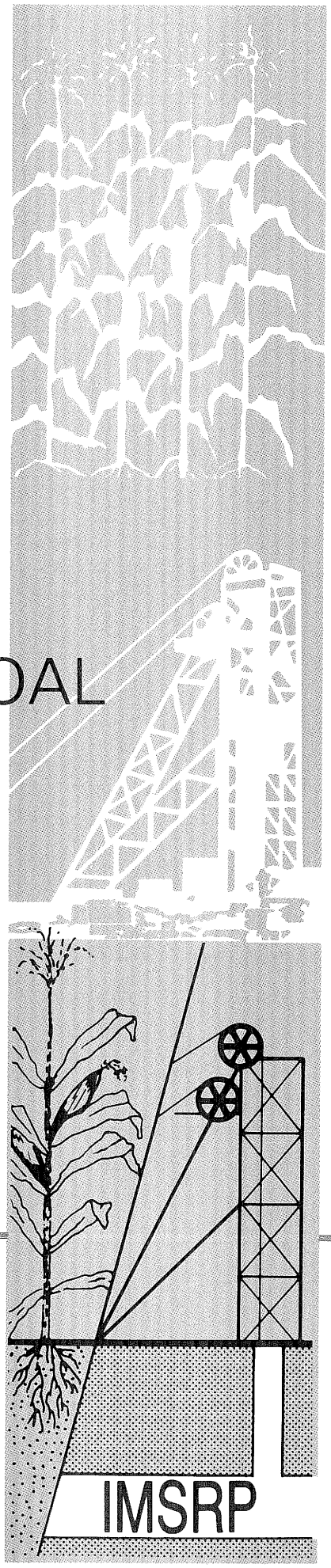
IMSRP-I



CROPS AND COAL

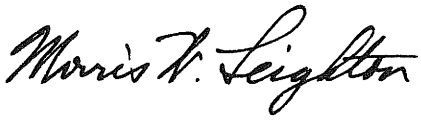
Illinois Mine Subsidence Research Program

COOPERATIVE VENTURE ON MINE SUBSIDENCE RESEARCH

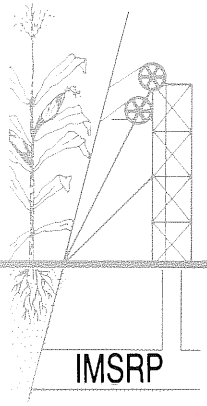
How can we maximize coal production and at the same time protect prime farmland in Illinois? Researchers with the Illinois Mine Subsidence Research Program (IMSRP) are committed to answering this question. Since 1985 when the IMSRP was started, scientists of many different disciplines from the Illinois State Geological Survey, Southern Illinois University, Northern Illinois University, Northwestern University, University of Illinois, and the U.S. Bureau of Mines have been looking into every aspect of coal mine subsidence. This collaborative effort is already yielding results. Since the IMSRP is one of the first multidisciplinary projects of its kind, this research is being closely watched by the rest of the nation.

All of us involved with the IMSRP commend the Illinois Farm Bureau and the Illinois Coal Association for their vision and determination in beginning this project. With funding from the state and federal governments and from industry, the IMSRP has expanded to include over a dozen organizations, and the cooperation between them has been outstanding. The investigative process is moving forward steadily as we identify problems caused by subsidence and find solutions to them.

With the results from our research, we hope to develop the guidelines necessary to safeguard the interests of the agricultural and coal industries. Productivity must be maintained in both areas, and legislation in the future must be based on sound technology. We feel confident that the work from the Illinois Mine Subsidence Research Program and the publications produced from it will provide the farmer, coal mine operator, policy maker, and general public with the answers they need on coal mine stability and subsidence.



MORRIS W. LEIGHTON
CHIEF, ILLINOIS STATE GEOLOGICAL SURVEY



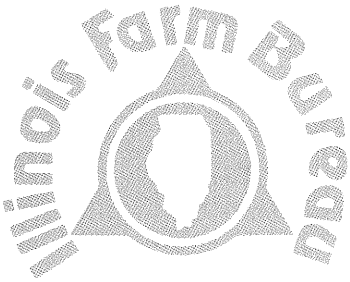
CROPS AND COAL

Illinois Mine Subsidence Research Program

ILLINOIS STATE GEOLOGICAL SURVEY

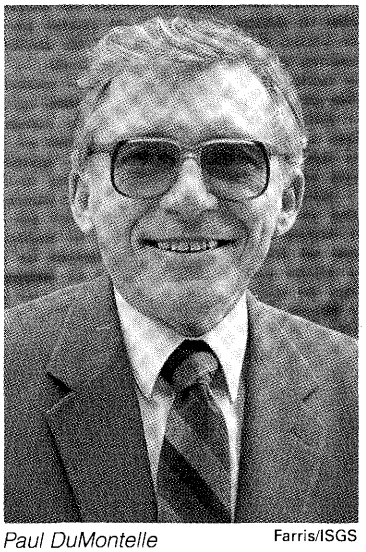
Natural Resources Building
615 East Peabody Drive
Champaign, Illinois 61820

(217) 333-4747

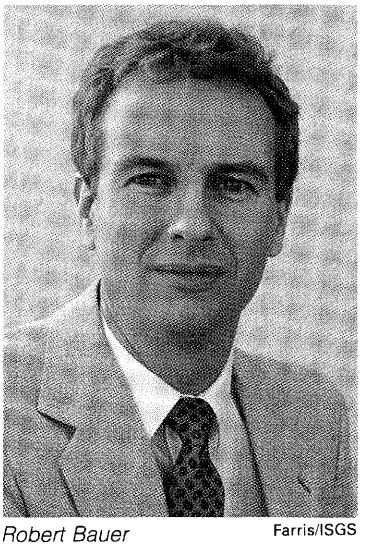


THE BEGINNING OF IMSRP

Paul DuMontelle, Director of the Illinois Mine Subsidence Research Program (IMSRP), describes the program as "a three-way collaboration between Illinois' two major industries, agriculture and coal, and scientists from all over the state. We're specifically concerned with active mines using high-extraction and room-and-pillar techniques. What we want to find out is how subsidence—the settling or sagging of acreage over underground mines—affects farmland. We also need to develop guidelines for mitigation or repair."



Paul DuMontelle Farris/ISGS



Robert Bauer Farris/ISGS

In the early 1980s, the Illinois Farm Bureau (IFB) and the Illinois Coal Association (ICA) began meeting to discuss their mutual concerns. Len Gardner from the IFB recalls, "Originally, we were more worried about the effects of strip mining, but subsidence gradually emerged as a serious problem. Farmers kept raising questions that no one had the answers to. The basic scientific research just wasn't there." Some of these questions were whether subsidence would have long-term effects on farmland, how different coal mining methods might affect the land, and what could be done to predict subsidence and plan for it in advance. Joseph Spivey from the ICA and Len Gardner realized the need for subsidence research in Illinois and started looking for the right people to conduct it and the money to fund it.

The Illinois legislators felt that subsidence research was important for the state and backed the program proposed by Gardner and Spivey. The U.S. Bureau of Mines (USBM) supplied federal funding. State funding was provided by the Illinois Coal Development Board of the Illinois Department of Energy and Natural Resources. Gardner and Spivey turned to the Illinois State Geological Survey and the Twin Cities Research Center of the USBM to conduct the research.

The Illinois Mine Subsidence Research Program was organized in 1985 under the direction of the Illinois State Geological Survey in cooperation with U.S. Bureau of Mines. It is one of the first comprehensive subsidence research programs in the United States and the only program to investigate subsidence impacts on crop yields. Farmers and the coal industry both stand to benefit from the results of this research. IMSRP participants are committed to increasing the productivity of both industries.

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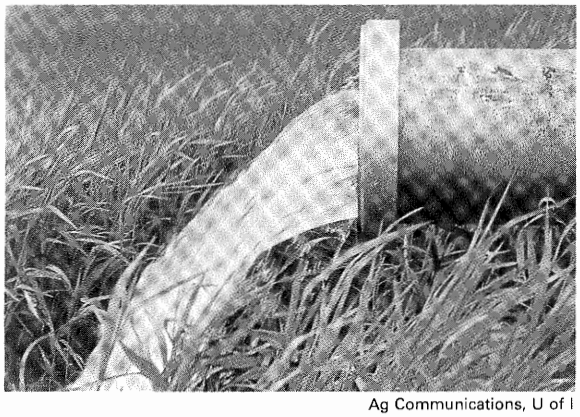
clockwise from upper left: healthy cornfield in Illinois, IMSRP monitoring surveyor, workers with continuous miner, corn ready for harvesting, and surface water management



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MORE ABOUT THE PROGRAM

The IMSRP, directed by the Geological Survey under Paul DuMontelle (Director) and Robert Bauer (Technical Manager), has brought together experts from all over Illinois. These researchers have been conducting a wide range of scientific studies since 1985. Projects are designed to investigate the strengths of floor and pillar materials in mines and to study subsidence over high-extraction mines (planned subsidence) and room-and-pillar mines (unplanned subsidence).

"For high-extraction and room-and-pillar mining, we need to develop specific formulas for determining the strength of materials that make up mine floors and coal pillars," states Robert Bauer. "For both types of mining, we'll be looking at techniques to repair land. And we'll be designing mine plans so that effects on the ground surface can be minimized." Bauer explains that researchers are also investigating the possible changes caused by mining in groundwater and surface water present in the glacial and bedrock materials overlying mines. "These hydrology studies deal more with high-extraction mining. We want to see if the changes in hydrology will have an impact on crops."

At present, researchers at the Geological Survey are monitoring subsiding overburden, which includes all earth materials overlying a mine, to determine what effect fracturing and subsidence will have on aquifers. Researchers began monitoring a site for a high-extraction retreat mine before the coal company started operations so that the entire mining process could be followed. Two other high-extraction mines will be monitored in the future. Agronomists at the University of Illinois at Urbana-Champaign recently completed a three-year investigation of crop-yields on unrepaired subsided areas. They will continue recording the soil temperature and moisture content of farmland overlying a high-extraction retreat mine, then expand their research to other types of mines in the future. Tentative plans are underway to involve Northern Illinois University in hydrology studies to be conducted with the University of Illinois and the Geological Survey.

ISGS

ICA

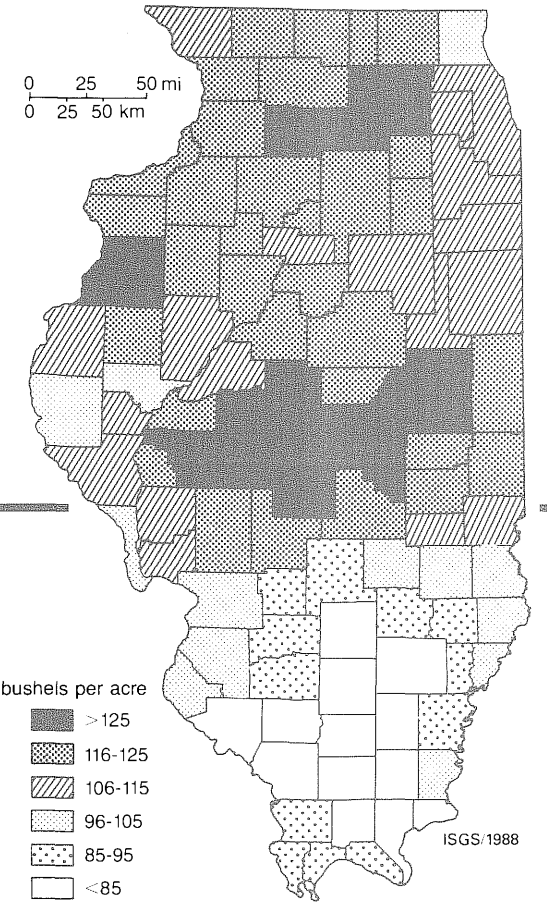
The research to improve mine design, which makes up a substantial part of this project, relates to the process of granting mining permits. When a coal company plans to open a mine, the company must submit a mine plan to the Illinois Department of Mines and Minerals (IDMM) for approval.

"The plan must show either maximum stability or planned predictable subsidence," Paul Ehret from IDMM explains. "In addition, the coal company must present a subsidence control plan for repairing damage to surface land. Basically, the law tries to avoid plans that lead to generally unstable mines and do not promote predictable subsidence." The best designs will incorporate floor strength data specifically for Illinois conditions. In Illinois, a layer of clay usually underlies the coal seam, often making the floor the weakest point in the mine. The coal pillars supporting the overburden can be pushed into a weak floor, causing the pillars and overburden (ground) to be lowered. At present, IMSRP researchers at Southern Illinois University at Carbondale are working in mines and in the laboratory to collect data on floor strength. They estimate in situ (or "in-mine") strengths by drawing correlations between laboratory and in situ strength testing of the mine floor. Researchers from the University of Illinois Civil Engineering Department are conducting similar work on laboratory and in situ strength testing of the coal pillars. In-depth reports on all projects will soon be available.

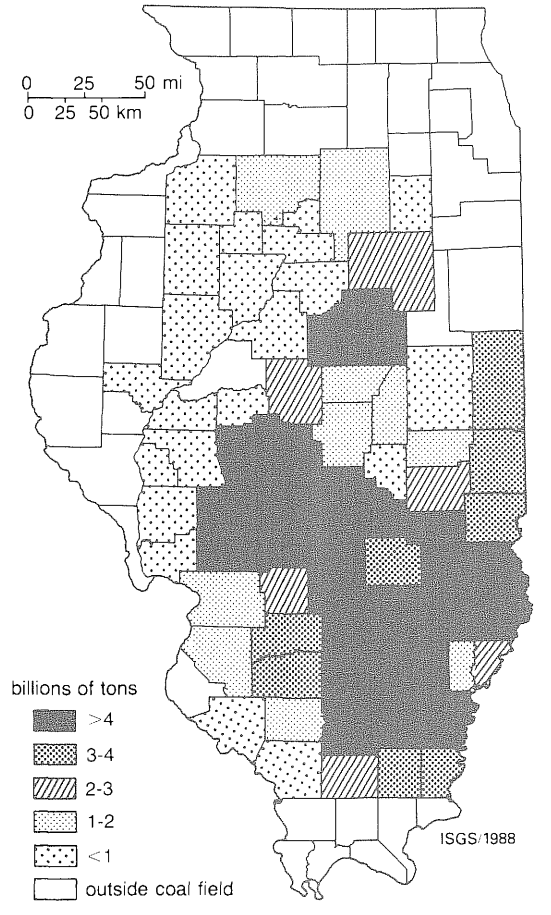
Coal companies and farmers are integral to the program. Farmers supply histories of land use, and allow access to their land for the various research projects. Coal companies supply labor, equipment, and sites. The IMSRP could not be carried out without the help of the agricultural and coal industries.

To promote cooperation and communication among all participants, an Advisory Board and a Technical Committee hold regular meetings during which members brief each other on developments and report progress. The Technical Committee includes members from the Illinois State Geological Survey, the U.S. Bureau of Mines, Southern Illinois University at Carbondale, the University of Illinois, the Illinois Department of Mines and Minerals, and two representatives from coal companies.

"Our job is to help design and guide projects," explains Robert Bauer, member of the Technical Committee. "We try to sort out the best techniques for all the studies and review each project's results." The Advisory Board reviews program and policy issues of the IMSRP, and includes the following organizations: Illinois Coal Association, Illinois Farm Bureau, Illinois State Geological Survey, U.S. Bureau of Mines, Southern Illinois University, Abandoned Mined Lands Reclamation Council, Illinois Department of Agriculture, Illinois Mine Subsidence Insurance Fund, coal companies, Illinois Department of Energy and Natural Resources, and Illinois Department of Mines and Minerals.



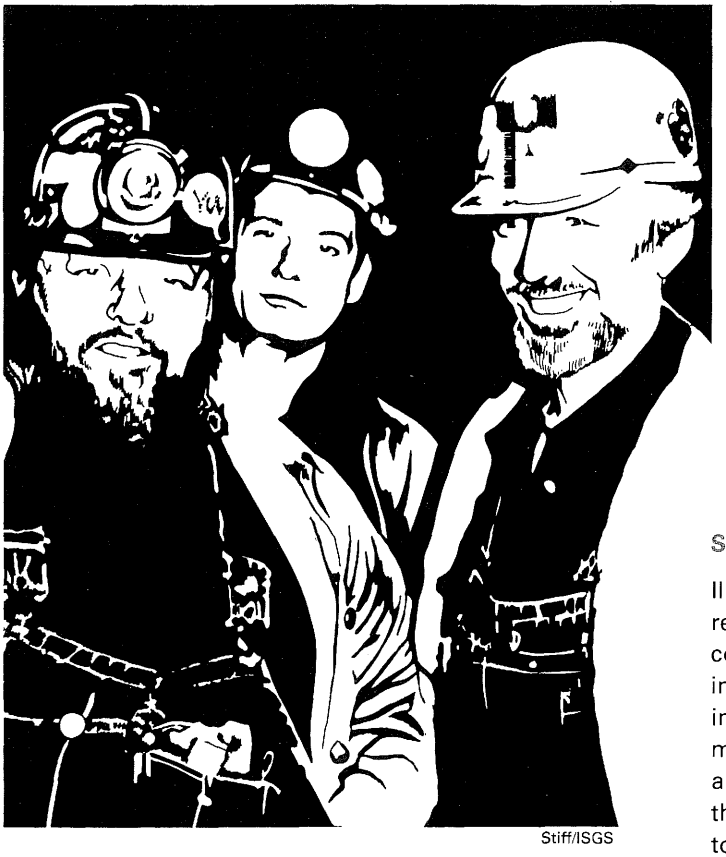
average corn yield per acre for 1977 to 1986



coal resources by county

AGRICULTURE AND COAL IN ILLINOIS

Coal and agriculture are essential to the health of the Illinois economy. Outside the greater Chicago area, agriculture generates more cash than any other industry in Illinois, and the coal industry makes the second largest contribution. Nationwide, Illinois agriculture ranks second in value of crops marketed and coal fifth in production. Obviously, both industries must work together if they are to succeed in the increasingly competitive national and world markets.



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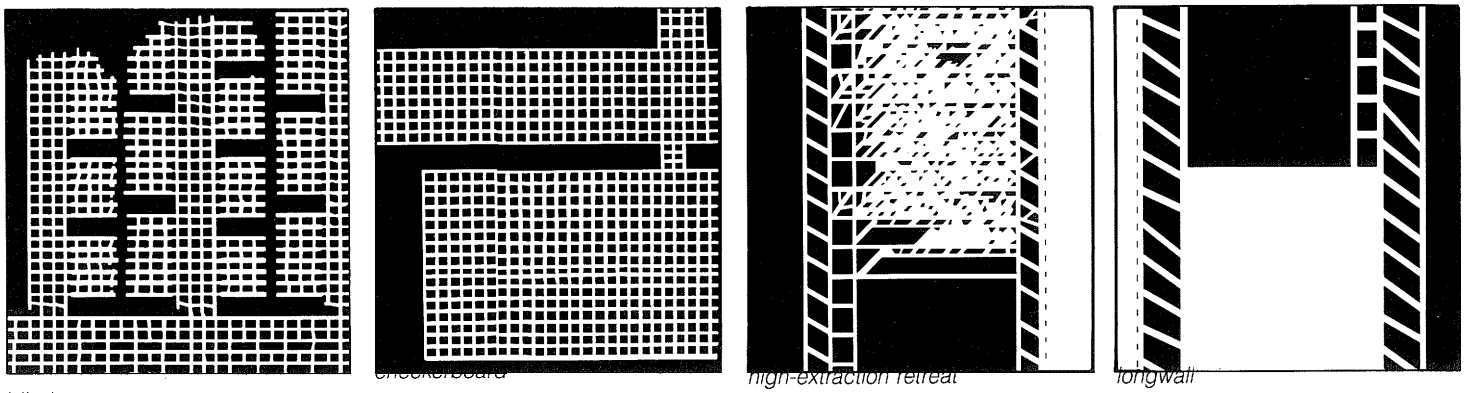
SOME BACKGROUND ON THE COAL INDUSTRY

Illinois is rich in coal resources, ranking sixth nationwide in overall resources and first in bituminous coal, the most widely used type of coal in the United States. The continued vitality of the Illinois coal industry depends on its ability to extract this resource effectively. The industry is improving mine design in response to safety and environmental concerns and also to increase its productivity. Coal companies are moving toward high-extraction mining, which recovers more coal than the room-and-pillar methods. At the same time, they are working to preserve farmland, avoiding damage to surface land, and repairing damage where it has occurred.



blind room *checkerboard* *high-extraction retreat* *longwall*

Mining Methods

Room-and-pillar is the most common underground mining technique today. High-extraction mining methods are coming into more frequent use as technology advances. In Illinois, high-extraction retreat has been practiced since the 1940s and longwall mining since the 1960s and 1970s. These methods recover 70 to 100 percent of the coal from the production area compared with 50 to 60 percent for room-and-pillar. Productivity is obviously greater with the high-extraction mining, but researchers need to learn more about the effects of these techniques.

In the room-and-pillar method, workers create openings or rooms as they mine. About 50 percent of the coal must be left behind as support pillars, which are typically about 40 by 40 feet. Blind room and checkerboard are the two room-and-pillar methods used. Miners using the blind room method leave every sixth or seventh room of a production area unmined so that a large pillar of coal remains for support. The checkerboard mine method leaves evenly spaced square pillars. Room-and-pillar mining tends to be more time-consuming than the high-extraction methods. For example, miners must set steel anchors (roof bolts) to support the roof as the continuous mining machine advances. An advantage of room-and-pillar is that an operator can fairly easily select acceptable work areas in a mine where coal quality, seam thickness, and floor and roof conditions vary considerably.

The high-extraction techniques, longwall and high-extraction retreat mining, remove most of the coal in a given area, resulting in rapid controlled subsidence. With high-extraction retreat, workers remove as much coal as possible in a small area until the roof starts to collapse; then they retreat to the adjacent room. About 70 to 90 percent of the coal in the production area is recovered with this method. With longwall, miners recover virtually 100 percent of the coal in the work area (or panel) by advancing a mechanized working face; the mine roof collapses behind the hydraulic supports at the working face. The size of the single area mined by these methods is typically 500 to 750 feet wide and up to 2000 to 7000 feet long.

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Subsidence

Subsidence differs markedly depending on the mining technique. First, the most subsidence that can occur varies. The maximum subsidence over a high-extraction retreat operation is about 4 feet, and over a longwall mine, 4 to 5 feet. Land overlying a room-and-pillar mine can subside 1 to 3.5 feet. Second, subsidence occurs within days to several weeks with the high-extraction methods, but it may occur any time or not at all with room-and-pillar. In fact, although most mines are stable, subsidence still occurs over some room-and-pillar mines that are more than 100 years old. Third, the ground surface effects vary according to the mining method.

"With room-and-pillar mining, even with the best engineering — and today's designs are much, much better than in the past — unplanned subsidence is still always a possibility," explains Paul Ehret from the Illinois Department of Mines and Minerals. A major problem with the room-and-pillar technique is that if and when the mine opening does fail, the subsidence may show up as discontinuous depressions forming at random times. Ponding can result from such a pattern, and the cost of grading or draining this land may be quite high.

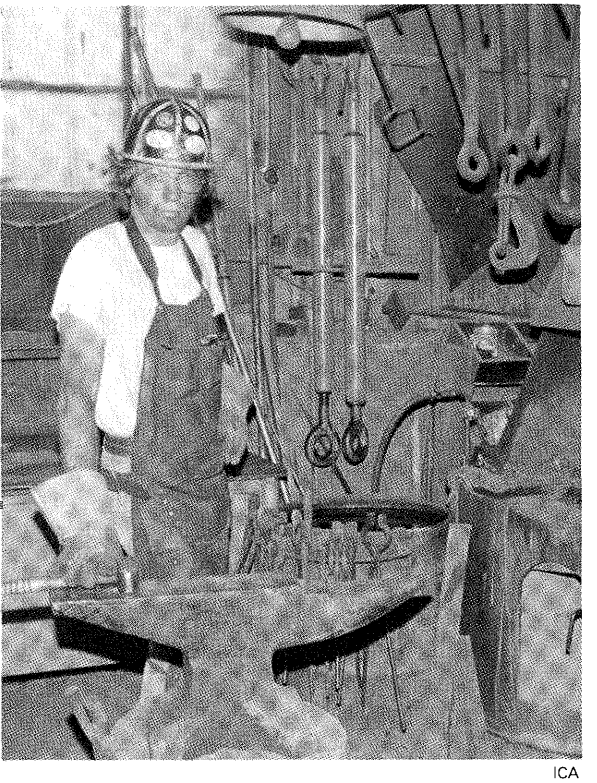
High-extraction methods always result in subsidence. Subhash Bhagwat, the Geological Survey's mineral economist, states, "Mine operators know how long the land will take to settle completely — usually within the first year and certainly within five. They also know where the land will subside and by how much." The surface effects of high-extraction mining are caused by the barrier pillars, which are long unmined walls left between production areas in the mine. Panel areas between the walls settle, resulting in ponding in some areas.

ICA

left, field of no-till corn; right, continuous miner moving from one room to another

Mitigation

Illinois laws now require coal mine operators to fix the damage caused by subsidence to land and structures, although many companies had already taken on this responsibility voluntarily. Coal companies can plan their repairs to land damaged by high-extraction techniques more easily than the discontinuous, randomly occurring depressions caused by room-and-pillar methods. Because the subsidence is planned, procedures can be established before mining begins so that possible damage can be averted. Houses and other structures can be jacked up from their foundations to a level position before mining operations start and then be lowered after the land has completely subsided. Plans can also be made in advance to bring land back to its pre-mined condition. Mine operators and farmers can decide ahead of time on the best ways to drain the land or grade it, if necessary, and even ensure than the original topsoil is replaced.



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FARMLAND AND SUBSIDENCE

No one yet knows the long-term effects of subsidence on farmland. Only now are researchers studying the effects on crop yield, soil, and groundwater. Researchers hope that the results of these studies will allow coal companies to disturb the land as little as possible while maintaining productivity.

Farmers cannot always control whether coal companies will mine their land. Many farmers own mineral rights to their land, but some have sold the rights or bought property on which the rights had been sold by the previous owner. Coal companies' mitigation efforts and Illinois laws help protect the farmer by bringing a balance between the coal and agricultural industries. Since 1983, coal companies are required to bring the land to its pre-mined state, compensate landowners for damage to structures, and pay farmers for lost crops. Illinois law precludes the use of waivers, even if signed by the landowner, to dismiss liability for repairing land and structures. In laws governing mine subsidence, Illinois has paid more attention than any other state to the needs of its farmers.

ISGS

clockwise from upper left: mining equipment repair shop, an example of subsidence that has been repaired, and chisel plow

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THE IMSRP AT WORK, 1985 to 1987

IMSRP researchers began field and laboratory studies in 1985 to obtain scientifically based answers to problems posed by the coal and agricultural industries.

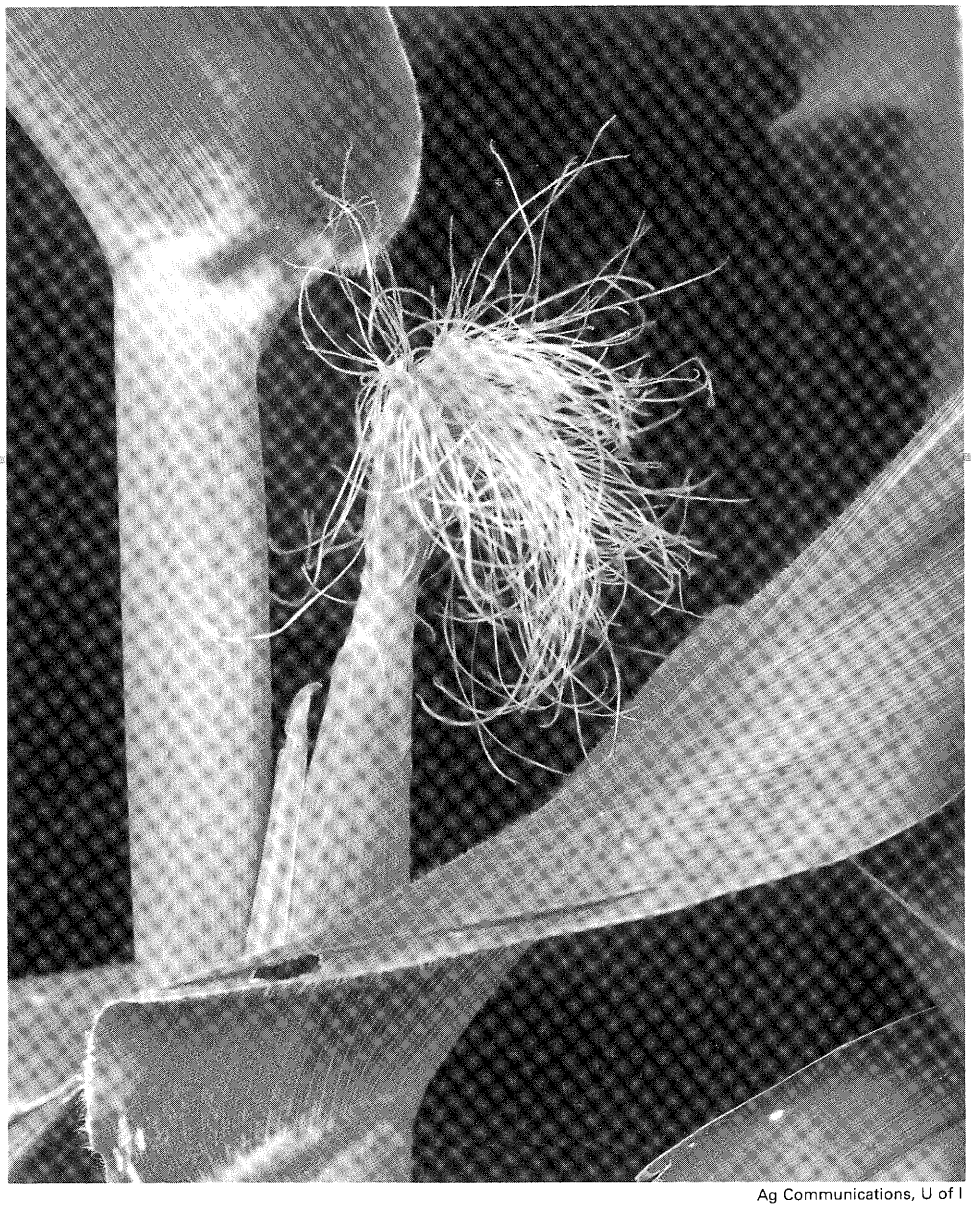
Dept of Agronomy, U of I

Agricultural Impacts — Corn Crop Yields and Soil Monitoring

For the 1985 to 1987 growing seasons, University of Illinois agronomists under the direction of Robert Darmody took aerial photographs through the spring and summer to identify and characterize subsidence areas over high-extraction mining. Crops from these areas were sampled and compared statistically with crops from unmined areas under the same farm management. Three classes of subsidence effects were established for high-extraction retreat and longwall mining. Scientists recorded weather and precipitation and combined variables to obtain significant results for each of the three years.

This study is complete. After three years of data collection and analysis, researchers have identified important relationships between crop yield and soil slope and type. They found the three-year average reduction in corn yield to be 4.7 percent over longwall mines and 1.8 percent over high-extraction retreat mines. An in-depth report will be published this year and made available to the public (High-Extraction Coal Mining in Illinois: Effects on Crop Production in 1985 to 1987, R. G. Darmody et al.). In their next major investigation, the researchers will study the impact on corn yields of the techniques that are now being used to repair subsidence-damaged farmland.

Agronomists are just now beginning to investigate the impact of subsidence on soil temperature and moisture. They have established sampling routines and long-term monitoring. Test soil pits were dug in areas overlying a high-extraction retreat operation before subsidence occurred, and equipment was placed in these pits to record soil moisture and temperature; the variables are measured continuously. The pits were dug up again to collect post-subsidence data. This ongoing study will continue at more sites with different soil types.



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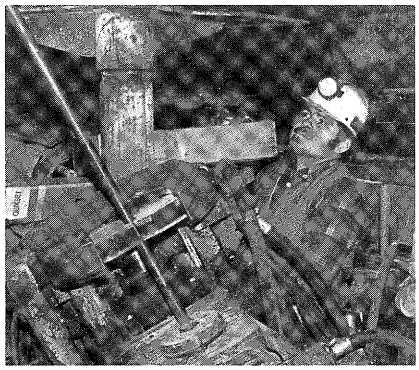

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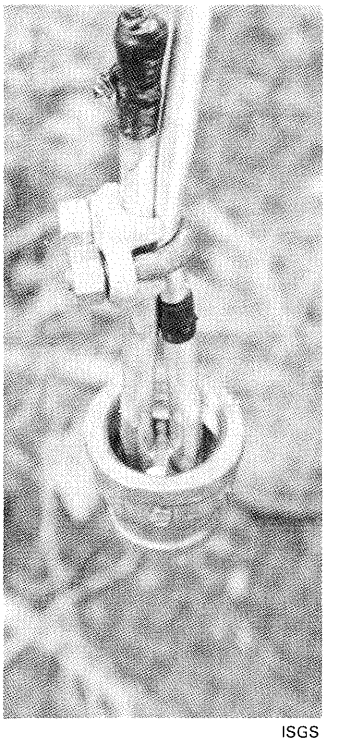
clockwise from upper left: IMSRP researchers survey in an elevation reference point in a soil test pit, corn pollinating, miner drilling to set roof bolts, and anhydrous ammonia application

The Subsidence Process

Surface survey Researchers at Southern Illinois University are conducting surface surveys over areas of a room-and-pillar mine with floor instability. In this mine, the pillars are being pushed into the floor by the overburden. Scientists have begun analyzing the data from these studies, and are attempting to correlate surface movements with downward movements of coal pillars in the mine.

Overburden Geological Survey researchers began investigating a site overlying a high-extraction retreat operation. Monitoring of the site began before mining occurred and continued through the mining process and afterwards (post-subsidence), so that the amount and location of fracturing in the overburden could be evaluated, as well as the impact of subsidence on glacial and bedrock hydrology. As expected, mining lowered water levels in piezometers (monitoring wells) in the bedrock 50 to 150 feet above the mine level at this site, but caused little change in surface piezometers. Besides installing and monitoring several types of instrumentation, researchers took core samples for extensive testing, completed a map of the area, and wrote a detailed site description. A second site has been obtained for overburden studies, and a third is currently under negotiation.



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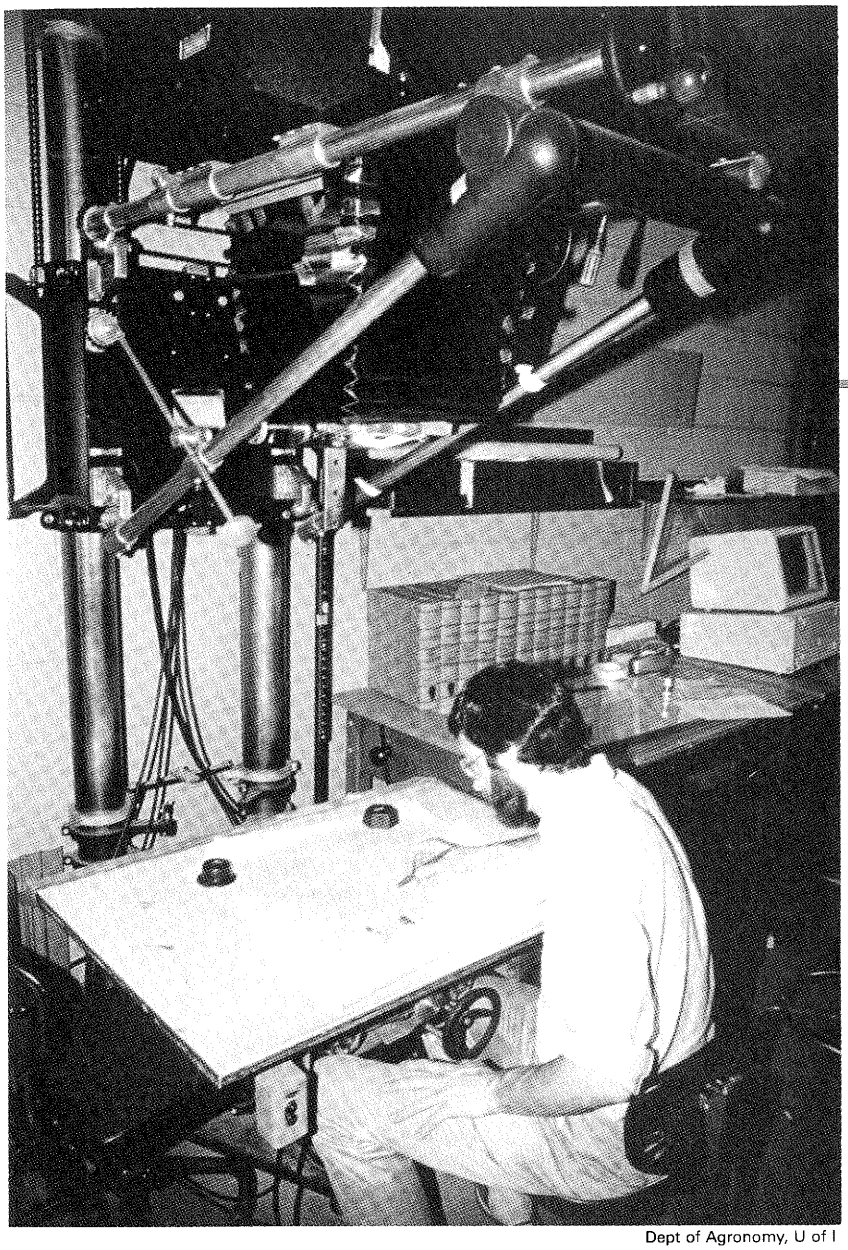
Rock Characterization Studies

Coal strength studies Coal strength and deformation characteristics are being studied by members of the University of Illinois Civil Engineering Department under the direction of James Mahar. Researchers are documenting the laboratory strength and deformation of coal samples, using size and shape as variables. This work will lead to large-scale testing of coal blocks in place in the mines.



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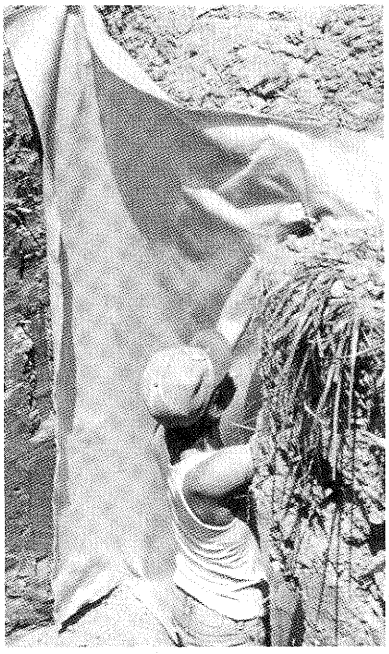
clockwise from left: anchor for monitoring device, IMSRP agronomist analyzing aerial photographs, IMSRP field researchers lining soil pit with geofabric to prevent backfilled materials from adhering to original materials, and miner drilling hole to set roof bolt



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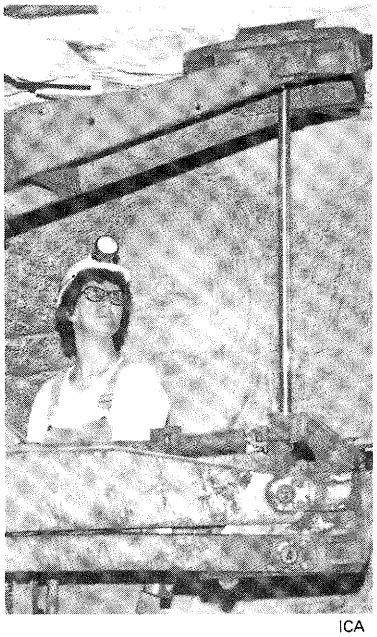

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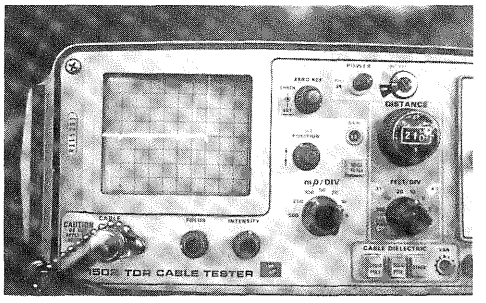
Floor studies This work is headed by Yoginder P. Chugh of the Southern Illinois University Mining Engineering Department. Here, scientists are investigating floor instability in high-extraction retreat and room-and-pillar mines. Analysis and correlation of data collected in these studies have begun. The scientists have isolated the most crucial tests of floor materials for mine design and the mine permitting process. They determined which laboratory engineering index properties best correlated with in-mine strength deformation characteristics. In-mine strength deformation characteristics were determined on-site with bearing capacity tests and a borehole shear tester. The bearing capacity test determines the strength and deformation characteristics of a large in-place sample of the mine floor. Two reports are being prepared, Laboratory Characterization of Immediate Floor Strata Associated with Coal Seams in Illinois and In-Situ Characteristics of Coal Mine Floor Strata in Illinois, Y. P. Chugh et al.



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Mitigation

In the coming year, members of the University of Illinois Agronomy Department will be working with coal companies and landowners to assess the effectiveness of drainage and other land repair methods on subsided lands.


ICA

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clockwise from lower left: roof bolting, equipment for monitoring overburden, underground equipment maintenance, and data pod for measuring soil moisture and temperature

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Data Synthesis and Predictive Modeling

This research began in 1986 at the U.S. Bureau of Mines, Twin Cities Research Center in Minneapolis-St. Paul. Using the information gathered from the other laboratory and field studies, the USBM staff is starting to model in the laboratory the deformational behavior of the mine floors.

Procedures and Guideline Design

Participants are currently identifying relationships between mine stratigraphy and the variables of subsidence. The findings from this work will be tested as written guidelines in preliminary predictive models. The results of IMSRP research will eventually be applied to the development of procedures and guidelines for mine design.

Database Management

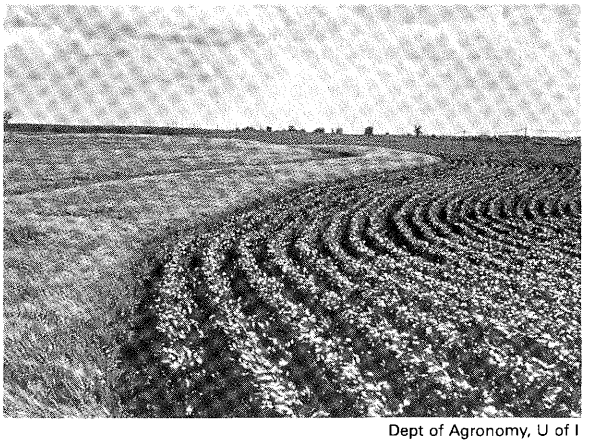
Each type of IMSRP research has been coupled with an extensive database management program. The system used by the Geological Survey and the University of Illinois compiles comprehensive files on rock mechanics, locations of samples, agronomy data, well logs, and other IMSRP research information. Integrated data filing and analysis programs at Southern Illinois University and the Geological Survey allow interpretation of data generated by the research, particularly the floor studies and surface surveys. Relational database management systems, statistical packages, and graphics programs are run on personal and mainframe computers to formulate preliminary hypotheses, tasks, and models for subsidence parameters. Programs are continuously being developed and refined by researchers so that subsidence information can be stored, retrieved, and used easily.

Bibliographic database management software is used at the Geological Survey to compile an extensive file of mine subsidence and related references. Facilities and routines have been established for searching and updating this database. Complicated search requests can be performed easily and quickly on-line; the output is currently accessible to IMSRP researchers both electronically and on paper. The bibliography is now being prepared for publication.

Technology Transfer

In addition to annual reports, the Illinois State Geological Survey will be preparing, publishing, and distributing manuscripts as a cooperative technical series. With this publication, this series is now underway. Brochures, booklets, and other information are also being prepared for distribution to the public. In addition, technical seminars will be conducted, and workshops will be available for researchers, agricultural advisors, and mining industry personnel. An exhibit booth has been prepared that will be taken to state and national meetings for one-on-one discussions of the individual projects of the IMSRP.

IMSRP is more than just a program to develop basic and applied research on subsidence. Informing the public on the research results is integral to the program. IMSRP participants plan to establish and participate in federal and nonfederal programs dealing with subsidence effects on prime farmland in Illinois. The findings of IMSRP research will be disseminated to coal and agricultural industry operators, as well as the state and federal agencies that are involved with subsidence effects. IMSRP will act as a clearinghouse for subsidence information through publications, conferences, and activities. In addition, IMSRP researchers will document their progress throughout the program in reports and other publications.



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ICA

clockwise from upper left: crop bordering grass waterway, surface facilities of a mine, and rotating drum of a continuous miner

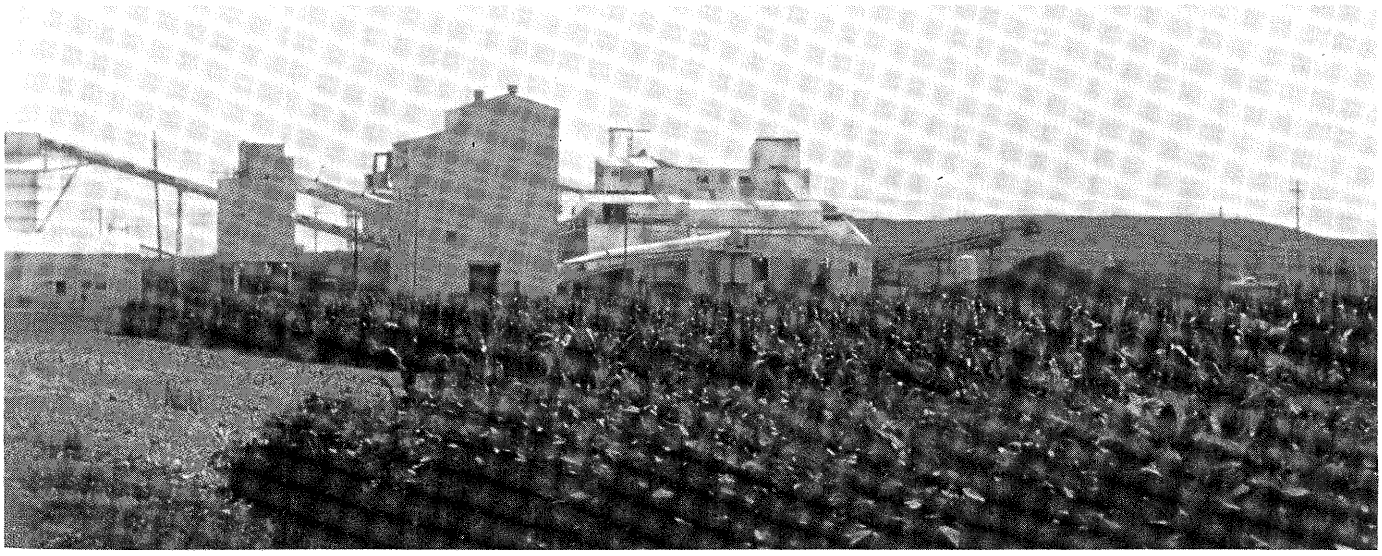
OUTLOOK

The Memorandum of Agreement between the Illinois State Geological Survey and the U.S. Bureau of Mines to cooperate on IMSRP projects is in effect until 1991. "The projects that we've started will be continued to this time," says director Paul DuMontelle. "The focus of our new projects is shifting from data collection to data analysis. We'll be placing a heavier emphasis on hydrology — subsidence effects on wells and aquifers will be investigated. Right now, we're concentrating on prediction methods and modeling for mine stability and subsidence, and there's a major trend toward developing techniques for repairing subsidence effects."

Stiff/ISGS

Robert Bauer elaborates, "With the individual data that we've collected — and we still need more — we'll be working with recommended mine design, modeling and prediction. All that work will be based on strength formulas tailored for Illinois conditions of mine floors and pillars. In the very near future, we're going to explore what mitigation techniques are being used and how successful they are. In the longer term, we'll combine what we've found in the mitigation work and the strength formulas so that we can improve mine design. For example, maybe we can find ways to soften the chain pillars that make the ground surface stick up between longwall panels and work to make land subside more uniformly with the high-extraction retreat mines. We think this work could have some advantages for drainage."

"In the next five years, we're going to need the support of the agricultural and coal industries more than ever," says Paul DuMontelle. "As the program develops and we fully analyze our data, we are beginning to see some concrete applications of our findings."



ISGS

WHO'S INVOLVED

Illinois State Geological Survey
Illinois Coal Association
Illinois Farm Bureau
U.S. Bureau of Mines, Twin Cities Research Center
Illinois Coal Development Board
Illinois Department of Mines and Minerals
University of Illinois at Urbana-Champaign
  Department of Agronomy
  Department of Civil Engineering
Northern Illinois University Department of Geology
Northwestern University
Southern Illinois University at Carbondale Department of Mining Engineering
Abandoned Mined Lands Reclamation Council
Illinois Department of Agriculture
Illinois Mine Subsidence Insurance Fund
Illinois Department of Energy and Natural Resources

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