DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

MISCELLANEOUS INVESTIGATIONS SERIES
(SHEET 1 OF 2) MAP I-1309

INTRODUCTION

Sanitary landfills are presently considered the most convenient, acceptable facilities for disposal of municipal solid waste. In a typical sanitary landfill, solid waste is deposited in trenches or pits called refuse cells, compacted by a bulldozer, and covered with a thin layer of soil or other cover material at the end of each day. Precipitation that infiltrates a landfill, however, reacts with some of the waste materials generating a complex and variable solution called leachate. Although each cell of solid waste is surrounded by relatively low permeability material, locally generated leachate can flow out of the landfill and can pose a serious pollution threat to ground water and surface water.

The two most common types of landfills are generally distinguished by the type of material that is buried: food-waste or putrescible landfills (sanitary landfills), and non-food waste or debris landfills (inert landfills). Leachate from putrescible landfills is generally higher in organic and dissolved solid pollutants than leachate from debris landfills. Because the regulations controlling the siting of putrescible landfills are usually stricter than those that relate to debris landfills, the physical evaluation criteria used in preparing this map were selected to satisfy the more restrictive requirements of food-waste sanitary landfills.

Many factors must be considered in the proper siting of a sanitary landfill in Fairfax County, Va., partly because of the great variability in the physical and chemical characteristics of the host earth materials, and partly because of existing distribution of established land use. These siting factors can be divided into three groups: (1) physical requirements, (2) community impacts, and (3) economic considerations. The analysis presented here deals only with some of the physical requirements necessary for a landfill site for food wastes with a working life of 5 to 10 years. Areas having the required physical characteristics shown on this map can be further evaluated by analyzing the community impacts and economic considerations associated with them. The result of such an evaluation will be a landfill site that best satisfies all the known criteria.

PHYSICAL CONDITIONS RELATED TO LANDFILL SITING

The major physical requirement of a potential landfill site is adequate protection of surface water and ground water from possible leachate pollution. Some degree of perviousness exists in nearly all types of cover material and some precipitation will infiltrate into the fill material (Otton, 1972). The Fairfax County area has an average annual rainfall of 45 in. Some of this rainfall will infiltrate and almost certainly produce leachate from landfills no matter how carefully each site is selected and designed. Leachate will eventually either emerge as surface flow into a collecting ditch or stream, or will disappear underground to combine with the existing ground-water system. Therefore, while it is almost impossible to prevent leachate from combining with either surface water or ground water, certain measures may be employed to reduce the amount of leachate generated.

Infiltration of precipitation into the landfill can be significantly reduced by covering the completed landfill with material of sufficiently low permeability. The landfill should ideally be located in a funnel-shaped depression so that leachate can be controlled and contained; the base of the landfill should be at least a few yards above the water table. If these two conditions are met, the leachate outflow can be monitored and, if necessary, the seepage collected and treated. Thus, a landfill site in Fairfax County should have: (1) sufficient loosely consolidated, low permeability cover material located at the site; (2) adequate thickness of low-permeability material beneath the base of the fill to provide a buffer zone to filter leachate before it reaches the water table; (3) no adjacent streams or large bodies of water; (4) no exposed bedrock or underlying areas of fractured bedrock; and (5) high natural leachate attenuation capacity of the material underlying and surrounding a landfill. Unfortunately, data concerning the last factor, although of extreme importance, are unavailable for Fairfax County and should be obtained in additional site investigation.

The first four requirements are analyzed on this map by combining information about thickness of overburden, type of overburden, topographic setting, and inferred bedrock fractures. These characteristics, and the effects of each on landfill siting, are discussed in the following paragraphs.

Thickness of Overburden

Overburden, for this analysis, is defined as nonconsolidated or loosely consolidated material overlying fresh, unweathered bedrock. The thickness of overburden is important in determining the potential volume of a landfill and in establishing a suitable leachate filtration or attenuation zone around and beneath a landfill. Fifty feet or more of overburden is considered to be most favorable in this analysis because it provides a large volume for a given surface area, thereby reducing the cost of land acquisition. Some areas having less than 50 feet of overburden may prove, after detailed site investigation, to be acceptable landfill sites, especially if the overburden material is capable of attenuating leachate.

Type of Overburden

The permeability and cation-exchange capacity of the overburden are important because permeability controls the rate of leachate movement and cation-exchange capacity determines the degree of pollutant attenuation. Generally, materials with low permeabilities contain clay minerals which can adsorb some pollutants. On the basis of relative cation-exchange capacities and varying permeabilities, the types of overburden in Fairfax County that are best suited for landfills are residual material (saprolite) on granitoid rocks, on schist, on gneiss, and on metagraywacke, which occur in the Piedmont province, and silt and clay, which occur in the Coastal Plain. Other surface materials in Fairfax County, including alluvium, colluvium and lag gravel, and Coastal Plain sand have relatively high permeabilities and generally low filtering capacities. Saprolite on hornfels, on diabase, and on mafic and ultramafic rocks is generally less than 10 ft thick, and, though clay-rich, is usually poor for landfill sites because of high water table and lack of cover material. Residuum on Triassic conglomerate, sandstone, siltstone and shale is generally less than 15 ft thick, and commonly has bedrock outcrops and shallow water table.

Topographic Setting

The concentration of leachate entering the ground-water system may be decreased by selecting a site where the distance leachate has to flow to reach the water table is relatively long, allowing for maximum attenuation of leachate. In the absence of a usable depth to water table map, the landforms map of Fairfax County was used to estimate the depth to water (Rogers, 1977). In general, the water table is a subdued plane approximately subparallel to the land surface. On uplands the water table is relatively deep (15–45 ft or more), but in valley bottoms, it is at or near the surface, and on valley walls it may range from 5–15 ft deep. In order to provide the maximum protection for ground water, only uplands were considered suitable for sanitary landfill sites. This also affords some protection for surface water because surface drainage on the uplands is generally limited to small swales and intermittent streams. As with thickness of overburden, this criterion may eliminate some potentially usable sites. Detailed investigations will provide the information required to judge the hydrologic favorability of a particular site.

Linear Features

Recent studies (Iwahashi and Heironimus, 1978; Froelich, 1978) have shown a correlation between the presence of bedrock fractures and linear features evident on aerial photographs or Landsat imagery. Ground water in Piedmont rocks is generally found in bedrock fractures. Because of their relatively high permeability, such fractured areas are probably zones of rapid ground-water movement. In order to protect the ground water in these fractured zones from leachate pollution, areas having linear features are judged to have limitations for sanitary landfill sites.

HOW THE MAP WAS MADE

The computer-generated composite map was made by combining four source maps (sheet 2) of Fairfax County, Virginia. Each source map shows one of the four physical characteristics related to sanitary landfill siting used in this report. Source maps were stored in a computer by a process called digitizing. This was done by superimposing a grid on each map and recording a latitude-longitude location and a number for the map unit that occurs in each cell.

The digitized maps were composited by the Multi-Scale Data Analysis and Mapping Program (Beavers, 1975). In making the composite map, new numeric values were assigned to the source map units (see table 1). Zero (0) was assigned to all units that do not meet the criteria for favorable landfill sites; units that meet the criteria were given other numbers. On the type-of-overburden map (sheet 2), one (1) was assigned to the units considered to have acceptably low permeability and high leachate filtering capacity. On the topographic-setting map (sheet 2), two (2) was assigned to the unit for upland areas. On the thickness-of-overburden map (sheet 2), four (4) was assigned to the unit for areas having 50 ft or more of overburden. On the linear-features map (sheet 2), eight (8) was assigned to the unit for areas showing no linear features on aerial photographs or Landsat imagery. The numbers 1, 2, 4, and 8 were used because when added to produce the composite map the result is a unique "score" for each of the 15 possible combinations (one comprising all four factors, four groups of three factors, six groups of two factors, and the four factors taken alone). Each "score" was then assigned to the appropriate unit (A, B, C, D, E, F, blank) for the composite map. The block diagrams (figs. 1–3) are an aid in visualizing the physical settings of the composite-map units.

Computer compositing is illustrated in the example below using a four-cell area.

Overburden thickness	Type of overburden	Topographic setting	Linear features
0 4 / 4 0	0 1 / 1 1	0 0 / 0 2	0 8 / 0 8
0 13 / 5 11			
E / F B			

HOW TO USE THE MAP

Map unit A includes areas that have all four of the characteristics deemed necessary, and therefore are likely to be best able to contain a sanitary landfill. Units B through E have three of the four required characteristics and may be considered for further evaluation if the siting problems associated with their deficiency can be solved. Those areas having only one or two of the requisite characteristics are shown as map unit F. Their specific characteristics cannot be discriminated on the composite map, but can be identified on the accompanying digitized source maps (sheet 2).

Calculating the Area Needed for a Landfill

The map is divided into sampling units called cells. Each cell is a three-by-three-character block on the map representing a 1200- by 1500-ft land area (about 41 acres). The volume of loosely consolidated material 40 ft thick in one cell of map units A, C, D, and E is 2,667,000 cubic yards (cu yd). The U.S. Environmental Protection Agency (EPA) recommends that 2.6028 cu yd of fill is required for 1 short ton of trash (T. Murlis, oral commun., May 23, 1980). Thus, one cell excavated to a depth of 40 ft will accommodate 1,024,537 short tons of solid waste. The Metropolitan Washington Area Council of Governments (oral commun., 1980) estimates that the population of Fairfax County (including Fairfax City and Falls Church) will be 707,900 in 1985. EPA's estimate of 1985 post-consumer solid waste generation, including commercial, is 4.67 pounds per person per day (EPA, 1979). Thus, the yearly solid waste generation for Fairfax County in 1985 is projected to be 603,325 short tons per day. If a landfill is 40 ft deep and is operating at maximum efficiency, 0.589 cell (24 acres) will accommodate one year's solid waste for Fairfax County. A landfill site chosen for a five-year lifetime, therefore, would require an area of at least three cells (123 acres). This calculation does not include such factors as site access, boundary irregularities, or depth to water table, any of which may reduce the filling capacity of a cell. On the other hand, many areas on the map have more than 50 ft of loosely consolidated material and thus more capacity.

Many citizens' complaints regarding sanitary landfills center around the duration of such installations, which typically have an operating life of ten to twenty years. Selection of smaller sites, insuring a maximum life of five years, and subsequent residential, industrial, or recreational development of landfill areas, could minimize social and environmental impacts of sanitary landfills in Fairfax County and in other urbanized counties (Dames and Moore, 1978).

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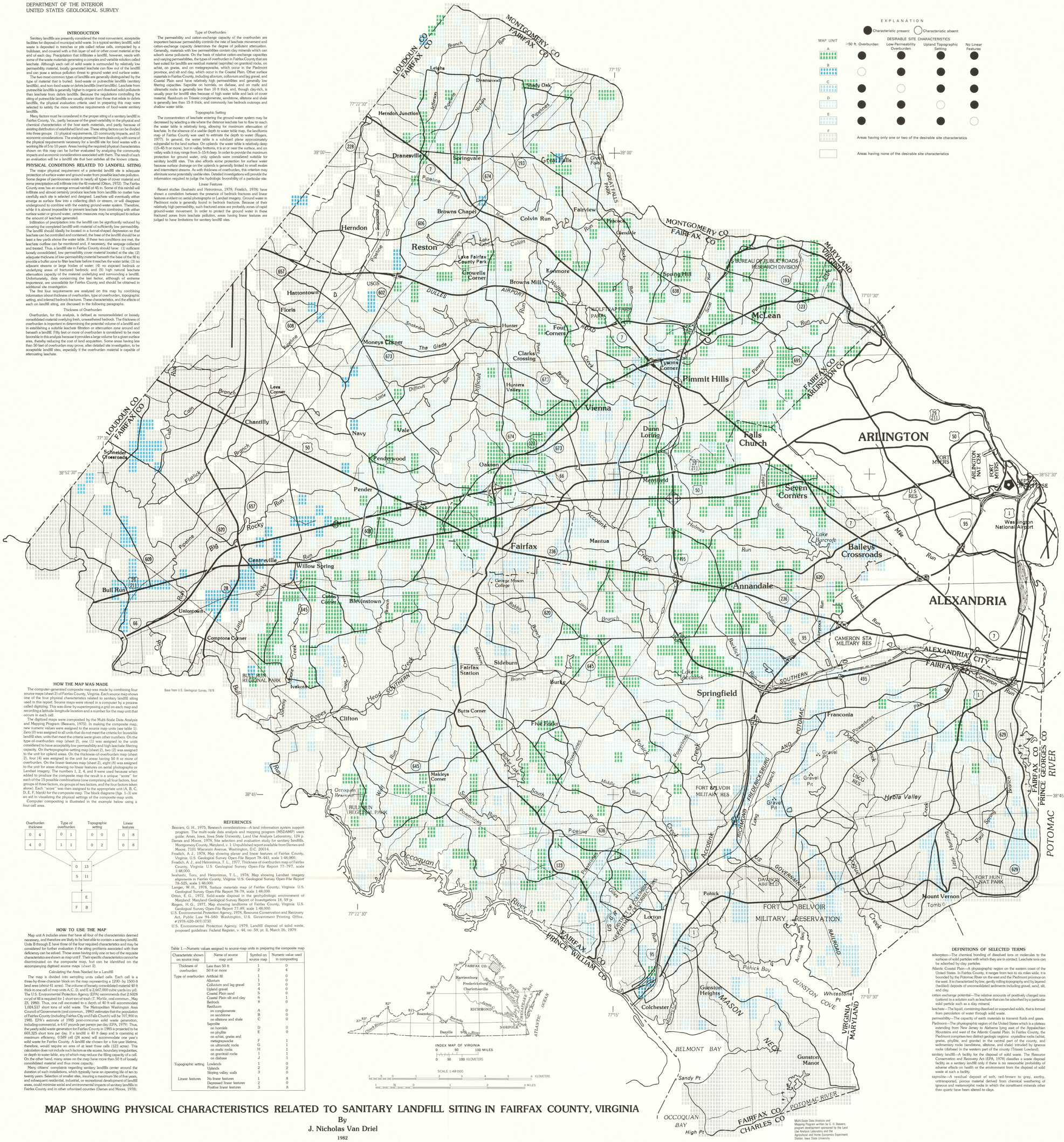
Table 1.—Numeric values assigned to source-map units in preparing the composite map

Characteristic shown on source map	Name of source map unit	Symbol on source map	Numeric value used in compositing
Thickness of overburden	Less than 50 ft	1	0
	50 ft or more	2	4
Type of overburden	Artificial fill	1	0
	Alluvium	1	0
	Colluvium and lag gravel	3	0
	Upland gravel	4	0
	Coastal Plain sand	5	0
	Coastal Plain silt and clay	6	1
	Bedrock	8	0
	Residuum		
	on conglomerate	A	0
	on sandstone	B	0
	on siltstone and shale	C	0
	Saprolite		
	on hornfels	D	0
	on phyllite	E	0
	on schist, gneiss and metagraywacke	F	1
	on ultramafic rocks	G	1
	on mafic rocks	H	1
	on granitoid rocks	I	1
	on diabase	J	1
Topographic setting	Lowlands	1	0
	Uplands	2	2
	Sloping valley walls	3	0
Linear features	No linear features	1	8
	Depressed linear features	2	0
	Positive linear features	3	8



MAP SHOWING PHYSICAL CHARACTERISTICS RELATED TO SANITARY LANDFILL SITING IN FAIRFAX COUNTY, VIRGINIA

By
J. Nicholas Van Driel

1982

Base from U.S. Geological Survey, 1978

Multi-Scale Data Analysis and Mapping Program written by G. H. Beavers; program development sponsored by the Land Use Analysis Laboratory and the Agricultural and Home Economics Experiment Station, Iowa State University

EXPLANATION

Characteristic present ○ Characteristic absent

MAP UNIT	≥50 ft. Overburden	Low-Permeability Overburden	Upland Topographic Setting	No Linear Features
A	●	●	●	●
B	○	●	●	●
C	●	○	●	●
D	●	●	○	●
E	●	●	●	○
F	Areas having only one or two of the desirable site characteristics			
	Areas having none of the desirable site characteristics			

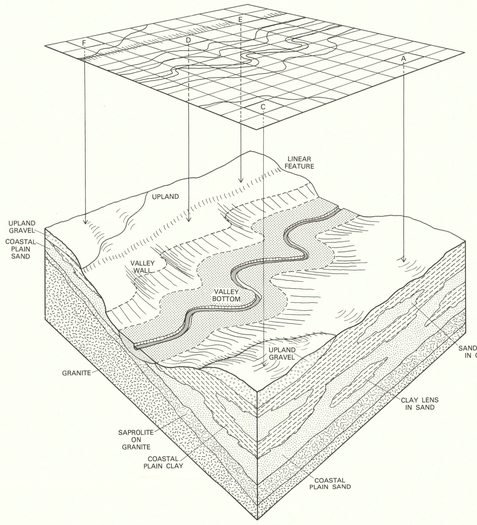


Figure 1.—Block diagram showing idealized surface and subsurface conditions on the Atlantic Coastal Plain and representative corresponding units from the composite map. Letters indicating map units are listed in explanation. Does not show all possible combinations of physical characteristics.

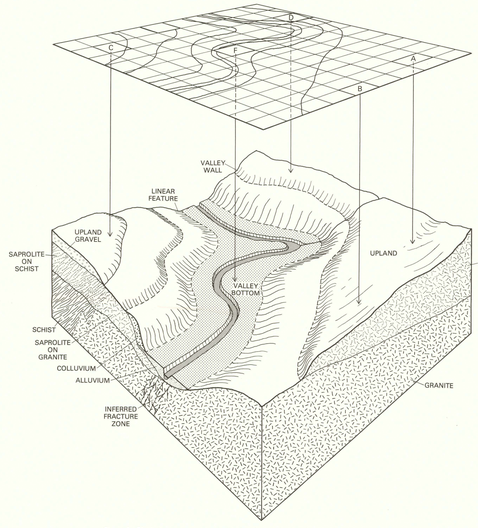


Figure 2.—Block diagram showing idealized surface and subsurface conditions in the Piedmont and representative corresponding units from the composite map. Letters indicating map units are listed in explanation. Does not show all possible combinations of physical characteristics.

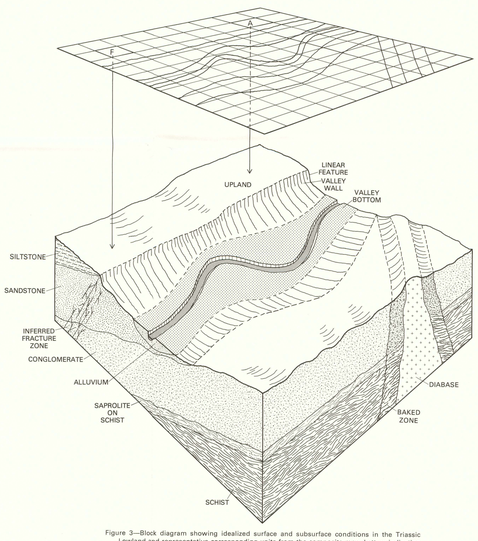


Figure 3.—Block diagram showing idealized surface and subsurface conditions in the Triassic Lowland and representative corresponding units from the composite map. Letters indicating map units are listed in explanation. Does not show all possible combinations of physical characteristics.

DEFINITIONS OF SELECTED TERMS

adsorption—The chemical bonding of dissolved ions or molecules to the surfaces of solid particles with which they are in contact. Leachate ions can be adsorbed by clay particles.

Atlantic Coastal Plain—A physiographic region on the eastern coast of the United States. In Fairfax County, it ranges from two to six miles wide; it is bounded by the Potomac River on the east and the Piedmont province on the west. It is characterized by low, gently rolling topography and by layered (bedded) deposits of unconsolidated sediments including gravel, sand, silt, and clay.

cation exchange potential—The relative amounts of positively charged ions (cations) in a solution such as leachate that can be adsorbed by a particular solid particle such as a clay mineral.

leachate—The liquid, containing dissolved or suspended solids, that is formed from percolation of water through solid waste.

permeability—The capacity of earth materials to transmit fluids and gases.

Piedmont—The physiographic region of the United States which is a plateau extending from New Jersey to Alabama lying east of the Appalachian Mountains and west of the Atlantic Coastal Plain. In Fairfax County, the Piedmont comprises two distinct geologic regions: crystalline rocks (schist, gneiss, phyllite, and granite) in the central part of the county, and sedimentary rocks (sandstone, siltstone, and shale) intruded by igneous rocks (diabase) in the western part of the county (Triassic Lowland).

sanitary landfill—A facility for the disposal of solid waste. The Resource Conservation and Recovery Act (EPA, 1976) classifies a waste disposal facility as a sanitary landfill only if there is no reasonable probability of adverse effects on health or the environment from the disposal of solid waste at such a facility.

saprolite—A residual deposit of soft, red-brown to gray, earthy, unstratified, porous material derived from chemical weathering of igneous and metamorphic rocks in which the constituent minerals other than quartz have been altered to clays.

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