PART 2

ADDRESSES AND CONTRIBUTED PAPERS

Muncie, Indiana
October 19, 1968

The address, "Urban Geology—A Need and A Challenge", was presented by retiring president, Dr. William J. Wayne, at the annual dinner meeting of the Academy at the Pittenger Student Center on Saturday evening, October 19, 1968. It is an excellent statement of the necessity of including geological knowledge in many phases of urban planning. Dr. Wayne is currently a member of the Department of Geology of the University of Nebraska. The address by Dr. Robert E. Gordon, Professor of Biology and Associate Dean of the College of Science at the University of Notre Dame, was given at the luncheon meeting on October 19 involving both the Junior and Senior Academy members. His subject, "Science, Communication, and the Critical Mass", deals with the public understanding of science as a function of the ability and effectiveness of the scientist's communication with the public.

PRESIDENTIAL ADDRESS

Urban Geology—A Need and A Challenge[1]

WILLIAM J. WAYNE[2]

The Scope of Urban Geology

Every use man makes of land is affected by the shape of the land and by the physical properties of the materials that lie beneath the surface. He depends on either the surface or the materials beneath it for food, water, and fuel; for building sites, building materials, and foundation support; for waste disposal; and for recreation.

Geology is the study of the earth. It encompasses investigation of the surface, the materials beneath the surface, and all the natural processes that have produced those materials and landforms. Environmental geology is one of the names currently in vogue for the specific phase of geology that deals with the interrelationships of geologic processes, earth materials, and the ways in which man has met and used this part of his environment.

Where man has congregated in large numbers and most extensively disturbed natural conditions is where most of the conflicts between man and his environment are likely to take place. Thus the geology of man's environment becomes most important in and near urban centers; the term *urban geology* is virtually synonomous with *environmental geology.* Urban geology involves the recognition and understanding of those geologic processes that continuously work to bring conditions on the earth's surface toward a state of equilibrium—the natural forces that operate more or less slowly but are powerfully effective in the creation of landscapes and the disruption of some of man's works on those landscapes.

Our population has increased greatly in recent decades, and with that population increase our intensive uses of land have also expanded greatly. Because of this expansion and the resulting elimination of open space surrounding urban centers, we find ourselves having increasingly less freedom to make mistakes in the development of land for uses more intensive than farming.

When an error is made in developing a homesite in a rural environment, rarely is more than a single structure and one family affected; an error of similar magnitude in developing homesites in an urban environment, however, can involve many dwellings and cause incon-

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[1] Approved for publication by the State Geologist, Indiana Geological Survey, Department of Natural Resources.

[2] Indiana Geological Survey; joined Department of Geology, University of Nebraska, Lincoln, in September 1968.

venience and unnecessary expense to many families. It is therefore in and near cities—the areas of large population concentrations—where it is of greatest importance that the men who guide our changes in land use recognize the ways in which natural forces act upon natural materials and upon the works of man. The failure to recognize potentially destructive geologic processes can lead to unnecessary expenses in the urban and urbanizing areas for engineering works, costly damage to structures, and perhaps even the loss of human lives.

Less spectacularly, damage may be to health, or may be limited to the inconvenience of wet basements or backed up drains. Nevertheless, as man's use of land expands, the need to have a complete and thorough knowledge of the geology of his environment becomes continuously more important. The costs of correcting mistakes increase many fold after available open land has been used up.

In comprehensive planning for the future development of a community, all the needs and interests of the area must be inventoried and evaluated. Ideally, potential problems should be forseen early in the planning process so that they can be adequately handled in the ordinances—zoning and others—that make planning effective. One basic phase of a comprehensive planning study—and one that is often neglected —is an evaluation of the geologic resources of the planning area.

The Role of a Geologist

Geologists are well equipped to contribute to several aspects of comprehensive studies in which conflicts of land use frequently arise. Unfortunately, geologists are sometimes asked to help explain the cause of a problem that might have been prevented if they had been consulted before the land was developed. They often find themselves cast in the role of trouble shooters and pessimists rather than advisors who can advance constructive suggestions that will help determine the optimum use of available land.

Application of geologic study to urbanizing environments requires the ability of a generalist who is particularly well versed in geomorphology, engineering geology, economic geology, and hydrogeology, and who also has an understanding and appreciation of the principles and administration of land-use planning. And he must be able to make the results of his geologic studies readily understandable to and usable by the non-geologically trained professional planners and citizens of the community to whom the decisions regarding urban development are entrusted.

Reports on urban geology should include a brief but adequate review of the general geologic features of the area for which the report is prepared (31). The report must be directed, though, toward specific geologic phenomena that are likely to be of concern in planning the community. Features of the land about which geologists are especially well qualified to supply knowledge and evaluation are: (*1*) economic mineral resources and potential; (*2*) geologic conditions that, if unrecognized, could become hazards to property or health; (*3*) water-supply potential; (4) waste-disposal sites; and (5) geologic significance of outstanding scenic and educationally stimulating natural areas.

Mineral Resources that Serve Urban Development

Mineral resources that are used extensively in construction, such as sand, gravel, and crushed stone, must be exploited close to their markets (Fig. 1). These resources have a large bulk and low value per ton and are generally surface mined. Maintenance of a high quality supply at a low delivered price is important to the growth of every expanding urban area. To keep construction costs low haulage distances for aggregates must be short, because much of the final delivered price is the cost of hauling (9, 24, 25).

Figure 1. Gravel pit in suburban area of Indianapolis (13, pl 5A) where operation is almost completely surrounded by urban land uses. A worked-out part of the pit not visible in this photograph has been reclaimed for recreational uses.

One of the most important pieces of information that a community should include in a comprehensive planning study is a map showing the distribution of potentially workable reserves of mineral resources. It is of no value to permit mineral extraction from land that has no mineral-resource potential, yet to restrict the industry from land that does. Only after the availability of the resource is known can a planner evaluate a particular area of a surface mineral resource and recommend a zoning ordinance that reflects that evaluation. Such a study was prepared for Marion County, Indiana, in 1958 (12) as a by-product of a county mapping project (13) and was used in designing zoning regulations for the county.

Among the major objections voiced by residents of many communities to the opening or continued operation of gravel pits, clay pits or crushed limestone quarries are the traffic, the dust of processing, the noise and rocks of blasting, and the resulting wasteland they must live with after the resource has been worked out (26). Some mineral-resource operators have become increasingly aware of this criticism in recent years, and many of them are becoming sensitive to the desires of their communities that they leave the worked-out land in a readily usable condition.

Mineral producers should be invited to participate in the development of operating standards to control traffic, noise, and dust that both they and their neighbors can accept and of subsequent land-use plans for the area when they leave it (1). The concept of sequential land use applies particularly well to the surface-mined bulk mineral commodities used in construction. While the deposit is being worked the land can be shaped according to a predetermined design, so that it will fit well into a second planned use after the resource has been worked out and the equipment removed (21). Reclamation according to such a plan is much less expensive than reclamation after abandonment. In many places the graded and shaped abandoned pit or quarry will have great value to the community as a recreation site, or as building lots, or an industrial site; thus it can be made into a desirable and productive area rather than a wasteland that remains an eyesore or health hazard (3).

Natural Hazards

Many millenia are needed for natural processes to create landscapes. Landscape-producing forces work in small increments, however, and only small amounts of time are required for some of these to take place. The force of earth or rock moving across an unstable slope or of flood water passing down a valley is great, and where the works of man happen to stand in the way, they may be damaged or destroyed.

Some natural hazards to life or property cannot be predicted well enough to let us avoid them entirely—the path of a particular tornado, for example. Many "accidents of nature" that result from failure to understand some fundamental geologic processes, however, can be recognized by an alert geologist and their potential for damage forecast so that land uses and construction standards can be designed to reduce or eliminate the danger.

From the earliest of civilization, man has used rivers for transportation, water supply, and waste removal. Consequently he has found the land along the rivers desirable places to build communities in spite of the knowledge that high water would come regularly; he accepted this inconvenience for the advantages of being able to use the river the rest of the time.

The flood plain, though, is the domain of the stream that built it. It is the relief valve of the river—the place where the excess water can spread out and slow down when upstream areas and tributaries deliver more water than the channel can carry. When man forgets this or fails to recognize it, he and his works can be damaged.

We no longer use any but the largest rivers for transportation. We have, however, inherted the floodplain locations and have developed them even further. One of the results of urban expansion on floodplains has been an increasingly great property loss and inconvenience each time a heavy runoff causes the land to be inundated. Increased urbanization upstream in the drainage basin also increases the runoff rate (11, 19). Thus we have had to design and build expensive flood control works to protect our investments from the inevitable high water.

Flood plains are underlain by sediments dropped by a river in flood. They are a normal unit on most geologic maps; therefore their delineation is one of the contributions of a geologic study to the planning process. Land-use regulation that restricts construction of damageable structures from areas of flooding is a far less expensive way of reducing future flood damage than is building more and bigger retaining structures and levees. Identification of flood plain land by geologic or soils mapping permits it to be zoned as future open land.

Gravity and water combine to produce downslope movement of masses of loose rock or soil on many hillsides. The degree of stability or instability of a particular slope is largely a factor of both steepness and moisture content and the kind of material that underlies it. For example, slopes of 1:1 are generally stable in the mudstones of Morgan County and western Brown County, Indiana; slopes of 2:1 are normally stable in unweathered young glacial till of central Indiana; but slopes of 3:1 are required for stability in the thick weathered part of the

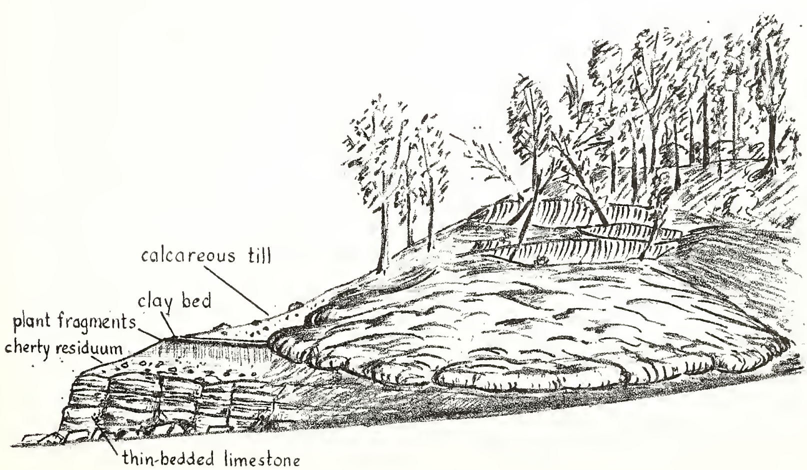

Figure 2. Terain sketch and diagram of the geology along State Road 46 in Owen County where mudflows and slump have resulted from an oversteepened slope and a perched water table held by a thin Pleistocene clay bed.

older glacial tills of southern Indiana. Where unusual conditions exist, such as a clay bed that serves to inhibit downward movement of moisture within a sequence of silty glacial sediments (Fig. 2), even more gentle slopes may develop.

Slopes that seem to be stable under natural conditions may become unstable if moisture content, loading, or steepness should be increased through urban development. Such an alteration is likely to result in slumps, slides, mudflows (Fig. 3), and, in areas of bedrock, rock falls, and rock slides. At the least, such mass wasting induced by changes in slope equilibrium is likely to bring on expensive maintenance problems, such as removal of debris from the base of road cuts (Fig. 3) or rebuilding retaining walls. Where structures are built on such slopes, damage or destruction can be extensive. In addition to the natural phenomena that can take place, recent studies in Illinois (34) have shown that the addition of detergents, such as those found in laundry wastes and septic tank effluent, to unconsolidated clayey sediments will decrease the strength of the material and increase its tendency to move downslope.

Most slopes that are likely to become unstable can be recognized in the field by a geologist who is trained in their evaluation; the local significance of this natural process should be reviewed in every geologic study for land-use planning (18, 28).

Not all land underlain by sensitive materials is on slopes, however. Areas underlain by muck, peat, marl, and other soft sediments that ac-

Figure 3. Mudflow on road cut in weathered Illinoian till along State Road 37 near Morgan-Monroe county line. The high clay content of the weathered till prevented it from remaining stable at the original cut dimensions, although a similar cut in unweathered till probably would have remained stable at that slope.

cumulated under conditions of ponding but are now above water level are outlined on those geologic maps that show surface materials in detail. Such sediments are unusually common in Indiana in resort areas around the natural freshwater lakes, as well as in some other parts of the state where bodies of water have been completely filled by sediments. These materials are not stable for foundations, and normal construction procedures cannot be used if they are developed intensively for urban uses. The high water table normally present would also create drainage and waste-disposal problems. Recognition and delineation of this material in the planning process is important if the land is to be used without danger or damage to its occupants.

Underground mining produces underground void space. Abandoned mine openings collapse and cause minor subsidence at the surface. Maps of underground mines on file in the offices of the Indiana Geologic Survey provide for Indiana the kind of information needed by planners who would avoid such land for construction until it has again become stable.

Water Supply

An automobile in every garage and electric power for every home made possible the development of large residential housing additions far from the edges of cities that would normally supply the utility needs of large numbers of families. Subdivisions have been created where each home has a private water supply and an electric pump to deliver the water to the home. Not all attractive home sites in Indiana have enough available ground water to supply a private home, though. And construction of several rural schools has been well along before anyone realized that some water supply other than a well drilled on the school grounds would have to be found before the school could open for classes.

An evaluation of the ground-water resources of the planning area should be included as a part of a comprehensive plan and should be available for the use of planning commissions in every urbanizing area. Hydrogeologic maps, which provide such an evaluation, can be prepared by a geologist, using the basic data derived from a geologic map and data on existing water wells. In Indiana generalized maps of this kind suitable for county and city planning purposes are being prepared by geologists in the Division of Water of the Department of Natural Resources (27).

Not all impoundments hold enough water to become ponds or lakes. Artificial lakes, both large and small, have been built over materials that allow the water to leak out as fast as it runs in as well as in places that are watertight. A geologic report for planning purposes would outline those places where high leakage rates could be expected and areas where lakes and ponds can be built successfully. Had such information been available and in use by the plan commissions of Indiana cities and counties, many investments and tax dollars of Indiana citizens could have been saved during the past quarter century.

Waste and Refuse Disposal

Different geologic materials and the soil profiles developed on them have different capabilities for absorption and transmittal of moisture. Although detailed planning for septic tank disposal fields probably is better done from a modern soils map and field studies, broad aspects of planning for on-site disposal of liquid household wastes can be done readily from the data available in a geologic study.

Movement of liquid wastes from the soil downward to the water table is an aspect of sewage disposal, though, that requires the attention of a geologist. Surface water that seeps downward through soil and highly permeable materials such as sand or gravel and fractured, weathered, or cavernous rock is likely to carry with it surface contaminants. Where sewage and other liquid wastes are disposed of in the soil, some of them are likely to be flushed downward, particularly during periods of heavy rainfall. Runoff from livestock feed lots is another source of concentrated contaminants that has entered and damaged some groundwater aquifers in Indiana.

In some parts of Indiana, where closely-spaced houses depend on both water wells and septic tanks, water supplies high in coliform bacteria are not unusual. Even though the bacteria may be filtered or have time to die before reaching a well intake, some wells have been seriously affected by a high nitrate content, which may cause illness, or by other chemicals or detergents that manage to reach an aquifer. A geologic report to a plan commission should outline areas where migration of liquid wastes is likely to damage nearby water supplies.

Septic tank disposal fields do not all function effectively—many are open to the surface. Nutrients from this effluent can cause very rapid eutrophication of lakes downstream, as can barn lot and pasture runoff.

When solid wastes are made part of the earth as in a dump or a sanitary landfill, they begin to undergo the same processes as do natural earth materials. Some of the rainwater that lands on the surface permeates the earth and passes through the soil and rocks on its way to a discharge area or to the water table. While it percolates through earth materials it dissolves any substances that may be soluble and carries the leachate away as part of the ground water. After it migrates beyond the limits of the landfill the leachate from a sanitary landfill can be expected to behave as would any vadose or phreatic water in the same geologic environment.

Our present knowledge about leachate migration is too meagre to permit us to speak in authoritative terms, although landfills that are located in impermeable or slowly permeable materials such as shale, clay, or clayey till or are separated geologically from an aquifer by such materials probably are unlikely to cause any contamination of ground water. Landfills in permeable materials, though, particularly limestone or dolomite, are likely to yield a leachate that will migrate rather rapidly and may cause considerable damage to underground water sources

(5, 20, 33). Areas geologically favorable and unfavorable for solid waste disposal sites should be outlined in every geologic report prepared as part of a comprehensive planning study (16).

Natural Areas

Where people are, they are expected to go to school, and they want to recreate. Many outstanding scenic areas or unusual outcrops that have geologic significance have been lost to recreation or education because they were not recognized by those who plan future land use, although they may have been well known to geologists, ecologists, and naturalists for a long time. Some of these areas, if the land is to be most advantageously used, probably should be considered for preservation as natural areas or for development into park sites. The geologist is remiss in his responsibility if he neglects to call attention to such areas so that the planner can understand their significance before they have been overwhelmed by urbanization. Once destroyed, they cannot be reclaimed (15).

Programs of Research in Urban Geology

Less than a decade ago, few geologists and fewer planners seemed to be aware of ways in which geologic data could be applied to land use problems (29). More recently, though, the United States Geological Survey has recognized the need to provide geologic data for use in land use planning (17). Several state geological surveys, most notably those of California and Illinois, have also undertaken studies intended to supply geologic information to planners (2, 6, 7, 10). The Indiana Geological Survey has provided reports to a few plan commissions or their consultants on request during the past decade; some of the reports have been published (8, 12, 30), and others are available only as file reports.

Some of the data needed to prepare geologic reports for use in comprehensive land-use planning studies of rapidly urbanizing parts of Indiana have been acquired by Indiana Geological Survey geologists as part of other studies during the past 15 to 20 years. Several specific new research programs will be needed, though, if our geologists are going to be able to answer the kinds of questions that we can now anticipate. At this time I would like to suggest the following program of research in urban geologic studies for Indiana:

1. *The preparation of county or urban community geologic reports.* —Geologic reports must be written specifically for use by a city, county, area, or metropolitan plan commission that is developing a comprehensive study of its area of jurisdiction and must be directed to that audience. A standard geologic report does not provide the needed information without interpretation. Table 1 is an outline that has served well in the preparation of such reports and can be adapted to most areas in Indiana and other midwest states.

Indiana Geological Survey geologists have prepared several county or community reports at the request of plan commissions or their consultants during past years, but many requests for information were received too close to the planning organization's deadline to permit the geologist to do more than quickly draw together a report based on information on hand but acquired for some other purpose. Unfortunately such reports will be as variable in quality and in value to the user as the amount and quality of data on hand for the geologist to use in their preparation. A special research program could anticipate areas for study far enough in advance that most rush jobs could be avoided when specific requests are received.

Geologic mapping for urban studies must be done on as large a scale as is practicable. At one time, maps prepared at 1 inch to 1 mile (1/63,360) were considered adequate and maps at 1/250,000 and 1/125,000 were thought satisfactory for many purposes. Urban studies will require greater detail, however. California geologists are mapping some urban areas on a scale of 600 feet to the inch (2), and the floodway mapping program of the U. S. Army Corps of Engineers is being done on an even larger scale.

County mapping for land-use studies probably will be satisfactorily presented on a map with a scale of an inch to the mile. Maps for a pilot study of Madison County, Indiana are being prepared at an inch to the mile although they were compiled at a scale of 1/24,000 (32). Highly urban areas as well as complicated or problem areas probably should be presented on a larger scale, however. The study should include a basic map showing the distribution of surficial geologic units described in a non-technical style and must be supplemented by a series of geologic planning maps on which attention is called to specific aspects of geology as related to land use (Table 1). These maps would include waste disposal, ground-water potential, slope stability, economic materials, and other subjects that may be appropriate (10, 16, 22).

2. *Geologic studies of ground-water contamination.*—Small scale studies of some wells in the limestone terrane of south-central Indiana a few years ago led to a recommendation presented in Bulletin S. E. 15 of the State Board of Health that much of the bacterial contamination of wells in such regions can be reduced or eliminated entirely by a more positive seal to prevent the entrance of surface water and storm water into the open annular space around the casing of a well (Fig. 4). Research in urban geologic problems should include additional studies of this kind in other geologic environments, undertaken on the university level or cooperatively by the State Board of Health, Division of Water, and the State Geological Survey.

3. *Migration of landfill leachates.*—Although contaminants are known to have reached the water table and to have migrated away from a landfill site under some conditions (4), few studies have been undertaken to determine the significance of different geologic conditions on the movement of leachate from sanitary landfills. Such a study has

been proposed on a state level in Indiana, to be done by three state agencies jointly. Detailed geologic and geophysical investigation of a study area in each of six different geological environments will be the responsibility of the Indiana Geological Survey. A water sampling program and water-quality analysis in and around each pilot site and the hydrology and evaluation of leachate migration and dilution will be undertaken by the State Board of Health and the Division of Water.

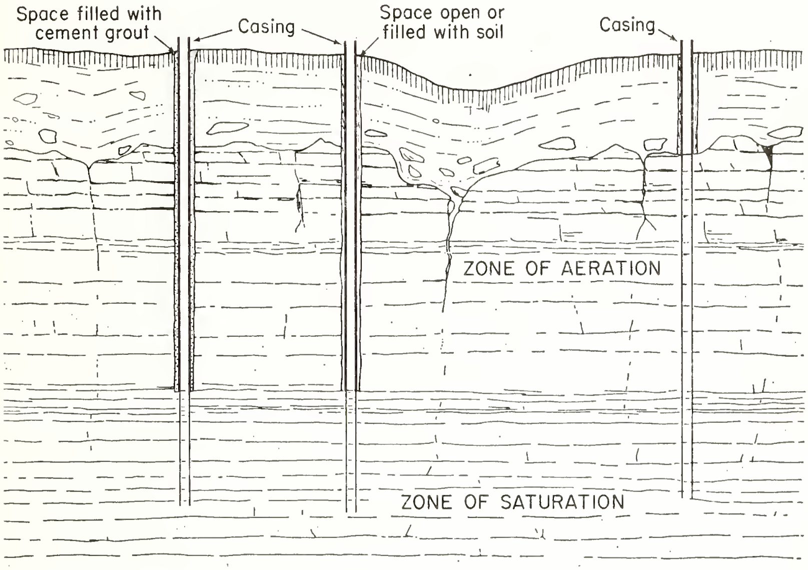

Figure 4. Many water wells in the areas of shallow bedrock in Indiana have been completed without sealing the annular space around the casing of the well to a great enough depth to keep seepage of contaminated vadose water from entering the hole. If the annular space has been left open or has been backfilled loosely with soil or with cuttings, it remains a conduit through which surface water can drain downward rapidly and enter water-producing zones. Wells in which this space has been filled with cement grout or, under certain conditions, with thick drilling mud, and in which the sealed casing extends downward far enough to keep out surface waters in permeable or cavernous rock, are not likely to be damaged by polluted surface water.

4. *Reclamation of quarried wasteland.*—Worked-out and abandoned land from which bulk mineral-industry commodities have been removed is a wasteland near many urban areas. Unconsolidated materials, such as gravel and sand, can be reshaped by a subsequent land owner if necessary, but the sand and gravel industry has started a continuing program of research to find better and more economical ways of preparing the land for re-use (14). Land underlain by consolidated rocks such as limestone are much more difficult to reclaim for subsequent productive use. A study of the rock properties that affect reshaping land as well as other possible techniques of converting worked-out land

at a reasonable cost might reduce the time involved for sequential beneficial use.

5. *Damages from natural hazards of geologic origin.*—Though much less spectacular in Indiana than in California (18) or Alaska (23), natural hazards exist in the state, and damages have taken place. Both field and laboratory studies of the geology and geometry of stable and unstable slopes would help in recognizing the conditions that produce instability of earth materials and in predicting more accurately where and under what conditions problems will occur in each geologic environment.

Such a research program as this will have to be undertaken as soon as possible if we are to be able to apply our geologic sophistication to aid in the solution of these urban problems where geologic data can help. The longer we wait to start, the longer we will find ourselves forced to answer questions without sufficient information. If planners are to call on geologists for help, the geologists must be in a position to supply it.

The Training of Geologists for Urban Studies

As a newly-developing use of geologic information, urban geology requires that the geologist limit his presentation and evaluation to those aspects of geology that apply directly to land use problems. It is an applied field of geology in which the practitioner needs to understand not only the geologic aspects of the problems but must also be aware of the principles and techniques of the land-use planning profession. Until 1967 few, if any, colleges and universities presented course material to train geologists to consider this field for employment. Some of the geologists who applied their knowledge to the solution of urban problems had picked up their background in the needs of communities through service on local planning commissions, and others did so through encountering the problems in the course of routine geologic studies and becoming interested in solving them. Most frequently the man was an engineering geologist, a ground water geologist, or an economic geologist.

Within the past year, a few universities have offered courses in urban and/or environmental geology. At Indiana University I presented a series of non-credit evening lectures on the subject in the spring semester of 1967 and offered a 3-hour credit course in it in the spring semester of 1968. At the same time Dr. James Hackett left the Illinois State Geological Survey to set up a graduate program in environmental geology at Virginia Polytechnic Institute. Paul Hilpman of the Kansas Geological Survey began teaching a two-semester course in urban geology at the University of Missouri in Kansas City in 1967, and an evening course was offered at Oregon in the spring of 1968. The University of Nebraska also has just added to its curriculum a one-semester course in the subject to be taught for the first time in 1969-70.

The Indiana course, as well as the one to be offered at Nebraska, was intended to introduce students to the ways in which geologic data can be used to help solve problems in land-use planning. It was designed to follow a course in physical geology and to present the subject to undergraduate majors and minors as well as provide a course in land use applications of geology to non-majors. At Indiana it was especially popular with graduate students in earth-science education. Those who had completed and done well in only one course in geology were able to complete the course successfully, but the amount of classroom participation was directly related to the geologic background of the individual students. No textbook exists that is suitable for this course, but the use of selected readings, many of which are cited here, provided material that was current as well as appropriate.

For a geology undergraduate who would like to direct his professional efforts into this field, the normal B. S. requirements in geology should be met if possible, but electives would have to include such courses as urban geography, land-use planning, and other courses in urban studies. It would be possible at Indiana University to qualify for a certificate in urban studies along with a strong A.B. degree in geology. On the graduate level a seminar in urban geologic problems coupled with regular advanced courses in hydrogeology, economic geology, limnology, and engineering techniques in geology would provide the required background to become a successful urban geologist.

A non-geologist who enters any phase of land-use planning should anticipate the inclusion of a course in urban geology about his fourth year, after he has acquired an adequate background in beginning geology and related courses in geography and allied subjects to enable him to master the material presented. He would not, of course, be trained to make geologic studies, but should at the conclusion of a course in urban geology be able to read a geologic report with understanding and to recognize the need for a geologic study in the planning process.

Summary

Urban land uses are rapidly converting open land into intensively used land. Generally, in planning those uses, a comprehensive study has included everything except an evaluation of the land in three dimensions. Geologists are eminently well equipped to supply the missing data, but they must also be aware of the needs of the urban community and the kinds of information needed by planners if they are to write reports usable by planners. Urban and environmental geology is a newly expanding field in the use of geologic data to help solve some urban problems in the planning stage. It is likely to become a part of the curriculum in many college geology departments within the next few years.

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TABLE 1. Outline of a geologic report to be used as part of a comprehensive planning study

1. Introduction
   a. Location and limits of area
   b. Purpose for which report is written
   c. Nature of the data available for preparation of the report (whether reconnaissance or detailed in nature, extent of field observations by author, how compiled, availability of reference material)
2. Summary of any highly significant problems
3. Regional geology—brief statement about geological setting of area
4. Geology of area that may apply directly to land use studies
   a. Topographic elements (description of major terrane features, major drainage lines, and upland areas; origin of features may be mentioned but only to extent needed to aid in understanding description.)
   b. Earth materials
      1.) Distribution, characteristics of consolidated rocks
      2.) Distribution, characteristics, thickness of unconsolidated materials, including floodplain sediments

      (For each unit at the surface, treatment should include such characteristics as drainage, lithology, permeability, attitude, jointing, bedding, bearing strength, and any unusual conditions such as planes of weakness, zones of uneven stability, high temporary water zones, solutionally enlarged openings. The major characteristics of each geologic unit used can often be conveniently summarized in a table or chart.)

c. Geological processes of importance
   1.) Weathering (type, products, depth, significance)
   2.) Mass wasting
   3.) Stream erosion and deposition
   4.) Shoreline erosion and deposition
   5.) Earthquakes

5. Mineral resources
   a. Distribution of known and potentially exploitable mineral resources
   b. Relationship of each local resource to local and regional economy
   c. Reclamation of worked-out and abandoned surface mines

6. Water resources
   a. Potential ground-water aquifers of area
      1.) Evaluation of each unit (note outstanding features, good and bad, regarding reliability, quantity, quality of water)
   b. Surface water resource potential
      1.) General statement on streamflow
      2.) Prospective impoundment sites

7. Waste disposal
   a. Liquid wastes—septic tank method of on site disposal—evaluation of each geological unit and the effect on ground water and surface water of disposal over it.
   b. Solid wastes—geological significance of sanitary landfills; evaluation of the geologic environments in the study area and the effect landfills in each one may have on local water quality.

8. Areas likely to cause unusual problems or hazards to urban development
   a. Flood plains
   b. Areas of potential slope failures and unstable foundation materials
   c. High water table
   d. Earthquake potential

9. Geologic features of unusual scenic attractiveness or educational value
10. References

Illustrations

1. Basic maps
   a. Areal geology
   b. Surface geomorphic elements
   c. Bedrock topography (in glaciated areas)
   d. Bedrock geology (if different from areal geology)
   e. Bedrock structure where significant.

2. Applied maps
   a. Natural hazard map
      1.) Floodplains, landslide or slump areas, unstable foundation areas, high water table areas.
   b. Thickness of unconsolidated materials
   c. Mineral resource map(s)
      1.) Areas likely to contain commercially exploitable resource, distinguished from total area where that resource is at or near the surface
      2.) Oil and gas map, including extent of current and abandoned pools and fields, and possibilities for underground storage
   d. Water resource maps
      1.) Ground-water availability and potential
      2.) Surface water development areas, impoundment possibilities
   e. Areas suitable for surface waste disposal
      1.) Sanitary landfill areas
      2.) Septic tank development (Internal drainage characteristics of surficial units and the soils developed on them)
   f. Potential natural areas and recreation areas based on geologic (geomorphic) features