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OBSERVATIONS CONCERNING THE USE OF DERIVATIVE MAPS IN COMPREHENSIVE COMMUNITY PLANNING

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Abstract

Geologic factors largely determine an area's physical environment and thus substantially affect the growth and development of a community. As a community grows, land which historically has been agricultural in use becomes urban. If the alteration of the physical environment is to harmonize with development, a careful geologic assessment of the environment seems appropriate.

The assessment of a community's physical environment is discussed and related to the development of derivative maps at a scale appropriate for use by planners. These derivative maps include: (1) topography; (2) slope distribution; (3) drainage; (4) bedrock geology; (5) surficial geology; (6) soils; (7) depth to bedrock; (8) plasticity; and (9) geologic constraint for general land use.

Introduction

Geologic factors largely determine an area's physical environment. These commonly control or substantially affect the growth and development of a community because of the necessity to alter the environment. McGill (1964) observes that rapidly changing patterns of urban growth pose unprecedented geologic problems in city and regional planning. Legget (1973) has devoted an entire text to the application of geologic information to urban planning.

Evidence of alteration of the geologic environment is common in a community experiencing rapid growth. Structures of many kinds are built on, with, or through geologic materials. Structures covering areas formerly undeveloped increase runoff and reduce natural infiltration and recharge of underground water. This increased runoff will require consideration in local drainage networks prior to construction. Supplies of water are depleted by use or contamination. Sand and gravel resources are consumed or covered by construction. The modification and alteration of the physical environment of urban areas is determined largely by engineers, architects, and planners who must in the final analysis assess and deal with the environment and the geologic factors affecting it.

Assessment of the physical environment of a community requires the use of a variety of climatic, topographic, pedologic, and engineering geologic data (Table 1). Possible data sources include the nearest university department of geology, the United States Soil Conservation Service, the local city engineering department, local engineering firms, the state geological survey, the state highway department, the local United States Weather Bureau office, and the United States Geological Survey. The next step requires analysis, interpretation, and synthesis of data into viable and realistic software models capable of assisting laymen, politicians, engineers, and planners in developing recreational areas, housing developments, transportation networks, routes for subsurface conduits, surface storm drainage, and other engineering and planning purposes.

TABLE 1: *Typical physical environment factors relevant to planning (Modified after Hilpman and Stewart, 1968)*

Topography	Drainage (surface)
Slope	Soils
Surficial Geology	Grain Size
Bedrock Geology	Plasticity Characteristics (shrink-swell)
Structural Geology	Permeability
Depth to Bedrock	pH (acidity or alkalinity)
	Climate

Derivative Map

A derivative map presents one or more types of closely related physical environmental data on a scale large enough to be useful for comprehensive planning, engineering, and construction (Kemmerly, 1973). A number of derivative maps based on topography, soils, bedrock geology, surficial geology, and bedrock and soil engineering data in various combinations can be prepared for a community for the purposes stated above. Derivative maps offer the greatest potential for utilization when prepared as transparent acetate overlays. By overlaying the derivative maps on the topographic map, the distribution of the intensity patterns of each variable can be located geographically and evaluated with respect to topography. A scale of 1:12,000 (1 inch= 1,000 feet) generally is appropriate, but the size of the study area and the complexity of bedrock geologic and unconsolidated surficial geologic deposits in a community may dictate the use of a larger scale (i.e., 1:10,000, 1:5,000, or larger). The selection of individual sites, although guided by derivative maps, will require additional on-site geologic and engineering tests to identify local variations in field conditions.

Topographic Map

A topographic map depicts the three-dimensional configuration of the terrain and works of man. The topographic map will serve as the base map for all derivative maps for the reasons described in the section entitled Derivative Map. The probability of the planner having complete topographic map coverage of his community is rather good. Hopefully, the topographic maps will be 7½-minute quadrangles (i.e., scale of 1:24,000) with a contour interval no greater than 20 feet. If not, the planner generally can obtain the appropriate topographic map coverage from the state geological survey in the state where he resides.

Slope Map

Because natural slopes frequently require modification to accommodate structures, slope distribution is a major economic consideration to the contractor, engineer, and planner. The cost of excavating soil and rock increases substantially when slopes are greater than 5 percent because of the larger quantities involved. Rock cropping-out in slopes further increases costs because of the need to blade, rip, or blast. Slopes in excess of 5 percent commonly exhibit rock outcrops particularly in arid, semi-arid, and subhumid climates.

A slope map can be prepared for an area by using a number of laborious field-tested methods. Figure 1 depicts a template used to measure slope variation on any 7½-minute topographic map with a 10-ft. contour interval by comparing contour line spacings on the topographic map with defined slope ranges on the instrument. Slope ranges are based on the ratio of change in elevation in feet to the horizontal distance traversed

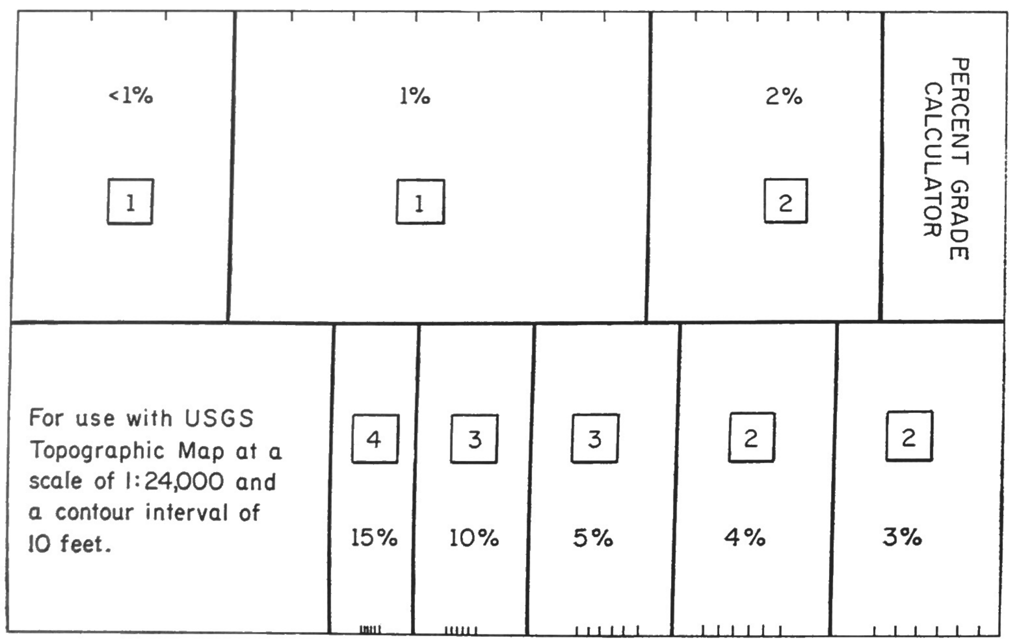

FIG. 1: *Percent grade calculator (Hilpman and Stewart, 1968)*

expressed in percent. The template is placed at right angles to any pair of contour lines. Contour line spacing for each slope category on the instrument is then checked with the spacing between the selected pair of contour lines on the topographic map. When the spacing between the selected pair of contour lines corresponds to the spacing between two lines on the template, the percent slope is read from the instrument. The template is then moved along the selected pair of contour lines until the spacing increases or decreases sufficiently to change slope categories. A boundary line is drawn on the topographic map at right angles to the pair of contour lines at the location where the slope changes categories. The process is repeated for each pair of contour lines over the entire study area.

Slopes are grouped into four categories: 0-2 percent, 2-5 percent, 5-15 percent, and greater than 15 percent. These particular categories were selected after an assessment of common grade limitations for various urban installations and activities (Fig. 2).

Drainage Map

A drainage map shows the network of perennial and intermittent streams and springs in an area. The map can be prepared from a composite of drainages shown on published topographic maps, county soil maps, aerial photographs, and field observations.

An accurate drainage map is important in planning storm drainage networks and transportation routes. Watershed geometry and local precipitation data, supplemented by runoff measurements, will enable the engineer to make preliminary estimates of the size and location of storm drainage networks and to design bridges, culverts, and fills for road networks. The drainage map will also aid the planner in making zoning decisions and identifying areas that are prone to flooding. Bridge, culvert, and fill construction disturb the balance between channel geometry and water flow. To restore the balance, local channels may require widening or straightening. Drainages that parallel roadfills may require lining to prevent infiltration into the fill. As more of a community is developed, substantially greater runoff volumes are to be anticipated. Buildings, parking lots, and streets increase the percentage of impermeable surface resulting in even greater runoff volumes. Increased runoff volumes become a serious problem in areas making a rapid transition from rural to urban land-use because of accelerated obsolescence of existing storm drainage networks.

Bedrock Geologic Map

Attempts should be made as early as possible in comprehensive community planning to obtain a bedrock geologic map of the area. A bedrock geologic map

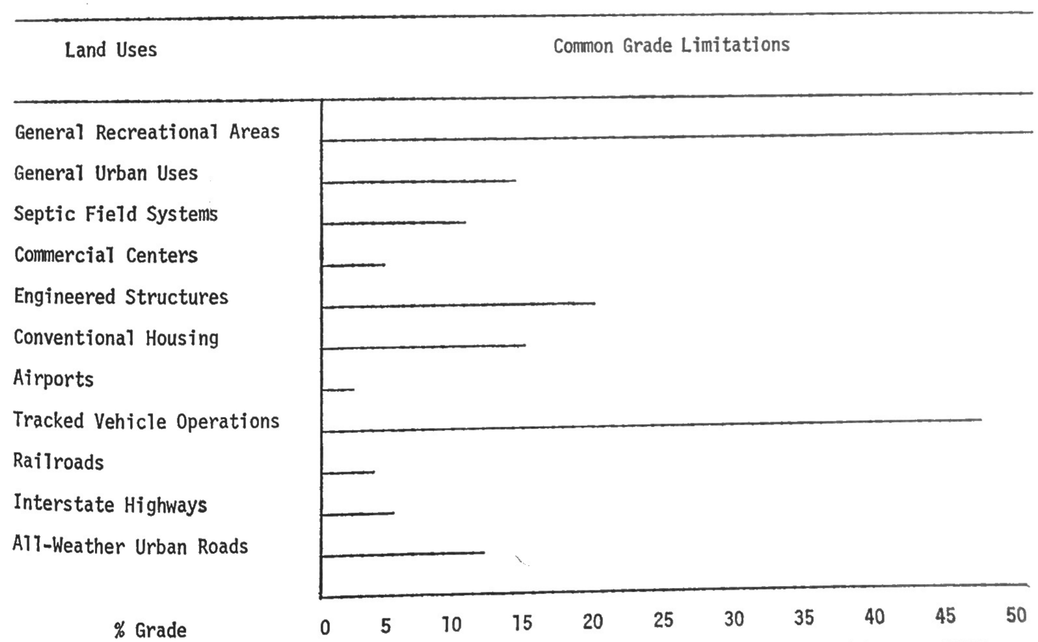

FIG. 2: *Ranges of slopes suitable for various urban installations and activities (Hilpman and Stewart, 1968)*

depicts the distribution, character, thickness, and structural attitude of the consolidated rocks in an area. Traditionally, geologic maps and their accompanying reports have been produced for geologists alone. As a result, planners have avoided consulting such maps and reports because of their apparent lack of application to community planning. Some confusion can be avoided in utilizing geologic maps if the planner concentrates on the variety of rock types present, their geographic distribution, thickness, and structural attitude. Generally, bedrock geologic maps include a cross section enabling the planner to assess the three-dimensional configuration of rock units including any faults and/or folds that may occur in the area. The bedrock geologic map also can be utilized as a bedrock-engineering feasibility map for correlating engineering test data and local experience with geologic units.

Surfical Geologic Map

A surficial geologic map depicts the exposed bedrock and any colluvium, alluvium, glacial deposits, windblown deposits, and artificial fill found in the area. Residual soils generally are excluded from a surficial geologic map. Alluvial and colluvial soils (transported) should be included on a surficial geologic map. Certainly not all of the above unconsolidated geologic deposits normally occur in any one area, but exposed bedrock, alluvium, colluvium, and artificial fill are rather common both individually and collectively in an area.

Colluvium will be briefly described because of a definite lack of understanding about such deposits by planner and geologist alike. Colluvium is material that has been moved down slopes by sheet wash and creep. Texture and composition of colluvium is determined by the up-slope material (generally weathered) from which the colluvium is derived. Frequently, colluvial units with large silt and clay fractions exhibit greater shrink-swell character than the underlying in-situ materials.

Alluvium and glacial deposits have such wide ranges in texture and engineering properties that detailed description is beyond the scope of this paper.

Artificial fill should be mapped separately because: (1) the excavation of in-situ materials alters their engineering properties; and (2) fill generally includes man-made materials such as bricks, lumber, and virtually any other materials available. Typically the geologic materials in artificial fill range from clay to boulders up to 3 feet in diameter. Such a heterogeneous mixture results in considerable settlement due to consolidation as a result of a reduction in void space. The rate of consolidation, however, is not linear with respect to time; consequently, maximum settlement occurs early in the life of the fill.

Soil Map

The local county soil survey bulletins provide a wealth of information. The typical bulletin describes the distribution of each soil type and provides detailed information concerning textures, permeability, plasticity, pH, and suitabilities for septic systems, streets, and other construction activities. The local soil map has the greatest potential for use when it is extracted from the soil survey and enlarged to the same scale as the topographic map. Typically, the scale of the soil map (1:20,000) differs little from the scale of a 7½-minute topographic map (1:24,000). The enlarged soil map allows each soil type to be located and characterized, enabling integration with other derivative maps for planning purposes.

Depth to Bedrock Map

A depth to bedrock map shows the distribution and thickness of unconsolidated deposits in an area. The primary application of a depth to bedrock map is to delineate bedrock depth with sufficient accuracy to indicate where consolidated rock will affect construction. Figure 3 shows several minimum excavation depths for various subsurface installations. The climatic conditions and local construction experience will dictate which depth requirements can be adjusted.

A major obstacle will be encountered in the installation of utility poles, fuel lines, underground cables and storage facilities, and water lines where the depth to bedrock is less than 3 feet unless the rock is capable of being bladed or ripped. Shale commonly can be excavated by conventional earthmoving equipment. Sandstone and limestone excavation depend upon weathering characteristics, thickness, intensity of jointing, and bedding characteristics. Many igneous and metamorphic rock types require blasting. Figure 3, the depth to bedrock, bedrock geologic, and surficial geologic maps can be integrated with the topographic map when subsurface projects are planned.

Plasticity Map

The shrink-swell characteristics of unconsolidated surficial deposits, including soils, affect foundation suitability. The United States Soil Conservation Service, with its county soil surveys, provides the planner with the most easily obtained plasticity data. A plasticity map can be prepared using the enlarged soil map showing the soil types and their distribution. The plasticity map is used to delineate soils most likely to undergo significant changes in volume as a result of fluctuations in moisture content (shrink and swell). Highly plastic soils then can be identified and generally avoided allowing maximum exploration efforts and resources to be utilized to select suitable construction sites and fill materials.

Moderate to highly plastic soils offer serious problems for roadbeds, basements, and foundations. These soils typically have low shear strengths and are susceptible to excessive compaction. Stresses developed by expanding or contracting soils can produce extensive cracking of structures. Soil expansion and contraction can be minimized in many instances by insuring proper drainage under and around the foundation. Proper drainage must be determined by the engineer, but one or more of the following procedures can help to

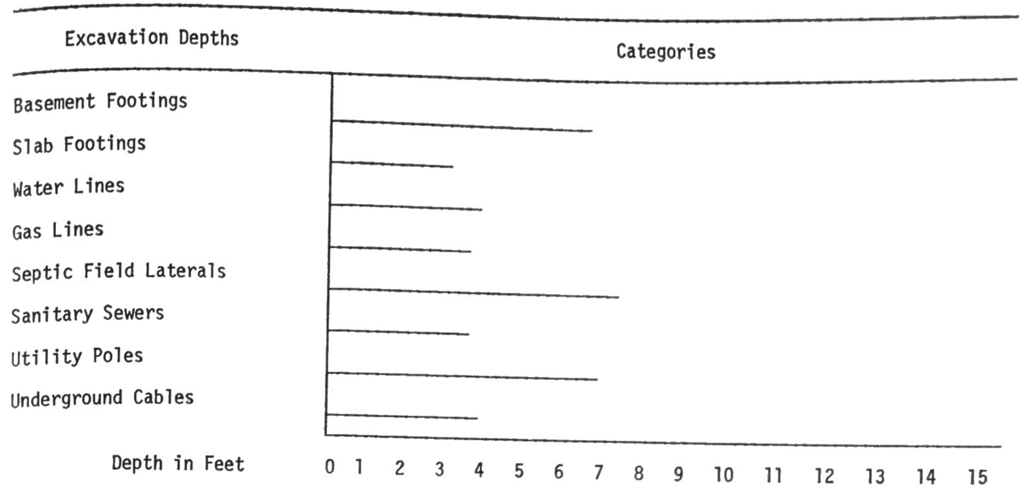

FIG. 3: *Minimum depth requirements for various urban projects in Eastcentral Oklahoma (Modified after Hilpman and Stewart, 1968)*

minimize such effects: (1) installing perforated pipe under the foundation; (2) extending guttering beyond the foundation; and (3) placing a concrete, asphalt, or plastic apron around the foundation. These same moderate to highly plastic soils should be avoided if possible as fill materials for the reasons stated above.

Geologic Constraint Map for General Land Use

Generally, derivative maps present a specific type of physical environment information. Frequently, however, urban planning depends upon several physical factors requiring decisions incorporating a combination of several derivative maps. The maps resulting from the combination of two or more derivative maps are termed suitability maps (Hilpman and Stewart, 1968). The planner, by combining the topographic, slope, drainage, bedrock geologic, surficial geologic, depth to bedrock, and plasticity maps in various sequences, can produce a number of highly interpretative maps. These indicate areas where minor, moderate, and major geologic constraints for general land use are expected to occur in the construction of streets, roadways, foundations, and subsurface utilities. Because of the interpretative nature of suitability maps the information should be used with care. An area mapped as having minor geologic constraints may be adequate for one set of project requirements, but only moderately suitable for another, depending upon the relative priority of the variables being considered in a particular project.

Summary

The systematic assessment of the physical environment of a rapidly growing community appears imperative if growth is to harmonize with the environment. The preparation of derivative maps tailored to the community's particular geologic, climatic, and hydrologic conditions on a scale conducive to planning will begin such an assessment. Derivative maps will be generalized and are based upon existing data, interpretation, and judgment. While useful for planning, engineering, and construction purposes, the derivative maps should not be relied upon for the evaluation of individual sites. On-site testing of individual sites is strongly recommended to determine if they meet requirements for a specific project.

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