THE GEOLOGICAL SURVEY OF WYOMING
Gary B. Glass, State Geologist

PUBLIC INFORMATION CIRCULAR NO. 18

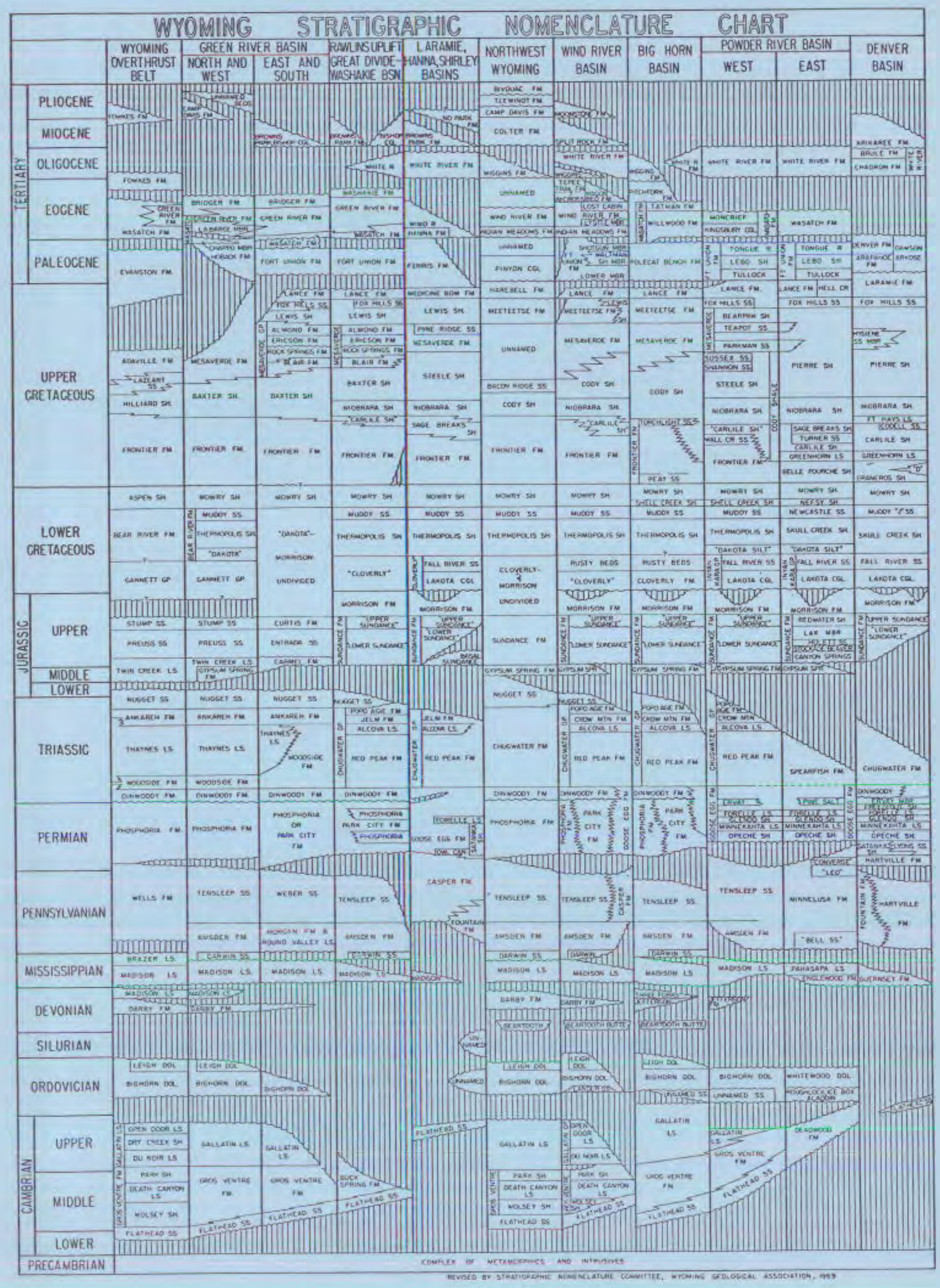
GEOLOGIC HAZARDS AND LAND USE PLANNING

(Extended Abstracts)

Edited by James C. Case

Abstracts of papers presented at the
Joint Conference of the Geological Survey of Wyoming,
Wyoming Geological Association and the
Univeristy of Wyoming Department of Geology and Geophysics
ANNUAL SPRING CONFERENCE - Laramie - April 28-30, 1983

WYOMING STRATIGRAPHIC NOMENCLATURE CHART



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1983

First Printing, of 1,000 copies, by
Central Duplicating, Cheyenne

Additional copies of this report are available
from

The Geological Survey of Wyoming
Box 3008, University Station
Laramie, Wyoming 82071

Front Cover. Squaw Creek Landslide across old U.S. Highway 26, six miles south of Jackson, Wyoming. Photo courtesy of Dr. William B. Hall and Dr. J.D. Love.

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GEOLOGY IN THE MASTER PLANNING PROCESS

Collin Fallat, Director of Agriculture, Planning, and Development Division, Wyoming Department of Agriculture

The purpose of a master plan, within the land use planning process, is to guide and direct future growth and development of a community. Wyoming Statutes 15-1-503 through 15-1-506 provides authority for counties and incorporated areas to develop master plans for the purpose of "promoting the health and general welfare". Language contained in § 15-1-504 mandates that a "planning commission shall make careful and comprehensive surveys and studies of conditions within the jurisdiction and environs in the master plan". § 15-1-504 provides an avenue for geologic hazard planning within the structure of the master plan; however, planning commissions have generally neglected geologic hazard planning, and have directed the emphasis of the master plan toward the infrastructure and physical development of the county and community. Limited geologic hazard planning in Wyoming can be traced to several factors. The population is generally unaware of geologic hazards, and how such hazards can adversely affect their community and personal property. The costs associated with inventorying and mapping geologic hazards is often considered prohibitive by communities, and local political realities often prevent adequate considerations of hazard conditions because of land ownership and land development objectives. The geology of Wyoming, like other western states, is condusive to a variety of geologic hazards to include: problem soils, landslides, avalanches, rock falls, earthquakes, ground subsidence, flooding, sand dunes and volcanic hazards. The author takes the position that a complete geologic hazard analysis should be the foundation of the master planning in the State of Wyoming.

LANDSLIDES AS WAMPETERS, PREDICTIONS AS FOMAS: THE STATE OF THE ART

Robert Palmquist, Assoc. Prof. of Geology, Northwest Wyoming Community College

Fomas and wampeters are terms coined by Kurt Vonnegut to express two important concepts; namely, "harmless, comforting lies" and "an object about which otherwise unrelated persons revolve". Landslides act as wampeters in that diverse disciplines are concerned with their location and potential for future movement. The diversity of the disciplines which range from planners and politicians through engineers to geologists requires that landslide data and limitations be clearly defined. Predictions are fomas in that they are based upon a poor understanding of the temporal aspects of landslides. This paper is dedicated to reducing the foma in landslide prediction so that the diverse disciplines concerned with landslide behavior can better interpret the data.

Landslide activity has a temporal distribution which is episodic with intervals of high activity separated by intervals of stability. This episodic activity results from the varying intensity of the fundamental causes - slope oversteepening by basal stream erosion and variations in fluid pressure resulting from climatic change. Given the numerous climatic and tectonic fluctuations of the Quaternary Period, many episodes of increased landslide activity should be expected. Over durations measured in thousands of years, the third fundamental cause of landslides - earthquakes - should have a more constant intensity. All areas have a landslide history that reflects increased activity during the moist phases of a glacial cycle as modified by episodes of increased basal erosion or by a constant high background level of seismicity. The episodic nature of landslides has not been considered by most geologists, engineers, and planners.

Landslides display two temporal distributions. Over the short term, their distribution is that of the triggering mechanism which may have a recurrence interval measured in days to centuries. The trigger causes an unstable slope to fail; it is the immediate cause of an individual landslide but it is not the cause of the slope instability. Variations in the fundamental causes - slope oversteepening, climate, and perhaps seismicity - cause episodes wherein the slopes are more or less stable. The fundamental causes vary in their intensity over durations measured in centuries to tens of thousands of years. Most geologists and engineers fail to distinguish between fundamental and triggering frequencies and hence the fomas!

Landslide inventory and susceptibility maps are based upon the distribution of landslide deposits and hence those areas which were unstable in the past. They are oftentimes used to predict both the area and the degree of instability in the future. In this prediction the slope inventory map is conservative. It overestimates the degree of hazard in <u>most</u> areas because it is the integration of several fundamental episodes of greater intensity. I predict that study will demonstrate that, in <u>most</u> areas, the intensity of landsliding today is less than it was as <u>recently</u> as 9,000 years ago. Of course, the landslide inventory map is based upon landslide deposits older than 9,000 years. Hence they are a foma.

Engineers and geologists are sometimes asked to predict the frequency of landsliding within an area so that a hazard evaluation can be made. Any estimate of landslide frequency must be based upon the modern triggering frequency and not the variations in the fundamental cause. The estimation of triggering frequency must be based upon only those landslides which have moved since the end of the Altithermal Interval. The resulting prediction will be valid only as long as the present activity episode persists. Again, if all landslides within an area are indiscriminantly used, then the prediction of frequency is a foma.

We can reduce the number of fomas being committed in the name of landslide hazard evaluation in several ways. First, and most importantly, landslides should be mapped by age; merely noting the presence or absence of a landslide is no longer sufficient. Age determinations must be in absolute terms; thus radiocarbon dates, dendrochronologic methods, and relative weathering techniques must be employed. Secondly, the overriding control by climate on landslide activity must be considered when evaluating both landslide history and hazard. Thirdly, the current practice of considering all landslide deposits within an area presents the "worst case" scenario for the area. Given the predictions that we live during an interglacial episode which has past its prime, we can expect that our landslides problems will approach the worst case. This is indeed the time to put landslides into their proper temporal perspective.

NATRONA COUNTY NATURAL HAZARD STUDY

Larry G. Clark, Consultant, Howard-Donley Associates, Inc.
Terry Howard, Consultant, Howard-Donley Associates, Inc.

The Natrona County Commissioners, recognizing potential threats posed to the health and safety of County residents from natural hazards, commissioned the Natrona County Natural Hazard Study. Chief purposes of the study were to identify existing and potential hazards, and to recommend mitigation of these hazards in the productive development of the urbanizing area of Natrona County, which includes 635 square miles of the county, centered around and including the City of Casper.

The study was a compilation of available information and data regarding local geology, sanitary septic disposal systems, precipitation, wind distribution, hydrology, and mineralogy, which was synthesized, interpreted, and displayed on referenced maps. Information from these maps identified potential natural hazards through a system of map overlays and presented the five categories referred to as Geotechnical Terrain Units. These units, and the potential natural hazards associated with each, were depicted on the Geotechnical Terrain Unit Maps. Each of the series of maps also indicated the recommended site specific investigation appropriate to evaluate suspected natural hazards and design, if necessary, for their mitigation.

Conclusions and recommendations for mitigation or elimination of natural hazards were described more fully in the report. Hazards considered include landsliding, subsidence, reactivation of sand dunes, shrink-swelling soil, erosion, and protection of water supply.

Included in the last section of the text, for the consideration of the County Commissioners, were recommended specific County-wide policies and procedures which, if adopted, would provide further protection of residents of the study area.

Also included in the last section of the text was homeowner's foundation care information. Many homeowners in the Casper area have experienced foundation problems resulting from expansive soils. The general public's lack of knowledge has, in some cases, directly caused or aggravated house foundation distress. The information contained in the report could help educate homeowners in proper foundation care and alert them to signs of possible trouble.

REMOTE SENSING AND DIGITAL TOOLS AND TECHNIQUES FOR THE INTERPRETATION AND MAPPING OF NATURAL AND MANMADE HAZARDS IN WYOMING

J. Bruce Keating, Remote Sensing/Cartography Coordinator, Bureau of Land Management

Wyoming has many tools available to identify and map potential and existing natural and manmade hazards. The availability and utility of some of the tools will be reviewed and will include both manual and computer assisted interpretations and use of this valuable data. The below listed tools and techniques, with examples, will be demonstrated.

TOOLS	TECHNIQUES
7.5 Minute Topographic Maps	Manual Photo Interpretation
7.5 Minute Orthophotoquads	Mapping Hazard Locations
Color IR Aerial Photography	Manual and Digital Slope/Aspect Maps
Natural Color Aerial Photography	Machine Assisted Vegetation Mapping
National High Altitude Photography	Geographic Information Systems
Digital Elevation Models	
LANDSAT Satellite	
Digital Resource Data	

Techniques to use and evaluate the tools in flood plain mapping, erosion potential, identifying existing and potential unstable soils and landslides, wildfire and vegetation mapping, and the identification of environmental factors for manmade hazard management will be shown with Wyoming examples. This presentation is a short tutorial intended to lead the participants to currently existing and new technological applications within Wyoming.

WATER RESOURCES AND THEIR RELATIONSHIP TO LAND USE PLANNING

Richard G. Stockdale, Groundwater Geologist, Wyoming State Engineer's Office

Water resources are becoming an increasingly important aspect of land utilization and land use planning. Many of the physical constraints associated with water resources as they relate to land use have long been recognized. What has not been so conspicuous, and certainly a more recent development, are the legal constraints associated with water resources and their ramifications on land use and land use planning. These same legal constraints also lead to the placement of physical constraints on land use as it relates to water resources.

Water resources for purposes of this paper will be divided into two categories; surface water and ground water. The surface water category will include legal and physical constraints associated with surface water appropriations: streams, lakes, reservoirs, dams, irrigation ditches, etc. The ground water portion will be restricted to legal and physical constraints associated with ground water appropriations: aquifers, recharge areas, geothermal resources, well construction, etc.

Wyoming Statutes govern the appropriation of all water in the State of Wyoming. Wyoming follows an appropriation doctrine which means that anyone desiring to utilize the waters of the State must make application to and receive the approval of the State Engineer prior to utilizing any of the State's water resources. As part of this procedure, water rights are "fixed" in terms of quantity of appropriation and the use for which the water may be applied. Deviations from original uses can be requested. However, changes can only be granted if the historic use of the appropriation is maintained and no other appropriator is injured by the change.

State and Federal Statutes govern dam safety and to some degree floodplain development. Reservoir permits are granted for specified purposes which may conflict with aesthetic interests when the stored water is utilized.

Perhaps the most obvious problem associated with surface water in urbanized areas is irrigation ditches. The existance of such ditches can be dangerous, related seepage problems can be a nuisance and damaging situation, and right-of-ways and associated easements can present problems.

Permits for ground water appropriations are also required. This gives the State some latitude in determining how many wells a particular area may support. Ground water appropriations are slightly different in that stock watering and domestic uses are "preferred uses". This designation may, however, have some constitutionality questions associated with it.

Well construction requirements as they relate to aquifer contamination, interference with other wells or surface water streams, property boundaries, etc. are additional considerations in land use planning. Protection of aquifer recharge areas and the land uses permitted in such areas are a major concern.

The use of ground water for various geothermal developments presents some unique problems. First and foremost is the problem of water disposal. Two methods of disposal are employed — reinjection and overland disposal. Both methods have implications in land use planning.

By virtue of legal constraints related to the appropriation doctrine, i.e. ditch right-of-ways, "fixing" of appropriations, use designations and well construction standards, physical constraints are imposed which affect and, in many cases, dictate the ultimate land use.

HAZARDS RELATED TO EOLIAN ACTIVITY IN WYOMING — OR — THERE'S DANGER IN THE WIND

Ronald W. Marrs, Prof. of Geology, Dept. of Geology and Geophysics, University of Wyoming

The Wyoming wind corridor is well known for its persistent high winds and as a potential source of wind energy. Surface eolian activity related to these strong winds has been studied at various locations within the wind corridor; but the geologic hazards related to this eolian activity are recognized only in a few places where local problems have already developed in response to construction or surface disturbance. Yet, the region of potential eolian hazard is widely distributed across Wyoming. Examples of various eolian-related hazards are found throughout the State. Aircraft and satellite imagery allow us to identify broader regions where these hazards are likely to be encountered.

The following list summarizes some of the more prominent hazards encountered when dealing with either ancient or modern eolian sediments:

1. Active sand encroaching on reservoirs, roadways, croplands, or other developed areas.
2. Wind erosion and its attendant exposure of subsurface installations or surface instability.
3. Surface stability problems inherent in both active and stabilized sand and loess.
4. Redistribution of damaging surface materials (saline deposits, toxic wastes, etc.) by winds.
5. Potential for broad-scale reactivation of stabilized sands and general desertification.

COAL MINE SUBSIDENCE AND LAND USE PLANNING

C. Richard Dunrud, Geologist, Branch of Engineering Geology, U.S. Geological Survey

Coal mine subsidence is the local lowering of the ground surface caused by mining the coal that previously supported the bedrock and surficial material above the mine (overburden). It includes a gradual downwarping of the overburden to form depressions (subsidence troughs, bowls) or its sudden collapse to form pits (cave holes, sink holes) (Figure 1, 2).

Depressions occur where the weight of the overburden exceeds the strength of the coal pillars or the rocks above and beneath them. Maximum vertical displacement within the depressions is less than the thickness of coal mined and commonly ranges from about 45 to 90 percent of the mining thickness in the Western United States. The surface area affected by downwarping commonly is greater than the mining area, and it increases with increasing overburden thickness. Downward movement of the overburden and ground surface toward the center of the depressions causes extension and local open cracks near the depression margins and local buckling inward from the zone of extension where shortening occurs (Figure 1).

Pits commonly occur above shallow mines where the overburden thickness is less than about 10 to 15 times the thickness of coal mined, and where the mine openings eventually move upward to the surface by successive collapse of mine roofs (stoping) (Dunrud and Osterwald, 1980, p. 17) (Figures 1, 2). The pits, which initially have vertical to overhanging walls, may be deeper than the mining thickness if the caved rocks can move laterally into adjacent mine cavities or if pits divert surface drainage into the mines and erosion occurs. Pits locally are as deep as three times the mining thickness in the Sheridan, Wyoming area (Figure 2). The surface areas of the newly formed pits commonly are less than the areas of the mine openings in plan view, but eventually they may be slightly greater than the mine areas after erosion and mass wasting have modified the pits into saucer-shaped depressions.

The time required for depressions to form and become stable commonly ranges from a few months to a few years after mining in areas where the coal is extracted by longwall or room-and-pillar methods. However, downwarping may continue for many decades above room-and-pillar mining areas, where the remaining pillars support the overburden and the rocks above and below them initially, but eventually weaken. The process of wetting and drying caused by fluctuating ground water levels appears to be one of the prime causes of eventual weakening of coal pillars and rocks above and below them. The time necessary for pits to form increases with overburden thickness and strength. For example, pits may perhaps form within a decade or so where the overburden is a few meters to roughly 10 m thick and it consists of soft shales and mudstones, whereas pits

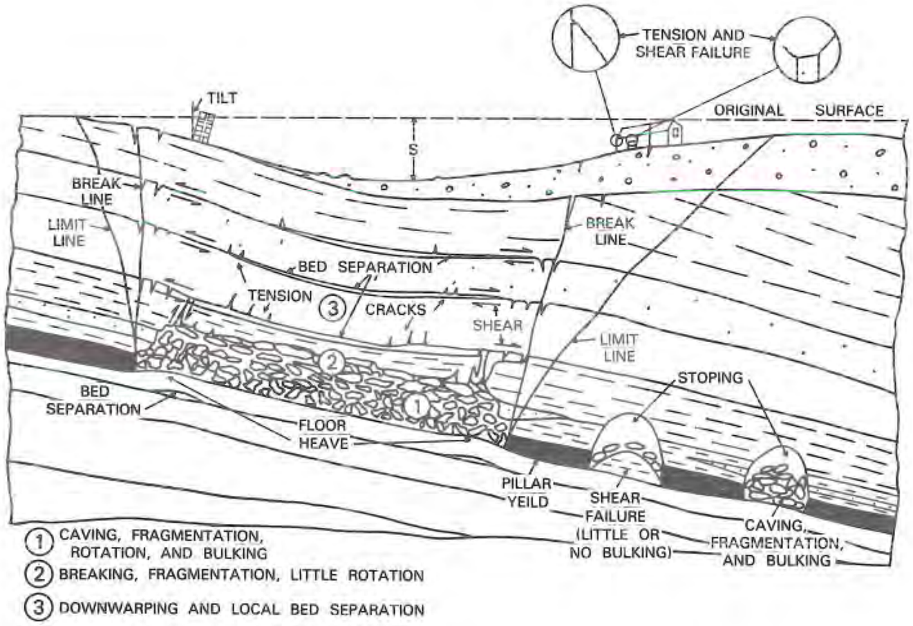

Figure 1. Conceptual diagram showing processes of subsidence. Downwarping may cause cracking near the margins of depression and local buckling toward its center. The effects of tilt commonly increase with increasing building height. The effects of extension (where cracks are located) and shortening (buckled ground between cracks) increase with increasing thickness of coal mined and with decreasing depth of mining. Severity of damage to buildings commonly increases with increasing size and rigidity of the structures. Pits are caused by successive collapse of mine roofs (stoping) where overburden, which consists of bedrock (stipple, dash, and clear pattern) and surficial material (circle and stipple pattern), is less than about 10 to 15 times the thickness of coal mined.

may form only after many decades to even several centuries after mining (Littlejohn, 1979, p. 22-30), where the overburden thickness approaches the maximum caving height (about 10 to 15 times the mining thickness) and the overburden consists predominantly of strong sandstone or carbonate rocks.

Subsidence depressions and pits may reduce the value and usefulness of the land, by damaging existing structures, and by impairing the function of structures, (Figure 1). For example, tilting of the ground surface can cause structures, such as multi-story buildings, smoke stacks, and water towers, to go out of plumb enough to cause excessive loads on foundations. Tilting may cause delicate machinery and equipment within buildings, such as power plants and factories, to malfunction, or it may reverse the gradients on such structures as canals and sewer lines. Horizontal ground strain caused by extension and shortening within depressions may distort rigid structures, such as masonry buildings, gas lines, sewer lines, bridges, railroads, and concrete pavement, and cause cracking and (or) buckling. In general, the vulnerability of structures in downwarped areas increases with increasing thickness of coal mined, with decreasing mining depth, and with increasing size and rigidity of the structures (Wardell, 1971, p. 211).

The sudden occurrence of subsidence pits can be a hazard to life as well as to property. Large cracks may locally pose a risk to life, particularly if they are covered with vegetation or with a thin veneer of soil or other surficial material (Dunrud and Osterwald, 1980, p. 17, 20). Collapse of the ground can occur suddenly and without warning where underground cavities occur near the surface and the added weight and vibration from movement of vehicles and travelers on foot or horseback can trigger surface collapse. Transportation routes located above shallow mines may be particularly vulnerable because of the vibration imparted by vehicular traffic. In the Sheridan, Wyoming area in 1982, for example, vibration and movement of surface mining equipment caused subsidence pit failure in about 6 months above mine openings that had been stable from 1940 to 1981. In Rock Springs, Wyoming, a 4-year-old boy narrowly escaped falling into a large pit that suddenly formed in a street near his home in 1976 (Denver Post, October 12, 1976).

The risk to life, property, and the environment is increased where fires occur in underground mines (Figure 3). Subsidence hazards are increased, and often are greatest, where the unmined coal burns and the air and water can become polluted with noxious and toxic chemicals emitted by the burning process through cracks and pits (Down and Stocks, 1978, p. 57-85; Dunrud and Osterwald, 1980, p. 30-41). Risk to life is greatest where cavities, that are filled with fire, smoke, and possible toxic gases, occur near the ground surface and where the vibrations and the added weight of pedestrians or vehicles triggers surface collapse. In Centralia, Pa., for example, a 12-year-old boy narrowly escaped death when a smoke-filled pit suddenly formed in a yard where he was playing (Current Science, 1981, p. 6-7). Depressions and smoking pits and cracks from subsidence and the fire, which reportedly has been burning for the last 20 years, forced the closure of Main Street (also State Highway 61) in early January, 1983 (Levine, 1983, p. 3A).

Figure 2. Aerial photograph showing subsidence depressions, cracks, and pits in the Sheridan, Wyoming area. Slopes of the rims of the pits decrease with age; pits range in depth from about 75 percent of the thickness of coal mined to as much as three times the mining thickness (kidney-shaped pit in right center), where surface water was diverted and subsurface erosion occurred. Small plumes of steam exit cracks in center.

Risks to life and property from subsidence above abandoned mines are increasing because more land near or above abandoned coal mines is being developed for residential and industrial use. Current risks above active mines commonly are low, because they usually are located in areas remote from populated areas; however, subsidence possibly may divert water at the surface or underground, such as springs, streams, or flows in aquifers and affect other mineral resources and vegetation. Subsidence above abandoned mines has locally damaged buildings, transportation routes, or utilities, and is potentially a problem, in or near urban areas such as Denver, Boulder, and Colorado Springs, Colorado (Foster, 1979, p. 1A); Rock Springs, Hanna, Kemmerer, and Glenrock, Wyoming; Des Moines, Iowa; Black Diamond, Renton (Rice, 1975), Auburn, Bellingham, Washington; Gallup, New Mexico; and Huntsville, Missouri (Dunrud, in press).

Subsidence causes several tens of millions of dollars damage to property and structures every year (Lee and Nichols, 1981, p. B73). According to the U.S. Bureau of Mines (Johnson and Miller, 1979, p. 9), future subsidence could occur in an estimated 133 km^2 (13,300 hectares) of land above abandoned underground mines in populated areas in 13 states west of the Mississippi River. They reported that future subsidence may involve more than 1,000 hectares of populated areas in the States of Colorado, Iowa, Kansas, Missouri, Utah, and Wyoming and may involve between 200 and 1,000 hectares of land in the States of Arkansas, Montana, New Mexico, North Dakota, Oklahoma, Texas, and Washington. Costs to control future subsidence in these areas are estimated at $3.7 billion (based on coal production from each State through 1975 and on an estimated rehabilitation cost of $74,100 per hectare or $30,000 per acre; see Johnson and Miller, 1979, p. 9).

Figure 3. Aerial oblique photograph showing subsidence depressions, cracks and pits in a major fire area in the Sheridan, Wyoming area. Steam and smoke exit from cracks and pits above fires in a coal mine and in an overlying coal bed (November, 1981).

Subsidence hazards can be minimized by reducing the severity of subsidence, by building specially designed, subsidence-resistant structures, by removing endangered structures, or by restricting residential or industrial development of land above abandoned coal mines that can be accurately located and areas of potential damage determined. In other countries and in local areas of the United States, for example, subsidence has been reduced above active mines from the usual 45 to 90 percent of the thickness of coal mined to as little as 5 to 15 percent of the mining thickness by hydraulically or pneumatically filling the mine openings with such material as mine refuse and sand and gravel (Briggs, 1929, p. 81-86; Wardell, 1971, p. 207). Backfilling costs reportedly are about 5 to 12 percent of the coal production costs in Poland and England, respectively (Cochran, 1971, p. 15).

Subsidence may be reduced in abandoned mining areas by filling the mine workings with mine refuse or other material through drill holes at the surface (Colaizzi and others, 1981, p. 10-15). The effects of subsidence on structures also may be reduced by constructing foundation support beneath the mines or by building structures to withstand the effect of displacement, tilt, and strain (National Coal Board, 1975, p. 65-73; Geddes, 1978-a,b, p. 579-596 and 949-968; Bell, 1978, p. 562-578). In some cases it may be cheaper and easier to purchase and remove structures from subsidence-prone areas than it would be to go through expensive litigation and mitigation procedures.

In order to make effective plans for the use of the land surface above abandoned underground mines, one should be able to estimate the nature, extent, and severity of subsidence. In order to make realistic estimates, information on existing subsidence; percentage and thickness of coal mined; mining extent, dates of mining, and mining procedures; and overburden thickness and strength, geology, and hydrology should be obtained. Detailed maps on geology, hydrology, topography, mining depth, location of mines, and the geotechnical properties of the coal and rock are effective tools in the land-use-planning process.

Past studies of the effects of subsidence within populated areas indicate that the time and money spent on careful site evaluation, mapping, and land use planning before development usually is much less than that spent on litigation and mitigation of subsidence damage after development has begun.

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EFFECT OF GEOLOGY ON ROAD AND STREET LOCATION, DESIGN, AND CONSTRUCTION

William F. Sherman, Chief Engineering Geologist, Wyoming State Highway Department

Normally, the effect of geologic conditions on road and street construction depends on the design features of the particular facility. As a simple example, steep cut slopes in many of our marine shales may be very unstable while flatter slopes in this same material will cause no problems. Another example could be an embankment placed at the base of a side hill landslide, which could be extremely stable. In fact, it could help the slope while a cut at this same location would be disastrous.

It is the primary function of the Engineering Geologist to interpret the geologic conditions and explain them in a sense so the planner and/or design engineer can minimize the adverse effects of geology in highway construction and maintenance.

It is the purpose of this presentation to illustrate examples where geologic conditions were considered in design and where they were ignored. Examples will also be discussed of design features which are utilized to minimize the adverse effects of geologic conditions.

The type of geologic information which is available in the Geology Branch of the Highway Department from past and ongoing geotechnical studies will be reviewed. This information is available to the public and can be useful to anyone involved in city, county, and state planning.

SOIL HAZARDS IN WYOMING

Larry C. Munn, Assist. Prof. of Soil Sciences, University of Wyoming, Plant Science Division

Soil hazard is used here to mean a soil property or condition which, under certain land uses, presents either a threat to human life or health or results in economic loss or unexpected higher costs. If the hazard is identified in advance, management strategy can be adjusted to compensate for the hazard, and the increased costs to overcome the limitation can be evaluated. While not as spectacular or threatening to human life as some geologic hazards, soil hazards in Wyoming result in threats to life and health, and economic losses or increased costs of hundreds of thousands of dollars annually.

In addition to providing mechanical support to plants, soils underpin buildings, roads, dams, ditches, etc. Often soil hazards result from construction on soils which lack bearing strength, are unstable, or exhibit shrink-swell, frost-heave, salt, and corrosivity problems. Installation of septic tank drain fields on heavy textured, slowly permeable soils results in health hazards. Flooding is not a soil problem per se, but morphological evidence of flooding in soil profiles is often ignored in siting structures.

In agriculture, hazards exist in many soils when developed for irrigation. Certain soil predispose crops to disease infestations; others are prone to severe erosion by wind or water. Selenium toxicity is a major liability to the cattle industry on significant areas of Wyoming rangeland. Cropland, rangeland and forest soils are all subject to compaction due to trafficing by equipment and livestock — some soils are particularly fragile in this respect.

Soils in Wyoming are usually closely related to the parent materials from which they developed — soil genesis in our cold, dry environment has been slow. The state encompasses soils developed from such diverse materials as coarse textured granite, mixed volcanics, raw organic materials and salty, clayey, marine shales. Superimpose differences in landform, climate and biological communities on these varied parent materials and you see a complex mosaic of soil individuals in the state — individuals of varied potentials, and hazards to land managers.