U.S. Geological Survey Water-Supply Paper 2375
National Water Summary 1988-89--Floods and Droughts:

MARYLAND AND THE DISTRICT OF COLUMBIA
Floods and Droughts

Precipitation in Maryland and the District of Columbia is derived from moisture transported from the Atlantic Ocean, the Gulf of Mexico, or the Caribbean Sea or is recycled from the midcontinent. Some storms in airmasses that originate in the arctic may be enhanced as they cross the Great Lakes. Annual precipitation in the region of Maryland and the District of Columbia averages about 42 inches. Floods can occur in any season and can affect the entire region. Droughts occur less frequently than floods; however, brief, local, and sometimes severe droughts have been documented.

One of the most destructive thunderstorms in Maryland and the District of Columbia was in August 1971 near the eastern edge of Baltimore. About 11 inches of rain fell within 10 hours (5.5 inches within 3 hours) and caused flooding that resulted in 14 deaths. The most severe, widespread flooding in the region was in June 1972. Hurricane Agnes produced about 14 inches of rain within 3 days. Nineteen lives were lost, and 103 dwellings were destroyed. Damage to roads and bridges was extensive. Many crops were destroyed through erosion or sediment deposition. Decreased salinity in Chesapeake Bay severely damaged the oyster industry.

The most severe drought of record was 1930-32; 1930 was the driest year since 1869, the beginning of record. Losses to agriculture were an estimated $40 million. The 1958-71 drought was regional in extent and produced the largest recorded annual departures from average stream discharge.

Flood-plain management is provided by local government agencies, with technical and financial assistance from State agencies and the Federal Emergency Management Agency. In Maryland, 112 communities participate in the National Flood Insurance Program. Flood warnings are provided by the National Weather Service through flood-stage and weather forecasts. An automated, pilot flood-warning system using radio telemetry has been established in Baltimore and the surrounding county. Expansion into two counties between Baltimore and Washington, D.C., is expected in 1989. Water management during drought is critical to the citizens of Maryland and the District of Columbia because 72 percent and 100 percent of their respective water-use needs are provided by surface-water supplies. During droughts, streamflow volume may be insufficient to provide adequate supplies for human consumption or to dilute effluent from sewage-treatment plants and industries.

GENERAL CLIMATOLOGY

Three principal sources of moisture contribute to precipitation in Maryland and the District of Columbia (fig. 1). During summer and early fall, moisture from the Atlantic Ocean often originates from a tropical airmass having surface dewpoints greater than about 70 degrees Fahrenheit. During winter, air moving inland from the ocean at low altitudes is considered to be polar maritime in origin, although often having tropical maritime air in the upper atmosphere. Air from the Gulf of Mexico and Caribbean Sea, moving northward both east and west of the Appalachian Mountains, is considered to be tropical maritime in origin; during winter, tropical air often will overrun colder air near the land surface between the mountains and the coast. In addition to the oceans, important moisture sources include local and upwind land surfaces, as well as lakes and reservoirs, from which moisture evaporates into the atmosphere. Typically, as a moisture-laden ocean airmass moves inland, it is modified to include some water that has been recycled one or more times through the land-vegetation-air interface. In addition, during fall and winter, substantial snowfall in extreme western Maryland is produced from initially dry, arctic airmasses that accumulate moisture as they cross the Great Lakes from Canada to Maryland. Passage of a closed low aloft associated with an intense surface storm augments precipitation in all areas, especially in and near the mountains.

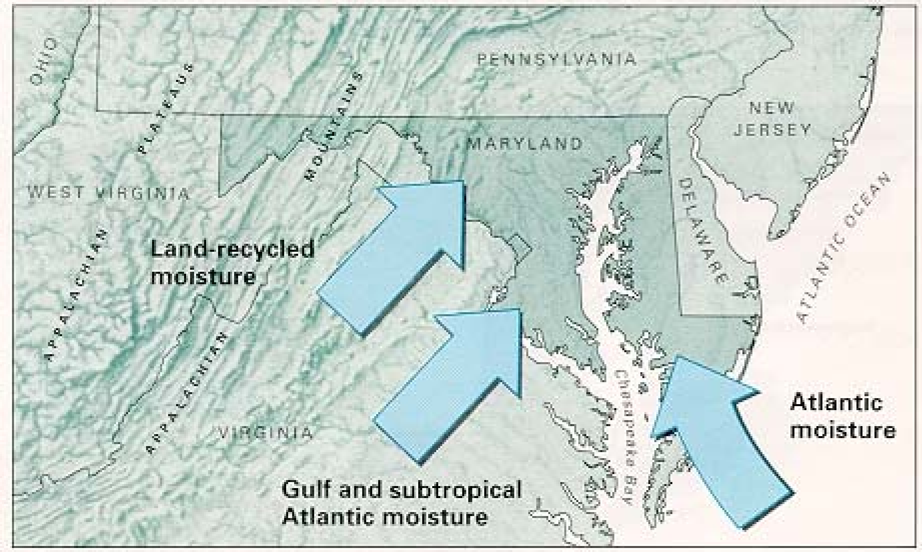


Figure 1. Principal sources and patterns of delivery of moisture into Maryland and the District of Columbia. Size of arrow implies relative contribution of moisture from source shown. (Source: Data from Douglas R. Clark and Andrea Lage, Wisconsin Geological and Natural History Survey.)

On the basis of a 30-year period of record (1951-80), statewide average annual precipitation is about 42 inches in Maryland and 43 inches in the District of Columbia. The minimum recorded average annual precipitation is 36.5 inches at Cumberland; the maximum is 47.3 inches at Oakland. The largest areal totals, exceeding 45 inches, are in extreme western Maryland, central Maryland, and southern Maryland east of Chesapeake Bay. Monthly distribution of precipitation in Maryland is uniform and averages 3-4 inches, except for a maximum of about 4-5.5 inches during the summer.

The record maximum recorded annual precipitation in Maryland was 76.5 inches at Towson in 1972. For the 12 months July 1971 through June 1972, total precipitation was 88.2 inches. This accumulation includes two exceptionally large monthly totals--20.0 inches in August 1971 and 14.4 inches in June 1972. The record minimum 1-year total was 17.8 inches at Picardy in 1930. The greatest recorded 24-hour total was 14.8 inches at Jewell on July 26-27, 1897.

Large storms sometimes cause loss of life and extensive property damage. Several types of storms can cause floods. Severe thunderstorms can affect large or localized areas, hurricanes can affect the entire region, and intense rainfall on existing snowpack has caused several notable floods in the region's history.

Large storms that produce exceptionally large quantities of precipitation generally are associated with a strong, northward-displaced Bermuda High off the Atlantic Coast. When coupled with a deeper than normal trough of low pressure over the middle United States, this pattern produces enhanced moisture flow from the southeast, which, if it persists for more than a few days, can cause intense precipitation east of the Appalachian Mountains. Storms that cause the precipitation can be either tropical or extratropical. The pattern can occur anytime, although it generally is more prevalent during the colder one-half of the year.

Most flash floods are caused by intense, localized, convective thunderstorms. These storms, which are most frequent in summer, occur in late afternoon and sometimes last well into the evening. A persistent, active frontal system lingering in the area also can gradually saturate the ground with slight to moderate rainfall for several days. Then, a single, intense storm moving along the frontal system can induce floods because of the saturated ground conditions.

Hurricanes and other convective tropical storms from the Gulf of Mexico and the Atlantic Ocean have inundated large areas with intense rainfall, commonly 6 inches or more in less than 24 hours. Flooding can be either local and sudden, or regional and prolonged.

Droughts occur when large-scale atmospheric circulation is persistently unfavorable to normal precipitation - producing mechanisms for several weeks, months, seasons, or years. A strong flow of air from the northwest tends to prevent moisture from the Atlantic Ocean and the Gulf of Mexico from reaching the area by pushing the coastal storm track further eastward. If this situation persists for more than a month, it commonly creates a drought. Another pattern that can produce a drought at any time of the year, although most often in the summer, is a strong ridge of high pressure in the upper atmosphere near the central Appalachian Mountains or mid-Atlantic area. Even though humidity in the lower atmosphere may be nearly normal, moisture aloft is deficient because of a large-scale descending flow of air that warms the airmass. A mixed layer of air extending from the surface of the Earth to a height of about 0.5 to 1 mile is capped by a warm air layer (temperature inversion) that inhibits the growth of convective clouds and decreases significant thunderstorm activity. This occurrence results in a drought that generally is augmented by excessive heat. During the winter, this pattern results in dry conditions, primarily because frontal systems are kept from the area.

MAJOR FLOODS AND DROUGHTS

Floods and droughts can have a pronounced effect on agriculture, industry, and people. Surface-water sources provide about 72 percent of the water used in Maryland and about 100 percent of that used in the District of Columbia (U.S. Geological Survey, 1986, p. 265). Any disruption of the source or quality of water supplies will have adverse effects throughout Maryland and the District of Columbia. Floods can damage structures, disrupt transportation routes, and degrade water quality. Droughts decrease available water supplies and adversely affect water quality. Water-related industries, such as fisheries, are particularly vulnerable to drought-related losses.

Several major historic floods and droughts have occurred throughout Maryland and the District of Columbia. Most of these events were areally extensive and have significant recurrence intervals--greater that 25 years for floods and greater than 10 years for droughts. These major events, and some of a more local nature, are listed chronologically in table 1; rivers and cities are shown in figure 2.

Table 1. Chronology of major and other memorable floods and droughts in Maryland and the District of Columbia, 1889-1988.

[Recurrence interval: The average interval of time within which streamflow will be greater than a particular value for floods or less than a particular value for droughts. Symbol: >, greater than. Sources: Recurrence intervals calculated from U.S. Geological Survey data; other information from U.S. Geological Survey, National Weather Service, State and local reports, and newspapers]

Flood or Drought	Date	Area affected (fig. 2)	Recurrence interval (years)	Remarks
Flood	June 1889	Potomac River basin.	50 to >100	Largest flood on record prior to the flood of 1936.
Flood	Mar. 28-30, 1924	Potomac River basin.	20 to >100	Snowmelt and intense rainfall runoff. Deaths, 5; damage $4 million.
Drought	1930-32	Statewide.	>25	Regional drought. Estimated crop losses in 1930, $40 million.
Flood	Aug. 23-24, 1933	Statewide.	10 to >100	Hurricane. Deaths, 13; damage, $12.3 million.
Flood	Mar. 17-19, 1936	Potomac River basin.	20 to >100	Thick ice, snowmelt, and intense rainfall runoff. Greatest flood since 1889.

				Damage, $2 million.
Drought	1953-56	Statewide.	10 to >25	Regional.
Flood	Oct. 14-16, 1954	North Branch Potomac and Youghiogheny River basins.	25 to >100	Hurricane Hazel. Deaths, 6; damage, $11.5 million.
Flood	Aug. 12-13, 1955	Monocacy River, Rock Creek, Anacostia River basins, and Baltimore.	5 to 10	Hurricane Connie. Fourteen lives lost when Schooner "Levin J. Marvel" sank. Damage, $2.5 million.
Drought	1958-71	Statewide	>25	Regional.
Flood	Sept. 12-13, 1960	Chester and Choptank River basins, Ocean City.	25 to 50	Hurricane Donna. Deaths, 2. Gale- to hurricane-force winds and high tides.
Flood	Aug. 1-2, 1971	Gunpowder and Back River basins.	25 to >100	Intense thunderstorm and flash floods. Deaths, 14; damage, $6.5 million.
Flood	June 21-23, 1972	Central Maryland, District of Columbia, Susquehanna River basin.	50 to >100	Hurricane Agnes. Multistate area. Greatest Maryland flood on record. Deaths, 19; damage, $80 million.
Flood	Sept. 23-26, 1975	Monocacy and Patapsco River basins.	10 to > 100	Hurricane Eloise. Fifteen bridges destroyed and 1,200 homes damaged. Damage, $6.2 million.
Flood	Feb. 24-26, 1979	Pocomoke River basin.	50 to 100	Snowmelt and intense rainfall runoff.
Flood	Sept. 5-6, 1979	Rock Creek, Jones Falls, East Branch Herbert Run	50 to >100	Hurricane David.
Drought	1980-83	Statewide, except for western part.	10 to 25	Multistate.
Drought	1984-88	Monocacy River basin, east of Baltimore, and Chesapeake	10 to 25	Estimated agricultural losses for 1986-88, $302 million.

		Bay		
Flood	Nov. 4-7, 1985	Potomac River basin.	2 to >100	Hurricane Juan combined with stationary front. Deaths, 1; damage, $5 million (nontidal) and $16 million (tidal).

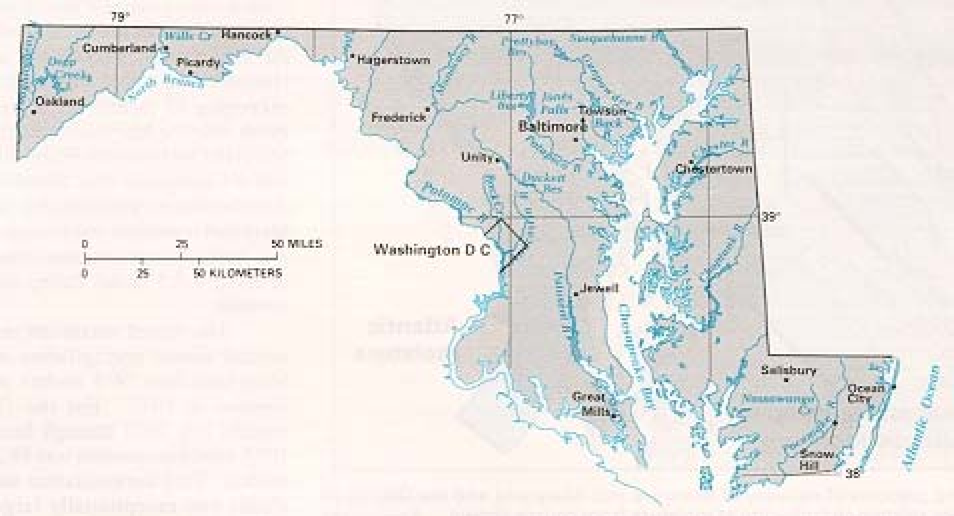


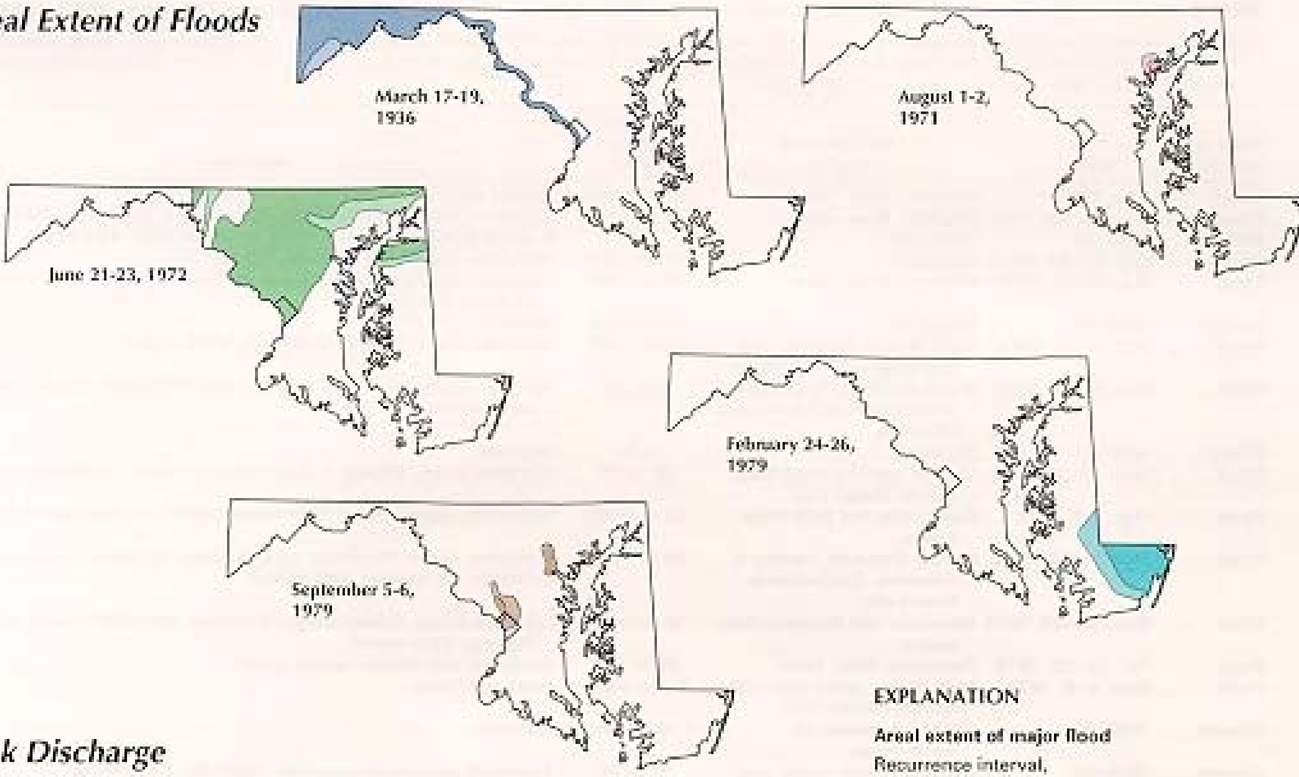
Figure 2. Selected geographic features, Maryland and the District of Columbia.

Documentation of flooding in Maryland and the District of Columbia began in the late 1800's, with records of major floods on the Potomac River in 1877 and 1889. Beginning in the 1930's, a comprehensive State and Federal program of streamflow gaging was initiated. To depict the magnitude and frequency of floods (fig.3) and droughts (fig.4) in Maryland and the District of Columbia, six streamflow-gaging stations were selected. Each has a long period of continuous records (40-60 years), is currently (1988) in operation, and is representative of hydrologic conditions in one of the principal geographic and physiographic areas of Maryland and the District of Columbia. All are located on unregulated streams. Stations were chosen to represent rural (site 2) and urbanized (site 5) areas. Streamflow data are collected, stored, and reported by water year (a water year is the 12-month period from October 1 through September 30 and is identified by the calendar year in which it ends).

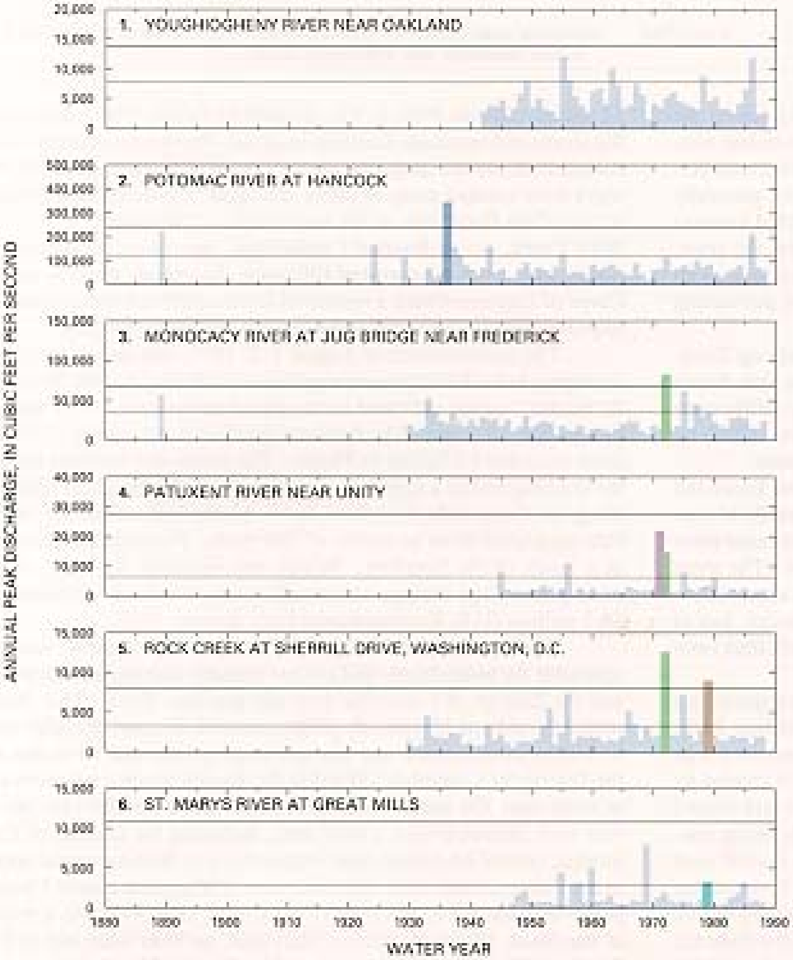
FLOODS

The five floods discussed in this section were chosen on the basis of flood magnitude, areal extent, property damage, and degree of representation of the flood for a particular geographical area. Areal extent and frequency of these floods (fig. 3) were determined by using recurrence-interval data from a network of more than 150 gaging stations. Magnitude of floods having 10- and 100-year recurrence intervals and the dates of memorable floods are also shown in figure 3.

Areal Extent of Floods



Peak Discharge



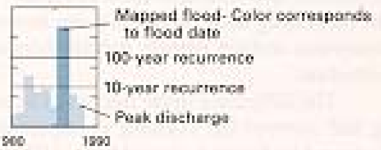
EXPLANATION

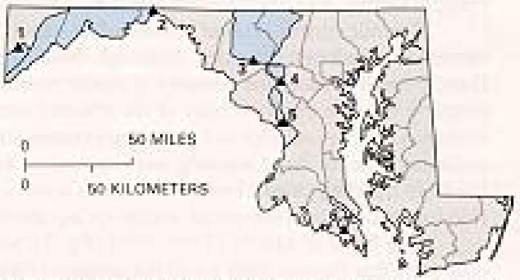
Areal extent of major flood

Recurrence interval, in years

25 to 50	More than 50	
🟦	🟦	March 17-19, 1936 (water year 1936)
🟪	🟪	August 1-2, 1971 (water year 1971)
🟩	🟩	June 21-23, 1972 (water year 1972)
🟦	🟦	February 24-26, 1979 (water year 1979)
🟫	🟫	September 5-6, 1979 (water year 1979)

Annual stream peak discharge





U.S. Geological Survey streamflow-gaging stations and corresponding drainage basins — Numbers refer to graphs

Figure 3. Areal extent of major floods with a recurrence interval of 25 years or more in Maryland and the District of Columbia, and annual peak discharge for selected sites, water years 1889–1988. (Source: Data from U.S. Geological Survey files.)

Flooding can occur during any part of the year but is most common during late winter and early spring and during the hurricane season from midsummer to early fall. Floods in late winter and early spring are caused by large frontal systems characterized by widespread steady rainfall of moderate intensity, generally from 2 to 4 inches. Many times, flooding is compounded because the ground is frozen and snow covered. The rain melts the snow, thus increasing total runoff, and the frozen ground functions as an impervious surface, thereby further increasing runoff by decreasing infiltration.

The difference in the frequency between winter-spring flooding and summer-fall flooding is imperceptible. Of the five floods illustrated in figure 3, two (March 1936 and February 1979) were caused by winter storms, two (June 1972 and September 1979) by tropical storms, and one (August 1971) by a thunderstorm.

Thunderstorm-related floods often result from localized rainfall of cloudburst intensity. Although flooding generally is confined to small streams, the intensity of thunderstorms can cause great property damage in the vicinity of the affected streams. The short timespan between rainfall and peak flows commonly does not allow sufficient time for flood warning and evacuation. As a result, loss of life from flooding caused by thunderstorms is more likely than from flooding caused by widespread winter-spring storms.

The flood of March 17-19, 1936 (fig.3), was preceded by a cold spell that formed thick ice in the streams of the Potomac River basin in western Maryland. In addition, the basin was covered with snow averaging 15 inches in depth. Rain and snowmelt caused by mild temperatures in early March saturated the ground and caused moderate rises in streamflow. By March 17, an extremely strong low-pressure system moved into the area and caused intense rainfall over the Middle Atlantic seaboard and the upper Potomac River basin. More than 4 inches of rain fell in less that 12 hours. Neither before nor since the 1936 flood have larger peak discharges in the Potomac River been recorded (fig. 3, site 2). Damage along the river was about $2 million (Grover, 1937, p. 35). A report by Grover (1937) describes the storm and resultant flooding in detail. Numerous bridges were damaged or washed away, and many miles of railroad track and highways were washed away or badly damaged. Considering the magnitude of the flood, loss of life was minimal. The peak discharge of Wills Creek, which flooded Cumberland, was twice the discharge having a recurrence interval of 100 years. As a result, the U.S. Army Corps of Engineers built a system of levees and made other channel improvements to protect Cumberland from future flooding.

The thunderstorm of August 1-2, 1971, was one of the most damaging in the Baltimore metropolitan area during the past 50 years. A "bucket" survey indicated an unofficial rainfall total of 11 inches in less than 10 hours. The National Weather Service gage in Baltimore recorded 5.5 inches in 3 hours. The storm and resultant floods are documented in a report by Carpenter (1974). Floods at stations along the Gunpowder and Back River basins had recurrence intervals equivalent to or in excess of 100 years. Fourteen people died as a result of the flooding. Bridge and roadway washouts were widespread. Total damage attributable to the flood was estimated at $6.5 million (U.S. Environmental Data Service, 1971).

The flood of June 21-23, 1972 (Hurricane Agnes), was responsible for more deaths and greater property damage in Maryland and the District of Columbia than any previous flood. This flood probably ranks as Maryland's greatest natural disaster. Rainfall was 14 inches in Baltimore and the surrounding area and 10 inches in the District of Columbia. Flood peaks having recurrence intervals of more than 100 years (some as much as twice the 100-year interval) were recorded over a wide area, including the District of Columbia, central Maryland from Hagerstown to Baltimore and north to the Pennsylvania State line, and parts of Maryland east of Chesapeake Bay and north of Chestertown (fig. 3, sites 3-5). As a result of the flood, 19 people died in Maryland; no lives were lost in the District of Columbia. The American Red Cross in Maryland reported 103 houses destroyed and 1,930 damaged, 17 farm buildings destroyed and 44 damaged, and 82 small businesses destroyed. Damage to residential, farm, and business structures was estimated at $48.5 million (National Oceanic and Atmospheric Administration, 1972, v. 76, no. 6, p. 63). Damage to State roads and bridges in Maryland was estimated to be $6.5 million and to county roads and bridges, $25 million (National Oceanic and Atmospheric Administration, 1972, v. 76, no. 6, p.63). Flooding along the larger streams and rivers severely damaged or destroyed crops through erosion or silt deposition. Excessive runoff into Chesapeake Bay decreased salinity levels and severely affected the shellfish industry. Damage to the industry was estimated to be somewhat less than that attributed to Hurricane Camille in 1969. Hurricane Agnes is described in greater detail in a report by Bailey and others (1975).

Flood of June 22, 1972 (Hurricane Agnes) on the Patuxent River at Laurel, Md. Flooding in Laurel along Main Street. (Photograph by Dennis F. Gillen, U.S. Geological Survey.)

Before 1979, significant storms in Maryland east of Chesapeake Bay that produced peak discharges having recurrence intervals greater than 50 years were not areally extensive. On February 19, 1979, however, a winter storm left 10 to 18 inches of snow in the area around Salisbury and Snow Hill. Moderating temperatures melted the snow, and the ground became saturated. During February 24-26, about 4 inches of rain was recorded in Salisbury and Snow Hill. Floods on the Pocomoke River and Nassawango Creek caused discharges nearly equal to those expected once in 100 years, on average. No lives were lost. Damage to property was minimal, as these streams are in an agricultural region. Some roads were temporarily closed when floodwaters covered low-lying bridge approaches.

Flooding that resulted from the storm of September 5-6, 1979 (Hurricane David), was confined to two small, widely separated areas. The hurricane began off the southeastern coast of Florida and moved northward along the Florida and Georgia coasts. After making landfall near Savannah, it moved inland, turned north, passed through the Carolinas, and entered Virginia. From there the hurricane moved northeastward through Washington, D.C., Baltimore, and into Pennsylvania and New Jersey. Rainfall of 5-6 inches was recorded north and northeast of Washington, D.C. On the western side of Baltimore, more than 4.5 inches was recorded. The flood on Rock Creek at Sherrill Drive, Washington, D.C. (fig. 3, site 5) had a discharge of about 1.5 times the discharge having a 100-year recurrence interval. In the Patapsco River basin on the western side of Baltimore, flood discharges on Jones Falls and East Branch Herbert Run (in western Baltimore) had recurrence intervals greater than 50 years. Damage from the flood was minimal in Baltimore and Washington, D.C.

DROUGHTS

A simple definition of drought, such as "extended period of dry weather," is an easily understood concept. Droughts, however, differ greatly in their extent, duration, and severity; these differences make quantitative analyses and comparisons among droughts difficult. A drought can affect many States and last 10-15 years, as during the 1960's. However, a drought affecting one or two counties and lasting 3-6 months may be more devastating locally.

A drought analysis summary for Maryland and the District of Columbia is presented in figure 4. Annual departures from average streamflow were determined, and recurrence intervals were assigned to droughts by using data from 38 gaging stations. The graphs indicate annual departures for six representative drainage basins. Large negative departures indicate periods of extreme drought. Positive departures indicate periods of greater than average streamflow. Four droughts of significant extent and duration are evident: 1953-56, 1958-71, 1980-83, and 1984-88. Although data are insufficient to define the extent of the 1930-32 drought, it probably was the most severe agriculture drought ever recorded in Maryland and the District of Columbia. Rainfall during that period was about 40 percent less than average. The year 1930 was the driest year since 1869. Crop losses for 1930 were estimated at $40 million (U.S. Weather Bureau, 1930, v. 35, no.13).

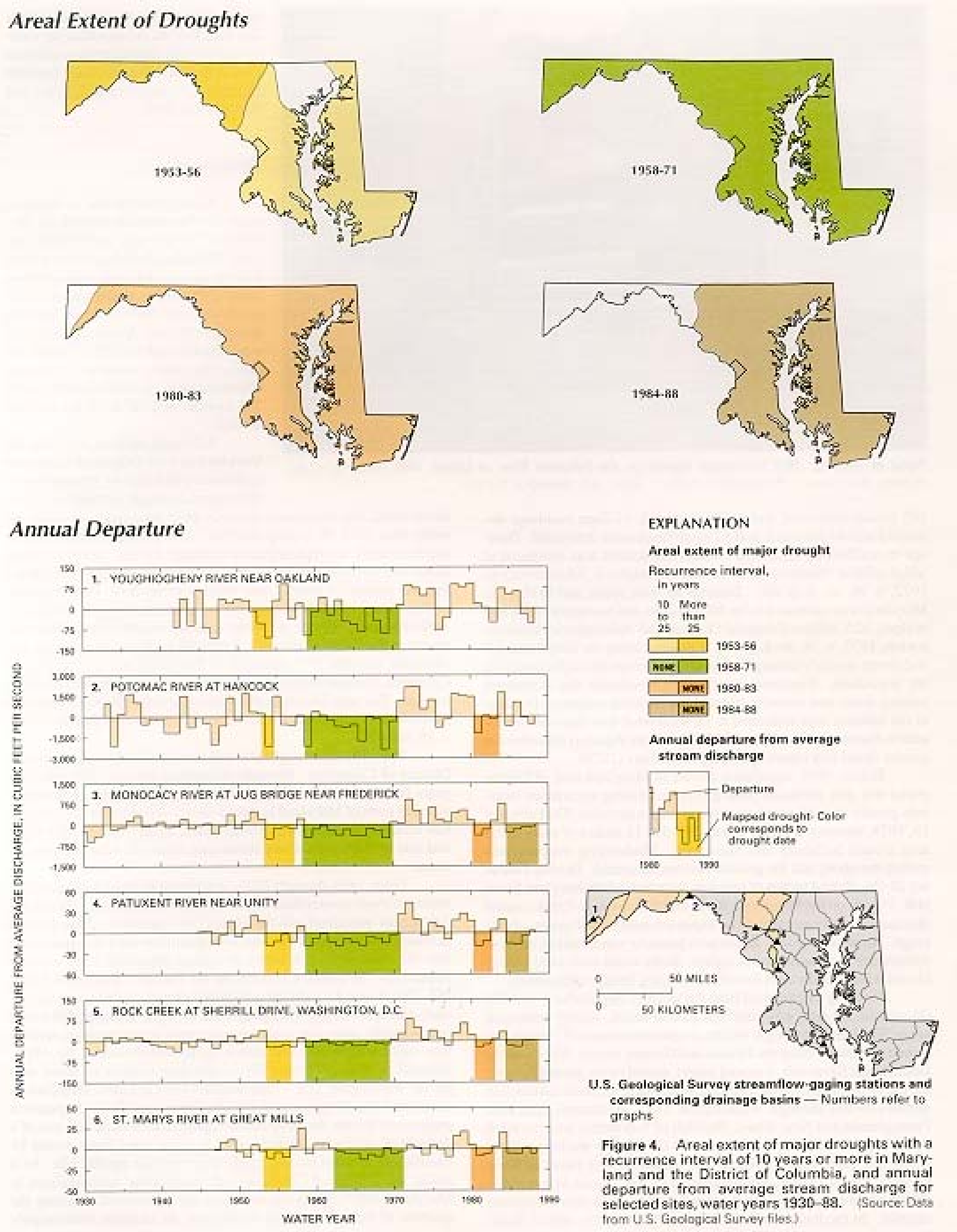


Figure 4. Areal extent of major droughts with a recurrence interval of 10 years or more in Maryland and the District of Columbia, and annual departure from average stream discharge for selected sites, water years 1930–88. (Source: Data from U.S. Geological Survey files.)

The 1953-56 drought affected almost all of Maryland and the District of Columbia. Drought recurrence intervals exceeded 25 years for those areas of Maryland west of Baltimore. For the remaining parts of Maryland and the District of Columbia, the drought had recurrence intervals of 10-25 years, except for the area north and east of Baltimore where recurrence intervals were less than 10 years.

From 1958 through 1971, a regional drought having recurrence intervals greater than 25 years caused streamflow deficiencies throughout Maryland and the District of Columbia. This drought persisted the longest of the four droughts illustrated in figure 4 and was the most severe in terms of annual departure from average streamflow. Streamflow records for the Patuxent River near Unity, Md. (fig. 4, site 4), indicate a negative departure from average annual streamflow nearly each year of the drought. Even though yearly rainfall totals were less than the long-term yearly average, rainfall was sufficient to prevent major agricultural losses. By 1966, streamflow in the Potomac River--the major source of water supply for Washington, D.C.--had declined to record lows. Withdrawals accounted for 80 percent of the available river flow. Population projections for the Washington metropolitan area indicated that, if a drought of similar magnitude were to recur, river flows would be insufficient to meet human needs and maintain aquatic life. As a result, the District of Columbia and surrounding municipalities in Maryland and Virginia signed water-use agreements limiting the quantity of water that can be withdrawn. In addition, water-supply structures were built in the Potomac River basin to augment streamflow during periods of large consumptive use.

The 1980-83 drought affected all but the westernmost part of Maryland. Recurrence interval of the drought was about 10 to 25 years throughout the affected area. The extent to which streamflow decreased during this drought is similar to that during the 1958-71 drought (fig. 4). No major agricultural drought developed, and water supplies were adequate for public supply use.

The last drought evaluated began in the fall of 1984 and continued through the summer of 1988. The drought affected Maryland east and south of Frederick and the District of Columbia. The recurrence interval for this drought ranged from 10 to 25 years. Many counties in Maryland were declared disaster areas because of large agricultural losses during the summers of 1986 and 1987. Losses for 1986, 1987, and 1988 were estimated to be $89, $113, and $100 million, respectively (Tony Evans, Maryland Department of Agriculture, oral commun., 1988). Water supplies for municipalities did not become critically low, although several towns restricted water use during each summer.

All six streamflow-departure graphs in figure 4 indicate that droughts have occurred about once every 10 years since 1930 but differed in severity and duration. Annual departure generally was most severe at the end of the 1958-71 drought. Greater than average streamflow in Maryland and the District of Columbia has alternated with short periods of less than average streamflow.

WATER MANAGEMENT

Contingency planning and response to floods or droughts require coordination and cooperation at Federal, State, county, and local levels of government. Responsibilities need to be defined for flood-plain management, flood-warning systems, and water-use management during droughts. In 1931, the General Assembly of Maryland established a Water Resources Commission to address conservation, allocation, and development of water resources in Maryland. The commission was to formulate a water conservation policy; control the priority, period, place, and quantity of use of water, and regulate streams to control floods and supplement low flows. Today, the Water Resources Administration of the Maryland Department of Natural Resources continues to respond to floods and droughts through its Flood Management and Water Supply Divisions. In the District of Columbia, the U.S. Army Corps of Engineers, the Department of Consumer and Regulatory Affairs, and the Office of Emergency Preparedness are responsible for water management.

Flood-Plain Management.--Flood hazards were addressed specifically by the Maryland General Assembly through the Flood Hazard Management Act of 1976. This legislation authorized a program to identify, prevent, and mitigate flooding. Today, the Flood Management Division of the Water Resources Administration implements a three-phase program that includes technical watershed study, flood-management-plan development, and funding.

Technical watershed studies, which are performed in cooperation with local jurisdictions and other State agencies, include determination of the history of flooding in a watershed and identification of areas subject to flooding. The studies determine the magnitude and frequency of floods and investigate the effects of floods on planned development. Alternative management techniques to control flooding and minimize flood damage are identified and evaluated. Watershed studies are funded through the Comprehensive Flood Management Grant Program. In addition, the Waterways Permit Division regulates flood-plain encroachment by issuing permits for any development on flood plains inundated by a flood having a recurrence interval of 100 years; the regulation applies to flood plains of nontidal streams and tidal wetlands.

Flood-Management plans are developed by local governments, with assistance from the State Flood Management Division, to guide activities in a watershed so that existing and potential flood hazards are minimized. Alternatives for hazard mitigation with regard to environmental, social, and economic concerns are considered. Local jurisdictions must develop a flood-management plan to be eligible for grant funds for flood-management projects.

The Flood Management Division serves as State coordinator for the National Flood Insurance Program of the Federal Emergency Management Agency. Presently (1988), 112 communities participate in the program by adopting ordinances that control development within flood plains inundated by floods having a 100-year recurrence interval.

Flood-Warning Systems.--An automated flood-warning system is operated in Baltimore and the surrounding county. The network is composed of streamflow-gaging stations and precipitation gages in upstream areas that are linked by radio to receiving stations. The National Weather Service operates a network of nine flood-forecast stations within Maryland and the District of Columbia. The Flood Management Division provides technical assistance for development and implementation of automated flood-warning systems.

Water-Use Management During Droughts.--In Maryland, the Water Supply Division of the Water Resources Administration is responsible for implementing water appropriation law. The Division consists of two interrelated and closely coordinated sections--the Water Appropriation Permit Section and the Water Supply Planning and Engineering Section. The Water Appropriation Permit Section analyzes the potential effect of individual appropriation requests on water resources and on other users of the resources. The Water Supply Planning and Engineering Section analyzes the areawide effects of collective water appropriation in view of a region's future water supply and demand. The results of this analysis are used to identify regional water-supply problems and to formulate management alternatives of resolving those problems. Although water supplies are currently adequate, rapid expansion of the community may increase the demand for water and cause severe shortages during the next prolonged drought.

In 1981, the Water Supply Division developed a Response Plan for Drought and Other Water-Shortage Emergencies. The plan provides for mitigating potential hardships by effective water-resources management and protection. The response plan lists actions that can be taken on the basis of existing authority to assist water suppliers in dealing with drought and other water-shortage emergencies. Potential actions include mitigation, preparedness, response, and recovery.

Mitigation involves management and planning activities to prevent or decrease the potential for water-shortage emergencies. These activities include watershed planning and development of supplemental supplies, water-conservation programs, and local drought and water-shortage emergency plans. Preparation and response activities incorporate various monitoring, alert, and response actions designed to provide timely and useful information and assistance during actual or impending water shortages. These actions include drought-monitoring programs, identification of emergency supply sources, and control of water withdrawals through the water appropriation permit program. Finally, recovery identifies actions to be taken after a water-shortage emergency, including a review of the response and technical assistance.

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Prepared by R.W. James, Jr., U.S. Geological Survey; "General Climatology" section by W.J. Moyer, Maryland State Climatologist, and A.J. Wagner, National Oceanic and Atmospheric Administration; "Water Management" section by G.T. Setzer, Maryland Department of Natural Resources

FOR ADDITIONAL INFORMATION: District Chief, U.S. Geological Survey, 8987 Yellow Brick Road, Baltimore, MD 21237, *info@md.water.usgs.gov*

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