

Expanded survey and preservation programs

Both the National Survey and the HABS take on added importance with the authority provided by the National Historic Preservation Act of 1966 to expand the National Historic Landmark Registry into a National Register of properties of national, regional, State, and local significance meriting preservation. The Act provides certain legal safeguards to registered properties that will make their preservation contingent on more than simple agreement to preserve. The additional surveys to be undertaken under the new legislation will center on districts, sites, buildings, structures, and objects of regional, State, and local significance. They will be accomplished by or under State authority, according to Federal criteria and standards, and with funds derived in part from matching Federal grants.

The prehistory and history of our Country encompass three phases of development: Prehistoric, Historic Indian, and Historic European. The first deals primarily with the Indian cultures of ancient America; evidence of these bygone cultures is entirely archeological. The second, that of the living Indian tribes, is usually ethnological (the study of living people and their culture). The third phase, the European period, is well documented in written historical records. In recent years, archeology has expanded into the realm of ethnology and history, and has proven itself essential to both.

During the past two decades, historians have found that archeology is essential to the full, and proper interpretation of colonial villages, the Revolutionary War and the later battles, and frontier settlements. Here are a few examples: (1) archeologists determined the exact location and size of George Washington's Fort Mifflin, built during the French and Indian War, in southwestern Pennsylvania; (2) archeological studies recently located the base of the flagpole from which the Star-Spangled Banner flew during the bombardment of

Baltimore by the British in the War of 1812; (3) archeologists pinpointed Reno's trenches at the scene of the Battle of the Little Bighorn, where General George Custer and his immediate command were killed, and located several previously unknown burials, made after that battle; (4) archeological excavations at Jamestown National Historic Site, the first permanent English settlement in what is now the State of Virginia, uncovered much additional information, particularly in the way of architectural knowledge and the material objects of everyday life. The Service is primarily responsible for the development of historic-site archeology in the United States.

In the United States today, many large areas are marked for eventual flooding, as a result of the multi-purpose dam construction on major rivers; and in the Southwest, long tracts of land are being trenched for the installation of oil and gas pipelines. Archeological sites, which normally would not be discovered, are being located and excavated on many of these projects—often they are of major significance to the interpretation of the Indian past.

This program started when, shortly after World War II, archeologists became aware of the many archeological sites being destroyed by the construction of reservoirs throughout the Country. To meet this challenge, the Committee for the Recovery of Archeological Remains was formed. Since then, the National Park Service and the Smithsonian Institution, with the cooperation of various governmental agencies and local institutions have developed and coordinated an archeological salvage program to recover from areas to be flooded a representative sample of the archeological materials and data. This is a far-reaching long-range program that will not be complete until the last reservoir is finished and flooded. The Service is not only responsible for the recovery of archeological remains in reservoir areas, but is also responsible for coordinating archeological work on all major pipelines. It coordinates the research, and allocates the funds to qualified agencies and institutions who carry on the job of salvage archeology. These programs constitute a large part of the archeological field work being done in the United States today.

The National Park Service has developed a comprehensive stabilization program to protect these ancient ruins once they are uncovered by archeologists. Archeologists strengthen ruins with concrete and steel in such a way that these modern additions do not detract from the appearance of the older structure. Various kinds of preservatives have been tested over long periods in attempting to slow down the natural erosion of certain ruins composed of adobe which are not protected by natural rock shelters, as are the ruins in Mesa Verde National Park. Also of major concern is the protection of these dwellings from rodents and other pests.

The stabilization unit, working out of the Southwest Archeological Center in Globe, Arizona has a full time job, not only in the actual stabilization work, but also in the developing of new and better ways for keeping these ruins intact.

Evidence of our historic and prehistoric heritage is being destroyed by many other Federal and private activities besides water control projects. Land leveling, urbanization and suburbanization, industrialization—in fact, any activity which alters the natural landscape is liable to destroy ancient remains. These aspects of salvage archeology have not been as well exploited as has the salvage of remains threatened with destruction by reservoirs.

The Antiquities Act of 1906 makes it a Federal offense to "appropriate, excavate, injure, or destroy any historic or prehistoric ruin or monument, or any object of antiquity situated on lands owned or controlled by the Government of the United States," and yet the Federal Government itself is the single biggest cause of such destruction. The Government, therefore, has a strong moral and legal obligation to investigate, and to salvage some of these remains before they are destroyed. Archeologists are agreed that the salvage program is a Federal responsibility.

To expand the current salvage program sponsored by this Service to include these other activities would require: (1) further directives by Congress, and (2) increased funding. A gradual buildup over a five year period would be necessary; otherwise lack of sufficiently trained professional archeologists could preclude the expeditious utilization of extensive funds.

Such a program would benefit the entire Nation. Many of these priceless remains have already been destroyed—others are being destroyed daily; in another two decades, the majority of those remaining, unless specifically protected in Federal preserves, will likewise be gone. The situation is literally a race against time.

MARINE SPORT FISHERY RESEARCH

Our inland waters cannot absorb the growing recreational needs, and the people are turning more and more to the marine environment to satisfy their recreation demands.

The myth of superabundance, the comforting but false conviction that our natural resources are inexhaustible, is as wrong about the oceans as elsewhere. Marine resources are dwindling as demands are growing. And it would be just as wrong to take assurance in a dream that technology can cure everything. But research can help in evaluating the effects of our own activities, defining the needs for regulation and instituting the scientific management of habitats and fish populations.

If we can accumulate knowledge in time, we can avoid the need for crash programs which have often characterized studies brought on by the failure of a fishery or by massive and irreversible changes in the environment.

National significance

Marine sport fishing is already a giant, and still growing. In 1955 there were 4.5 million salt-water anglers who fished 58 million man-days. Ten years later we find over 8 million anglers fished nearly 96 million man-days and spent nearly \$800 million doing it. These 8 million anglers caught 737 million fish weighing 1.4 billion pounds. If the present trend continues, there will be 12 million salt-water anglers in 1975. It is estimated that salt-water fishing will account for 30% of the National angling effort in the year 2000.

Needs

In the National interest, a recreational resource of this magnitude requires measures of supply and demand. The drain on the supply is not just a question of salt-water sport fisherman. The marine fishes are also sought by increasing numbers of American as well as foreign commercial fishermen. Such species as tunas, swordfish, albacore, salmon, bluefish, and many others are both sport and commercial fishes.

As the supplies diminish, effective resource planning and the strategy of resource use will have to take into account not only the economic costs, but the social cost of lost recreational opportunities.

The oceans, bays, sounds, and tidal areas are absorbing a significant share of the astounding increase in demands for recreational fishing, but marine fish stocks are not inexhaustible.

Increasing pressures from commercial and sport fishing are already threatening the supply of certain species. Some of our most popular species are tied to the coast and its estuaries during some stage of their life history. These are the areas most vulnerable to rapid changes and degradation from industry, agriculture, and residential developments. The effects of pollution, sedimentation, channeling, ditching, diking, filling, and drainage are sometimes dramatic but all too often are insidious and difficult to discern until too late. Although some very good research has been completed, virtually nothing is known on a broad enough scale to either evaluate the effects of changes in terms of biological, economic or sociological implications.

There is at this time no systematic and periodic way of measuring the amount of fishing, the catch by species and area, the resources and facilities involved, and their economic values.

Also lacking are management and development programs. This gap stems from two deficiencies—the lack of knowledge to guide management and totally inadequate funding at the State level where major responsibility rests for these functions. More than one-half of the States have no clear-cut statutory or organizational authority for management of marine game fishes, and only six have a salt-water license, a source of funds that support the substantial management and development program of inland fisheries by the States.

Criteria

The Federal Government function in marine game fish research comes about in a number of ways.

First, because many of the marine game fish are migratory, they are interstate, inter-regional and in some instances international resources. Some coastal species may range during their migrations between Florida and Maine, and subject to taking by commercial and sport fishermen of every State they pass through or by. No one State has the resources to study the fish over its whole range.

Second, there is the Federal responsibility to see that Federal civil works, military installations, and other Federal activities do as little harm as possible (or no harm at all) to fishery resources.

Third, there is the reason of the sheer size of the need. There are at least 150 species of marine game fish, only about 10% of which have been extensively studied. The water area that these fish range is enormous. Research involving mixed species, boundless water areas, and wide ranging habits make for a very large-scale research program, quite outside the resources or area of freedom available to the States—not that the Federal Government could or should do the work alone, any more than the States could or should. Effort currently is concentrated largely in the Fish and Wildlife Service, the State game and fish and conservation agencies, and in the colleges and universities.

Alternatives to the marine game fish research program of the Bureau would be to shift the responsibility and funding to the State and universities. Fragmented and local research that would result from this transfer would be more expensive and ill-suited to the wide-ranging problems of migratory marine fishes. The States have shown little inclination to assume this responsibility on their own or with Dingell-Johnson funds. Although the universities share this function, the species of fish involved are rarely important game fishes. Most university research is supported by the National Science Foundation, Office of Naval Research, and the National Institute of Health, which have little or no interest in game fishes. The National Science Foundation discourages applied research.

Course of action

The aims of the marine game fish program is best expressed in the language of the Act (Public Law 86-359) authorizing it, "To undertake for the purpose of developing wise conservation policies and constructive management activities, a continuing national program of research on migratory game fishes including migration, identity of stocks, growth, mortality, variations in survival environmental influences both natural and artificial, pollution and the effects of fishing".

We propose to meet these aims as follows:

1. Determine a rational basis for marine game fish conservation through development of principles for habitat improvement, regulations, artificial propagation, selective breeding, and predictions of abundance.
2. Develop methods for continuous measurement of the amount and distribution of salt-water angling and the catch.
3. Describe the natural history and migrating of marine game fish species including big game fishes such as marlins and sailfish.
4. Determine the environmental requirements of marine game fish species, and document how they have been and will be affected by man's activities.
5. Promote the dissemination of new knowledge and the training of marine fishery biologists.

The Sandy Hook Marine Laboratory, Highlands, N.J., was established in 1960, followed by the Tiburon Marine Laboratory, Tiburon, Calif., in 1962 and the Narragansett Marine Game Fish Laboratory, R.I., in 1966. Two more, the Eastern Gulf Marine Laboratory, Panama City, Fla., and the Western Gulf Marine Laboratory, Port Aransas, Tex., are currently (1967) being constructed. Still two more laboratories are proposed for the future, one in eastern Florida, the other in southern California. In addition two vessels (65 feet and 107 feet) are maintained for research in coastal waters.

Objective

The broad objectives of the marine game fish program are divided into two categories; i.e., research objectives and management and development objectives. There is an apparent relationship between the two, but the final completion of a research objective is not necessarily a prerequisite for full or partial completion of a management or development objective.

Research Objectives

Research objectives are designed to develop the following:

1. Methodology for sampling catch and effort;
2. Life histories and ecology of the 50 most important and estuarine-dependent game fishes;
3. Life history, population dynamics, and migration of pelagic big game fishes such as marlins and sailfish;
4. A survey of facilities and resources;
5. Evaluation of artificial reefs;

6. Fish culture techniques for important anadromous and marine game fishes;
7. Behavior studies in the laboratory and in the field on the response to light, temperature, food and other factors;
8. Information on disease and parasites of anadromous and marine fishes;
9. Effects of pollution, especially pesticides, on marine game fish.

Management and Development Objectives

Management and development objectives concern the following:

1. Periodic collection of angling and resource statistics;
2. Access and facility development;
3. Estuarine acquisition;
4. Pollution control in coastal rivers, estuaries, and coastal areas;
5. Artificial rearing and stocking of selected species such as salmon, steelhead, striped bass and shad;
6. Habitat development—artificial reefs;
7. Fish passage facilities;
8. Stream clearance.

Work in progress

In 1965, the Sandy Hook laboratory initiated a major program. The R/V *Dolphin* makes monthly surveys of the continental shelf from Cape Cod to Cape Hatteras to map the seasonal distribution of eggs, larvae, and juvenile stages of game fishes and to determine the nature of dependence upon the estuarine zone by species inhabiting the continental shelf. Another major effort centers on the life history and migration of bluefish, a top angling species. In the behavior tank at Sandy Hook bluefish are observed in relation to light regime, color vision, sound perception and feeding. SCUBA divers in the Atlantic and Pacific are observing the daily movements and feeding behavior of important game fishes.

Sea surface temperatures obtained monthly along the Atlantic and Pacific coasts using infrared radiometers from U.S. Coast Guard aircraft have been useful in predicting and explaining the movement and availability to anglers of migratory game fishes.

A new project to test artificial reefs was started in 1966. Placed in the right places, these reefs attract fish and provide spectacular fishing. Test areas have been selected off the New Jersey coast where evaluations will be made of sites, materials, fish behavior, and food production.

An investigation of Atlantic sharks is being carried on at Narragansett Marine Game Fish Laboratory and includes studies on distribution, migration, systematics, and life history. More than 100 angling clubs have formally registered as cooperators on data collection and tagging for this investigation.

At the Tiburon Marine Laboratory cooperation has been established with the International Game Fish Association and Woods Hole Oceanographic Institution for tagging and recovery of marlins and sailfish along the Pacific Coast. More than 4,000 have been tagged. The purpose of this program is to determine the migration and exploitation of these prized game fish. In the 1965 tagging, 438 striped marlin and 167 sailfish were tagged. A new record was achieved in 1966, when 735 striped marlin, 283 Pacific sailfish, and 22 roosterfish were tagged. During the first quarter of 1967, 492 marlin and 136 sailfish have been tagged. A total of 30 marlin and 2 sailfish tags have been recovered through the first quarter of 1967.

A small project on marlin and sailfish is underway in the temporary facilities of the Eastern Gulf Marine Laboratory in the Gulf of Mexico, where research is providing the facts for a new and exciting fishery for billfishes. This project is pinpointing the seasonal movements and location of billfishes on the basis of ocean climate variations.

In the field of education, graduate students have been assisted in studying life histories of important marine game fishes at the University of Miami, Texas Agricultural and Mechanical College, Oregon State University, and the University of North Carolina. As many as 40 summer assistants (high school, college and graduate students) are engaged each year at Sandy Hook.

Expected benefits

Research findings will lead to improved opportunities for recreation by defining good fishing grounds, explaining and predicting fluctuations in abundance, by preventing unwise or uninformed restrictions, and by increasing abundance through scientific habitat improvement or enlargement.

Fishing is one of the most wholesome forms of recreation. It is a personal participation sport and can lead to the development of real and satisfying skills. It is available to everyone and ranges widely in cost. The bridge and pier fisherman, the surf caster, and the rowboat angler may find satisfaction as real as the yachtsman or charter boat fisherman.

In addition to the conservation and sociological benefits, improved opportunities for recreational fishing in salt-water carries strong economic benefits. In 1965, for instance, the national average annual expenditure of the salt-water fisherman was \$96.29; Atlantic Coast fishermen spent \$79.27 per year; Gulf Coast fishermen spent \$84.50 per year; Pacific Coast fishermen spent \$143.11 per year.¹

RESEARCH IN OUTDOOR RECREATION

Situation and outlook

Participation in outdoor recreation has been growing at a tremendous rate—far faster than the general rate of increase in population. Many indicators provide evidence for this. Trends in park and forest attendance show it. Expenditures for recreation equipment show it. New activities—ballooning, sand sailing, spelunking—are coming into being all the time, and participation in them soars. This happened with water skiing a few years ago.

A variety of surveys verify the growth. For example, the results of a recent survey sponsored by the Bureau of Outdoor Recreation showed a 50% increase in the volume of participation in 16 major outdoor, summertime activities during the period 1960 to 1965. This is more than double the expected increase in these activities, based on projections made a number of years ago from the data from the comparable 1960 survey.

This present situation has been building up for a number of years. And the end of this boom is not in sight. An examination of recent trends in recreation activity and of the factors that are given impetus to these trends leads to the conclusion that the pressures on resources and facilities will be even stronger in the future. Projections based on the 1965 data now indicate that the volume of participation in major activities will increase fourfold in the period 1960 to 2000 rather than threefold as projected from the 1960 data used by the Outdoor Recreation Resources Review Commission. This is a conservative estimate because it does not take into consideration the possible impact from new facilities or from improving the quality of existing resources and facilities. The boom will continue to grow at a pace much faster than population growth. Unless careful planning is undertaken to channel this volume of activity, needs can only be met on a crisis-by-crisis basis. In many instances, the resource base at existing areas could be irreparably damaged, or lands suitable for outdoor recreation may be preempted for other public or private purposes.

National significance

The growth in outdoor recreation is a nationwide phenomenon. People are getting outdoors more than ever.

Both public agencies and private enterprise have responded to people's demands for additional outdoor recreation opportunities, and their efforts continue. The major concern, however, is how both public and private response can be made more effective in meeting the needs in the future.

Congress was aware of some of the same concerns already expressed, and authorized the Secretary of the Interior to prepare and maintain a continuing inventory and evaluation of the Nation's outdoor recreation needs and resources and to formulate and maintain a comprehensive recreation plan for this Nation. Congress directed that the needs and demands of the public for outdoor recreation and the availability of resources to meet these needs, both now and in the future, shall be set forth in this plan.

A need for systematic planning

The main problem in planning for outdoor recreation at the national level—or at the State or local levels—is one of determining what additional investments are needed for land and water, for facilities, and for complementary programs. The distribution of these investments, geographically and in relation to the kinds of people who need them the most, is no less an issue. Funds for investment are far from adequate, and competition for resources is steadily

¹ 1965 National Survey of Fishing and Hunting. U.S.D.I., Fish and Wildlife Service, Bureau of Sport Fisheries and Wildlife, Resource Publication 27.

driving their price up. Obviously, additional tools are needed to assist planners and policy makers in developing priorities for spending available funds and for gauging overall needs now and in the future. Those who make the plans and decisions for outdoor recreation do not have the benefit of information that would be generated in a private market situation. We believe that this problem can be overcome to a considerable degree by the development of a model of the kind of market that does exist.

Assumptions and constraints

Participation in outdoor recreation is known to be dependent upon many considerations. People have certain amounts of leisure time available to spend on recreation—after work, on weekends, on vacations, upon retirement, etc. These blocks of time can be measured, along with the way in which people are spending them. People with college educations frequently have more diverse recreation interests than people who do not. Younger people, who constitute an increasingly larger share of our population, are more active in outdoor recreation than other age groups, and their interests are different. Increases in disposable family income, tied to general economic productivity as are increases in leisure time, educational attainment, and other considerations, mean that more money is available for recreation travel and equipment. The new affluence present in large segments of our society should also mean that, as a Nation, we can spend more on providing leisure-time opportunities (resources and facilities), and these opportunities, in turn, will stimulate increased participation.

Many of these considerations and other variables that appear to be producing increased use of recreation areas and facilities are measurable. These variables can be introduced in an equation which represents, or models, the existing situation. In other words, it simulates what is happening in the present "market." Once this has been done satisfactorily and the relationship between the variables is determined, the effect of changes in the "market"—caused by acquiring certain types of resources or developing certain kinds of facilities—may be determined by introducing these elements in a model.

Illustrative research examples

The Bureau of Outdoor Recreation has a contract study underway by the Bureau of Economic Research at Rutgers University for development of a supply-demand model for estimating the demand for specific types and quantities of recreation resources and facilities. The model will be designed to accomplish this in relation to individual major outdoor recreation activities. Estimates will be made for 1980 and 2000 at the Census Division level as well as nationally. The relative significance for participation in an activity of each of the important variables interacting in the outdoor recreation system will be determined through multiple regression analysis.

The data for the model will come from a number of sources. The major source is the interview records from the 1965 Survey of Outdoor Recreation Activities and the 1960-61 National Recreation Survey, both conducted by the Bureau of the Census. These data will provide a measure of participation in individual activities for incorporation in the model. They will also provide data on the socio-economic characteristics of the consumer. On the supply side, the main source will be the Bureau of Outdoor Recreation's nationwide inventory of public outdoor recreation areas and facilities. In addition, certain other data obtained from Bureau of the Census sources will be incorporated in the model. These data collection projects are discussed briefly.

Survey of participation in outdoor recreation activities

The main ingredients for the model being developed by Rutgers University are the interview records of the 1965 Survey of Outdoor Recreation Activities, sponsored by the Bureau of Outdoor Recreation, and the 1960-61 National Recreation Survey, sponsored by the Outdoor Recreation Resources Review Commission.

In both surveys, Bureau of the Census interviewers determined the frequency of the respondent's participation in major activities in terms of the number of different days on which he did an activity while on his vacation, other overnight recreation trips, outings, or at other times when there were a few available hours. In addition, the respondent's education, family income, age, sex, color, family size, occupation, and other socio-economic characteristics were recorded in the survey. Certain preference information also was among the primary content of the interview.

One product of the Rutgers study will be an analysis of trends in outdoor recreation activity between 1960 and 1965, based on a comparison of the two surveys.

Inventory of public outdoor recreation areas and facilities

As authorized in its Organic Act, the Bureau has conducted an inventory of Federal, State, and local public recreation areas. These data now are being used by Rutgers for developing the supply elements of the model. The inventory covered all Federal and State and county recreation land and water. It also included the recreation land under municipal administration in all cities with more than 50,000 people and in a sample of cities and towns with between 10,000 and 50,000 people.

In general, the content of the inventory was descriptive of the recreation area with regard to type, location, acreage characteristics, use intensity classification, physiography, facility units and acres, activities supported on the area, use characteristics, multi-use features, etc.

Benefits

The model, when fully developed, will be useful as a tool in the determination of the impact of adding new facilities or resources to the system in terms of how these additions will affect consumption (participation). This can be done for different geographic areas, depending upon the kinds of data that are available. For example, if data on participation are available only for people interviewed in a sample survey that is reliable for groups of States (Census Divisions or Regions), then the model will be specific for that level. But, if data become available for the people living in individual counties or metropolitan areas, the model will be of much greater utility. Similarly, the model can be made as specific as necessary for different groups of people (age groups, income groups, ethnic groups, etc.), depending upon the data fed into it.

The development of such a model is not something that will replace the need for intelligent and carefully derived policy judgments on the part of administrators and lawmakers. Nor will it obviate the need to test alternatives in the crucible of public opinion. But the development of such a tool will be a major step toward establishing a more systematic approach to developing alternatives because, with such a tool, the effect of each alternative on the overall system can be evaluated.

BRIEF DESCRIPTIONS OF ADDITIONAL PROGRAMS IN OUTDOOR RECREATIONS

SPECIAL AREA STUDIES

A prerequisite to preservation, management, and development of our Nation's remaining unprotected historic and natural resources is investigative study. The Department conducts research studies to identify the best available examples of major American geological and ecological types, unique examples of flora and fauna, nationally significant historic lands and buildings, and lands of nationally significant recreational opportunities.

These studies determine the suitability and feasibility of adding proposed areas to the National Park System. Research is conducted to determine the national significance of an area and to consider all the alternative land use, management, and administrative arrangements for an area. An economic analysis is frequently made to determine the effect of the proposal upon the local economy.

Our studies of areas proposed for addition to the National Park System must consider how the area may be developed and managed to conserve the resources and still make them available to the American people. We urgently need to develop methods to determine the optimum visitor capacity of an area. We need to know the best transportation system for an area which will not seriously alter the resources being conserved while permitting the largest number of people to experience a quality park visit. The importance of planning an entire region around a park rather than just the park is also becoming an obvious research need. Likewise we need to know just what is wilderness and how to manage these special areas.

Frequently bureaus of the Department combine efforts to conduct special research studies of a resource or recreation need. Such research includes the past scenic road and parkway study, the recent trail and river studies, and the present investigation of islands.

PROGRAM FOR NATURAL SCIENCES RESEARCH IN ECOLOGY AND ESTHETICS, NATIONAL
PARK SERVICE, DEPARTMENT OF THE INTERIOR

The national parks contain the finest examples of America's natural and cultural heritage that have been set aside and preserved for specific uses and enjoyments of the people. The natural areas should be a reasonable portrayal of the natural American landscape, and the geologic and biotic resources contained therein, as they would be were it not for the advent and impact of post-Columbian culture, technology, and activities. The historical and archeological areas should present the cultural essence of the time and peoples involved. The Parkscape program also includes the beautification of urban areas to improve the aesthetic condition in which everyday life takes place. To maintain or restore the ecological, cultural, and aesthetic integrity of these areas is the business of the National Park Service; but to be effective, the efforts must be guided by hard facts and sound scientific, historical, and archeological principles. Basic resources must be identified and understood prior to undertaking responsible management activities and interpretive efforts. A great deal of knowledge that is already available must be brought to bear upon existing problems. When sufficient knowledge is not available, additional knowledge is sought through the Service's research programs. Accomplishment of such research involves research biologists, archeologists, and historians employed by the Service, cooperative studies with other Federal and States agencies, universities, and other organizations. The spectrum is broad, involving botanical, zoological, geological, ecological, historical, archeological, and horticultural research. Major research programs have involved such nationally significant resources as the Mesa Verde ruins, Independence Hall, and the giant sequoia groves of California.

RARE AND ENDANGERED SPECIES

Since colonization of America, nearly 50 kinds of vertebrate animals have become extinct in the United States and its possessions as a result of man-caused changes in the environment and overhunting. At least 78 other species of mammals, birds, reptiles, amphibians, and fishes now are so rare that they, too, may be lost forever unless special efforts are exerted for their preservation.

Conventional wildlife management measures, though effective for many species, are not sufficient for certain less adaptable forms. Information is needed regarding their status, distribution, habits, habitats, and limiting factors before effective management measures can be devised.

A research station on endangered wildlife has been established. It is the headquarters for Federal research on rare and endangered wildlife species. The program is coordinated with State agencies, universities, and interested groups. The program includes ecological studies of threatened wildlife in their natural habitats, laboratory investigations of physiological, nutritional, genetic, pathological, behavioral, and other problems, and the propagation of endangered species in captivity for release to replenish wild populations. Nucleus populations in captivity will preserve basic stocks in the event wild populations are lost. Surplus animals reared in captivity will be utilized in living exhibits for scientific and recreational viewing by the public.

The economic benefits of wildlife to the human race are significant, but are dwarfed by the ethetic considerations. The enrichment of life is hardly confined to the billfold. The disappearance of a species is a permanent loss. This new program is dedicated to preservation for human good of such unusual animals as the whooping crane, California condor, Hawaiian goose or nene, blackfooted ferret, and many others.

MIGRATORY BIRD HABITAT AND PRODUCTION RESEARCH

Under the Migratory Bird Treaty Acts with Great Britain (for Canada) and Mexico, the Federal Government, through the Bureau of Sport Fisheries and Wildlife, is responsible for preservation and enhancement of the migratory bird resource. Increasing human populations and attendant cultural developments place mounting pressures on both the game (waterfowl, snipe, woodcock, doves, pigeons, etc.) and the non-game (songbirds) species. Inimical factors may be expected to intensify.

Major needs are to understand population dynamics, habitat requirements, and ecological relationships of the individual species as a basis for conservation planning and action programs. Seasonal distribution, behavioral traits,

migrational phenomena, food and cover preferences, recruitment to the population, and drain factors and rates are being studied; population inventory and habitat evaluation techniques are being developed; characteristics of consumptive and non-consumptive users of the resource are being probed. Advanced methods in taxonomy, physiology, ecology, pathology, biometrics, questionnaire surveys and automatic data processing are being employed in this research.

Resulting data form the basis for annual Federal hunting regulations, selection and development of National Wildlife Refuges, restoration and creation of favorable habitats in non-Federal ownership, protection of agricultural crops from bird depredations, and the delineation of the role of birds in the community of living things.

Migratory birds are an integral part of the environment, a recreational base of great magnitude, and an ethetic asset of incalculable value. The maintenance of this resource on a level compatible with other human needs adds to the quality of day to day life.

OTHER WILDLIFE HABITAT AND PRODUCTION RESEARCH

Resident (nonmigratory) wildlife faces a bleak future because of direct spatial competition from a burgeoning human population. Intensive land management for urban, industrial, and agricultural development is, for the most part, incompatible with successful wildlife conservation.

Ways must be found of satisfying the minimum habitat requirements of wildlife in the land utilization plans of the future. This will require a thorough understanding of biological needs of the several species and how these can be meshed with cultural developmental activities.

Although resident wildlife is largely a responsibility of the States, the Bureau of Sport Fisheries and Wildlife is inextricably involved because of having to provide technical guidelines to Federal land managing agencies and to honor cooperative agreements with States under the Wildlife Research Unit and Foreign Game Introduction Programs. Research is undertaken to define the habits, habitat requirements, ecological relationships, and population dynamics of individual species to provide basic information for intelligent, integrated resource management. These studies require the employment of refined skill in all the basic sciences and new advances in specialized technology such as microtelemetry.

Findings are being employed by the Forest Service and Bureau of Land Management in timber and range management plans, by the States on wildlife lands and in the formulation of hunting regulations, and by private landowners in agricultural operations. Wildlife research will insure the perpetuation of optimum wildlife crops in years to come adding to recreational opportunities for the people and sustaining a healthy ecosystem for posterity.

Natural habitats are extremely important to the wildlife contained within the National Park System. The occurrence of truncated ungulate ranges, overzealous predator control programs of the past and the like, make intense management programs imperative. These programs can only succeed if they are built upon adequate knowledge obtained through research.

SPORT FISH HABITAT AND PRODUCTION RESEARCH

The National surveys of fishing and hunting show that the number of sport fishermen has increased from 20.8 million in 1955, and 24.3 million in 1960, to 28.3 million in 1965. The report of the President's Science Advisory Committee, "Improving the Quality of our Environment," drew attention to the deteriorating quality of the aquatic environment. These opposing forces—the increasing need for sport fishing vs. the decreasing quality of habitat—underscore the need of fishery resource managers for knowledge to make their operations more effective. Obtaining this knowledge is the objective of fish habitat and production research.

Two kinds of knowledge are needed: how to use and improve the productivity of natural waters for sport fishes; and, to supplement this natural production, how to produce hatchery fish more efficiently and utilize them more effectively. For the former, studies are made to learn the ecological facts and principles governing the distribution and abundance of sport fishes in both salt and fresh waters. Improvements in the production and utilization of hatchery fish are made by applying results of research in the husbandry sciences: nutrition, pathology, genetics, cultural methods, and environmental requirements. These problems transcend State boundaries, and it becomes a Federal responsibility to

assure the continuity and comprehensiveness of needed research. This Federal responsibility is vested in the Bureau of Sport Fisheries and Wildlife.

The expected benefit of this research is the preservation of a priceless heritage—the rights of those who wish to seek and enjoy sport fishing, and the right of others to know that the opportunity is there.

ENVIRONMENTAL ACTIVITIES

CONTROL OF SULFUR-BASED AIR POLLUTANTS

Introduction

Air pollution in the United States today shows increasing signs of a rapidly approaching acute stage. Recent estimates indicate that pollutants are being released to the air above our Nation at a rate of 133 million tons per year. Unless important progress is made in the development of air pollution control technology, the 336 million people that are expected to be living in this country by the year 2000 may have to contend with an increase of as much as 60% in pollutant output. Since American industry—a major contributor of pollutants to the air—is outdistancing the population in growth, the pollution rate 30 years hence might be even greater.

Although contaminants from many sources foul the air we breathe, sulfur oxides, resulting principally from the combustion of fossil fuels and the utilization of sulfur-bearing ores, constitute a major facet of the air pollution problem. Recent estimates indicate that almost 25 million tons of sulfur oxides are funneled to the atmosphere in the United States annually. About 60% of these result from the combustion of coal, while another 20% are produced from the combustion of petroleum products—particularly residual fuel oil.

The effect of exposure to low levels of concentration of sulfur oxides for extended periods is not fully understood, but there is ample evidence that high concentrations can severely affect human health and also damage lands, plants, and materials of construction. Increasing urbanization, along with growing population and associated industrial expansion, is raising the concentrations of sulfur oxides in the atmosphere above many cities. The Public Health Service recommends 0.1 part per million (ppm) as the maximum desirable ground level concentration of SO_2 in air, but average concentrations in a few of our major cities may be as much as 0.2 ppm with maximum daily and hourly concentrations of 0.7 and 1.7 ppm, respectively.

Interior Department's systems approach

The Department of the Interior, principally through the Bureau of Mines, is dedicated to a "systems approach" in the search for a solution to the SO_2 -air pollution problem. In this approach the entire situation is considered so as to arrive at a best overall solution in preference to individually optimizing various elements of the problem. The objective is to balance human and natural-resource-conservation needs for reducing emissions of SO_2 against such factors as: (1) Reserves and supplies of low-sulfur fuels; (2) alternative energy sources; (3) alternative methods for suppressing or otherwise abating SO_2 ; (4) processing economics; (5) dislocation of industry; and (6) other important economic and sociological considerations.

Economic and technical considerations

(1) Fuel resources

The United States is fortunate in having tremendous reserves of low-cost coal, amounting to more than one-and-a-half trillion tons. This makes coal our most abundant mineral fuel resource with reserves large enough to last more than a thousand years at present consumption rates. Low-sulfur coal—that is coal with less than 1% sulfur—comprises roughly two-thirds of the Nation's coal resources, but unfortunately it is impractically remote from the areas of greatest need, and thus its required use could involve high transportation costs. Also, more than three-quarters of our coal reserves are comprised of low-quality western subbituminous coal and lignite, both of which are low in sulfur. In addition an appreciable amount of the reserves are widely dispersed and not available in blocks large enough to be classified as long-term supply sources for electric utility plants. Furthermore, some low-sulfur coal is in deposits whose geological conditions entail high mining costs.

One possible economic solution might be to take advantage of mine-mouth power generation together with extra-high-voltage transmission, since mines

are usually in rural areas—remote from the more densely populated areas of volume-power utilization. The difficulty with this type of scheme is that the SO_2 atmospheric concentrations over large geographical areas eventually may be at levels high enough to endanger human life, vegetation, and materials. Tall smoke stacks—even those 800 feet high—are not a permanent solution to the problem because rural communities might be contaminated at distances as far as 25 miles from a given power plant.

Most U.S. crude petroleum is relatively low in sulfur, and residual fuel oil produced from it usually contains approximately 1.5% sulfur. However, less and less residual oil is being produced by U.S. refineries each year; at present it amounts to only about 8% of the domestic crude oil output. Many foreign crudes are much higher in sulfur content, and the usual residual fuel oils produced from them and imported into this country contain as much as 3% sulfur. During refinery operations, the sulfur tends to concentrate in the high boiling fractions—the ones with the lowest value per gallon. Since residual fuel oil sells for less than the crude from which it is produced, there is no economic incentive to process it further to remove the sulfur.

Technological aspects of sulfur control

(a) Precombustion removal of sulfur

The problem in removing sulfur from coal is compounded by the fact that not only do some coals contain as much as 6% sulfur, but the sulfur in all coals occurs in two major forms—organic and pyritic. Organic sulfur, which may be as much as 20 to 60% of the total, is actually part of the coal structure, and there is no known practical way by which this sulfur can be removed. Pyritic sulfur is at least theoretically removable; combined in mineral form as pyrites, it is physically imbedded in coal—not chemically bound to it.

Depending on their size, pyrite particles can be removed from coal with varying efficiency by such conventional coal cleaning processes as jigging, dense media, and concentrating tables. But, these processes are designed primarily to reduce ash content. If the coal is crushed sufficiently, the finer pyrite particles can be released. Information is available for only a few coal seams, but indications are that coal must be crushed to less than 100-mesh size to release most of the pyrites. Since material this fine cannot be transported except at greatly increased freight rates, release of the pyrites by crushing would have to be done at the point of use.

Success with these physical methods would have a very beneficial effect on the sulfur content of coals now being mined. If only an additional 0.5% of sulfur could be removed, more than 67 million tons of our present production would become "low-sulfur coal" containing less than 1% sulfur.

A variety of chemical methods—acid treatment, air and biological oxidation, gasification, carbonization, hydrogenation, and solvent extraction—through which coal is converted to other products have been suggested as means for removing sulfur. Right now, none of the methods except gasification appears to be economical, nor do they show prospects of becoming so in the near future. Gasification is the exception because it offers potential additional advantages for combining steam and gas turbine cycles to increase overall central station efficiency.

The sulfur compounds occurring in *residual fuel* oil are chemically bound to the oil molecules and their removal could require drastic treatment. Three major types of chemical processes have been suggested for reducing the sulfur content, and from a technological standpoint there should be no major obstacles for application to residual oils. The processes are (1) treating and extraction processes, (2) thermal and contact-catalyst processes, and (3) hydrosulfurization. Unfortunately, the processes are not simple, and there are serious economic obstacles to their use. Of the three methods, hydrosulfurization appears to hold the most promise.

Estimates for different-size plants and for differing processes and final-product specifications show costs ranging from 37 to 77 cents per barrel for any reasonable reduction in sulfur. Assuming an optimistic 50 cents per barrel as the cost of reducing sulfur, this would represent a price increase of about 25%—or about 7 cents per million Btu—over present posted prices for residual oil.

Another method for reducing the sulfur content of residual fuel involves blending the high-sulfur residuals with low-sulfur distillate to achieve low average levels. Estimates show that the cost of such blending would be extremely high. For example, reduction in sulfur from 3% to 2%, could increase the cost per mil-

lion Btu from 33 cents to 43 cents. Thus, the blending route is even more costly than that predicted for hydrodesulfurization.

(b) *Sulfur-fixation during combustion*

One way to reduce sulfur oxide emissions from combustion processes is to use an additive that ties up the sulfur oxides as a solid alkaline sulfate. Limestone and dolomite have been tested to a limited extent for this purpose because of their availability and low cost. Such additives increase the load of the solids-removal system and could contribute significantly to the fireside deposit and corrosion problem. On the other hand, these materials have a major advantage in that they can be added to the coal and crushed with it and thus can be used with existing boilers with little or no additional equipment. Test work in the United States, Japan, and Germany has shown some success, but results in general are erratic, indicating the need for considerably more research.

(c) *Removal of sulfur oxides from stack gases*

Research has been under way for many years to find acceptable methods for removing sulfur oxides from stack gases. Earliest efforts were devoted to scrubbing the gases with *alkaline aqueous solutions and slurries*. Unfortunately all wet-scrubbing methods suffer from one fundamental disadvantage—unless an exceptionally high level of SO₂-removal is achieved, ground level concentrations in the vicinity of the stack base may be little improved, and in some cases even worsened. This can occur since the cold, and therefore relatively heavy, effluent gases tend to descend quickly from the top of the stack, minimizing opportunity for diffusion into the surrounding atmosphere.

Because of the disadvantages with *wet-scrubbing processes*, recent research on SO₂ removal has been directed toward techniques operating at increased temperature levels (200–900° F.). They also have the advantage in that a marketable product—sulfur or sulfuric acid—could be produced to help offset the operating costs of the processes. At present, several dry processes are at various stages of development, and may find applicability for powerplant use.

Interior's sulfur-control research program

Many methods have been proposed for solving the sulfur oxides problem resulting from fuel combustion, but either the engineering technology is not yet developed or the economics are unfavorable. The Department of the Interior's Bureau of Mines, therefore, within limitations of its budget, is making an all-out effort to bring the most promising methods to an economically acceptable level. Any developments for alleviating an air pollution problem that do not consider the economic and resources aspects of control could have serious impact on the nation's overall economy.

In its work the Bureau is applying the *systems approach* because no one method can be expected to prove best for all conditions. Methods under investigation range all the way from those in which the sulfur is removed from the fuel prior to combustion, through those that remove the sulfur oxides from the products of combustion before discharge to the atmosphere, to development of new and improved combustion systems that provide electric power at much higher efficiencies than those now conventionally used. Supplementary studies have been made to determine the sulfur content of our coal resources and their availability, as well as to develop improved methods for measuring the sulfur content of coal as it moves through a coal cleaning plant.

(1) *Pre-combustion removal*

Pyrites, the principal sulfur-containing mineral in coal, occurs as discrete particles that theoretically can be released by fine grinding of the coal. Once the pyrites are released, the problem of separating them from the coal remains. The Bureau is exploring several approaches; a dry-cleaning procedure using a mixture of air and magnetite to effect a specific-gravity separation; froth flotation techniques; and magnetic separation.

(2) *Sulfur-fixation*

There is conflicting information in the literature on the effectiveness of limestones (and dolomites) for reacting with the sulfur gases during combustion of coal and fixing them in the ash residue. In some cases, appreciable SO₂ removal is reported, and in others, none at all. The difference in results may be caused by a variety of factors not yet fully explored. They include reactivity of the limestone, ratio of limestone to sulfur oxides, temperatures in the furnace, and

methods and places of limestone injection. To evaluate these variables, the Bureau is investigating all of them on a rational basis.

(3) *Improved combustion methods*

An entirely different approach to alleviate the sulfur problem involves the use of new combustion principles that theoretically develop electric power at considerably higher efficiencies than those presently used. The Bureau is investigating several of these principles, including magnetohydrodynamics, electrogasdynamics, and combined cycles. Also under investigation is the combustion of coal in a fluidized bed, a method that offers advantages from improved heat and mass transfer and from lower temperatures within the bed. Lower bed temperatures may lead to reduced emissions of sulfur and nitrogen oxides, as well as greater efficiency by reduction in corrosion and ash deposits.

(4) *Stack gas treatment*

The Bureau is studying the removal of sulfur oxides from the stack gases generated when fuel is burned. Some of these approaches depend on reacting and fixing the sulfur oxides with various chemicals which can be regenerated and reused after adsorption. The sulfur is recovered either as sulfuric acid or in elemental form, each of which can be marketed. Among the processes under investigation are:

(a) *Alkalized alumina process*

Oxides of sulfur are removed from hot stack gases by absorption on free-falling and entrained pellets of alkalized alumina. The pelleted absorbent is regenerated and released sulfur converted to hydrogen sulfide through application of heat and a reducing agent, such as producer gas. Subsequent treatment of the H_2S in a Claus reactor produces recoverable elemental sulfur.

Under the sponsorship of the Public Health Service, a small pilot plant (550 cubic feet per hour) was built at the Bureau's Pittsburgh Coal Research Center, Bruceton, Pa., in 1961 and operated for three years. A completely integrated unit handling 55,000 cfh is now being used at the center to investigate continuous operation of the absorption-regeneration cycle and other variables.

(b) *Rock-phosphate process*

Bench-scale tests have proved that, following catalytic oxidation of SO_2 to SO_3 , the SO_3 is completely removed from stack gas at $400^\circ C$ by contact with phosphate rock. Furthermore, the SO_3 and water vapor in the gas stream form sulfuric acid vapor and react with the calcium phosphate in the rock. This process presents the possibility of preparing a fertilizer or a fertilizer intermediate, while at the same time removing noxious sulfur oxides from flue gases. A considerable portion of the Nation's sulfuric acid is consumed at present in the preparation of superphosphate fertilizer.

(c) *Manganese-oxides process*

While manganese oxides were found in a preliminary screening investigation to be highly absorbents of SO_2 from combustion gases at 130° to $330^\circ C$, an improved, low-cost regeneration scheme is needed to reconvert the spent oxides to usable, active manganese oxides. Physical regenerating methods under study consist of thermal treatments at various pressures. Chemical methods involve use of the following gases at various temperatures and pressures: H_2 , CO , CH_4 , air, CO_2 , steam, H_2S , and producer gas. Reducing solids, i.e., coal, coke, manganese matte, and iron pyrites, will be considered also for regeneration tests. To reduce attrition losses in the absorber development of a harder manganese oxide absorbent will be sought. This involves investigating methods such as coprecipitation with other oxides, impregnation on supports, and pelletizing.

(d) *Teller process*

Dr. A. J. Teller of Cooper Union University, New York City, has conducted laboratory studies of an absorption system using chromatographic-type base materials such as alumina or chromosorb, impregnated with an absorption agent. The absorbing compound may be organic; i.e., amines, amides, quinones; or inorganic, such as metal sulfites. The absorption product must be regenerable thermally.

Under a cooperative agreement with Cooper Union, additional research is being funded by the Bureau of Mines in order to study the process variables. Different aspects of this work is being conducted simultaneously at Cooper Union and at the Bureau's Pittsburgh Coal Research Center.

(e) *Exploratory schemes*

The Bureau is continuing to test various minerals for their capacity to remove sulfur oxides from flue gas. Materials found active might either be discarded after a single pass, or regenerated. Many minerals such as *shales* and phosphate rock contain compounds known to react with SO_2 under certain conditions.

The most promising materials found in these laboratory tests will be studied further, using an actual flue gas from combustion of pulverized coal. Both a small and a large coal-fired furnace are available for such studies.

(5) *Other sulfur control research*

Interest and concern for sulfur-based air pollutants and their control is not only nationwide, but is springing up throughout the world. Foreign countries reporting particular activity in sulfur-control research and development include England, Germany, and Japan. Although work is under way in many areas on means for fixing sulfur during combustion, the most important advances have been made in the recovery of SO_2 from stack gases. The foreign countries where such research is under way, and the scale of experimentation involved are indicated in the following table:

Process	Location	Size of installation (megawatts)	Byproduct
1. Alkalized alumina.....	England.....	¹ 50	Sulfur.
2a. Catalytic oxidation.....	United States.....	12	Sulfuric acid.
2b. Catalytic oxidation.....	Japan.....	.02	Ammonium sulfate.
3a. Reinluft (activated char).....	England.....	² 15	Sulfuric acid.
3b. Reinluft (activated char).....	Germany.....	5	Do.
4. Activated char.....	Japan.....	1.9	Do.
5. Manganese oxide.....	do.....	2	Ammonium sulfate.

¹ Proposed.

² No longer in operation.

It is particularly interesting to note that of the four differing approaches to SO_2 recovery represented in the table, the Department of the Interior, through the Bureau of Mines, has contributed important pioneering research to three.

(6) *Summary*

With increasing urbanization, growing population, and associated industrial expansion, sulfur oxide concentrations in the atmosphere over our cities will increase unless some limitation is placed on their discharge. Since most of the sulfur oxides result from burning coal and residual fuel oil, the problem already is recognized by legislation that sets specifications for fuels to be used in Federal facilities, electric utilities, and industrial plants.

While the United States has appreciable reserves of low-sulfur coal, much of it is located at too great distance from the electric utility market—the major user—or is held captive by the steel industry for metallurgical purposes. Neither is there a sufficient domestic supply of low-sulfur residual fuel oil to meet demands now met principally by imports of high-sulfur residuals. For these reasons, unless research finds a solution to the sulfur-emission problem, restrictions will inevitably put a stop to the use of high-sulfur fuels and result in increased costs.

Natural gas conceivably could offer an acceptable alternative if it were available in sufficient quantity. However, this is one of the highest-quality, most convenient energy resources in the country. Conservation principles require us to consider future, as well as present needs. Proved reserves of natural gas are sufficient for between 16 and 17 years of consumption at the present rate. Without doubt, more natural gas will be discovered in the future, but any general shift to this fuel would raise requirements to more than offset increased supplies.

Nuclear power presents another possible answer to the sulfur dioxide problem. Great advances have been made in the development of nuclear reactors, but there is still much to be learned about their economic and safe operation. The handling and disposal of nuclear waste is another problem. Supplies of low-cost fissionable material are limited and will continue to be so unless new reserves can be discovered or until breeder reactors become practical.

While theoretically sound ways to solve the sulfur oxide problem are known, all processes under study to date are either technologically incomplete or economically unfavorable. The lowest cost routes for a variety of conditions are still to be determined, and new and improved methods must be sought.

SOLID WASTE DISPOSAL

Each year U.S. citizens throw away more than 150 million tons of solid waste—approximately 4.5 pounds per capita per day. By 1980, the figure will rise to 5.5 pounds of refuse for each person. The accumulation comprises paper, garbage, tin cans, bottles, trash, and just plain junk. It must be gathered and disposed of in some manner, and the current annual cost of disposal is about \$3 billion.

Most solid waste is plowed underground by bulldozers; some is burned in open heaps, as at Washington's Kenilworth dump; about 37 million tons is burned in more-or-less modern incinerators. The residues of the incinerators each year contain more than 3 million tons of iron and 200,000 tons of mixed nonferrous metals, mainly aluminum, zinc, copper, lead, and tin. Final burial of the total raw wastes and burned residues in sanitary (and not too sanitary) landfills, results in an irreplaceable annual loss of 9 million tons of metal. This is tantamount to stealing each year many millions of dollars from the national economy.

In 1964, 86.3 million automotive vehicles were registered in the United States. That same year 9.3 million new ones were built and 6.8 million were discarded—cars that were wrecked, worn out, or merely too dilapidated. By 1975 the number of vehicles scrapped is expected to approach 10 million annually. The projection is based on the assumption that the historical relationship between automobile registration and automobiles scrapped will remain relatively constant, and on the assumption that registrations will increase at the 1954 to 1965 rate.

In 1965, approximately 6.7 billion tons of material was dug from the U.S. soil to produce 0.5 billion tons of coal, 2.4 billion tons of crude ore along with marketable products such as sand and gravel and clay, as well as 3.8 billion tons of mining waste. Further processing of the crude ore yielded about 0.4 billion tons more waste materials to be stored in tailings, ponds, or slag heaps.

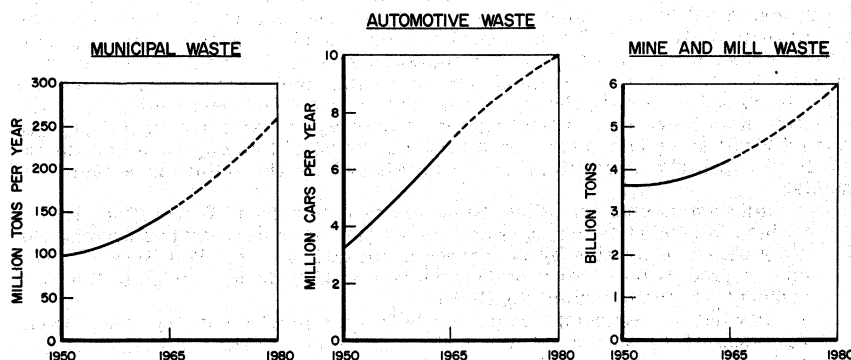
THE THREAT OF ACCUMULATING WASTE

FIGURE 34

Meanwhile, the grades of available ores continue to decline, and user specifications for industrial minerals and fossil fuels are becoming more stringent. If the national economy continues to grow at the expected rate, the domestic minerals industry will be handling at least 9.5 billion tons of material a year by 1975—and producing nearly 6 billion tons of waste. Obviously, the production of solid wastes is increasing rapidly, and the problems arising from it are many-faceted and complex.

Take, for example, the scrap automobile situation. The technology of iron and steel making has been undergoing a revolution in recent years. As a result, only high-grade ferrous scrap is in demand; the market for lower-grade automotive scrap is gradually declining in spite of steadily increasing steel production. Better methods must be devised for upgrading automotive scrap and new uses for it must be found, or the junkyards will continue to grow.

Social pressures also are mounting against defacement of the land by mine waste, slag piles, dumps, tailings, slime ponds, and other waste storage. Not only do these create scenic blights, but they take up space that could be used

more productively—space that already is hard to find in many heavily populated communities. Waste storage often creates hazardous conditions and contributes to water and air pollution. Moreover, many solid wastes contain potentially valuable mineral and metal constituents which should be recovered and recycled to the production stream.

The importance to the overall economy of recycling materials is evident. Of the total copper consumed in the United States each year, 42% is reclaimed or "secondary" copper. Recycling accounts for 58% of our lead, 45% of our iron, 26% of our zinc, and 19% of our aluminum. These returns are derived only from materials that are easily treated, however. Millions of dollars worth of metals are discarded each year, because they are locked chemically and mechanically into materials from which they cannot be separated by standard smelting technology.

Here, in the United States, we now enjoy a high standard of living far beyond precedent for any country in the world. But, in attaining that standard, we have consumed in the past three decades alone more minerals and fuels than previously were used by all the people of the earth throughout its history. As a result, much of the copper now produced on the North American continent comes from ores containing less than 1% copper, as compared to grades of 5 to 20% copper used 60 years ago. An increasing percentage of domestic iron ore is taconite, a rock considered unusable only a few years ago when direct-shiping hematite was available. This trend toward the use of leaner ores is evident for many other metals.

The lesson is clear: The United States has exhausted or nearly exhausted its rich deposits which were easily discovered and easily mined, and is being forced to import rich ores or use domestic ores of lower quality. Clearly, the natural resources of the entire world will not be adequate to supply increasing demand indefinitely unless far more efficient systems for recycling used materials can be devised.

The Department of the Interior, charged with conservation and wise use of the Nation's resources, has consistently sought ways to reuse the waste products and scrap generated by the minerals industries and the consuming public. Through the Bureau of Mines, the Department has been actively seeking solutions to solid waste problems for more than two decades. In general, the objective has been to develop new and improved methods for recovering metal values from wastes and for refining substandard primary metals. The approach has been that of applying scientific knowledge and expanding the technology of extractive metallurgy to solve difficult secondary metals problems. The value of this approach and the innovative capability it requires, are demonstrated by the following accomplishments:

Cadmium-magnesium alloy bomb casings, left from World War II, remained in stockpiles for years and were assumed to be worthless because the alloy defied separation by known metallurgical practice. The Bureau developed a process for recovering both metals, at significant savings to the Government, through vacuum distillation.

Drawing on technology from the heavy chemicals industry, the Bureau has successfully used amalgam electrolysis to recover tin, cadmium, and zinc from process residues.

Processes have been developed in which two waste materials effectively refine each other. Galvanizers' dross containing iron is mixed with zinc die-cast scrap containing aluminum, and the mixture is melted. The iron from the dross combines with aluminum from the die castings to form solid crystals of iron-aluminum compounds. These are easily separated by filtering or centrifuging, and the zinc from both scrap materials can be refined.

Another process developed by the Bureau uses a different type of waste material for removing aluminum from die-cast scrap. Spent galvanizers' sal skimmings, containing too much chlorine for treatment at smelters, is added to the molten scrap to cause volatilization of aluminum chloride. The zinc is refined, and the skimmings become marketable when the chlorine content is reduced below 2%.

A process recently patented by the Bureau removes alumina from zinc with the aid of ferric chloride. Unique features of the method are that both iron and chlorine in the ferric chloride are effective refining agents; and ferric chloride, which normally boils below the temperature of the operation, is prevented from escaping by using a carrier flux of other salts.

In the past there has been a tendency to look askance at recycling; the idea of reusing "junk" was considered degrading. Nevertheless, the Bureau of Mines has persevered—sometimes at only token levels of funding, and often alone—in this field of research.

The growing realization of the importance of waste reclamation has generated social pressures for additional actions by the Federal Government. With the passage of the 1965 Solid Waste Disposal Act, the Bureau's responsibility was clearly indicated. Under the provisions of the Act, the Secretary of the Interior was given responsibility for dealing with "... problems of solid waste resulting from the extraction, processing, or utilization of minerals or fossil fuels..." This is interpreted to include the return to the industrial base of metal scrap and mineral residues from all sources.

The scope of the Department's activity is spelled out in the Act as follows:

"The Secretary shall conduct, and encourage, cooperate with, and render financial and other assistance to appropriate public authorities, agencies, and institutions, private agencies and institutions, and individuals in the conduct of, and promote the coordination of research, investigations, experiments, training, demonstrations, surveys, and studies relating to the operation and financing of solid waste disposal programs, the development and application of new and improved methods of solid waste disposal and the reduction of the amount of such waste and unsalvageable waste materials."

In carrying out these provisions the Secretary is authorized to:

1. collect and make available, through publications and other appropriate means, the results of such research and other activities including appropriate recommendations in connection therewith;
2. cooperate with public and private agencies, institutions and organizations, and with any industries involved, in the preparation and the conduct of such research and other activities; and
3. enter into contracts or make grants-in-aid to public or private agencies and institutions and to individuals for research, training, projects, surveys, and demonstrations."

The Department of the Interior, through the Bureau of Mines, immediately initiated an expanded program to:

1. Delineate the factors causing and contributing to waste disposal problems in mineral and mineral-related industries; establish the magnitude and nature of the waste products; identify the problems that demand priority of attention; appraise the effectiveness of waste disposal practices; provide estimates of waste that may accumulate from future operations; and make recommendations for the improvement of waste disposal practices;
2. In areas where the scope of the problem was already clearly identified (automobile scrap, incinerator waste, alumina plant red mud), develop new or improved techniques of solid waste recovery and utilization and demonstrate their applications; alternatively, develop nonpolluting methods for disposing of solid waste where no valuable constituents can be identified and for which no use can be found;
3. Devise methods for separation of components of nonferrous scrap by continuation of research previously underway;
4. Interest and train college students in the field of solid waste utilization and disposal.

Work on auto scrap was divided into two phases: (1) upgrading to an acceptable feed for steelmaking and (2) finding alternative uses.

The presence of copper in automobile scrap is a major barrier to its use in steelmaking; a maximum of 0.15% copper is permitted for steel that is to be shaped by deep drawing. Tin, aluminum, and lead are other unwanted, but less troublesome, impurities. Methods investigated for the effective removal of impurities have included physical sorting, leaching, and pyrometallurgical treatments.

Good progress has been made on a project designed to determine the exact location and composition of nonferrous components of typical scrap automobiles and to find the most economical method of stripping these components from the hulk. Representative models of junk cars were disassembled and analyzed and the results transmitted to the Institute of Scrap Iron and Steel, the American Federation of Independent Scrap Yard Dealers, and the American Foundryman's Society. These organizations, in turn, disseminated the information to their in-

dividual members, many of whom have reported that this information has helped them in processing automobile scrap. Promising results have also been obtained from experiments in chemical leaching of residual copper from automobile scrap. An efficient selective leaching agent has been developed, and preliminary cost estimates for commercial-scale processing have been favorable.

Less successful to date, but still showing promise, are two furnace treatments. One involves heating the auto hulk in a rotary kiln at a temperature that liquifies low-melting nonferrous metals and embrittles the copper so that it can be flaked free and separated. The other treatment involves melting the scrap and preferentially tying up the copper in a slag fraction.

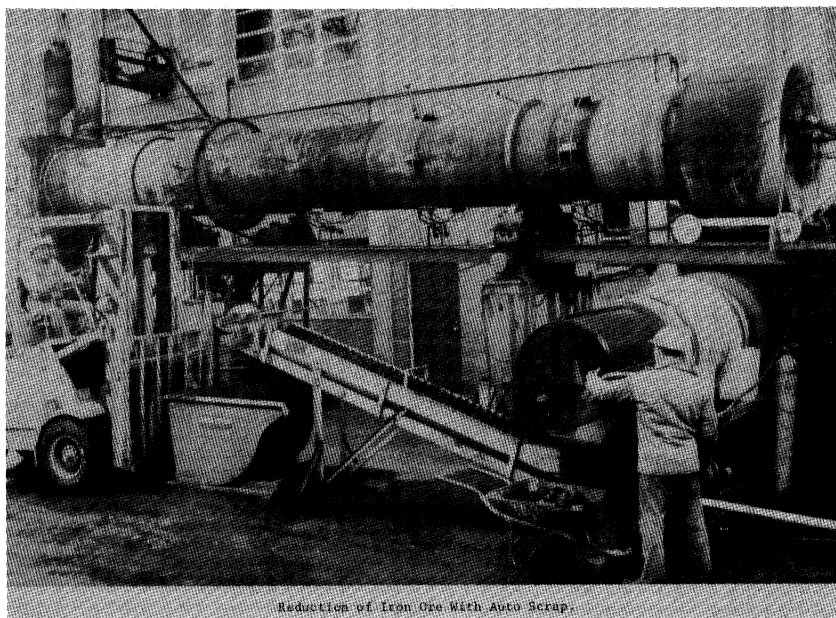
The Bureau is highly optimistic about a process that utilizes steel scrap in an entirely different manner. Chopped-up scrap is heated in a rotary kiln with nonmagnetic taconite—a material that previously has resisted treatment for recovery of its iron content. The iron in both the ore and the scrap is converted to a magnetic iron oxide which can be readily concentrated. At this stage, a conventional iron-oxide pellet can be made containing more than 63% iron, or another Bureau technique can be applied to yield a prereduced pellet with an iron content of more than 80%. By late 1968 a prototype plant will begin operation near the western end of the Mesabi Range to demonstrate the process. The plant will have a daily capacity of 600 tons of crude ore. Since the process requires ore and scrap in about a 20-to-1 ratio, the test plant will use 30 tons of scrap per day. A commercial processing plant turning out 5 million tons of high-grade ore concentrates a year would consume 600,000 tons of scrap.

Still another project, started last year and aimed at recovering the metal and mineral content of municipal incinerator wastes, already has attracted wide interest. Separation and recovery of the valuable mineral constituents poses several technical problems, but none of these appear unsurmountable. When the project has been further advanced it is probable that the recovery method will be demonstrated in a model municipal waste plant to be built in cooperation with the Public Health Service.

One other project, still in an early stage, already has shown promise of partial achievement of objectives. Work on centrifugal dewatering of red mud from Jamaican-type bauxite has been sufficiently encouraging to stimulate a major manufacturer of centrifuges into conducting a number of tests for the Bureau at no charge. Success in this phase of red mud research would result in substantial recovery of alumina and soda for processors of bauxite. Subsequent problems, recovery of iron and titanium and the final disposal of the residue, are yet to be solved.

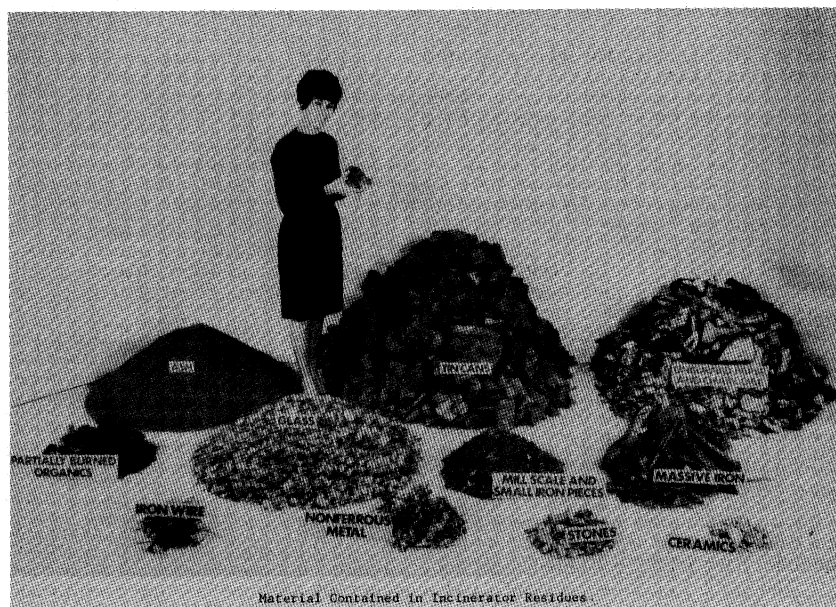
A contract and grant program aimed both at training personnel and conducting basic research was begun by the Bureau this year and is now operating at an annual level of \$600,000. None of the projects begun to date are sufficiently advanced for a meaningful assessment of progress.

Hundreds of samples of mine and mill wastes have been subjected to extensive scientific scrutiny to establish their chemical and physical properties and to determine the most likely materials for mineral recovery or conversion to useful products. A preliminary study of the magnitude and sociological significance of the solid waste problem is scheduled for completion by the middle of 1968.



Reduction of Iron Ore with Auto Scrap.

FIGURE 35.—Reduction of iron ore with auto scrap.



Material Contained in Incinerator Residues.

FIGURE 36.—Material contained in incinerator residues.

The Department is not alone in research on solid wastes. The Public Health Service, Department of Health, Education and Welfare, conducts a program twice as large as Interior's which includes research, training, demonstrations, and community planning in the field of municipal waste disposal (but not constituent recovery). Individual states and cities are becoming interested and co-operating with the HEW program.

Industry is moving as rapidly as possible to develop new machines to treat auto scrap and make it acceptable to steel manufacturers. But the total effort to date has made only a dent on the massive problem of solid waste accumulation.

In spite of increasing public concern, solid waste disposal lacks the glamor and urgency that surround air- and water-pollution control. Yet it is virtually certain that solving solid waste disposal problems will require as much or more technical creativity as that demanded by other fields. The challenges will call for all the imagination that can be generated by the combined physical and biological sciences; all the ingenuity that can be brought to bear by chemical, metallurgical, mechanical, civil, and sanitary engineers; and the integrated application of sophisticated systems analysis on the Federal, State, and community levels.

RESEARCH ON EARTHQUAKES

Introduction

Hundreds of damaging earthquakes have occurred during historic time in the earthquake belt of the western United States. Many more can be expected to occur in the future. In the California-Nevada region alone, about 60 earthquakes of magnitude 6 or greater have been recorded in this century, and many have been experienced in other states of the western earthquake belt: in coastal Oregon and Washington, Utah, and Montana. Less severe earthquakes have been widespread in the west, and in the area east of the Rocky Mountains as well.

Although great earthquakes—those of magnitude 8 or greater—are relatively rare, they can be expected to cause large future losses in life and property unless we can expand our knowledge so as to minimize their effects. Three great earthquakes have occurred in California during the past 110 years: on the famed San Andreas fault in 1857 and 1906, and in Owens Valley in 1872. Others recorded in the United States occurred in 1811 and 1812 in the vicinity of New Madrid, Missouri—in the Mississippi Valley region—illustrating that the portion of our country lying east of the Rocky Mountains is by no means immune from the hazard of great earthquakes.

The Good Friday earthquake in Alaska in 1964 stimulated present interest in research on the nature and causes of these phenomena and the reduction of the hazards attending them.

Populations in earthquake-prone areas in the western United States are expected to increase to at least one-fifth of the total national population by the year 2000. The Urban Land Institute estimates that, by then, one-seventh of our total population will be concentrated in less than one-third of the area of the State of California, primarily in the coastal region; the "earthquake country" of the San Andreas fault. Many moderate, a few severe, and perhaps one great earthquake can be expected to occur in California and other earthquake-prone areas during this period of rapid population growth.

Recognizing the critical and immediate need to develop sound guidelines for safe and economic urban development for this expanding population, the U.S. Geological Survey has organized a broad, coordinated, interdisciplinary earthquake research program at its National Center for Earthquake Research (NCER) in Menlo Park, California. About 100 geologists, geophysicists, mathematicians, and technicians are engaged in this research program. The various elements of this program are:

Seismological studies

Small earthquakes and aftershocks are being studied along a segment of the San Andreas fault zone that stretches from San Francisco 200 miles south to Cholame, near which a sequence of moderate earthquakes occurred in June and July, 1966 (fig. 37). A network of fixed seismograph stations is being established in this area. Thirteen such stations, primarily in the San Francisco Bay area south of San Francisco, are now in operation, and a total of 31 are scheduled for installation by the end of FY 1967. Earthquake signals from these seismograph stations are transmitted (telemetered) over telephone lines to NCER and recorded there for study.

The telemetered seismograph network is supplemented by a network of 20 portable seismograph stations that can be moved into the field for special studies within hours after an earthquake occurs. Earthquake signals are recorded on special slow-speed, low-power, magnetic-tape recorders that can operate unattended for up to 10 days on a single reel of tape. Magnetic tapes from the portable stations are then "played back" and recorded in visual form for analysis at NCER.

These portable stations already have been used successfully to study earthquakes in many areas: in Colorado, in the Yellowstone National Park region of Montana and Wyoming, and in Chile, Nevada, Alaska, and California. Earthquakes can be located with unprecedented accuracy with the new telemetered and portable seismograph networks. An example is the study of the aftershocks of the 1966 earthquake sequence in the Parkfield-Cholame area. In this study, using accurately recorded earthquake waves and supplementary information (extrapolated from explosions) on the speed at which these waves travel in the earth's crust, aftershocks were found to lie vertically below the surface fracture zone of the San Andreas fault at depths ranging from near the surface to 15 kilometers. We believe this is the first time that earthquakes have been shown to occur directly in a mapped fault zone.

Some segments of the San Andreas fault zone are "active" with many small earthquakes and a few moderate ones. Other segments are strangely quiet. An example of a quiet zone is the area of our telemetered Peninsula cluster of seismographs southwest of Menlo Park, through which we are keeping the earthquake pulse of a segment of the San Andreas fault that broke violently during the San Francisco earthquake of 1906. Another quiet zone is the segment of the San Andreas fault zone south of Cholame that broke in the great Fort Tejon earthquake of 1857.

The areas of frequent small or moderate earthquakes are also areas where "fault creep" or slippage is commonly observed, whereas creep is generally not observed in quiet zones.

We are investigating the significance of these observations.

In addition to our seismological studies of earthquakes, we are recording seismic waves generated by explosions to study the deep structure of the earth's crust and upper mantle. Early studies of earth structure emphasized a broad reconnaissance of the structure of the continent. We are now making much more detailed studies of the deep structure of the San Andreas fault to obtain information on the broad geologic environment in which earthquakes occur, and on the speed with which earthquake waves travel, permitting their accurate location.

Preparations are under way to begin a study of the relations between the intensity of ground motion associated with earthquakes and the nature of geological materials on which buildings are constructed.

Other geophysical studies

To study the relations among earthquakes, fault creep, and regional crustal deformation in earthquake-fault zones, scientists at NCER are conducting comprehensive studies of crustal strain. Such studies are made by repeatedly reobserving the slowly changing locations of survey markers and analyzing their movements in relation to the geologic conditions and earthquake activity in fault zones. Experimental observations of earth tilt and space and time fluctuations in the earth's gravity and magnetism in fault zones are also under way.

A modern, well-equipped rock-deformation laboratory is nearing completion at NCER. In this laboratory, rock samples will be subjected to pressures and temperatures that we expect deep in the earth's crust and upper mantle to study how rocks may actually deform and fail when an earthquake occurs. These studies will be coordinated with actual measurements of rock stress in specially drilled holes in active fault zones.

Geologic studies

Geophysical research on earthquakes is closely coordinated with a variety of geologic studies. These include research on the regional geologic and tectonic framework of earthquake-fault zones in the California-Nevada region and Alaska, research on the relations of basement and volcanic rocks to movements along the San Andreas fault, study of the relations of the evolution of sedimentary basins to the geologic history of the San Andreas fault system, detailed mapping of recent fault breaks, and studies of the relations between land forms and fault-displacement rates. These studies are particularly valuable in determining from the historic and geologic record where earthquakes may occur. They have shown, for example, that total displacements along the San Andreas fault zone have

probably been as much as several hundred miles during the past 100 million years of the earth's history, and that fault movements associated with earthquakes have a tendency to occur repeatedly along the very same fault strands, rather than through broad fault zones.

Engineering-geology studies of earthquake hazards in Alaska and California are also under way. These studies include research on the stability of San Francisco Bay muds, submarine slides associated with the 1964 Alaska earthquake, and on geologic and seismic hazards associated with nuclear-reactor siting problems in California.

At the present state of our knowledge, a good geologic map showing the accurate locations of active faults is the most reliable and useful earthquake-hazard map available. The usefulness of such geologic maps will, of course, be greatly enhanced as our understanding of the geophysical observations of earthquake phenomena in relation to the geologic framework and history is improved.

Conclusion

The earthquake studies reviewed above have as their goal a substantial reduction of potential earthquake losses of life and property during the next ten years, especially in establishing reliable guidelines that will permit Americans to live in relative safety in earthquake-prone areas. As our knowledge of earthquakes expands, we may acquire a capability for specific earthquake prediction—the time, place, and magnitude of future earthquakes. Such knowledge would be of great value in warning people to stay away from particularly hazardous areas, and in alerting police and fire departments and public and private officials responsible for the continued availability of water and power and access to transportation routes, so that they could make adequate advanced preparations for a future earthquake.

The U.S. Geological Survey regards earthquake research as an opportunity for science and the community to form a partnership in tackling the many problems associated with earthquake hazards. We believe that this partnership will protect our society, enrich our culture, and strengthen our science.

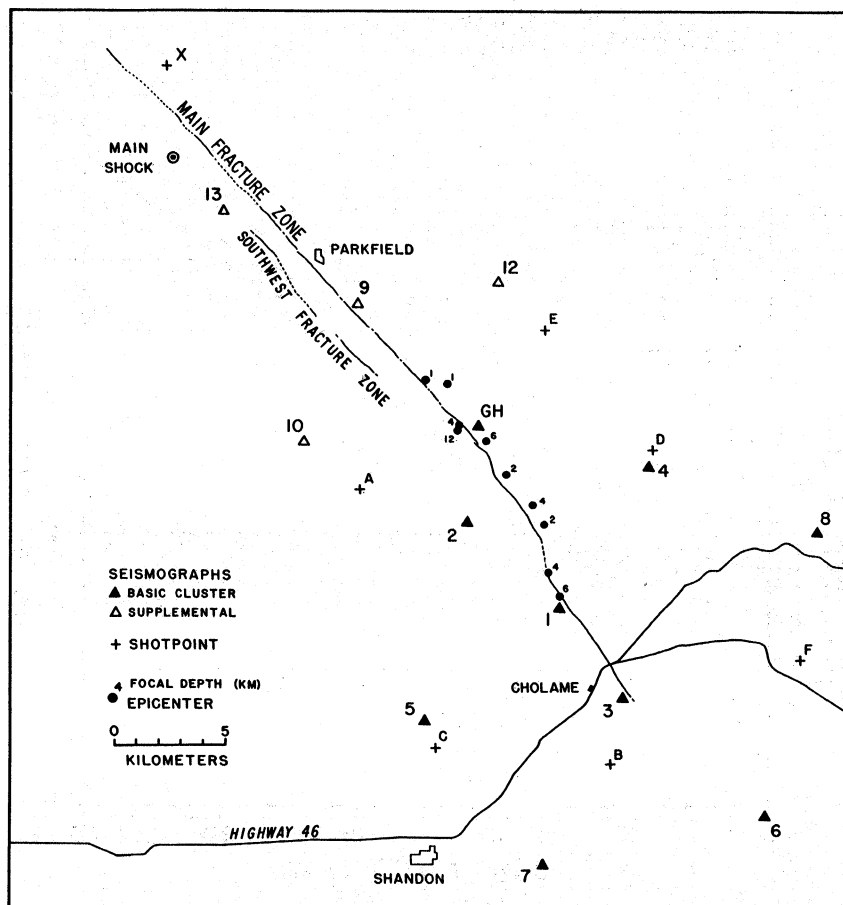


FIGURE 37.—Sketch map of the Parkfield-Cholame region, California, showing U.S. Geological Survey seismograph stations, epicenters of July 17, 1966, after-shocks, calibration shot locations, and the surface fracture zones associated with the 1966 earthquake sequence (from a map by R. D. Brown and J. G. Vedder, U.S. Geological Survey). The epicenter of the main shock was provided by Prof. T. V. McEvilly, University of California at Berkeley.

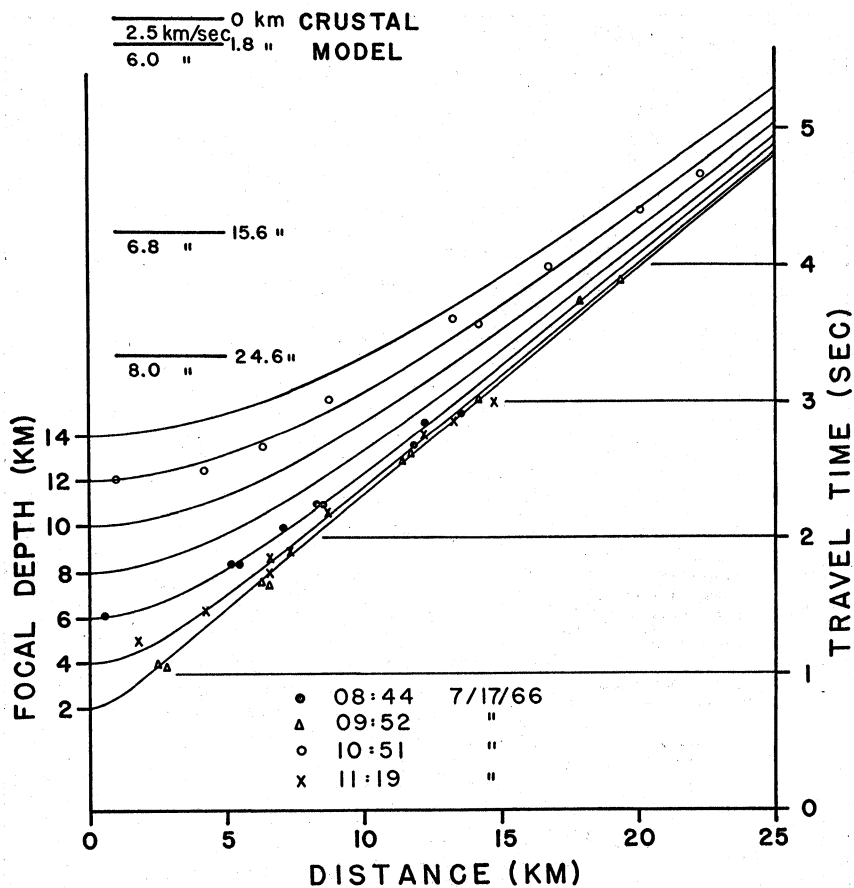


FIGURE 38.—Theoretical traveltime curves for earthquakes with focal depths from 2 to 14 km and the crustal model from which they were calculated. Observations from four July 17 aftershocks are plotted on the diagram for comparison with the theoretical curves.



FIGURE 39

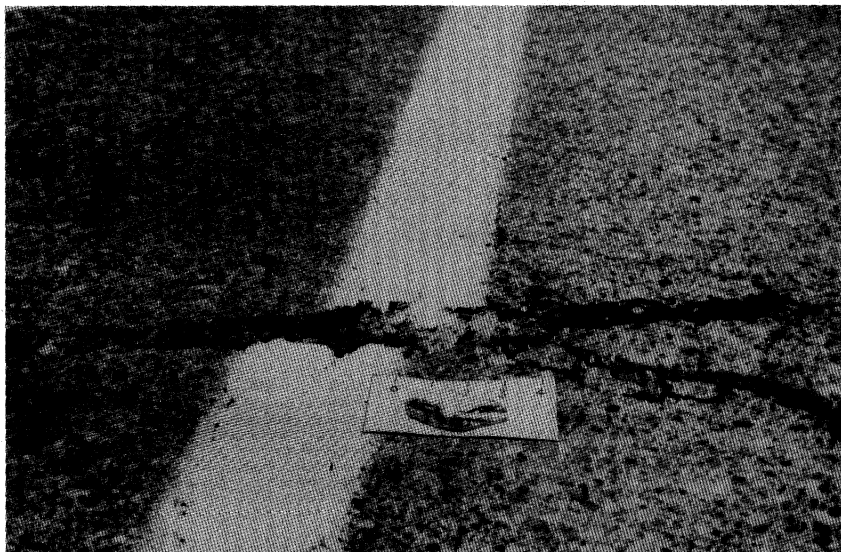


FIGURE 40.—Offset of California State Highway 46 across the San Andreas Fault near Cholame, California, the day after the moderate (magnitude about $5\frac{1}{2}$) Parkfield-Cholame earthquake of June 27, 1966. Offset was about two inches.

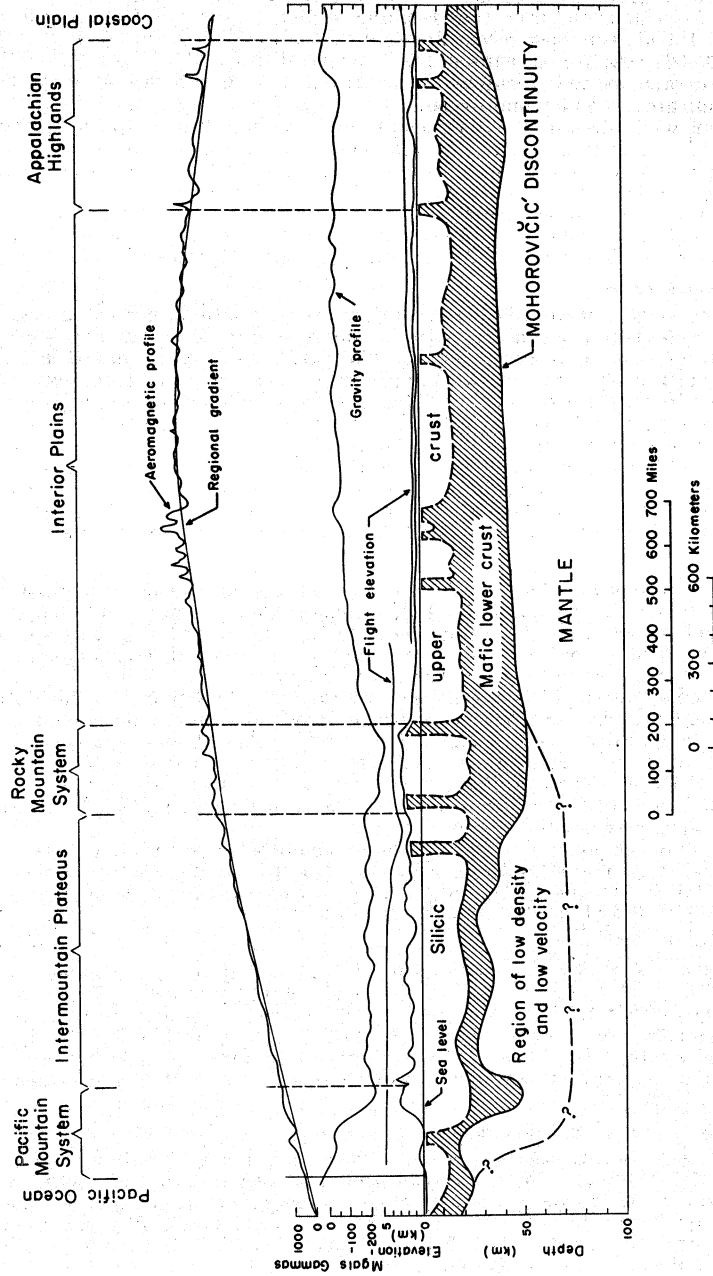


FIGURE 41.—Structure of the continent from coast to coast as determined by Geological Survey scientists from seismic, gravity, aeromagnetic, and geologic studies in the VELA-UNIFORM (nuclear-test detection) and International Upper Mantle research programs.

EXPLOSIONS AND FIRES IN COAL WORKINGS

Situation and Outlook

Although progress has been made over the years in reducing the occurrence of coal-mine explosions and fires, they remain significant causes of death and injury to miners. During the most recent five-year period for which statistics are available (1962-66), explosions caused 132 mine fatalities and 165 injuries. Fires, during the same period, resulted in 19 deaths and 30 injuries. Clearly, both records indicate a need for improvement.

Moreover, while fires in active mines are an immediate threat to the safety of men working underground, those in abandoned coal workings and inactive coal deposits, pose an insidious danger to lives, health, and property of people living in or near coal-mining areas. In the Appalachian region alone, more than 200 such fires are known to be burning uncontrolled, some of them dangerously close to urban centers. And nearly 500 coal-mine refuse banks are afire in 15 states. Approximately 40% of these banks are within a mile of a town.

National significance

While the high accidental death and injury rates in mining have long been on the public conscience, a concern with the depreciation of human and environmental values is of more recent origin. The "after cost" of a mine disaster is easily documented in terms of the manpower loss and the human tragedy. It is not so easy to estimate the demoralizing effect on communities of fires in coal formations or in culm banks. Objectionable fumes pollute the general atmosphere and, if they accumulate in poorly ventilated spaces, can even kill. The economic losses extend far beyond value of the coal consumed, for the development of adjacent properties may be prevented and surface structures may be damaged by subsidence. Fires within 30 feet of the surface destroy vegetation, and outcropping fires have ignited homes and forests causing widespread destruction.

Needs

The occurrence of any fire or explosion requires the coincidence of at least two factors: a source of ignition and a local accumulation of combustible material.

Much fruitful work has been done on reducing and controlling these factors, of which the development of "permissible explosives" and continuous monitoring of working areas for methane are but two examples.

Local accumulations of combustibles are probably inevitable by the nature of mining operations, and there may be an irreducible minimum of ignitions. However, the transition from a small flame into a mine disaster can occur only when substantial concentrations of combustible material have been allowed to accumulate. Here proper ventilation of underground workings can limit the danger. In this field there is much still to be learned and much of our basic knowledge has yet to be fully applied.

Fires in inactive mines and culm banks demand better criteria for assessing their cost to the community. The urgency of applying costly existent methods to control such fires and the advisability of looking instead for new concepts of control can only be judged in terms of a known need.

Government involvement

The Bureau of Mines was established in 1910 to improve health conditions, increase safety, and conserve resources in the mining industry. The Federal Mine Safety Code of 1953 provides guidance for Federal inspectors in bituminous coal and lignite mines. Public Law 738, 83rd Congress, authorized the appropriation of up to \$500,000 annually for control of outcrop and underground fires, and these operations were greatly expanded by the Appalachian Regional Development Act of 1965.

Application of science and technology

Three classes of fire and explosion hazards are being fought by applying science and technology. These hazards are: (1) accumulation of methane in cavities and in the strata overlying mine workings; (2) accumulation underground of float coal dust layers which may yield combustible dispersions even when they are diluted with rock dust in accord with existing legal codes; and (3) the formation of mixtures of coal dust and methane that are combustible although each fuel by itself is too much diluted to support combustion.

The tendency of methane to concentrate in layers can be dangerous even when the rate of ventilation is based on the rate of methane emission. The methane

is rendered harmless only if it is mixed completely with ventilation flow. Fire-damp may accumulate in cavities and build up to large accumulations. A thin roof layer may act as a fuse in spreading the explosion from one region of accumulated methane to another. A weak explosion may intensify as it propagates by rapidly moving accumulated fire-damp with air ahead of the flame front. Current studies by the Bureau of Mines are providing information on flame speeds and turbulence characteristics of burning layers of fuel.

Float coal dust can form dangerous clouds even when it is dispersed by a weak explosion or aerodynamic disturbance. A strong disturbance in a properly rock-dusted mine will usually disperse both coal and rock dust in the air, and such a mixture will be nonflammable. But when the aerodynamic disturbance is weak, only the most recently deposited layer, which is usually float coal dust, may be lifted off. The dispersal of a $\frac{1}{32}$ -inch layer of coal dust is enough to make a flammable cloud in a typical mine entry. Studies are now under way to elucidate the basic steps by which this skimming process occurs and the dust clouds are formed. This information is needed to develop practical means of combatting the float coal dust hazard.

A third problem arises from the possibility that coal dust and methane may supplement each other in an explosion. Current practices call for increasing the percentage of noncombustible dust by one percent for each 10th of a percent of methane in a mine atmosphere. There is reason to be concerned whether this practice adequately evaluates the equivalence between coal dust and methane from the point of view of explosion hazard. Equivalences have been evaluated for ignition and for marginal combustion; currently, equivalences are being determined for steady-state flame propagation. These investigations should substantiate the adequacy of existing practices or define necessary preventive measures.

In still another approach to reducing explosions and fires in mines the Bureau is seeking means of suppressing explosions at the moment of ignition. This includes adaptation for mine use of industrial explosion suppression systems and commercially available foams. In addition, studies have led to permissible explosives of reduced incendivity, and means of further reducing incendivity are being explored. Ways of improving ventilation of the working "faces" from which coal is extracted are progressing. The possibility of draining methane from coal beds in advance of mining also is being investigated, with a view to predicting methane concentrations and establishing the geological conditions and physical properties of coal that contribute to methane being retained. Developments in high-speed excavation (Project Badger) may possibly be applied to extinguishment of culm bank fires, where the problem is bringing water to deep-seated burning sites.

Projected costs

The value of reducing fatal explosions and fires cannot, of course, be measured in dollars only, but the dollars are impressive. Through fiscal year 1966, 160 mine fires were extinguished, saving more than 545 million tons of coal at a cost of approximately one cent of Federal funds per ton. Other contributions to protecting the Nation's forests and watersheds increase the value of the effort. Finally, numerous estimates have been made of the economic losses due to air pollution. In many of the coal-producing areas, fires in mines and culm banks are a major source of dangerous pollutants.

BRIEF DESCRIPTIONS OF ADDITIONAL PROGRAMS FOR IMPROVEMENT AND PRESERVATION OF ENVIRONMENTAL VALUES

ECOLOGICAL RESEARCH AND SURVEYS

Man depends on plants and animals directly for food and fiber and for recreation and aesthetic gratification. Man depends somewhat less directly on living organisms for a whole range of services which he cannot otherwise meet, including capture and storage of the sun's energy by plants, replenishment of oxygen in the air, nutrient and other mineral cycling through breakdown of organic tissues into simple chemical compounds again available for use, and a host of other services and functions.

The living organisms that perform these functions occur in communities, the members of which are determined by their ability to tolerate the conditions of the site and interactions with the other members of the community. Their tolerance levels are not necessarily identical, but they overlap in the range of con-

ditions present on the site. As conditions change, new organisms with tolerances that fall within the new ranges may become a part of the community; some of those originally present may be eliminated. The less rigorous the conditions of the site, the greater will be the variety of the inhabitants. Many affects these communities both through directly influencing the plants and animals and indirectly through influencing the characteristics of the environment. Weather modification, disposal of waste heat, and altered drainage patterns as in Everglades National Park are some of the many influences.

In order to decide how best to manage our biological resources, ecological studies in the Department are directed to understanding: (1) The characteristics and functioning of these living systems, (2) the role these systems play in the economy of man, and (3) the tolerances of these systems to change, including man-caused change.

A basic requirement is, therefore, studies that will provide "baselines" in a wide range of environmental types that will permit assessment of the degree and effect of future changes.

EUTROPHICATION

The process by which, against a geological time frame, a lake evolves from a clear, sparkling body of water into a gradually darkening one, then degenerates into a swamp and eventually dries up is known as eutrophication. The effect of man's waste discharges on the environment is to speed up this process to bring about the problem, which we know today as accelerated eutrophication, that brings, within the time frame of man, at least the first stages of this process by which a lake dies. Even this first stage of the problem is significant in that it takes a lake from the position of being a usable resource for recreation, a water supply, and a thing of scenic beauty to a body of water that serves none of these purposes well, if at all.

As with all of the subtle processes of nature, the first step in attempting to effectively control eutrophication is to learn to understand it. Current work is underway to establish what the triggering mechanism is that brings about the massive growths of algae and other organisms that are the beginnings of this dying process. Determining what keys this self-feeding, self-accelerating cycle of organism growth, and what can be done when this system is understood, to either slow or prevent its action is the object of the program.

The highest degree of scientific and technological skills is required to devise and implement studies that will measure the micronutrient contents of the lake and determine the effect of the minute quantities of material on the growth rates of the biota of the lakes. Engineering skills are utilized for the design and the development of treatment systems that permit the removal of these micronutrients from the environment in specially designed isolated ecosystems, which will permit the evaluation of the effect of these micronutrients on the overall ecology of lake systems. It is a project that requires the highest degree of competence in the earth, life, and physical sciences and in engineering.

The ultimate goal of this program is to permit us to control the environment of our lakes so that we can preserve these natural resources.

ANIMAL POPULATION CONTROL

Many hundreds of species of animals in North America share man's environment, compete with him and directly, or indirectly, affect his life. When the human population of an area increases, and changes the area's land usage, obviously something has to give. If, for instance, humans introduce sheep, there may be less forage for some animals but more food for animals that prey on sheep. The Bureau of Sport Fisheries and Wildlife has the job of searching out ways to cope with these conflicts, trying to do so while causing the least harm to life generally.

Stating it bluntly, some animals sometimes may have to be killed for the benefit of others if all other methods are ineffective. The control agents used must be selective, to protect other species which should not be killed, and they should have a temporary life limited to the time needed for the job at hand, and should not persist in the environment.

But control methods are not limited to lethal agents. Researchers working on control methods screen new chemicals with a wide range of biological activity, from birth control to "No Visitors Allowed." This research involves the identification of compounds useful as attractants, repellents, soporifics, antimetabolites, and chemosterilants. New products recently registered for use in fish and wild-

life management include antimycin for the control of rough fish, an avicide to control starlings at livestock feedlots, and a rodenticide for the control of pocket gophers. Now being tested in the field are a chemosterilant which may be used against coyotes, and a distress-producer which shows promise for cutting down on blackbird damage to corn and other cereals. This compound is mixed with grain. Those birds which eat the treated grain—say, 10 percent of a flock—lose muscular coordination and sound their distress cries, which may frighten away the unharmed 90 percent.

Ungulate populations in national parks and monuments, wildlife refuges, and other areas often suffer (1) from ranges that extend beyond the park boundaries and that have been drastically modified by man and (2) from the almost complete lack of predator populations due to past predator extermination programs. This results in exploding populations combined with inadequate food supplies, thence severe winter starvation periods. Considerable research is required to determine range condition, migration patterns, etc., and to determine the most effective and biologically feasible methods for managing and controlling these populations. In national park areas, this program is carried out with the aim of maintaining as natural an ecological condition as possible.

PESTICIDE USE AND CONTROL

The sale of pesticidal chemicals in the United States is reported to be increasing at the rate of 10 to 12% each year, and is expected to total \$2 billion by 1985. An almost unbelievable amount of chemicals is applied to land and water areas of the country. Many pesticides are highly toxic to fish and wildlife, and their large-scale use constitutes a grave threat to these resources.

The Department's Bureau of Sports Fisheries and Wildlife and other Federal agencies are engaged in a united effort to bring about safer methods for pest control. These methods include the development of biological as well as chemical control agents. Promising materials are tested on several species of fish and wildlife, and data from these and other studies are used to determine the relative hazards of different pesticidal formulations to major species of fishes, birds, and mammals. Appropriate caution statements are included on the label of each pesticide registered by the Department of Agriculture.

Encouraging progress is being made in the development of improved control methods. Low-volume concentrations of malathion are effective against a number of economically important insects at dosage rates not found harmful to most species of fish and wildlife. Another new insecticide, Abate, controls mosquitoes with little apparent danger to fish and wildlife. Rather than broadcast two pounds per acre of highly toxic heptachlor for fire ant control in southeastern States, entomologists are now able to curb this pest with less than an ounce of Mirex per acre in a formulation which poses no significant hazard to wildlife. Similarly, there is a growing list of herbicides that can be used to control aquatic weeds without appreciable danger to fish and their food organisms.

Senator JACKSON. That completes the hearing today. We stand adjourned.

(Whereupon, at 12:40 p.m. the committee adjourned.)



