sion-making body for the DEQ. And he is said to have conscientiously avoided interfering in the council's actions.

Had Hathaway still been governor when the legislature met this year, however, he would have witnessed at first hand that Wyoming's efforts to cope with the problems of energy resource development are entering a new and possibly far-reaching phase. The legislators were now reacting sharply to the pell-mell, disorderly growth which industrial development had produced at Rock Springs, in southwestern Wyoming, and at Gillette, in the Powder River basin in the northeastern part of the state.

Gillette, with about 10,000 inhabitants, has more than tripled in population since the mid-1960's as the result of an oil boom. Two-fifths of the inhabitants live in an ugly sprawl of mobile home parks. As the legislators realized, Gillette and other towns in the Powder River basin would soon be feeling the impact of a much bigger boom as the mining and conversion of the basin's rich coal reserves accelerated. The Powder River Basin Resource Council (PRBRC), a group of young environmentalists and ranchers, was warning that disaster was about to overtake the basin and its traditional ranching and farming economy.

The Legislature Reacts

To meet this impending on-rush of energy development, the legislature enacted several important measures. It raised severance taxes and provided for special assistance to towns impacted by development; it required that coal strippers obtain the consent of the owners of the land overlying the coal; it mandated state and local land use planning; and, perhaps most important, it required anyone planning to build a major industrial facility to obtain a state permit, which could be denied if the proposed facility would have an unfavorable environmental, social, or economic impact. Enactment of such legislation was remarkable for a legislature that has been regarded by some as too accommodating to development interests, and especially to the energy companies.

These developments in Wyoming are not likely to be lost on Hathaway, for he knows that the coal development frenzy is now as much a worry of the ranchers and farmers who expect the best of him as it is of the environmentalists who expect the worst.

No one can safely predict what Stanley Hathaway will do if, as seems most likely, he is confirmed as secretary. If he listens closely to his friends back home, Hathaway could conceivably do more to protect the Northern Plains and its agricultural economy than any one else President Ford might conceivably choose to lead the Department of the Interior. Given Ford's preoccupation with the energy problem, the job this season isn't going to go to some one who has the look of an environmentalist.—LUTHER J. CARTER

RESEARCH NEWS

Crop Forecasting from Space: Toward a Global Food Watch

Every 9 days a satellite passes over a field of hard red winter wheat somewhere in Kansas, measuring the light reflected from the growing crop at four different wavelengths. The young plants are green, but later they flower and turn yellow, as each characteristic stage of growth is recorded by the scanning spectrometer aboard the spacecraft. The multispectral images, telemetered to ground stations, end up in Houston in a computer programmed to distinguish the wheat from other crops and to estimate the acreage planted to it. At the same time weather information from the target area, gathered from the national meteorological network, is used to predict the likelihood of higher or lower than normal yields from the crop. The information is combined to give an estimate of the amount of grain that will be harvested in the area later this summer.

Although still experimental and just getting under way, the operation is a prototype for what may become a global watch on the world's food supply. The hope is that it will make possible reliable estimates of production of major food crops in time to give warnings of damage from droughts, frosts, and other disasters and to prevent shortages from taking the world by surprise. At present only fragmentary data are available on upcoming world harvests, the United States being virtually the only country that publishes monthly forecasts of its production. A worldwide information system could thus make possible more rational management of food grains that are increasingly in short supply in much of the world.

The key question is how well such a system can be made to work, and that is the object of the current effort, known as the Large Area Crop Inventory Experiment (LACIE). It makes use of the Landsat satellites of the National Aeronautics and Space Administration (NASA) and of weather data collected by the National Oceanic and Atmospheric Administration (NOAA). Crop estimates will be compared with those produced by the U.S. Department of Agriculture (USDA), which is also providing agricultural information to aid in constructing and applying the computer algorithms. The initial scope of the joint experiment is the wheat crop in the Great Plains of the United States; extension to other areas is to follow. Eventually, perhaps, other crops such as rice will be included.

Techniques for remote sensing of crops are not new. Numerous experiments have been done with Landsat I (formerly called the Earth Resources Technology Satellite), which was launched in 1972 (*Science*, 13 April 1973, pp. 171–173). Indeed, according to LACIE project manager R. B. MacDonald of the Johnson Space Center, in Houston, Texas, the feasibility of recognizing crops from multispectral data was established as early as 1966 with data taken from aircraft. Work at Purdue, the University of Michigan, and other laboratories resulted in knowledge of the spectral signatures of crops and method for analyzing spectral data which are the basis for the present experiment. What is novel about the LACIE project is the scale of the effort, which encompasses hundreds of thousands of square kilometers, and the attempt to automate the process so as to provide forecasts within weeks of collection of the data.

Both Landsat I and Landsat II cover the entire globe every 18 days, surveying a north-south strips of land 185 kilometers wide at each pass. (Because of a dead tape recorder on Landsat I, it provides data only within range of ground stations.) The scanners on the spacecraft can detect fields as small as a few acres (1 acre = 0.004 square kilometer); actually each digital unit of a picture, or pixel, corresponds to about 1 acre, but several pixels are needed to derive usable information. When the data arrive at the Johnson Space Center, they are first processed to correct for differences in illumination caused by varying sun angles and changing atmospheric conditions, particularly haziness and moisture. The latter corrections are difficult but important, since they often amount to larger changes in total radiance than the variations between one crop and another. No data at all are obtained from areas covered by clouds, which leads to gaps that complicate the analysis.

Several methods are used to extract crop information, since the project is experimental and the forecasters are still feeling their way. In one procedure, a photographic image is assembled from the data from sample parcels of land —about one in five of the 80-square-kilometer segments into which the data are grouped. Then an agricultural interpreter armed with a crop calendar for the region and a knowledge of farming practices identifies the fields in the photograph. These "training data" are then used to classify the remaining segments. Alternately, computer algorithms are used to cluster the data directly according to certain carefully developed criteria, and the fields are classified as wheat or other crops on that basis. The result, in either case, is a map of each segment and a table of the amount of land (actually the number of pixels) in each category.

As data from the next pass of the satellite come in and are processed, a correlation technique is used to compare the analysis with earlier ones, eventually building up firmer estimates. The repetitive technique also calls attention to changes in the wheat acreage, such as might be caused by farmers plowing under a portion of the crop that failed to germinate. The aggregation of estimates from each small segment gives a grand total by state or region.

A second part of the project involves forecasting how much grain will ultimately be produced from the acreage under cultivation. This is done with the aid of computerized models of the relationship between weather and crop yield. According to James McQuigg, director of NOAA's new Center for Climate and Environmental Assessment in Columbia, Missouri, such models are constructed by comparing many years of historical data on weather and yields and establishing a statistical linkage between them (a regression model). Different models are used for different parts of the wheat belt, and they allow for factors that would lead to higher yields, such as the introduction of new grain varieties or greater use of fertilizers. Weather data for the current year (beginning when the previous crop is harvested) is collected by crop district—there are about nine districts per state —and are used with the regression model to project the yields for the coming harvest.

The weather data include monthly averages of temperature, precipitation, and, in some instances, potential evapotranspiration, which serves as a measure of the stress to which the crop is being subjected. McQuigg finds that even relatively simple models are able to account for variations in yield due to weather fluctuations within a moderate range. Episodes of severe weather, such as frosts, high winds, or the heat storms that plagued parts of the Great Plains last year, are handled separately at present; experienced climatologists simply adjust the yield predictions for the affected regions on a case-by-case basis.

Production Estimates

Combining the acreage estimates and the yield forecasts for each local area and aggregating over the whole crop area gives a figure for wheat production in the coming year. The estimates can be revised monthly, at least when the system is more fully operational, as new acreage and weather information become available. The comparison of LACIE forecasts with those made by USDA on the basis of its detailed monthly surveys of selected field plots throughout the wheat growing region will serve as a means of checking and improving the accuracy of the computer algorithms.

MacDonald and other LACIE scientists are optimistic that the project will prove successful, but they are at pains to point out the preliminary nature of their present methods and the difficulties still to be overcome. A forecast at any given time, for example, must take account of the different stages of growth of wheat in different regions—harvesting of winter wheat begins in May in Texas, while the crop's second stage of growth is just getting under way in North Dakota. It is not yet certain that provision of data every 18 days (Landsat II is the only coverage now available in most areas outside the United States) will be sufficient, considering the data missed because of cloudiness. And the reliability of the computer algorithms is still to be proved. Nonetheless, MacDonald expects to have some initial results by the end of 1975 and believes that the technical feasibility of the system might be established—and the first operational forecasts made—as early as late 1978.

USDA officials are somewhat skeptical that the present satellite system will prove to be more accurate than existing methods of crop forecasting in the United States. But they are more sanguine about its prospects for overseas use, since the department's world crop estimates are based on reports by agricultural attachés and on other fragmentary, often late information. The international implications of LACIE and the operational system that may follow it are certain to be controversial. The Soviet Union and Sri Lanka, among others, have expressed concern that commercial traders could make use of information about their food production in ways that would be adverse to their national interest. Moreover, there is what a State Department official describes as "lots of concern and confusion" about the intelligence uses to which such a global system under U.S. control could be put.

There is no doubt that a reliable global forecasting system would have a major impact on grain and other food markets. (Presumably, all parties would eventually benefit from more accurate data.) The commercial and diplomatic impact would be eased, NASA officials hope, by gradually phasing satellite operations into the USDA system, with forecasts released through the present crop reporting system, which includes elaborate safeguards against premature release of information or prior access by special interests. The raw Landsat data (as distinct from analyses based on them) are available to anyone.

Earlier attempts to forecast crops with aerial data have faced verification problems because ground truth information on actual production is hard to get accurately for areas smaller than a whole state. Since LACIE encompasses many states and is to run for at least another 2 years, its forecasts can be carefully scrutinized for accuracy. If the experiment is successful, operational systems could come quickly. Landsat III, to be launched in 1978, will have a fifth multispectral channel, and NASA planners are already thinking about a new spacecraft and advanced scanners with more channels and greater resolution. The prospects are thus substantial that by the end of the decade the technological means to manage a global food watch, if not the wisdom, will be available.

—ALLEN L. HAMMOND

Diabetes (II): Model Systems Indicate Viruses a Cause

Some epidemiological and genetic evidence suggests that viruses may be instrumental in causing at least one type of diabetes in humans. That evidence, which was discussed in a previous article, does not prove the hypothesis, however, and it does not point to any one virus as the culprit. Much more convincing evidence, many investigators believe, is the demonstration that viruses can produce a diabetes-like disease in laboratory animals. The model systems produced in this fashion are not completely satisfactory because they do not reproduce many of the complications observed in human diabetics. Nevertheless, they do appear to provide a highly useful new way to study the initiation of diabetes, the progression of the disease, and the genetics of susceptibility.

The possibility that viruses may be linked to diabetes has for a long time intrigued investigators. Their interest was aroused by the common observation that many viruses replicate in the pancreas. Several viruses produce pancreatitis, that is, inflammation of the pancreas, and some occasionally produce more lasting damage. But until a few years ago, there was no evidence that such infections resulted in any symptoms of diabetes.

In the early 1960's, two Italian investigators, E. Barboni and I. Manocchio, reported that some cattle developed hyperglycemia (high concentrations of sugar in the blood) and lesions of the pancreas after they had been infected with foot-and-mouth disease virus, a small, RNA-containing virus belonging to the family known as picornaviruses. Their experiments were performed on only a few animals, however, and apparently no other investigators attempted to reproduce them, so the significance of their observation was not noticed.

A major breakthrough occurred a few years later when John E. Craighead of the University of Vermont discovered that a diabetes-like disease could be produced in certain strains of mice by encephalomyocarditis (EMC) virus, a picornavirus first isolated from the heart of a domestic pig dying of myocarditis (an inflammation of the muscular walls of the heart) in the Republic of Panama. Craighead's work was subsequently confirmed and extended by Abner L. Notkins and his associates at the National Institute of Dental Research.

The EMC virus, like many other picornaviruses, replicates primarily in the myocardium, central nervous system, lacrimal and parotid glands, and the pancreas of experimental animals. In the pancreas, many picornaviruses replicate in and often damage the acinar cells (see box), but the infection only rarely produces ill effects in the animals. But Craighead discovered one strain of EMC virus, known as the M variant, that replicates (in the pancreas) exclusively in the islets of Langerhans, the insulin-secreting cells of the pancreas. No other known virus, Craighead says, demonstrates this exclusivity.

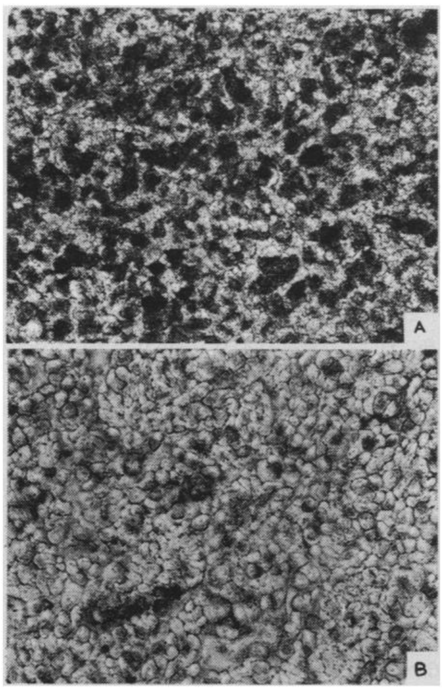

Fig. 1. Purified beta cells from two strains of mice infected with EMC virus. Beta cells from C57 black male mice (A) contain normal numbers of insulin-secreting granules, while those from SWR male mice (B) are largely degranulated. [Source: Abner L. Notkins and Ji Won Yoon, National Institute of Dental Research]

In certain strains of adult male mice, the M variant of EMC virus produces a transient infection in which virus can be recovered from the pancreas for as many as 18 days after inoculation. Notkins has shown by immunofluorescence techniques that viral antigens are found exclusively in the beta cells of the islets. The infection produces a spectrum of effects, ranging from mild or no alterations in glucose metabolism through transient hyperglycemia to a persistent diabetes-like syndrome. Symptoms of this syndrome include persistent hyperglycemia, glucose in the urine (glucosuria), excessive thirst and appetite, and decreased production of insulin—which are the usual criteria for defining diabetes. The more severe symptoms, Craighead says, are analogous to the juvenile or acute-onset form of human diabetes, while the milder symptoms are more like the maturity-onset form. Craighead has shown that the infection produces kidney lesions that are similar to those appearing as a side effect of human diabetes, but it is unknown whether other side effects also occur.

Both Craighead and Notkins have shown that the severity of the diabetic symptoms is directly related to the amount of damage to beta cells of the islets. This damage has also been described by K. F. Wellmann and his associates at the Kingsbrook Jewish Medical Center in Brooklyn and by H. Müntefering of the University of Dusseldorf in West Germany. Typically, the uniform architecture and arrangement of cells in the islets is distorted and there is swelling and accumulation of fluids in the pancreas. The beta cells begin to lose their granules—the organelles that actually produce insulin—and there is some death of beta cells