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GROUND-WATER FLUCTUATIONS IN VIRGINIA

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The Virginia Division of Mineral Resources initiated a ground-water observation-well program in January 1960 with monthly tape measurements of the water level in an abandoned well near Charlottesville. Between August 1963 and November 1967, automatic water-level recorders were installed in this and 18 other wells located in 18 counties (Figure 1). This program was established to: (1) compare changes in local climatic conditions with changes in ground-water storage, (2) analyze the causes and characteristics of water-level fluctuations as they relate to individual wells and their aquifer systems, (3) obtain information on ground-water storage and head changes in areas of large ground-water withdrawal, and (4) provide basic information for study of specific hydrogeologic units. On March 1, 1968, maintenance of 13 of the 19 observation wells was transferred to the Virginia Division of Water Resources, along with the responsibility for continuation and expansion of the observation-well program. The Division of Mineral Resources will continue to operate the Grottoes, Staunton, Luray, Loft Mountain, Gordonsville, and Charlottesville observation wells until certain ground-water studies in progress have been completed.

Eight of the observation wells were drilled at sites selected by the Division of Mineral Resources on Federal, State, and county properties; six of these were drilled for the Division of Mineral Resources, three of which were constructed specifically for observation-well purposes. The other 11 were water wells abandoned by municipalities, industries, or private owners because of low yield or because the well was no longer needed. Although the location, type of construction, and available data for several of the wells were less than optimum, the wells were the most favorable that could be obtained and fulfilled the initial requirements of the program. Each observation well is equipped with an automatic water-level recorder that provides a continuous record of water-level fluctuations with an accuracy of approximately ± 0.1 foot (Figure 2). Monthly tape measurements of the water levels in each well

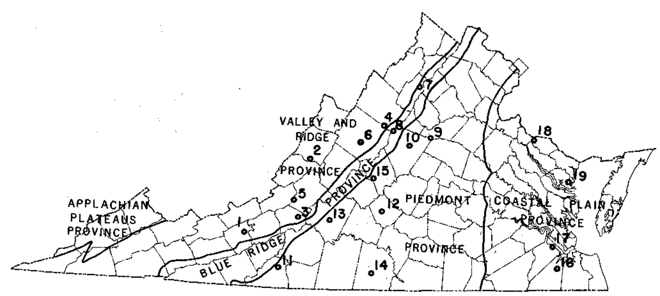

Figure 1. Locations of observation wells: (1) Claytor Lake, (2) Douthat, (3) Roanoke, (4) Grottoes, (5) Daleville, (6) Staunton, (7) Luray, (8) Loft Mountain, (9) Gordonsville, (10) Charlottesville, (11) Fairystone, (12) Appomattox, (13) Bedford, (14) Halifax, (15) Colleen, (16) Suffolk, (17) Smithfield, (18) Montross, and (19) Kilmarnock. Principal physiographic provinces of Virginia are also indicated.

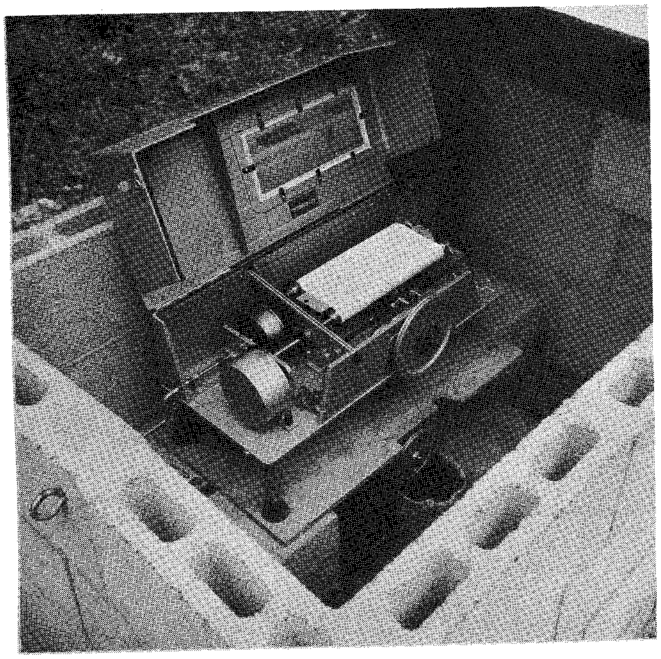

Figure 2. Water-level recorder at the Gordonsville observation well.

are also made to provide a basis for scaling the charts.

An aquifer may be defined as a stratum or zone below the surface of the earth which transmits water at an appreciably greater rate than adjacent strata or zones, and which yields water in usable quantities. The depletion or addition of water stored in an aquifer, or the deformation of an aquifer, will cause the water level to fluctuate in wells hydraulically connected with that aquifer. Such fluctuations may range in amplitude from a fraction of an inch to several tens of feet, and vary in duration and frequency from a few seconds to many years; they may also be periodic or irregular in their occurrence. Changes in atmospheric pressure and disturbances of or within a well also cause water-level fluctuations, but compared to conditions of water storage and aquifer deformation these causes are insignificant and none were recognized in the records from any of the 19 observation wells.

A net addition or depletion of water in an aquifer will cause a change in water levels in wells that penetrate the aquifer. This is the most common cause of water-level fluctuations in Virginia. Under conditions of natural discharge, the daily change in water levels is usually very small, although seasonal fluctuations may amount to many feet. Under artificial-discharge conditions, which occur when wells are pumped, daily water-level changes may exceed natural seasonal fluctuations. The rate at which the water level in a well changes is directly proportional to the rate of flow of water into or out of the aquifer or aquifers the well penetrates. The rate of flow is controlled by the transmissibility of and the head on the aquifer. The head is the pressure exerted on a unit area by water between the upper surface of an aquifer or aquifer system and the point at which the pressure is determined. A reduction of this pressure will cause a corresponding drop of water levels in wells in that aquifer or aquifer system. Under natural conditions water may be lost from an aquifer directly through seepage or spring flow, or indirectly through evapotranspiration. The drop in water level caused by spring or seep discharge will continue at a diminishing rate until it reaches the same elevation as the spring or seep, or until discharge comes into equilibrium with recharge. Evapotranspiration produces diurnal and seasonal fluctuations of water levels, the magnitude and occurrence of which are dependent upon the type of vegetation and the season and the climate, and are directly related to temperature changes. Daily effects are generally very small in Virginia, although seasonal effects may cause the water level to change several feet.

Water may also be lost from an aquifer through flowing or pumped wells. A naturally flowing well has an effect similar to that of a spring. A pumped well lowers the head in an aquifer with the magnitude of influence decreasing outward from the well. The amount of drop in the water level depends upon the transmissibility of the aquifer and the rate of recharge, and is proportional to the rate at which water is withdrawn from the aquifer. In localities where a group of wells are pumped simultaneously at high rates, such as in some urban and industrial portions of the Virginia Coastal Plain, the surrounding area in which water levels are influenced may have a radius of several miles. When pumping of a well or group of wells ceases, the water level tends to return to its original position.

Daily water-level fluctuations that correspond to alternating periods of pumping and recovery are characteristic of records from observation wells directly influenced by nearby producing wells (Figure 3). These fluctuations are in many instances superimposed on long-term fluctuations. When the water-level fluctuations in a well are compared to the local geology and ground-water

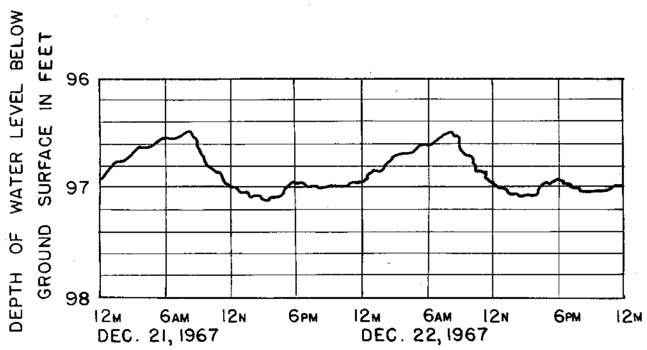

Figure 3. Hydrograph depicting water-level fluctuations in the Kilmarnock observation well induced by local pumping.

withdrawals, many hydrologic properties of an aquifer may be determined.

Aquifers are recharged naturally by infiltration of precipitation, melted snow, or surface water. In shallow aquifers, and in very permeable or fractured rocks, infiltration and percolation of water are rapid and the water level rises quickly in response to recharge (Figure 4). Water levels in wells that obtain water from deep or confined aquifers have a buffered or subdued fluctuation in response to recharge, small amounts of which may not produce any noticeable change. In addition to the short-period response to recharge, there are seasonal and long-term water-level fluctuations due to the cumulative effect

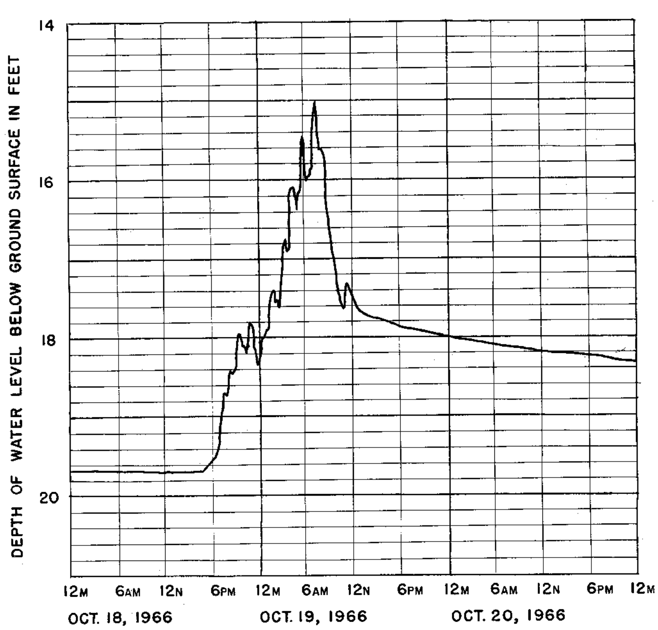

Figure 4. Hydrograph depicting water-level fluctuations in the Roanoke observation well in response to 3.37 inches of rain received on October 18 and 19, 1966.

of climatic or surface-water conditions. Artificial recharge by methods such as injection wells, galleries, impoundments, or water-spreading is not presently used to any significant degree in Virginia.

When stress is applied to or released from an aquifer, there is a respective rise or drop of water levels in wells that penetrate it. Although fluctuations of water levels from such causes are generally small, the change is sometimes measured in several tens of feet. The amount of fluctuation is proportional to the magnitude of applied stress, and the form of fluctuation is dependent upon the type of stress and physical properties of the aquifer.

Earthquakes may produce alternating increases and decreases in stress on an aquifer which may be of sufficient intensity to cause water-level fluctuations in wells thousand of miles away. In sedimentary aquifers under increasing stress, water is squeezed from between the grains and forced from the aquifer, raising the water level in wells. When the direction of stress is reversed or no longer applied, water in the well flows back into the aquifer. Alternating, periodic reversals continue for the duration of the earthquake forces. Fractured-rock aquifers may be affected similarly. The Luray observation well is a good example of a well in a fractured-rock aquifer that responds to earthquakes (Figure 5A).

Periodic water-level fluctuations in wells penetrating aquifers that extend below the ocean may result from changes in pressure due to tidal fluctuations. At high tide the ocean exerts a greater pressure on the aquifers than at low tide, and the water levels are correspondingly higher. The resulting semidiurnal fluctuations of water levels in such wells are proportional in amplitude to that of the tides, and generally are fairly uniform in magnitude except when storms cause abnormally high tides (Figure 5B).

Earth tides, which also cause periodic water-level fluctuations in wells, are analogous to ocean tides in that both are directly related to the gravitational attractions of the sun, the moon, and the earth. The variations in gravitational attraction produce semidiurnal fluctuations of the water level, with peak water levels reached about 45 to 50 minutes later each day; maximum amplitudes occur at the new-moon and full-moon stages. Semidiurnal earth-tide fluctuations have been identified only in the Luray and Gordonsville observation wells which are in fractured metamor-

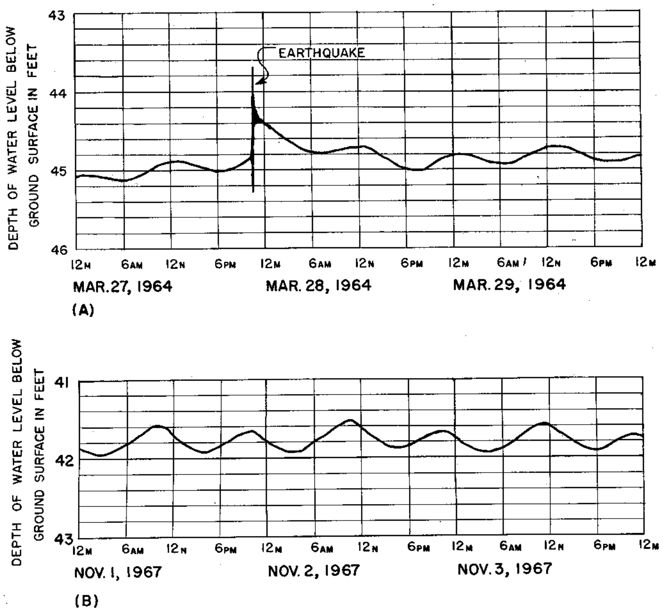

Figure 5. Hydrograph depicting water-level changes (A) in the Luray observation well due to earth-tide effects and the effects of the Alaskan "Good Friday" earthquake on March 27, 1964, and (B) in the Suffolk observation well due to ocean-tide effects.

phic rock, and are not influenced by pumping during periods when earth-tide effects are recorded.

The following are summaries of significant geologic, topographic, and location data for each observation well in relation to the characteristics and probable causes of water-level fluctuations. The basic data for each of the 19 wells are listed in Table 1.

The Claytor Lake well (Figure 1, No. 1) is located in Pulaski County near the southern boundary of Claytor Lake State Park, within 400 feet of the lake. It is on a gentle slope about 20 feet above maximum lake level. The well penetrates 319 feet of shale, limestone, dolomite, and sandstone in a major fault zone. The hydrograph from this well reflects fluctuations in lake level but does not appear to be greatly influenced by precipitation. A short-term water-level fluctuation of approximately 0.2 foot was recorded in response to the Japan earthquake of May 15, 1968.

The Douthat well (Figure 1, No. 2) is located in Bath County near the northern boundary of Douthat State Park, approximately 100 feet east of Wilson Creek. The well penetrates 336 feet of thin, interbedded sandstones and shales. Water-level fluctuations are small but well defined, and are directly related to local precipitation. Many individual rainstorms during the cooler months are delineated by a rapid rise in water level. Only very heavy rains cause a net gain in groundwater storage during the months of higher temperature and maximum plant growth (Figure 6A). There are no local wells being pumped, but several springs and seeps occur along Wilson Creek. The water level in this well fluctuated approximately 0.2 foot in response to the Japan earthquake of May 15, 1968.

The Roanoke well (Figure 1, No. 3) is located in Roanoke County on the Nelson-Roanoke Corporation property in southeast Roanoke. The nearest surface drainage is Carvens Creek that is more than 1000 feet east of, and at an elevation approximately 35 feet below, the well site. Precipitation and melting snow have a marked and immediate effect on the water level in this well which has risen as much as 5.4 feet in 6 hours following a heavy rain (Figure 4). The similarity between the well and local stream hydrographs suggests the well penetrates a portion of a cave or fracture system that may drain the surrounding area. There is little long-term fluctuation in the water level (Figure 7).

The Grottoes well (Figure 1, No. 4) is located in Rockingham County near the western boundary of Shenandoah National Park, approximately 1 mile east of Grottoes on the northeast side of State Road 661. The well penetrates 210 feet of unconsolidated clay and gravel and 140 feet of shale, but installation of 235 feet of casing has left only the shale aquifers open to the well bore. Water-level fluctuations may be affected by pumping of local industrial and municipal wells as the water level in this well is 50 to 70 feet below the elevation of Shenandoah River, and unusually deep water levels have been measured in several other wells in this area. Individual periods of precipitation are poorly defined, but seasonal climatic changes seem to have considerable influence on the water-level fluctuations (Figure 8).

The Daleville well (Figure 1, No. 5) is located in Botetourt County on the edge of a narrow stream valley, approximately 5 miles west of Daleville on the northwest side of State Road 640. Because the well obtains water from a shallow weathered zone in carbonate rocks, the water level reacts rapidly to individual rainstorms, with recorded fluctuations up to 1.5 feet. The water level in this well fluctuated approximately 0.2

Table 1.—Observation-well data.

Physiographic province	Well number and designation	Date of recorder installation	Depth (feet)	Diam. (inches)	Yield (gpm)	Depth of casing (feet)	Contributing aquifer zones (depth in feet)	Depth to bed-rock (feet)	Major lithology	Topographic setting	Elevation of well site above local drainage (feet)	Maximum water-level fluctuations (feet below ground surface)
Valley and Ridge	1 Claytor Lake	8/65	319	6	75	56	57-214	20	Shale and limestone	Gentle slope	34	19.5-26
	2 Douthat	8/65	336	6	45	52	63-336	7	Shale	Gentle slope	25	29.5-32
	3 Roanoke	8/66	100+	6	5+	—	?	15+	Shale and limestone	Gentle slope	40	15-20
	4 Grottoes	5/67	350	5	3	235	210-230	210	Shale	Gentle slope	130	183.5-204
	5 Daleville	10/67	399	7	18	27	30-31	4	Limestone and dolomite	Stream valley	5.7	3-5.5
	6 Staunton	11/67	250	8-6	234	90	95-240	15	Limestone and dolomite	Slope in valley	25	20-23.5
Blue Ridge	7 Luray	8/63	280	6	15	52	56-150	11	Slate and meta-basalt	Low divide	60	37-65
	8 Loft Mtn.	6/64	240	6	22	30	38-155	8	Slate and meta-basalt	Steep slope	15	4-33.5
Piedmont	9 Gordonsville	9/64	98	6	7	11?	Below 11	10	Phyllite and quartzite	Hilltop	50	15-36
	10 Charlottesville	5/65	409	6	1	58	Below 58	52	Phyllite	Hillslope	22	14-19.5
	11 Fairystone	5/67	250	6	5	9.5	45-50	5	Phyllite	Hillslope	80	16.5-23.5
	12 Appomattox	9/67	288	8	13	93	105-110	92	Mica schist	Hilltop	65	50-51.3
	13 Bedford	10/67	?	6	½	?	?	?	Granite gneiss	Gentle slope	150	64.9-65.1
	14 Halifax	10/67	?	8	?	?	Below 50	?	Hornblende gneiss	Level upland	60	45-45.5
	15 Colleen	10/67	275	6	12	50	60-167	48	Granite gneiss	Hilltop	70	34.5-35.5
Coastal Plain	16 Suffolk	3/66	1006	20-12	2118	884	446-884	—	Sand and clay	Level plain	15	32.7-42.5
	17 Smithfield	7/67	?	6	?	?	Below 50	—	Sand and clay	Level plain	20	—
	18 Montross	7/67	641	4-2	10	641	608-628	—	Sand and clay	Level plain	30	137.5-139.0
	19 Kilmarnock	7/67	706	4-2	20	706	706-716	—	Sand and clay	Level plain	30	91.8-93.1

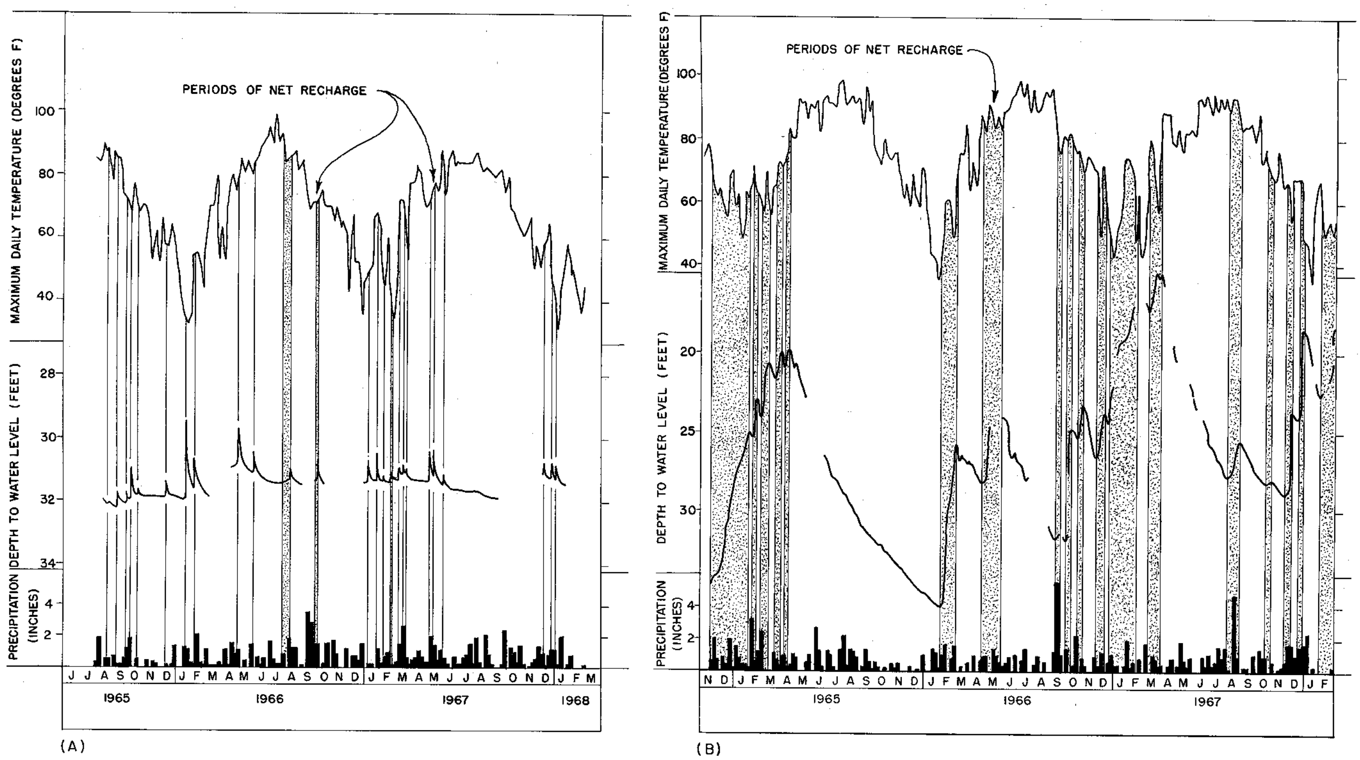

Figure 6. Comparison of water-level fluctuations in the Douthat (A) and the Gordonsville (B) observation wells showing the effects of saprolite thickness on fractured-rock aquifers. The relationships of net recharge (vertical lines and stippled areas), or discharge, to maximum daily temperature and cumulative precipitation for 6-day periods are shown. Thick saprolites in the Gordonsville area result in long-term positive reactions of water levels following heavy precipitation, and thin saprolites in the Douthat area allow rapid recharge.

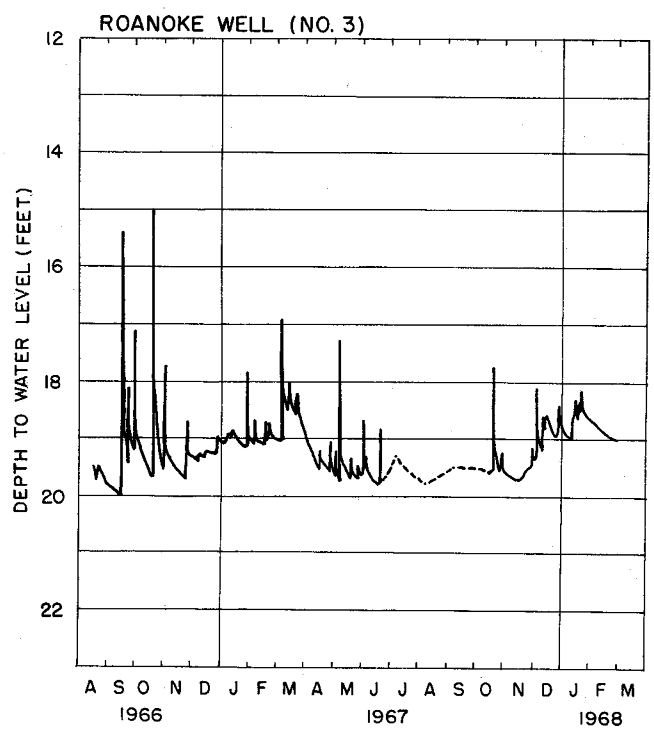

Figure 7. Hydrograph from the Roanoke observation well depicting water-level fluctuations characteristic of fractured-rock aquifers overlain by thin saprolite.

foot in response to the Japan earthquake of May 15, 1968.

The Staunton well (Figure 1, No. 6) is located in Augusta County near the southern corporate limit of Staunton, on the east side of State Road 613. The well was drilled in a stream valley that parallels the axis of an anticline in carbonate rocks. During construction and development of this and another well several hundred yards to the south, it was demonstrated that the area is underlain by an extensive water-filled cave system when sinkholes developed in the stream bed and in an adjoining draw. One sinkhole was approximately 20 feet in diameter and 65 feet deep, and another developed in the stream bed and captured a major portion of the surface water passing through the valley. Hydrographs from this well are similar to those of the Roanoke and Daleville wells, with a maximum recorded fluctuation of 2.5 feet. Of the five observation wells known to be affected by the Japan earthquake of May 15, 1968, the water level in this well showed the greatest fluctuation (approximately 0.8 foot).

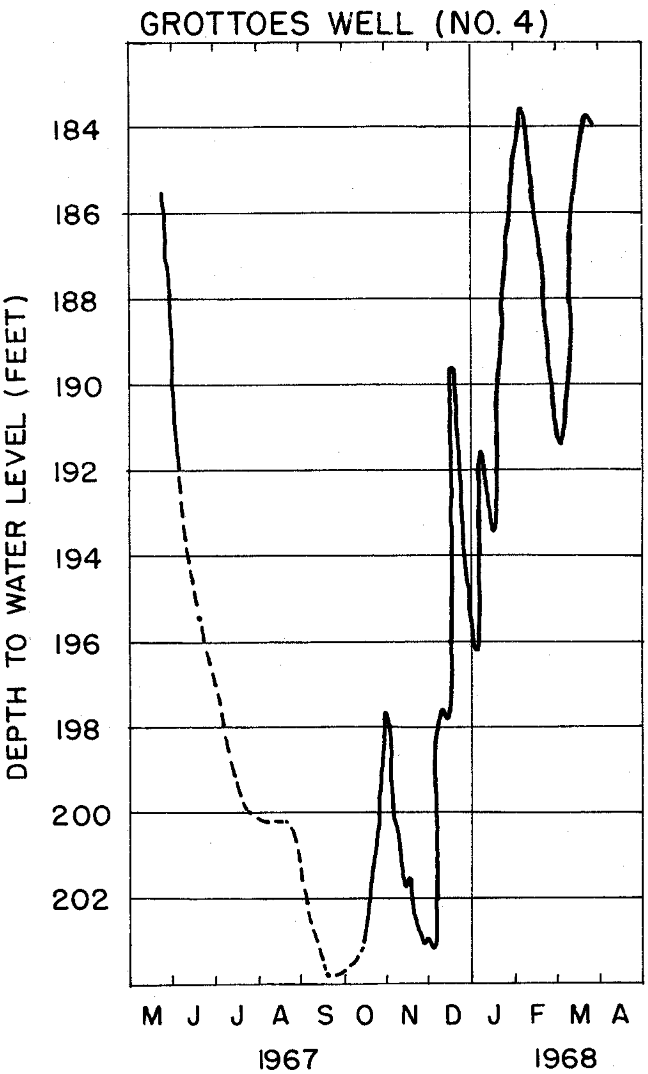

Figure 8. Hydrograph from the Grottoes observation well depicting water-level fluctuations in a fractured-rock aquifer overlain by a thick sequence of unconsolidated clay and gravel.

The Luray and Loft Mountain observation wells (Figure 1, Nos. 7, 8) are located in the Blue Ridge province. Both are in Shenandoah National Park, one at Park Headquarters near Luray and the other near Ivy Creek in the Loft Mountain development. Each well penetrates steeply dipping slates and metabasalts, and each is affected by intermittent pumping of nearby wells. Fluctuations as great as 25 feet due to local pumping have been recorded in the Loft Mountain well; recovery after pumping is rapid in each well. Hydrographs from these wells are quite similar to those obtained from observation wells in the Valley and Ridge province, and show a relatively rapid rise in water levels following major rainstorms. The hydrograph from the Luray well is illustrated in Figure 9. Small amounts of precipitation have little effect on water levels, particularly in the warmer months. As each of these wells is in a heavily forested area, it is probable that evapotranspiration has considerable effect on fluctuations of the groundwater level. Significant water-level fluctuations occurred in the Luray well in response to the Alaskan earthquake of March 27, 1964 (Figure 5A), and minor fluctuations were recorded at the time of the Japan earthquake of May 15, 1968. The recorder on the Loft Mountain observation well was not in operation at the time of either of these quakes. Semidiurnal earth-tide fluctuations are also common in the Luray well (Figure 5A).

The Gordonsville well (Figure 1, No. 9) is located on a low, wooded hill in Orange County, on the west side of U. S. Highway 15 approximately 2 miles north of Gordonsville. The well is in steeply dipping phyllites and quartzites. Water-level fluctuations in this well, which are

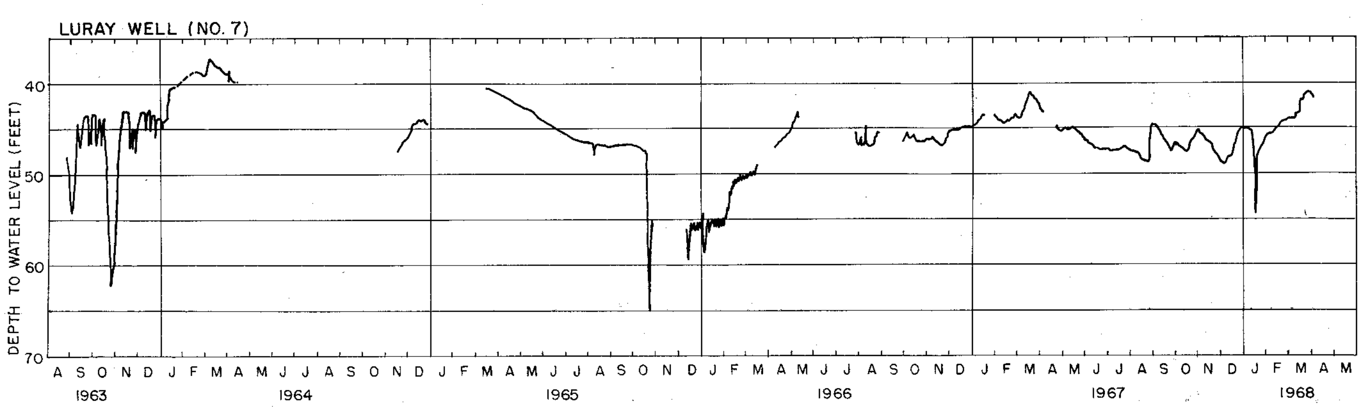

Figure 9. Hydrograph from the Luray observation well depicting water-level fluctuations in a fractured-rock aquifer that is intermittently affected by local pumping.

the greatest in observation wells not affected by pumping, are long term and correlate with annual temperature fluctuations (Figure 6B). The hydrograph curve is modified by semidiurnal fluctuations of low amplitude due to earth-tide effects.

The Charlottesville well (Figure 1, No. 10) is located in Albemarle County, in Key West subdivision 1 mile north of Charlottesville. Monthly tape measurements of the water level in this well were made from January 1960 until an automatic water-level recorder was installed in May 1965. The well penetrates relatively impermeable phyllites. The hydrographs from this well show a significant drop in the average ground-water level beginning in late 1962 and ending early in 1965. The average water level has been rising intermittently during the last 3 years, and is currently near the 1960 level (Figure 10). The water level reacts to individual rainstorms in the cooler months, but only very heavy rains increase the net ground-water storage during the growing season. Large withdrawals of ground water from a nearby well have no effect on the water level in the observation well.

The Fairystone observation well (Figure 1, No. 11) is located in Patrick County on a hillslope at the west end of the lake in Fairystone State Park. The fluctuation trends are quite similar to those of the Charlottesville and Gordonsville wells. Water levels drop throughout the growing season and do not begin recovery until significant rainfall occurs in the late fall (Figure 11). It should be noted that in August 1967, when 7 inches of rain were recorded in a 6-day period by the weather station at Philpott Dam a few miles to the east, the water level in this observation well rose only 3 inches. In contrast, precipitation during the winter months that amounted

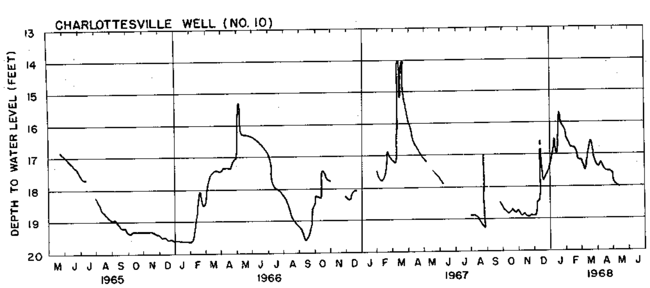

Figure 10. Hydrograph from the Charlottesville observation well depicting water-level fluctuations characteristic of fractured-rock aquifers overlain by thick saprolite.

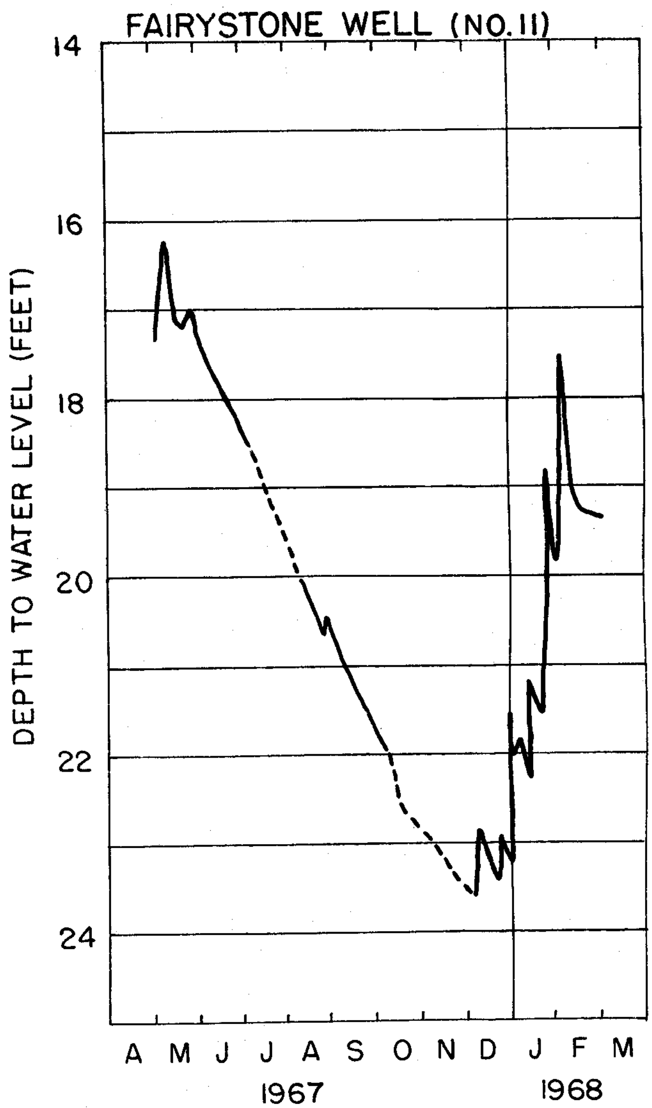

Figure 11. Hydrograph from the Fairystone observation well depicting water-level fluctuations characteristic of fractured-rock aquifers overlain by thick saprolite.

to less than 3 inches in 6-day periods, often resulted in water-level rises up to 30 inches. During the growing season most of the precipitation is intercepted before it can infiltrate to the water table or bedrock-fracture systems.

The Appomattox, Bedford, Halifax, and Colleen observation wells (Figure 1, Nos. 12-15) were established late in 1967 in or near these four communities located in Appomattox, Bedford, Halifax, and Nelson counties, respectively. Because the period of observation has been short, records of characteristic water-level trends are not yet available. These are all deep, low-yield wells located on hilltops or slopes much above local drainage, and in areas where a thick saprolite has developed on the bedrock. To date the hydrographs from these wells are quite similar, each having low-amplitude fluctuations of water levels with little indication that individual rainstorms have significant effects.

The Suffolk well (Figure 1, No. 16) is located in Nansemond County, on State Road 642 approximately 5 miles northeast of Suffolk. This well is at an elevation of 15 feet above mean sea level and is cased and screened to collect water from four sand aquifers between depths of 546 and 874 feet. The water level in this well, as in the three other Coastal Plain observation wells, rises considerably above the confined aquifers.

The well is situated in the large industrialized and urbanized portion of southeastern Virginia from which several million gallons of ground water are withdrawn daily. This pumping has produced a gradual, slightly irregular lowering of the water level in this well (Figure 12). Although the average maximum monthly variation in water level for this well is only 1.1 feet, the water level has dropped a total of 8.5 feet during the 2 years of record. This occurred despite a 14 percent increase in precipitation and a continuous drop in the mean annual temperature for the Suffolk area. The aquifer head has been lowered 25 feet during the last 12 years, and there is no indication by comparison with temperature and precipitation records that the lowering was the result of climatic changes. Daily fluctuations are almost entirely the result of tidal influence on the deep aquifers (Figure 5B). These regular, short-term changes in water level are generally less than 0.2 foot except when influenced by unusually high tides.

The Smithfield well (Figure 1, No. 17) is located on the west side of State Highway 10, approximately 1 mile north of Smithfield in Isle of Wight County. This is a heavily pumped area, and the water-level fluctuations in this well are of large amplitude when nearby wells are pumped. Because of maintenance problems with the recorder, there are no continuous long-term records from this well; but monthly tape measurements indicate the water level dropped from 72 feet in August 1967 to 78.6 feet in early January 1968, and then rose slightly in February 1968.

The Montross well (Figure 1, No. 18) is located in Westmoreland County, about 0.5 mile east of Montross on State Highway 3. The well was drilled at the edge of a wooded area behind the Washington and Lee High School at an elevation of 140 feet above mean sea level. The water level ranges from 1 foot below to 3 feet above mean sea level. Daily fluctuations of the water level are caused by local pumping because several wells in the area each derive large quantities of water from the deep sand aquifer that supplies water to the observation well. One of these wells is less than 0.5 mile away and was pump tested at 844 gallons per minute. Lowering of the water level due to pumping occurs every 1 to 2 days, and generally starts in the late afternoon or evening and lasts 6 to 10 hours. During this period, the water level drops about 0.3 foot, and then makes a slow but usually complete recovery between pumping periods. A slow, fairly steady lowering of the water level occurred during the last four months of 1967 when there was little precipitation, but in the spring of 1968 this level appeared to be rising slightly. Because of the short time this observation well has been in operation, there are not sufficient data to determine the long-term trends of the water level. However, drilling and construction records for wells in this area indicate that water levels in wells that obtain water from the same aquifer as the observation well may have dropped 10 feet or more in the last 30 years.

The Kilmarnock well (Figure 1, No. 19) is located in Lancaster County, near the west corporate limits of Kilmarnock. The well was drilled

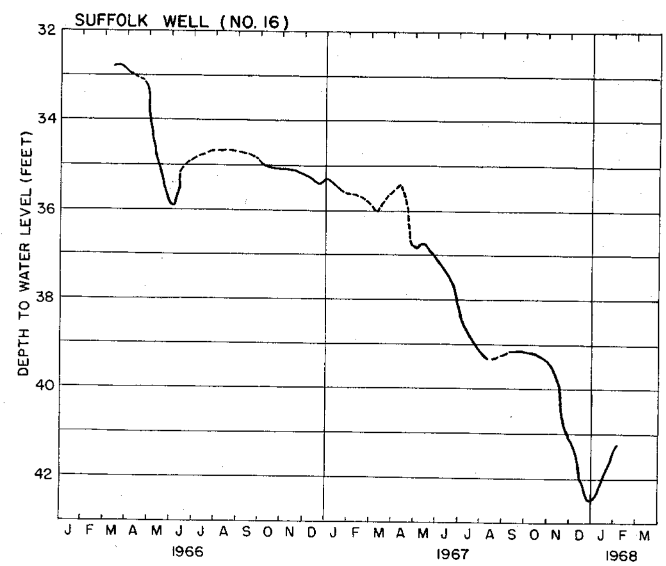

Figure 12. Hydrograph from the Suffolk observation well showing the general decline of water levels which has probably been induced by regional pumping.

at the edge of a wooded area behind Lancaster High School at an elevation of 80 feet above mean sea level. The water level is approximately 15 feet below mean sea level, and appears to have a relatively small fluctuation. Many wells are pumped in the Kilmarnock area, and although none has a very high yield, they appear to be the principal cause of water-level changes in the observation well. There are two prominent periods of pumping and subsequent lowering of the water level in this well: from approximately 7:00 a.m. to 4:30 p.m. when the drop is about 0.6 foot, and approximately 6:00 p.m. to 7:00 p.m. when the water level is lowered about 0.2 foot (Figure 3). Recovery occurs during the 12-hour evening and early-morning period, usually returning the water level to about the same level as the previous day. Precipitation with subsequent infiltration recharges the aquifer at a slow rate. Individual storms or periods of rain cause little change in daily fluctuations due to the depth of the sand aquifer, but seasonal variations in precipitation have caused the water level to fluctuate more than 1 foot since August 1967.

In the Valley and Ridge and Blue Ridge provinces where saprolite is commonly thin and bedrock well fractured, natural recharge is rapid. Discharge from springs and seeps is also rapid, and ground water accumulated from storm precipitation may be stored for only short intervals of time. Similarly, drawdown and recovery of pumping wells are also rapid. Low water levels are usually attained in August or September and may approach local stream elevations during extended dry periods. Average fluctuations due to seasonal climatic variations are generally less than short-term fluctuations caused by precipitation. The elevation of wells above local stream levels may have little effect on the range or rate of water-level fluctuations.

In the Virginia Piedmont where saprolite is commonly thick, and where bedrock fractures are apparently fewer and less extensive than in the western provinces, a large amount of the total ground-water storage is in the saprolite and above local stream elevations. The effect of precipitation is delayed by the saprolite which retards the downward percolation of surface water to the fractured-rock aquifer or the water table if it occurs in the lower portion of the saprolite. During the growing season, much of the water is extracted from the saprolite by transpiration processes before it can percolate beyond the plant root systems. As a result, even very heavy rains between May and October add little water to the subsurface reservoir. The majority of domestic, municipal, and industrial water wells in the Piedmont province have been located for convenience on the tops or upper slopes of low hills where the saprolite is generally thick. The six Piedmont observation wells that are located on the tops or upper slopes of hills have recorded maximum annual fluctuations of nearly 20 feet, with the lowest water levels occuring between October and February. In wells that penetrate shallow fractured-rock aquifer zones where annual water-level fluctuations are relatively large, there is a loss of head in the autumn and early winter months, which may result in a significant decrease in yield. None of the Piedmont observation wells have large yields. Some wells that have penetrated extensive fracture zones have relatively high yields, and in the ones that are also located in areas of thin saprolite, water-level fluctuations may respond to precipitation much the same as water levels in the Valley and Ridge and Blue Ridge wells.

Sharply defined, semidiurnal fluctuations of nearly 0.4 foot have been recorded in the Luray and Gordonsville wells and appear to be related to earth tides. Very small semidiurnal fluctuations also appear in the hydrographs from several other Valley and Ridge and Piedmont observation wells. The occurrence and magnitude of semidiurnal fluctuations of water levels in wells that penetrate fractured-rock aquifers may be related to the degree of confinement of water within the aquifer. The extent and orientation of local bedrock fractures may also be a related factor.

Low-amplitude water-level fluctuations caused by distant earthquakes were recorded in the observation wells having the largest yields and which penetrate fractured-rock aquifers. A direct relationship appears to exist between the amplitude of these fluctuations and the yield of the wells in which they were observed. Extensive fractured-rock aquifers apparently deform more under stress from seismic forces than aquifers composed of unconsolidated sediments or saprolite and poorly fractured rock. The regional geologic structure may also be a contributing factor in the occurrence and magnitude of these water-level fluctuations as only observation wells in the Valley and Ridge and Blue Ridge provinces have recorded seismic activity since the observation-well program began.

A gradual loss of head in deep aquifers in the Virginia Coastal Plain has occurred during the last several decades due to the increased use of ground water by industries and municipalities. The period of low precipitation that occured in the early and middle 1960's may have also affected the head on deep aquifers, but was not the primary cause of the lowering of water levels in southeastern Virginia. All four observation wells located in the Virginia Coastal Plain are screened in deep aquifers, and individual periods of precipitation register no measurable effect on their hydrographs. Seasonal effects due to precipitation are usually poorly defined in the well records. Daily fluctuations caused by local pumping may approach the average monthly fluctuation in some wells. Cyclic water-level fluctuations of low amplitude, and which are correlative with ocean tides, may occur in many deep wells situated near the ocean or bay areas, although these fluctuations may be masked by local pumping.

Further evaluation of ground-water storage and water-level fluctuations in the Virginia Coastal Plain requires expansion of the observation-well network. This would be of particular importance where use of large industrial and municipal ground-water supplies has significant effect on the ground-water resources.

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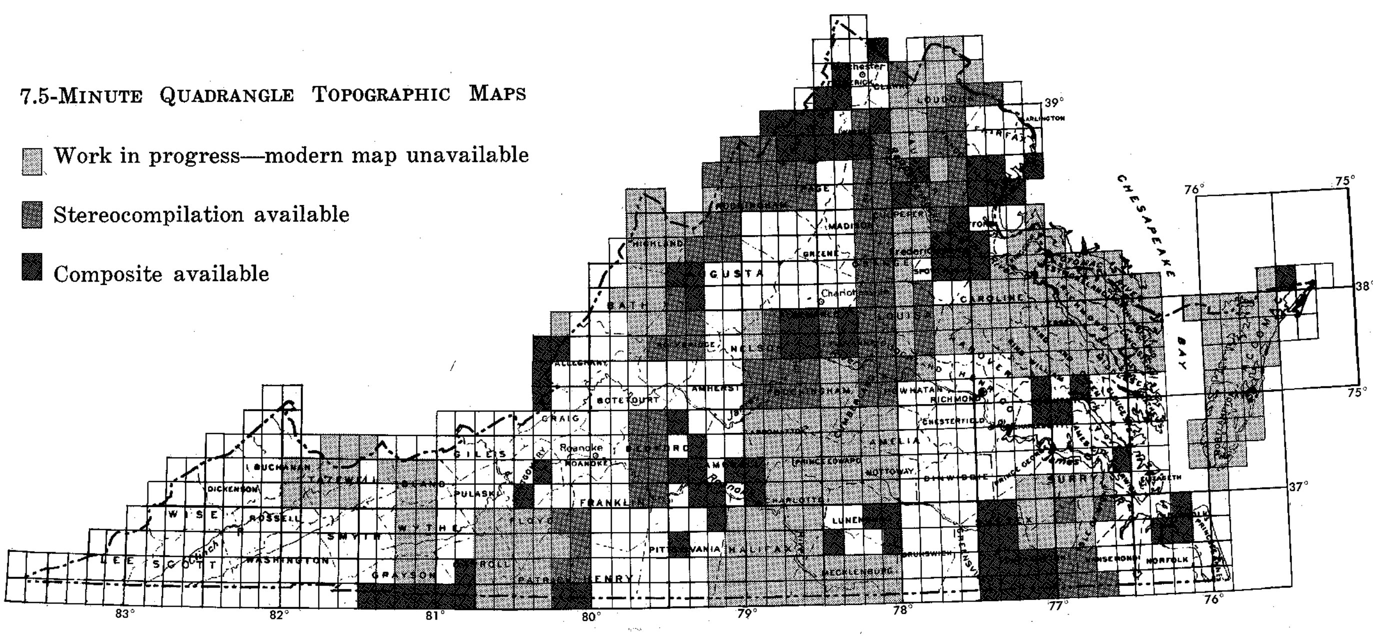
PROGRESS OF TOPOGRAPHIC MAPPING

The following statistical compilation and status maps indicate the progress of the 7.5-minute quadrangle topographic mapping program in Virginia through June 30, 1968.

	Number of 7.5-minute Quadrangles	*Percent of State*
Number of quadrangles	807	100
Mapping in progress	427	53
Preliminary maps available	178	22
Modern maps published	380	47
Total number of available maps	558	69

MODERN TOPOGRAPHIC MAPS IN PROGRESS



Shaded areas represent 7.5-minute quadrangles where topographic mapping was in progress as of June 30, 1968. Stereocompilations are advance maps that show topography, drainage, and buildings; they have no cultural names and have not been field checked. Composites are advance maps that show topography, drainage, buildings, and cultural names and have been field checked. Blue-line prints of advance maps are available at 50 cents each from the U.S. Geological Survey, Topographic Division, 1109 N. Highland St., Arlington, VA 22210.

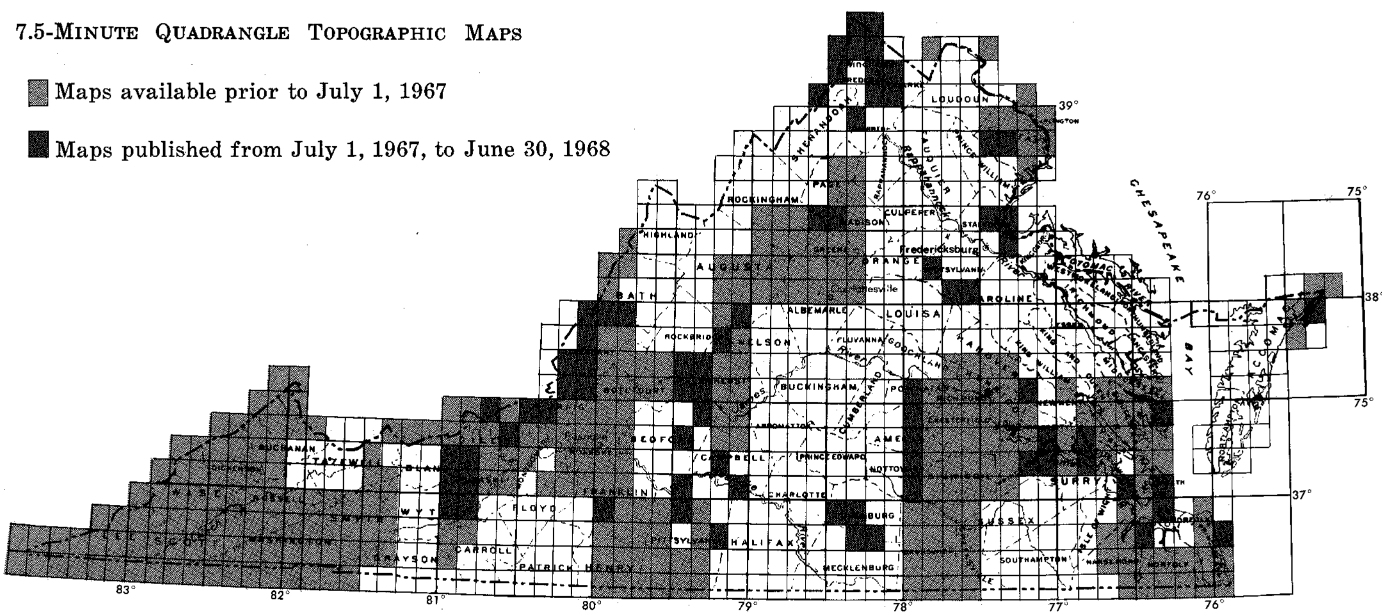
Virginia Division of Mineral Resources
Box 3667
Charlottesville, VA 22903

Return Requested

PUBLISHED MODERN TOPOGRAPHIC MAPS

7.5-MINUTE QUADRANGLE TOPOGRAPHIC MAPS

- Maps available prior to July 1, 1967
- Maps published from July 1, 1967, to June 30, 1968



Modern maps published from April 11, 1968, through June 30, 1968, are as follows:

Alleghany	Fort Mitchell	Lunenburg	Quinton
Amelia Court House	Glengary	Max Meadows	Rocky Mount
Belmont	Goode	Norfolk North	Rucker Gap
Callaghan	Java	North View	Stafford
Capon Bridge	Ladysmith	Partlow	Strasburg
Castle Craig	Leesville	Passapatanzy	Widewater
Eggleston	Long Island	Powhatan	Wightman

Shaded areas represent 7.5-minute quadrangles where maps that conform to modern topographic standards are available. These published maps may be obtained at 50 cents each from the Virginia Division of Mineral Resources, Box 3667, Charlottesville, VA 22903. A State index to topographic maps is available free.