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Evaluation of the Streamflow-Data Program in Pennsylvania

U.S. Geological Survey
Water-Resources Investigations 82-21

Prepared in cooperation with the
Pennsylvania Department of Environmental Resources

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By Herbert N. Flippo, Jr.

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December 1982

UNITED STATES DEPARTMENT OF THE INTERIOR

JAMES G. WATT, SECRETARY

GEOLOGICAL SURVEY

Dallas L. Peck, Director

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The following factors may be used to convert the inch-pound units published herein to the International System of Units (SI).

Multiply Inch-pound Units	By	To obtain SI units
square miles (mi^2)	2.590	square kilometers (km^2)
cubic feet per second (ft^3/s)	0.02832	cubic meters per second (m^3/s)

EVALUATION OF THE STREAMFLOW-DATA PROGRAM IN PENNSYLVANIA

By Herbert N. Flippo, Jr.

ABSTRACT

The stream-gaging program in Pennsylvania is subject to budgetary constraints in the next several years. Elimination of those gaging stations that have no current-purpose use and little utility in providing regional flow-characteristic information is the most effective way to reduce costs.

The efficient design of a network of gaging stations for obtaining regional information requires knowledge of the information in the data base and an assessment of the potential for improving the accuracy of data-transfer mechanisms. The analytical technique known as Network Analysis for Regional Information is used to assess acquired streamflow information and to evaluate its transferability within previously determined regions of homogenous streamflow characteristics. Regression equations that relate low-, mean-, and flood-flow characteristics to basin parameters are the data-transfer mechanisms used in the evaluation. This analysis showed that only minor improvements in the regression equations can be expected after 20 additional years of data collection at gages in the 1980 program. Transfer mechanisms with less model error are needed for improved data transferability.

A more efficient program can be achieved by discontinuing selected gages in the planning-and-design network. To this end, 11 continuous-record and 25 partial-record gages were selected to be discontinued by April 1, 1980. Additionally, 6 continuous-record and 29 partial-record gages are suggested to be discontinued at the end of the 1985 water year.

INTRODUCTION

Purpose and Scope

Continuing increases in cost of operations, restrictions on funds and manpower, and expanding needs for more kinds of hydrologic information have made necessary the design of a more efficient stream-gaging program for Pennsylvania.

Information on streamflow characteristics can be used both for the data-collection site and to develop information-transfer mechanisms that will provide reliable estimates of flow characteristics at sites for which little or no data are available. Consequently, in anticipation of needs for streamflow data at sites removed from management gages, there has been a gradual accretion in planning-and-design gages whose records could be used to derive better data-transfer mechanisms. Most planning-and-design gages have been operated on small streams with the objective of developing a capability for providing estimates of flow characteristics with a 10-year-record equivalency at any point on any stream (Page, 1970). An evaluation of streamflow data was needed to determine how well data-transfer goals have been met and to assess the future worth of data collected at planning-and-design gages for achieving improved data-transfer capability. This report summarizes the findings of such an evaluation.

As an improvement upon the methodologies of earlier program reviews, this study uses a statistical procedure for evaluating the utility of operating stream gages to transfer data from collection sites to other sites where streamflow information is needed. Information can be transfered by applying regional logarithmic regression equations that have been developed by regression of observed streamflow characteristics against basin characteristics. Such equations are available for estimating flood discharge, mean streamflow, and low-flow discharges of most unregulated streams in Pennsylvania. The statistical procedure used to evaluate the potential for improving data-transfer capabilities, in the context of accumulated records and the regression equations thus far developed, is known as Network Analysis for Regional Information (NARI). As a tool for network management, the results of the NARI evaluation can be most readily applied in assessing of the utility of gages operated solely for planning and design purposes.

For a particular regression equation, use of NARI techniques permits the network manager to specify the inherent limits of accuracy for information transfer and allows quantitification of tradeoffs between numbers of gaging stations and record lengths. Thus, with the objective of optimizing, within budgetary and other practical constraints, the information content of streamflow records, the network manager can use the NARI results to make sound decisions on how much effort should be expended on continued collections of streamflow records by present gages, on establishing new gages, and on developing better data-transfer models.

In this program evaluation, the NARI procedure was applied to statistical characteristics of regional regression equations derived for estimation of average (annual mean) discharge, 0.02 and 0.01 probability flood discharges, and 7-day, 10-year low-flow discharges. The information content in the means of annual peaks and 7-day minimum discharges, as well as that in the standard deviations of mean annual discharges, annual peaks, and annual 7-day minima, were also evaluated by the NARI procedure.

On the basis of the NARI evaluation, suggestions are made for modification of the gaging program, particularly for discontinuing gages in the planning-and-design network. Managerial, legal, and contingency justifications for operation of individual gages, many of which have not been previously documented, are also noted, but not evaluated.

Previous Network Reviews

The stream-gaging program of the U.S. Geological Survey in Pennsylvania has evolved largely in response to needs for specific data. Locations of the various types of stream gages operated in the 1980 water year are shown on the map of figure 1. Periodic reviews have served to modify the several networks in the gaging program to more effectively meet changing needs of surface-water managers and to obtain background hydrologic information with transfer value. These reviews have not always been technically adequate in assessing the potential for improving information-transfer capabilities by means of additional record collections at nonmanagement gages.

The first program review for Pennsylvania that assessed some of the information content of available streamflow data was made by Page (1970). This study used observed standard errors of estimate, as measures of predictive accuracy, for 34 regression equations of statewide applicability that related an equal number of streamflow characteristics to the most significant of 12 basin characteristics. These standard errors of estimate were compared with those calculated, from a theoretical relation between standard error and index of variability, for record equivalencies of 10 years for minor streams--those draining less than 500 mi^2--and 25 years of major streams in Pennsylvania. This comparison showed the equivalency objectives for minor streams to have been generally met only for the means and standard deviations of annual and monthly flows. The standard errors of regression showed the accuracy goals for major streams had not been met. Subsequently, Page recommended only 20 of the 101 continuous-record gaging stations then in operation for planning and design purposes for further review to determine if usage of their data for other purposes was sufficient to warrant continued record collections.

Cursory annual reviews of the gaging program resulted in discontinuance of only 1 of these 20 gages in the 10-year period ending with the 1979 water year. However, in the same period, 42 other of the 247 gages in operation in 1970 were discontinued, and 7 gages were changed from continuous-record to partial-record operation. These changes resulted primarily from reassessments of current-purpose needs by cooperators and by managers of special-purpose hydrologic studies.

USE AND PUBLICATION OF STREAMFLOW DATA

Streamflow data collected by the U.S. Geological Survey (USGS), which consist primarily of stage and discharge records, are regularly used by State, Federal, and local agencies, as well as by engineering consultants. Usage by educational institutions is less frequent. Direct usage by the public is most commonly recreation oriented. Table 1 briefly describes types of streamflow data and their usage in both raw form and as statistical summarizations.

It has been the practice of the Survey to publish compilations of streamflow and water-quality data systematically. Records of stage and discharge of streams, as well as contents and stage of lakes and reservoirs, were first published for calendar years 1907-08 in the U.S. Geological Survey series titled "Surface Water Supply of the United States." Subsequently, this water-supply paper was published annually for records collected through September 30, 1960. Five-year compilations were published for 1961-65 and 1966-70. Monthly and yearly summaries of streamflow data were compiled in two reports: "Compilation of Records of Surface Waters of the United States through September 1950" and "Compilation of Records of Surface Waters of the United States, October 1950 to September 1960." Records of chemical quality, water temperatures, and suspended sediment were published annually from 1941 through 1970 in a series of water-supply papers titled "Quality of Surface Waters of the United States."

Streamflow data were published annually for water years 1961 through 1974 in the cooperative reports "Water Resources Data for Pennsylvania, Part 1." Quality data were presented in Part 2 of this series. For water years beginning with 1975, data for streamflow, water quality, and ground water are published in reports of similar titles, but also designated "Water Resources Data, Pennsylvania, Water Year ___," after which follows the water year and a volume code for the relevant major drainage basin. Most quality-of-water information published in this series for 1975-78 water years, except for quality monitor and sediment data, were collected by the Pennsylvania Bureau of Water Quality. Beginning with 1979, only quality of water information collected by USGS has been included in this series.

Table 1.--Types of streamflow data and their commonly used summarizations

Gage type[1]	Data type		Commonly used summarizations of data
	Systematic	Irregular	
N,Y	Stage--continuous or one or more recordings per hour	High-water mark profiles	Stage frequency--floods Stage profiles--floods
	Discharge--periodic measurements; instantaneous and daily flow via stage-discharge relationship	Channel geometry and hydraulic characteristics	Hydrographs--stage, discharge Flow characteristics: Mean (daily, monthly, annual) discharge rates and volumes, plus basic statistics Discharge frequency--floods and low-flows Discharge duration (cumulative-frequency distribution) Mass curves (double, residual) of discharge Channel geometry and hydraulic characteristics
CSG	Stage--peaks and occasional observations	High-water mark profiles	Stage frequency--floods
	Discharge--occasional measurements; peak discharge via stage-discharge relationship	Channel geometry and hydraulic characteristics	Discharge frequency--floods
LF	Stage--occasional observations		
	Discharge--occasional measurements		Discharge frequency--low flows
CLF	(Combination of CSG and LF	types)	Discharge frequency--floods and low flows Stage frequency--floods
R	Stage--continuous		Stage hydrographs
WW	Stage--periodic, usually one or more daily observations	Discharge measurements	Stage hydrographs
PG	Stage--continuous Storage contents of reservoirs		Stage hydrograph Content variations
AP	Stage--peaks only		Stage frequency--floods

[1]See table 2 for explanation of codes.

Results of interpretive studies on the availability and distribution of streamflow, the effects of drought and flood, the chemical character of surface waters, and the relationships between surface waters and ground waters are presented in publication series of the Survey, including professional papers, water-supply papers, bulletins, circulars, hydrologic-investigations atlases, open-file reports, and water-resources investigations. Catalogs of these publications are published monthly under the title "New Publications of the Geological Survey." Findings of investigations made in cooperation with the Pennsylvania Department of Environmental Resources are usually published in a series of that agency.

PRESENT STREAM-GAGING NETWORK

Legal Authority for Data Collection

Most collections of data on streamflow, on contents of lakes and reservoirs, and on the quality of surface waters are related to use and conservation of water resources. In Pennsylvania, use of these resources is under the riparian rights doctrine of common law, which provides no mechanism for determining availability or scarcity of the resources before investments are made or conflicts among users arise. Consequently, virtually all streamflow data are collected under cooperative agreements between the U.S. Geological Survey (USGS) and other agencies and within the scopes of their respective agency missions. Under these agreements, Federal agencies fund the entire costs of data collections made for them by USGS. State and local governments are required by law (Public Law 70-100) to fund at least 50 percent of cooperative scientific and technical investigations.

Enabling legislation and regulatory policies that provide the authority to operate gaging stations and collect stream-related data are summarized below.
U.S. Geological Survey--Congress makes specific appropriations, annually, for gaging streams and performing functions related to water resources. For example, Public Law 96-126 (93 Stat. 961) makes appropriations (under 93 Stat. 954) to the Department of the Interior "...to perform surveys, investigations, and research covering...water resources of the United States, its territories and possessions, and other areas as authorized by law." Authority for the Secretary of the Interior to acquire lands and easements"...for use by the Geological Survey in gaging streams and underground water resources" is given by the Act of December 24, 1942 (56 Stat. 1086), as amended (U.S.C. 36 b).

Pennsylvania Department of Environmental Resources--Authority to perform water-resource investigations by this principal gaging-network cooperator is contained in Section 1804 of the Administrative Code of 1929, that provides: (c) "To collect such information relative to the existing conditions of the water resources of the State as, in the opinion of the department, shall be necessary for the utilization of waters, and for the conservation, purification, development, and equitable distribution of water and water power resources..."; (d) "To establish and maintain gauging stations on rivers and their tributaries"; and (f) "To maintain a complete inventory of all the water resources of the Commonwealth; collect all pertinent data, facts, and information in connection therewith; classify, tabulate, record, and preserve the same...".

U.S. Army Corps of Engineers--Since passage of the General Survey Act of 1824, Congress has authorized, through various Public Laws, specific Corps projects for the development and management of water resources. In keeping with its mission to design, construct, operate, and maintain major river and harbor projects, streamflow data are acquired, usually under agreements with USGS, as needed to meet project objectives.

Federal Energy Regulatory Commission--Utility companies licensed by this agency must obtain flow records near the site where they regulate or divert a stream. The usual procedure in obtaining these records is for the Commission to contract with USGS to collect the required data, for which the utility company reimburses the Commission.

U.S. Soil Conservation Service--The Watershed Protection and Flood Prevention Act (P.L. 566), as amended (P.L. 95-113, 91 Stat. 913) authorizes the agency "...to conduct such investigations and surveys as may be necessary to prepare plans for works of improvement...", and "...to obtain the cooperation and assistance of other Federal agencies in carrying out..." these plans.

Other Cooperators--Several cities, counties, and water authorities, operating under their respective statutes and ordinances, provide at least 50 percent of the funds for streamflow-data collections at 24 gages in the State.

Summary of Gaging Stations

Stream gages operated by the Pennsylvania District of the U.S. Geological Survey, as of October 1, 1979 (fig. 1), are listed in downstream order in table 2. The first two digits, and zeroes that immediately follow, of the 8-digit station numbers have been omitted in figure 1. The last two digits are also omitted where equal to zero; otherwise, they are set off by a decimal. Miscellaneous flow-measurement and sampling sites are not included in table 2. Coded entries in the column headed "Data Usage By A Cooperator" show the interests in streamflow records that have been reported by the various cooperating agencies. Much of the cooperator support in data collections is for ongoing managerial programs in water-quality surveillance, pollution abatement, flood forecasting, flood control, flood-plain management, water-supply monitoring, hydropower generation, and water-resource assessment. This study makes no attempt to evaluate or justify cooperator support of gage operations for specific design. The utility of gage operations for these purposes, even those that rely in part on flow characteristics estimated through use of a regional regression equation, cannot be adequately addressed through NARI procedures. Some gaging activities are supported by cooperators wholly or partly on the basis of agreements with third-party agencies. In such cases, third-party usage has been considered "cooperator usage."

Applications of streamflow data by parties other than cooperators are documented in table 2 under "Other usage." This category of usage, which has not been inventoried in detail, provides a rough measure of nonsupportive use of the records.

Current usage of data by the USGS that is directly related to data collections funded under a specific investigative study is noted in table 2. Some indicated uses are contingent upon interpretative analysis made by the Survey under a separate cooperative agreement with a cooperator. For example, many partial-record gages are operated primarily to provide information for planning and design--usage class P--on the part of the cooperating agency. However, final summarizations of the data into forms suitable to the purposes of that agency are usually done by the USGS.

Table 2.--Stream gages operated by the Pennsylvania District of USGS and known usage of collected data

[Key to: Gage type and accessory equipment--

AP - Annual peak stage recorder (no daily discharge)
CSG - Crest-stage, partial-record gage
CLF - Both crest-stage & low-flow, partial-record gage
D - 'DARDC' data transmitter
G - 'GOES' satellite data transmitter
LF - Low-flow, partial-record gage
N - Network, continuous-record gage
PG - Pool-stage recorder
QW - Automatic water quality monitor
R - Continuous stage recorder (no discharge)
S - Automatic sediment sampler
TH - Thermograph
TM - Telemark stage interrogator
WW - Rated wire-weight gage
Y - Special purpose, continuous-record gage

Data usage--

BC - Discharge for biological and chemical sampling
C - Discharge for chemical sampling
FF - Federal flood forecasting
IM - Monitor impoundment inflow
L - Compact or legal requirements
LM - Monitor impoundment level
MP - Monitor for public or industrial withdrawal
MW - Monitor for industrial waste-water release
OM - Monitor impoundment outflow
ORG - Organic load determinations
OSM - Federal mine-drainage assessment
P - Flow characteristics for planning and design
QW - Stage and discharge for water quality monitor
RO - Rainfall-runoff modeling
RR - Reservoir regulation
SED - Sediment load determination
SHF - Self-help local flood forecasting
SMR - State mine restoration study
T - Long-term trend of flow
WQR - Water-quality relationships
/M Monthly sampled collected
/Q Quarterly sample collected]

Table 2.--Stream gages operated by the Pennsylvania District of USGS and known usage of collected data

Delaware River Basin

Gage No.	Station Name	Area (Mi^2)	Year Record Began	Gage Type	Accessory Equipment	Data Usage By A Cooperator	Other Usage
01427650	N Br Calkins Cr nr Damascus	7.0	1962	CSG		P	
01427950	W Br Lackawaxen R nr Aldenville	40.6	1975	CLF		P;IM	
01428900	W Br Lackawaxen R at Prompton Res	59.6	1960	PG		LM;FF	
01429000	W Br Lackawaxen R at Prompton	59.7	1944	Y	TM	OM;RR	
01429300	Dyberry C ab Res nr Honesdale	45.8	1975	CLF		P;IM	
01429400	Gen Edgar Jadwin Res nr Honesdale	64.5	1959	PG		LM;FF	
01429500	Dyberry Cr nr Honesdale	64.6	1943	Y	TM	P;OM;RR	
01430000	Lackawaxen R nr Honesdale	164.	1974	CSG		P;OM	
01431000	Middle Cr nr Hawley	78.4	1945	CSG		P	
01431500	Lackawaxen R at Hawley	290.	1938	N	TM	BC/M;FF;RR	FF
01431680	Mill Brook nr Paupack	4.8	1960	CSG		P	
01432000	Wallenpaupack Cr at Wilsonville	228.	1909	Y		OM;L	
01438300	Vandermark Cr at Milford	5.4	1962	CSG		P	
01439500	Bush Kill at Shoemakers	117.	1908	N		T;BC/M	
01440300	Mill Cr at Mountainhome	5.8	1961	CSG		P	
01440400	Brodhead Cr nr Analomink	65.9	1957	Y		BC/M	
01440900	McMichaels Cr nr Stroudsburg	63.9	1975	CLF		P	
01442500	Brodhead Cr at Minisink Hills	259.	1950	N		T;BC/M	
01446600	Martins Cr nr East Bangor	10.4	1961	CLF		P	
01446650	Martins Cr at Martins Creek	43.4	1970	LF		P	
01446900	Bushkill Cr nr Easton	72.	1970	LF		P	
01447500	Lehigh R at Stoddartsville	91.7	1943	Y	TM	C/Q;IM;FF;RR	FF
01447680	Tunkhannock Cr nr Long Pond	18.	1965	Y		MP	
01447720	Tobyhanna Cr nr Blakeslee	118.	1961	Y	TM	BC/M;IM;FF	FF
01447780	Lehigh R at F. E. Walter Res	289.	1961	PG	TM	LM;FF	

Table 2.--Stream gages operated by the Pennsylvania District of USGS and known usage of collected data--(continued)

Delaware River Basin

Gage No.	Station Name	Area (Mi^2)	Year Record Began	Gage Type	Accessory Equipment	Data Usage By A Cooperator	Other Usage
01447800	Lehigh R bl F. E. W. Res Nr W. Haven	290.0	1957	Y		OM;RR	
01448500	Dilldown Cr nr Long Pond	2.4	1948	N		P;T	
01449000	Lehigh R at Lehighton	591.	1977	WW		FF	
01449360	Pohopoco Cr at Kresgeville	49.9	1966	Y	TM/TH	IM;FF;RR	
01449790	Pohopoco Cr at Beltzville Lake	96.3	1971	PG	TM	LM;FF	
01449800	Pohopoco C bl Beltzville Dam	96.4	1967	Y	TH	OM;C/Q	
01449850	Sawmill Run bl Beltzville Lake		1979	WW		FF	
01450000	Pohopoco Cr at Parryville	109.	1941	WW		FF	C/Q
01450455	Buckwha Cr at Little Gap	42.5	1975	CLF		P	
01450500	Aquashicola Cr at Palmerton	76.7	1939	N		BC/M	
01451000	Lehigh R at Walnutport	889.	1946	Y	TM	BC/M;FF;RR	FF
01451192	Lehigh R at Allentown	1037.		WW		FF	
01451500	Little Lehigh Cr nr Allentown	80.8	1945	N		T;BC/M;P	
01451800	Jordan Cr nr Schnecksville	53.	1966	Y		P;T	
01452000	Jordan Cr at Allentown	75.8	1944	N		T;BC/M;P	
01452300	E Br Monocacy Cr nr Bath	5.3	1962	CLF		P	
01452500	Monocacy Cr at Bethlehem	44.5	1948	N		T;C/O;P	
01453000	Lehigh R at Bethlehem	1279.	1909	Y	TM	T	WQR;BC/M
01454600	Polk Valley Run at Hellertown	2.1	1963	CSG		P	
01454700	Lehigh R at Glendon	1359.	1966	Y		BC/M	WQR
01458900	Tinicum Cr nr Ottsville	14.7	1971	CLF		P	
01459500	Tohickon Cr nr Pipersville	97.4	1935	N		T;BC/M	
01465500	Neshaminy Cr nr Langhorne	210.	1934	Y	TM	C/M;FF	FF
01465770	Poquessing Cr at Trevose Rd, Phila	5.1	1964	Y		C/M;WQR;P	
01465780	Poquessing Cr ab Byberry Cr, Phila	13.2	1965	CSG		P	

Table 2.--Stream gages operated by the Pennsylvania District of USGS and known usage of collected data--(continued)

Delaware River Basin

Gage No.	Station Name	Area (Mi^2)	Year Record Began	Gage Type	Accesory Equipment	Data Usage By A Cooperator	Other Usage
01465795	Byberry Cr at Grant Ave, Phila	7.1	1964	CSG		P	
01465798	Poquessing Cr at Grant Ave, Phila	21.4	1965	Y		C/M;WQR	
01467036	Pennypack Cr Tr at Hatboro	4.4	1978	Y		RO	
01467042	Pennypack Cr at Pine Road, Phila	37.9	1964	Y		C/M;WQR	
01467043	Stream 'A' at Philadelphia	1.2	1965	Y		RO	
01467045	Pennypack Cr bl Verre Rd, Phila	42.8	1964	CSG		P	
01467048	Pennypack Cr at Lower Rhawn St., Phila	49.8	1965	Y		C/M;WQR	WQR
01467050	Wooden Bridge Run at Philadelphia	3.3	1965	Y		P	
01467086	Tacony Cr at County Line, Phila	1.7	1965	Y		C/M:WQR	
01467089	Frankford Cr at Torresdale Ave, Phila	33.8	1965	Y		C/M;WQR	WQR
01467500	Schuylkill R at Pottsville	53.4	1975	CLF		P	C/M
01467948	W Br Schuylkill R nr Cressona	52.5	1975	CLF		P	C/M
01468500	Schuylkill R at Landingville	133.	1974	N	TM	T;P	FF
01469500	Little Schuylkill R at Tamaqua	42.9	1919	N		T;BC/M	
01470190	Little Schuylkill R at Pt. Clinton	132.	1975	CLF		P	
01470500	Schuylkill R at Berne	355.	1947	Y	D	BC/M;SED	FF
01470720	Maiden Cr Trib at Lenhartsville	7.5	1965	Y		P	
01470748	Sacony Cr nr Virginville	54.1	1965	CLF		P	
01470756	Maiden C at Virginville	159.	1973	N		T;P	
01470766	Schuylkill R at Temple	641.	1977	CLF		P	
01470779	Tulpehocken Cr nr Bernville	66.5	1974	N	TM/TH	T;P;FF;RR	
01470810	Northkill Cr at Bernville	18.8	1975	CLF	WW	P	BC/M
01470818	Little Northkill Cr nr Bernville	21.2	1975	CLF		P	
01470870	Blue Marsh Lake nr Pleasant Valley	175.	1979	PG	TM	LM;FF	
01470960	Tulpehocken Cr bl Blue Marsh Dam	175.	1965	Y	TH	BC/M;OM	FF

Table 2.--Stream gages operated by the Pennsylvania District of USGS and known usage of collected data--(continued)

Delaware River Basin

Gage No.	Station Name	Area (Mi^2)	Year Record Began	Gage Type	Accessory Equipment	Data Usage By A Cooperator	Other Usage
01471000	Tulpehocken Cr nr Reading	211.0	1950	N	TM	P;FF;T;RR	C/M;WQR
01471510	Schuylkill R at Reading	880.	1902	N		P;FF;T	WQR
01471660	Schuylkill R at Birdsboro		1979	CLF		P	
01471800	Pine Cr nr Manatawny	15.6	1961	CLF		P	
01471980	Manatawny R at Pottstown	85.5	1974	N		P;T	
01472000	Schuylkill R at Pottstown	1147.	1926	Y	TM	T	C/M;WQR;FF
01472080	Pigeon Cr nr Parker Ford	12.	1969	WW		P;T	C/Q
01472110	Stony Run at Spring City	4.1	1969	WW		P;T	C/Q
01472157	French Cr nr Phoenixville	59.1	1968	Y		BC/M	BC/M
01472162	Schuylkill R at Phoenixville	1280.	1971	CLF		P	
01472174	Pickering Cr nr Chester Springs	6.	1967	Y		BC/;P;T	C/Q
01472190	Pickering Cr nr Phoenixville	31.4	1972	WW		BC/;P;T;OM	
01473000	Perkiomen Cr at Graterford	279.	1914	Y	D	P;BC/Q	FF
01473100	Zacharias Cr nr Skippack	7.3	1960	CSG		P	
01473120	Skippack Cr nr Collegeville	53.7	1966	Y		P;BC/	
01473170	Valley Cr nr Valley Forge	22.	1972	WW		P;T	C/Q;WQR
01473193	Schuylkill R at Port Kennedy	1691.	1979	CLF		P	
01473470	Stony Cr nr Norristown	20.4	1975	CLF		P	
01473500	Schuylkill R at Norristown	1760.	1979	CLF		P	
01473950	Wissahickon Cr at Bells Mill Rd	53.6	1965	Y			WQR
01474000	Wissahickon Cr at Mouth at Philadelphia	64.	1965	Y		C/M;WQR	BC/M
01474500	Schuylkill R at Philadelphia	1893.	1931	Y	G/QW/TM	T;P;SHF	BC/M;WQR;FF
01474505	Schuylkill R ab Passyunk Ave, Phila	1893.	1978	R			
01475300	Darby Cr at Waterloo Mills nr Devon	5.1	1972	Y		P;T	C/Q
01475510	Darby Cr nr Darby	37.4	1964	Y		P;T	

Table 2.--Stream gages operated by the Pennsylvania District of USGS and known usage of collected data--(continued)

Delaware River Basin

Gage No.	Station Name	Area (Mi ^{2})	Year Record Began	Gage Type	Accessory Equipment	Data Usage By A Coopertor	Other Usage
01475530	Cobbs Cr at US Hwy No 1 nr Philadelphia	4.8	1964	Y		C/M;WQR	
01475550	Cobbs Cr at Darby	22.	1964	Y		P;T	
01475555	Hermesprota Cr at Darby	1.	1975	CLF		P	
01475560	Stony Cr at Prospect Park	2.3	1975	CLF		P	
01475600	Muckinipattis Cr at Glenolden	3.5	1975	CLF		P	
01475850	Crum Cr nr Newtown Square	15.8	1977	CLF		P	
01476000	Crum Cr at Woodlyn	33.3	1975	CLF		P	
01476435	Ridley Cr nr West Chester	9.7	1975	CLF		P	C/Q;P
01476500	Ridley Cr at Moylan	31.9	1975	CLF		P	
01476836	E Br Chester Cr nr West Chester	10.8	1975	CLF		P	C/Q;P
01476853	E Br Chester Cr at Cheyney	22.8	1975	CLF		P	
01476950	W Br Chester Cr nr Chester Heights	18.	1975	CLF		P	
01477000	Chester Cr nr Chester	61.1	1931	N	TM	T;BC/M;FF	FF
01478150	E Br White Clay Cr at Landenberg	25.6	1970	LF		P	
01478200	Mid Br White Clay Cr nr Landenberg	12.7	1960	CSG		BC/Q	
01479700	W Br Red Clay Cr nr Kennett Square	17.	1970	LF		P	
01480300	W Br Brandywine Cr nr Honeybrook	18.7	1960	N		T	P
01480500	W Br Brandywine Cr at Coatesville	45.8	1969	Y		T;P	
01480610	Sucker Run nr Coatesville	2.6	1964	CSG		P	;P
01480617	W Br Brandywine Cr at Modena	55.	1969	Y	TM	T;SHF;WQR	FF
01480675	Marsh Cr nr Glenmore	8.6	1966	Y	TM	IM	FF
01480685	Marsh Cr nr Downingtown	20.3	1973	N	TH	OM	SHF
01480700	E Br Brandywine Cr nr Downingtown	60.6	1965	Y	TM	BC/M;MP	FF;SHF
01480870	E Br Brandywine Cr bl Downingtown	89.9	1972	Y	QW/TM/D	T;P;SHF;OM	BC/M;WQR;FF
01481000	Brandywine Cr at Chadds Ford	287.	1962	Y	OW/TM/D	T;BC/M;P;SHF;WQR	FF

Table 2.--Stream gages operated by the Pennsylvania District of USGS and known usage of collected data--(continued)

Delaware River Basin

Gage No.	Station Name	Area (Mi^2)	Year Record Began	Gage Type	Accessory Equipment	Data Usage By A Cooperator	Other Usage
01494980	Big Elk Cr at Lewisville	31.2	1975	WW		T	
01495320	Little Elk Cr nr Lewisville	13.4	1975	WW		T	

Table 2.--Stream gages operated by the Pennsylvania District of USGS and known usage of collected data--(continued)

Susquehanna - Potomac Basins

Gage No.	Station Name	Area (Mi^2)	Year Record Began	Gage Type	Accessory Equipment	Data Usage By A Cooperator	Other Usage
01516350	Tioga R nr Mansfield	153.0	1976	N	QW/TM/D/G	P;RR;WQR	OSM;FF
01516500	Corey Cr nr Mainesburg	12.2	1954	N		T;P	
01516780	Tioga R at Mansfield		1979	CSG		P	
01517900	Tioga R at Tioga Lake		1979	PG	D	LM	
01518000	Tioga R at Tioga	282.	1938	N		OM	WQR;BC/M
01518400	Crooked Cr at Middlebury Center	74.2	1979	AP	D	IM	
01518498	Crooked Cr at Hammond Lake		1979	PG	D	LM	
01518700	Tioga R at Tioga Junction	445.	1976	N	QW/TM/D/G	BC/M;OM;P;RR;WQR	FF
01519200	Cowanesque R nr Elkland		1979	AP	D	P;IM	
01520000	Cowanesque R nr Lawrenceville	298.	1951	Y	TM/TH	OM	WQR;C/M;FF
01530850	Bentley Cr at Ridgebury	47.2	1970	LF		P	
01531250	N Br Sugar Cr Trib nr Columbia Cross	8.8	1962	CSG		P	
01531500	Susquehanna R at Towanda	7797.	1913	Y	G	C/Q;P	RR
01532000	Towanda Cr nr Monroeton	215.	1914	N		T;BC/M;P	FF
01532200	S Br Towanda Cr at New Albany	13.3	1963	CSG		P	
01533250	Tuscarora Cr nr Silvara	11.8	1963	CSG		P	
01533400	Susquehanna R at Meshoppen	8720.	1976	N	D	P	FF;RR
01534000	Tunkhannock Cr nr Tunkhannock	383.	1914	Y	TM	BC/M	FF
01534180	Lackawanna R at Stillwater Lake	37.1	1959	PG		LM	
01534300	Lackawanna R nr Forest City	38.8	1958	Y		OM;C/Q	WQR
01534490	Aylesworth Cr at Aylesworth Lake	6.2	1972	PG		LM	
01534500	Lackawanna R at Archbald	108.	1939	Y	TM	OM	WQR;SMR;FF
01536000	Lackawanna R at Old Forge	332.	1938	Y		BC/M;RR	
01536500	Susquehanna R at Wilkes-Barre	996.	1899	Y	G/D	C/Q	FF;RR
01537000	Toby Cr at Luzerne	32.4	1941	Y		P	C/M;WQR

Table 2.--Stream gages operated by the Pennsylvania District of USGS and known usage of collected data--(continued)

Susquehanna - Potomac Basins

Gage No.	Station Name	Area (Mi^2)	Year Record Began	Gage Type	Accessory Equipment	Data Usage By A Cooperator	Other Usage
01537500	Solomon Cr at Wilkes-Barre	15.7	1940	N		P	WQR
01538000	Wapwallopen Cr at Wapwallopen	43.8	1919	N		BC/M	
01538800	Huntington Cr nr Pikes Creek	4.9	1960	CSG		P	
01539000	Fishing Cr nr Bloomsburg	274.	1938	N	G	C/Q	
01540200	Trexler Run nr Ringtown	1.8	1963	Y		P	
01540350	Catawissa Cr at Catawissa	149.	1970	LF		P	
01540500	Susquehanna R at Danville	11220.	1899	Y	G	BC/M	RR
01541000	W Br Susquehanna R at Bower	315.	1913	N		C/M	IM
01541180	W Br Susq. R at Curwensville Lake	365.	1965	PG	TM	LM;FF	FF
01541200	W Br Susquehanna R nr Curwensville	367.	1955	Y	TM	OM	C/M;WQR
01541248	Anderson Cr at Curwensville	76.5	1974	WW		C/Q;SMR	
01541303	West Branch Susq. R at Hyde	474.	1978	N	G/TM	P;RR;FF	FF
01541340	Beaverdam Run at Glendale Lake	41.9	1963	PG		LM	
01541500	Clearfield Cr at Dimeling	371.	1913	Y		C/Q;RR	OSM
01541800	Alder Run nr Kylertown	12.6	1974	WW		C/O:SMR	
01542000	Moshannon Cr at Osceola Mills	68.8	1940	N		C/Q	
01542310	Moshannon Cr nr Moshannon	263.	1974	WW		C/Q;SMR	
01542330	Black Moshannon Cr nr Phillipsburg	2.3	1970	LF		P	
01542500	W Br Susquehanna R at Karthaus	1462.	1940	Y	G/D	C/Q;SMR;RR;FF	OSM;FF
01542720	Wilson Run at Penfield	8.3	1962	CSG		P	
01542790	Bennett Br Sinnemahoning Cr at Driftwd.	357.	1974	WW		C/Q;SMR	
01542810	Waldy Run nr Emporium	5.2	1964	Y		P	
01542950	Sinn. Portage Cr nr Emporium	60.	1976	LF		P	
01543000	Driftwood Br Sinn. Cr at Sterling Run	272.	1913	Y		C/Q	
01543500	Sinnemahoning Cr at Sinnemahoning	685.	1938	Y	G/D	C/Q	OSM;FF

Table 2.--Stream gages operated by the Pennsylvania District of USGS and known usage of collected data--(continued)

Susquehanna - Potomac Basins

Gage No.	Station Name	Area (Mi^2)	Year Record Began	Gage Type	Accessory Equipment	Data Usage By A Cooperator	Other Usage
01543700	First Fk Sinnemahoning Cr at Wharton	182.0	1970	LF		P	
01543900	First Fk Sinnemahoning Cr Res	243.	1956	PG		LM	
01544000	First Fk Sinn. Cr nr Sinnemahoning	245.	1953	Y		C/Q;RR	
01544500	Kettle Cr at Cross Fork	136.	1940	N		T;P	
01544800	Kettle Cr at Kettle Cr Res	226.	1962	PG	TM	LM;FF	FF
01545000	Kettle Cr nr Westport	233.	1954	Y		OM	C/Q;WQR
01545500	W Br Susquehanna R at Renovo	2975.	1907	Y	QW/TM/D/G	C/Q;P;WQR;RR;FF	OSM;FF
01545600	Young Womans Cr nr Renovo	46.2	1964	N		T;C/M	
01545800	W Br Susquehanna R at Lock Haven	3345.	1974	AP	G/TM	P;RR;FF	FF
01546500	Spring Cr nr Axemann	87.2	1940	N		T;BC/M	
01547100	Spring Cr at Milesburg	142.	1967	Y		T	
01547200	Bald Eagle Cr bl Spring at Milesburg	265.	1955	Y		IM	WQR
01547480	Bald Eagle Cr at F.J. Sayers Dam	339.	1971	PG		LM	
01547500	Bald Eagle Cr at Blanchard	339.	1954	Y	TH	OM	
01547700	Marsh Cr at Blanchard	44.1	1955	N		RR	FF
01547800	S Fk Beech Cr nr Snow Shoe	12.2	1969	Y		P;SMR	
01547950	Beech Cr at Monument	152.	1968	Y	QW	C/Q	OSM;WQR
01548000	Bald Eagle Cr at Beech Cr Station	559.	1910	N	TM	T;RR;FF	WQR;FF
01548020	Bull Run nr Loganton	2.	1963	CSG		P	
01548408	Wilson Cr above Sand Spring Run	12.6	1978	R	S	P	
01548413	Mitchell #2 nr Antrim	0.2	1978	Y		P	
01548416	Anna S #1 nr Antrim	0.5	1978	Y		P	
01548417	Basswood Run ab Hunter Dr nr Antrim	0.6	1978	R	S	P	
01548418	Hunter Drift nr Antrim	0.6	1978	Y		P	
01548422	Rattler Run nr Morris	0.3	1978	R	S	P	

Table 2.--Stream gages operated by the Pennsylvania District of USGS and known usage of collected data--(continued)

Susquehanna - Potomac Basins

Gage No.	Station Name	Area (Mi^2)	Year Record Began	Gage Type	Accessory Equipment	Data Usage By A Cooperator	Other Usage
01548500	Pine Cr at Cedar Run	604.0	1918	Y		C/Q	OSM
01549500	Blockhouse Cr nr English Center	37.7	1940	N		P;T	
01549580	Little Pine Cr at Little Pine Cr Dam	165.	1950	PG		LM	
01549700	Pine Cr bl Little Pine Cr nr Waterville	944.	1957	WW		BC/M	
01550000	Lycoming Cr nr Trout Run	173.	1913	N		BC/M;T	OSM
01551500	W Br Susquehanna R at Williamsport	5682.	1895	Y	D/G	P;RR;FF	WQR;FF
01551830	Loyalsock Cr nr Forksville	131.	1970	LF		P	
01552000	Loyalsock Cr at Loyalsockville	443.	1925	N		BC/M;T	OSM
01552500	Muncy Cr nr Sonestown	23.8	1940	N		T	
01553050	White Deer Hole Cr nr Elimsport	18.2	1961	CSG		P	
01553130	Sand Spring Run nr White Deer	4.9	1968	Y		P	
01553500	W Br Susquehanna R at Lewisburg	6847.	1939	Y	G/D	BC/M;P;RR;FF	FF
01553700	Chillisquaque Cr nr Washingtonville	134.	1979	Y		P	
01554000	Susquehanna R at Sunbury	18300.	1937	Y	G/TM/D	C/M	FF
01554500	Shamokin Cr nr Shamokin	54.2	1939	N		C/Q;SMR	
01555000	Penns Cr at Penns Creek	301.	1929	Y		P;T	
01555250	Mahanoy Cr at Dornsife	117.	1970	LF		P	
01555251	Mahonoy Cr nr Herndon	155.	1974	WW		C/Q;SMR	
01555500	E Mahantango Cr nr Dalmatia	162.	1929	Y		BC/M	
01555570	Wiconisco Cr nr Elizabethville	79.2	1970	LF		P	
01555578	Frankstown Br Juniata R at E. Freedom	47.4	1970	LF		P	
01556000	Frankstown Br Juniata R at Williamsburg	291.	1916	Y	G	BC/M	
01556400	Sandy Run nr Bellwood	5.6	1962	CSG		P	
01556500	Little Juniata R at Tipton	93.7	1946	AP		P	
01557100	Schell Run at Tyrone	1.7	1958	AP		P	

Table 2.--Stream gages operated by the Pennsylvania District of USGS and known usage of collected data--(continued)

Susquehanna - Potomac Basins

Gage No.	Station Name	Area (Mi^2)	Year Record Began	Gage Type	Accessory Equipment	Data Usage By A Cooperator	Other Usage
01557500	Bald Eagle Cr at Tyrone	44.1	1944	N		T	
01558000	Little Juniata R at Spruce Creek	220.	1938	N	G	T;C/M	
01559000	Juniata R at Huntingdon	816.	1941	Y	G/TH/D	C/Q;P;RR;FF;T;L	WQR;FF
01560000	Dunning Cr at Belden	172.	1939	Y	G	P;BC/	
01562000	Raystown Br Juniata R at Saxton	756.	1911	Y	G/TM	T;C/M;IM;FF	WQR;FF
01563100	Raystown Br at Raystown Lake	959.	1972	PG		LM	
01563200	Raystown Br Juniata R bl Raystown Dam	960.	1969	Y	G/TH/D	OM	FF
01563500	Juniata R at Mapleton Depot	2030.	1937	Y	G/TM/D	P;RR;FF	FF
01564500	Aughwick Cr nr Three Springs	205.	1938	N	G	T	
01565700	Little Lost Cr at Oakland Mills	6.5	1963	Y		P	
01565920	Lick Run nr East Waterford	8.4	1962	CSG		P	
01567000	Juniata R at Newport	3354.	1899	Y	G/D	T;SED	C/M;WQR;FF
01567500	Bixler Run nr Loysville	15.	1954	Y		P;T	
01568000	Sherman Cr A Shermans Dale	200.	1929	N		T	
01568400	Clark Cr at Dehart Res	21.7	1940	PG		LM	
01568500	Clark Cr nr Carsonville	22.5	1937	Y		OM	
01568700	Stony Cr ab Res Site nr Dauphin	11.5	1974	Y		P	
01569340	Newburg Run at Newburg	5.3	1964	CSG		P	
01569800	Letort Spring Run nr Carlisle	21.6	1976	N		P	
01570000	Conodoguinet Cr nr Hogestown	470.	1967	Y	D	BC/M	WQR;IP;FF
01570500	Susquehanna R at Harrisburg	24100.	1890	Y	QW/D/G	BC/M;T;P;SED;L	OSM
01571000	Paxton Cr at Penbrook	11.2	1973	AP		P	
01571110	Yellow Breeches Cr nr Walnut Bottom	16.4	1970	LF		P	
01571185	Mountain Cr at Pine Grove Furnance	13.9	1970	LF		P	
01571190	Mountain Cr nr Mt. Holly Springs	37.4	1970	LF		P	

Table 2.--Stream gages operated by the Pennsylvania District of USGS and known usage of collected data--(continued)

Susquehanna - Potomac Basins

Gage No.	Station Name	Area (Mi^2)	Year Record Began	Gage Type	Accessory Equipment	Data Usage By A Cooperator	Other Usage
01571500	Yellow Breeches Cr nr Camp Hill	216.0	1954	Y	D	C/M	FF
01571824	Swatara Cr on Spittler Rd at Ravine	44.6	1970	WW/LF		C/Q;SHF;SMR	
01572900	Reeds Cr nr Ono	8.6	1962	CSG		P	
01573000	Swatara Cr at Harpers Tavern	337.	1919	N	TM	T;C/Q;SED	FF
01573086	Beck Cr nr Cleona	7.9	1963	Y		P	
01573160	Quittapahilla Cr nr Bellegrove	74.2	1975	N		T;BC/M;SHF	
01573560	Swatara Cr nr Hershey	483.	1975	N	TM	T;SHF	FF
01574000	W Conewago Cr nr Manchester	510.	1928	N		T;BC/M	
01574390	W Br Codorus Cr at Lake Marburg	23.2	1972	PG		LM	
01574500	Codorus Cr at Spring Grove	75.5	1929	Y		P	WQR
01574900	WB Codorus Cr at Indian Rock Res	93.7	1962	PG		LM	
01575000	S Br Codorus Cr nr York	117.	1927	Y		C/M	WQR
01575500	Codorus Cr nr York	222.	1940	Y	TM	P;RR;FF	WQR;FF
01576000	Susquehanna R at Marietta	25990.	1931	Y		T;P;C/Q;L	
01576320	Stony Run at Reamstown	3.5	1964	CSG		P	
01576500	Conestoga R at Lancaster	324.	1928	Y		T;C/M;P;L	FF
01576787	Pequea Cr at Martic Forge	148.	1977	Y	TM/S	P;ORG;SED	
01578200	Conowingo Cr nr Buck	8.7	1963	CSG		P	
01578400	Bowery Run nr Quarryville	6.	1962	Y		P	
01600700	Little Wills Cr at Bard	10.2	1970	CLF		P	
01613050	Tonoloway Cr nr Needmore	10.7	1965	Y		P	
01614090	Conococheague Cr nr Fayetteville	5.	1960	Y		P	
01638900	White Run nr Gettysburg	12.4	1961	CLF		BC/M	

Table 2.-- Stream gages operated by the Pennsylvania District of USGS and known usage of collected data--(continued)

Ohio - St. Lawrence Basins

Gage No.	Station Name	Area (Mi 2)	Year Record Began	Gage Type	Accessory Equipment	Data Usage By A Cooperator	Other Usage
03007800	Allegheny R at Port Allegheny	248.0	1974	N	TM	P	OSM;SED;FF
03009680	Potatoe Cr at Smethport	160.	1974	N	TM	P	WQR;OSM;FF
03010500	Allegheny R at Eldred	550.	1939	N	TM	T;C/M;RR	
03010750	Oswago Cr at Shinglehouse	98.7	1974	N	TM	P	FF
03011800	Kinzua Cr nr Guffey	46.4	1965	Y	TM	BC/M;IM	
03012550	Allegheny R at Kinzua Dam	2180.	1935	Y	TM	OM;RR	
03015000	Conewango Cr at Russell	816.	1939	Y	TM	C/Q;FF	FF
03015080	Akeley Run nr Russell	9.6	1962	CSG		P	
03015390	Hare Cr nr Corry	12.3	1964	CSG		P	
03015500	Brokenstraw Cr at Youngsville	321.	1909	N		T;P;C/Q	OSM
03016000	Allegheny R at West Hickory	3660.	1941	Y		P;C/Q;FF;RR	FF
03017800	Minister Cr nr Truemans	10.8	1970	CLF		P	
03020000	Tionesta Cr at Tionesta Cr Dam	479.	1940	Y	TM	C/Q;OM;RR	
03020440	W Br Caldwell Cr nr Grand Valley	4.4	1964	CSG		P	
03020500	Oil Cr at Rouseville	300.	1932	Y	TM	T;BC/M;FF	FF
03021350	French Cr nr Wattsburg	92.	1974	Y	TM	P;IM	
03021410	W Br French Cr nr Lowville	52.3	1974	Y	TM	P;IM	
03021520	French Cr nr Union City	221.	1909	N	TM	C/Q;OM;RR	
03022540	Woodcock Cr at Blooming Valley	31.1	1974	N	TM	IM	
03022554	Woodcock Cr at Woodcock Cr Dam	47.7	1974	Y	TM	OM;RR	
03024000	French Cr at Utica	1028.	1932	Y		P;C/Q	
03025500	Allegheny River at Franklin	5982.	1914	Y	D	P;C/M;FF;RR	FF
03026400	Richey run at Emlenton	5.9	1963	CSG		P	
03026500	Sevenmile run nr Rasselas	7.8	1951	Y	TM	P;IM	
03027500	E Br Clarion R at E Br Clarion R Dam	73.2	1948	Y	TM	C/M;OM;RR	

Table 2.--Stream gages operated by the Pennsylvania District of USGS and known usage of collected data--(continued)

Ohio - St. Lawrence Basins

Gage No.	Station Name	Area (Mi^2)	Year Record Began	Gage Type	Accessory Equipment	Data Usage By A Cooperator	Other Usage
03028000	W Br Clarion R at Wilcox	63.0	1953	N	TM	C/M;P;IM;RR	
03028500	Clarion R at Johnsonburg	204.	1945	Y		P;FF;RR	
03029000	Clarion R at Ridgeway	303.	1940	AP	TM	FF;P;L	C/M;FF
03029170	Toby Cr at Portland Mills	126.	1974	WW		C/M;SMR	
03029200	Clear Cr nr Sigel	8.7	1960	CLF		P	
03029500	Clarion R at Cooksburg	807.	1938	Y	D	P;C/Q	FF
03030500	Clarion R nr Piney	951.	1944	Y		P;C/Q;L	
03030600	Piney Cr at Piney	72.2	1970	LF		P	
03030852	Clarion R at Callensburg	1163.	1979	AP		P	C/M;SMR
03031500	Allegheny R at Parker	7671.	1932	Y	TM	P;C/Q;FF;RR	FF
03031780	Mill Cr nr Brockway	2.1	1965	CSG		P	
03031950	Big Run nr Sprankle Mills	7.4	1963	Y	TM	P	
03032500	Redbank Cr at St. Charles	528.	1918	Y	D	C/M;SED	OSM;FF
03034000	Mahoning Cr at Punxsutawney	158.	1938	N		T	FF
03034500	Little Mahoning Cr at McCormick	87.4	1939	Y		P;IM	
03036000	Mahoning Cr at Mahoning Cr Dam	344.	1938	Y	TM	C/Q;OM;RR	
03036500	Allegheny R at Kittanning	8973.	1934	Y	TM	P;IM	OSM
03038000	Crooked Cr at Idaho	191.	1937	Y	TM	P;IM	OSm
03039000	Crooked Cr at Crooked Cr Dam	278.	1909	Y	TM	C/Q;OM;RR	
03040000	Stony Cr at Ferndale	451.	1938	N	D	T;P;C/M;SED	OSM
03041000	Little Conemaugh R at East Conemaugh	183.	1939	N	D	P;C/M;T	
03041500	Conemaugh R at Seward	715.	1938	Y	TM	P;C/Q;IM;RR	
03042000	Blacklick Cr at Josephine	192.	1952	N	TM	P;C/Q;IM	
03042280	Yellow Cr nr Homer City	59.5	1967	N		T;MP	
03042500	Two Lick Cr at Graceton	171.	1951	N	TM	P;C/Q;IM	OSM

Table 2.--Stream gages operated by the Pennsylvania District of USGS and known usage of collected data--(continued)

Ohio - St. Lawrence Basins

Gage No.	Station Name	Area (Mi^2)	Year Record Began	Gage Type	Accessory Equipment	Data Usage By A Cooperator	Other Usage
03044000	Conemaugh R at Tunnelton	1358.0	1939	Y	TM	C/Q;OM;RR	
03045000	Loyalhanna Cr at Kingston	172.	1939	N		T;SED;IM;RR	
03045300	McCune Run at Keystone State Park	1.7	1970	LF		P	
03047000	Loyalhanna Cr at Loyalhanna Cr Dam	292.	1939	Y	TM	C/Q;OM;RR	
03048500	Kiskiminetas R at Vandergrift	1825.	1937	Y		P;C/Q;OM;RR	FF
03049000	Buffalo Cr nr Freeport	137.	1940	N		T	
03049100	Little Buffalo Cr at Cabot	4.7	1959	CSG		P	
03049500	Allegheny R at Natrona	11410.	1938	Y	TM	P;BC/M;RR	OSM;FF
03049800	Little Pine Cr near Etna	5.8	1962	Y		P	
03049810	Pine Cr at Etna	66.8	1970	LF		P	
03070420	Stony Fork Trib nr Gibbon Glade	0.9	1977	Y	QW/S	C/M;SED	
03070455	Stony Fork near Elliottsville	7.4	1977	Y	QW/S	C/M;SED	
03072000	Dunkard Cr at Shannopin	229.	1940	N		T;C/Q;P	
03072500	Monongahela R at Greensboro	4407.	1938	Y		P;C/Q;FF;RR	FF
03072880	Browns Cr nr Nineveh	17.5	1963	CSG		P	
03073000	S Fk Tenmile Cr at Jeffferson	180.	1931	Y		P;C/Q	
03074500	Redstone Cr at Waltersburg	73.7	1942	Y		P;C/Q	OSM
03075070	Monongahela R at Elizabeth	5213.	1933	Y		C/Q;FF	FF
03077500	Youghiogheny R at Youghiogheny R Dam	436.	1939	Y	TM	OM;RR	
03079000	Casselman R at Markleton	382.	1920	Y		P;C/Q;FF	OSM
03080000	Laurel Hill Cr at Ursina	121.	1918	N		T;P;C/Q;IM	C/Q
03081000	Youghiogheny R bl Confluence	1029.	1940	N	D	C/ ;FF	WQR
03082500	Youghiogheny R at Connellsville	1326.	1908	Y	TM/D	C/Q;FF;MP;RR	FF
03083100	Jacobs Cr at Jacobs Creek	94.9	1970	LF		P	
03083500	Youghiogheny R at Sutersville	1715.	1920	Y	TM	C/Q;FF;RR	FF

Table 2.--Stream gages operated by the Pennsylvania District of USGS and known usage of collected data--(continued)

Ohio - St. Lawrence Basin

Gage No.	Station Name	Area (Mi^2)	Year Record Began	Gage Type	Accessory Equipment	Data Usage By A Cooperator	Other Usage
03083600	Gillespie Run nr Sutersville	4.0	1959	CSG		P	
03084000	Abers Cr nr Murryville	4.4	1948	Y		C/Q;T	
03085000	Monongahela R at Braddock	7337.	1938	Y		T;BC/Q;SED;FF;RR	OSM;FF
03085500	Chartiers Cr at Carnegie	257.	1940	Y		P;C/Q;FF	
03086000	Ohio R at Sewickley	19500.	1933	Y		T;FF;RR	C/M;FF
03100500	Pymatuning Res at Pymatuning Dam	158.	1933	PG		LM	
03101500	Shenango R at Pymatuning Dam	167.	1934	Y		C/Q;OM;RR	
03102500	Little Shenango R at Greenville	104.	1913	Y		T;C/Q;P;IM	OSM
03102850	Shenango R nr Transfer	337.	1965	Y	TM	P;IM;RR	
03103500	Shenango R at Sharpsville	584.	1938	Y	TM	C/M;P;OM;RR	
03104760	Harthegig Run nr Greenfield	2.3	1968	Y		P	
03105500	Beaver R at Wampum	2235.	1932	Y		P;C/M;FF;RR	
03106000	Connoquenessing R nr Zelienople	356.	1919	N		T;P;BC/M;FF	
03106140	Wolf Cr nr Slippery Rock	86.6	1976	Y		P	
03106300	Muddy Cr nr Portersville	51.2	1963	Y		P;OM	
03106500	Slippery Rock Cr at Wurtemburg	398.	1911	Y		T;C/M;P	OSM
03107500	Beaver R at Beaver Falls	3106.	1935	Y	TM	P;BC/M;FF;RR	FF
03108000	Raccoon Cr at Moffatts Mill	178.	1941	Y		P;C/M	OSM
04213040	Raccoon Cr nr West Springfield	2.5	1968	Y		P	
04213200	Mill Cr at Erie	9.2	1964	CSG		P	

Table 3.--Regional equations for selected flow characteristics used in application of Network Analysis for Regional Information (NARI) technique

[Key to: Flow characteristics, in ft^3/s--

Q_A - mean flow;
Q_S - standard deviation of mean flow;
$\bar{x}$ - mean (arithmetic) of annual peak discharge or 7-day minimum average;
s - standard deviation of mean (arithmetic) of annual peak discharge or 7-day minimum average;
Q_{50} - 50-year (0.02 probability) flood discharge;
Q_{100} - 100-year (0.01 probability) flood discharge;
$Q_{7,10}$ - 7-day average minimum discharge of 10-year recurrence interval.

Basin characteristics--

A - drainage area, in square miles, for that part of the basin lying upstream from a selected site on an undeveloped stream;
E/100 - mean elevation, in hundreds of feet above sea level, of the basin;
F - forested area, in percent of drainage area plus 1 percent, within the basin;
G - a geologic index, dimensionless, that was empiricaly developed by correlation of bedrock geology with low-flow characteristics;
Pi - a precipitation index, in inches, equal to the annual precipitation on the basin for the 1941-70 period minus the average annual potential evapotranspiration;
S - channel slope, in feet per mile, for the reach of the principal channel that lies between the points at 10 and 85 percent of the distance along the reach from the selected site to the drainage divide;
St - storage area, in percent of drainage area plus 1 percent, for lakes, ponds, and swamps in the basin.]

Equations for mean discharge[1]

Region of fig. 2	Discharge characteristic, Y (log_{10})	No. of records used	Regression constant, C (log_{10})	Regression coefficients for indicated basin characteristics: A	S	St	Pi	E/100	F	G^2	Standard error of estimate s (percent)	Multiple correlation coefficient (percent)
1[3]	Q_A	59	-1.057	0.977			0.990				12	98.4
1[3]	Q_S	59	- .938	1.012			.451				16	96.7
1[4]	Q_A	18	- .930	.994			.925				9	99.2
1[4]	Q_S	18	- .980	.935			.563				15	95.7
2	Q_A	28	- .497	.989			.580				8	99.8
	Q_S	28	- .742	.965			.309				9	99.6
3	Q_A	82	-1.004	1.011			.935				9	99.8
	Q_S	82	- .974	.962			.531				13	99.5
4	Q_A	46	- .665	.999			.684				8	99.8
	Q_S	46	-1.040	1.034			.413				16	99.2
5	Q_A	63	- .930	.987			.914				11	99.6
	Q_S	63	- .695	.981			.261				14	99.2

Table 3.--Regional equations for selected flow characteristics used in application of Network Analysis for Regional Information (NARI) technique--(continued)

Equations for flood discharge[1]

Region of fig. 3	Discharge characteristic, Y (log_{10})	No. of records used	Regression constant, C (log_{10})	Regression coefficients for indicated basin characteristics: A	S	St	Pi	E/100	F	G^2	Standard error of estimate s (percent)	Multiple correlation coefficient (percent)
1	Q_{50}	31	1.217	1.003	0.443						26	29.2
	Q_{100}	31	1.283	.994	.450						28	96.7
2	$\overline{x}$	51	2.103	.794							25	97.1
	s	51	2.010	.741							38	92.9
	Q_{50}	51	2.684	.744							32	95.0
	Q_{100}	51	2.791	.733							34	94.1
3	$\overline{x}$	8	1.636	.891							40	92.6
	s	8	1.002	1.136							53	92.4
	Q_{50}	8	2.130	.875							30	95.2
	Q_{100}	8	2.196	.888							30	95.3
4	$\overline{x}$	21	1.900	.769							31	97.2
	s	21	1.548	.740							46	93.6
	Q_{50}	21	2.243	.756							29	97.2
	Q_{100}	21	2.293	.754							31	97.0
5E	$\overline{x}$	62	1.425	.814			0.376				29	96.7
	s	62	1.045	.746			.657				53	89.2
	Q_{50}	62	1.356	.745			.945				39	93.5
	Q_{100}	62	1.365	.727			1.041				44	91.8
5W	$\overline{x}$	70	1.972	.795							26	97.0
	s	70	1.754	.754							40	92.6
	Q_{50}	70	2.443	.757							32	95.1
	Q_{100}	70	2.518	.751							34	94.1

Table 3.--Regional equations for selected flow characteristics used in application of Network Analysis for Regional Information (NARI) technique--(continued)

Equations for flood discharge[1]

Region of fig. 3	Discharge character- istic, Y ($\log_{10}$)	No. of records used	Regression constant, C ($\log_{10}$)	Regression coefficients for indicated basin characteristics: A	S	St	Pi	E/100	F	G^2	Standard error of estimate s (percent)	Multiple correlation coefficient (percent)
6A[5]	$\bar{x}$	50	1.905	0.840							21	95.5
	s	50	2.060	.715							46	78.0
	Q_{50}	50	2.505	.790							28	91.3
	Q_{100}	50	2.633	.775							32	88.7
6B[6]	$\bar{x}$	24	2.700	.864					-0.446		37	69.7
	s	24	2.473	1.023					-.443		69	49.3
	Q_{50}	24	3.250	.981					-.496		45	67.0
	Q_{100}	24	3.382	1.001					-.519		50	64.0
7A[5]	$\bar{x}$	25	2.559	.808					-.352		26	93.7
	s	25	2.077	.737					-.080		44	84.7
	Q_{50}	25	2.883	.727					-.142		34	88.6
	Q_{100}	25	2.950	.706					-.100		39	85.8
7B[6]	$\bar{x}$	16	2.383	.863		-0.849					40	80.9
	s	16	2.147	.882		.332					66	64.9
	Q_{50}	16	2.890	.871		-.574					56	69.0
	Q_{100}	16	2.986	.878		-.430					62	64.8
8	$\bar{x}$	15	1.447	.826				-0.704	.548		31	96.1
	s	15	1.500	.885				-1.178	.643		43	93.5
	Q_{50}	15	2.401	.819				-1.127	.593		29	96.2
	Q_{100}	15	2.587	.820				-1.323	.604		31	95.5

Table 3.--Regional equations for selected flow characteristics used in application of Network Analysis for Regional Information (NARI) technique--(continued)

Equations for low-flow discharge[1]

Region of fig. 4	Discharge character-istic, Y (log_{10})	No. of records used	Regression constant, C (log_{10})	Regression coefficients for indicated basin characteristics: A	S	St	Pi	E/100	F	G^2	Standard error of estimate s (percent)	Multiple correlation coefficient (percent)
1	$\overline{x}$	20	-3.861	1.195			1.848			0.274	32	92.2
	s	20	-2.821	1.070			1.083			.238	38	87.1
	$Q_{7,10}$	20	-6.248	1.534			2.718			.433	38	93.8
2	$\overline{x}$	27	-1.772	1.003			.804			.269	19	98.6
	s	27	-2.127	.969			.917			.165	25	97.4
	$Q_{7,10}$	27	-2.883	1.051			1.283			.367	24	98.1
3	$\overline{x}$	18	-3.349	1.036			1.907			.176	23	99.0
	s	18	-3.313	.989			1.723			.126	32	97.9
	$Q_{7,10}$	18	-4.073	1.111			2.038			.228	20	99.3
4	$\overline{x}$	17	-4.298	1.280			2.196				26	97.6
	s	17	-3.456	1.158			1.452				20	98.1
	$Q_{7,10}$	17	-6.038	1.488			2.946				44	95.4
5	$\overline{x}$	25	-3.526	1.021			1.908			.192	20	98.8
	s	25	-3.783	1.015			2.090			--	23	98.3
	$Q_{7,10}$	25	-4.927	1.027			2.417			.435	31	97.8
6	$\overline{x}$	21	-3.395	.941			1.976			.284	21	97.8
	s	21	-2.553	.776			1.319			.197	24	95.7
	$Q_{7,10}$	21	-4.541	1.059			2.425			.351	28	97.1
7	$\overline{x}$	24	-4.082	.955			2.445			.312	19	99.0
	s	24	-3.953	.968			2.212			.179	33	96.5
	$Q_{7,10}$	24	-5.209	.934			2.958			.432	28	98.0

Table 3.--Regional equations for selected flow characteristics used in application of Network Analysis for Regional Information (NARI) technique--(continued)

Equations for low-flow discharge[1]

Region of fig. 4	Discharge characteristic, Y (log_{10})	No. of records used	Regression constant, C (log_{10})	Regression coefficients for indicated basin characteristics: A	S	St	Pi	E/100	F	G^2	Standard error of estimate s (percent)	Multiple correlation coefficient (percent)
8	$\bar{x}$	18	-2.724	0.879			1.389			0.307	30	96.9
	s	18	-2.200	.804			.855			.232	35	94.9
	$Q_{7,10}$	18	-3.990	.907			1.997			.398	35	96.6
9												
	$\bar{x}$	13	- .728	.971							12	99.6
	s	13	-1.213	1.035							23	98.7
	$Q_{7,10}$	13	- .944	.957							20	98.8
10	$\bar{x}$	19	-2.367	1.348	0.599						25	97.9
	s	19	-2.499	1.294	.557						32	96.6
	$Q_{7,10}$	19	-2.876	1.409	.650						44	94.6
11	$\bar{x}$	17	-1.917	1.076						1.483	31	96.6
	s	17	-1.422	1.035						--	33	95.5
	$Q_{7,10}$	17	-2.774	1.110						2.380	34	96.3
12	$\bar{x}$	19	-4.055	.956			1.955			.859	25	98.2
	s	19	-3.661	1.038			1.387			1.087	33	96.9
	$Q_{7,10}$	19	-7.051	1.162			3.279			1.357	45	96.8

[1] Form is log Y = log C + a (log A) +...+g(G) Small letters denote regression coefficients.
[2] Used as a linear (non-logarithmic) variable in equation 2.
[3] For drainage areas greater than 20 mi^2.
[4] For drainage areas less than 20 mi^2.
[5] For drainage areas greater than 15 mi^2.
[6] For drainage areas less than 15 mi^2.

REGIONAL REGRESSION ANALYSIS

Regional regression equations for mean discharge (Herb, unpublished report), flood discharge (Flippo, 1977), and low-flow discharge (Flippo, 1982) are the mechanisms for the transfer of flow characteristics that have been developed for application throughout Pennsyvlania. The model form of these equations is:

$$Y = f\ (A^a, E^b, F^c, G^d, Pi^e, S^f, St^g), \qquad (1)$$

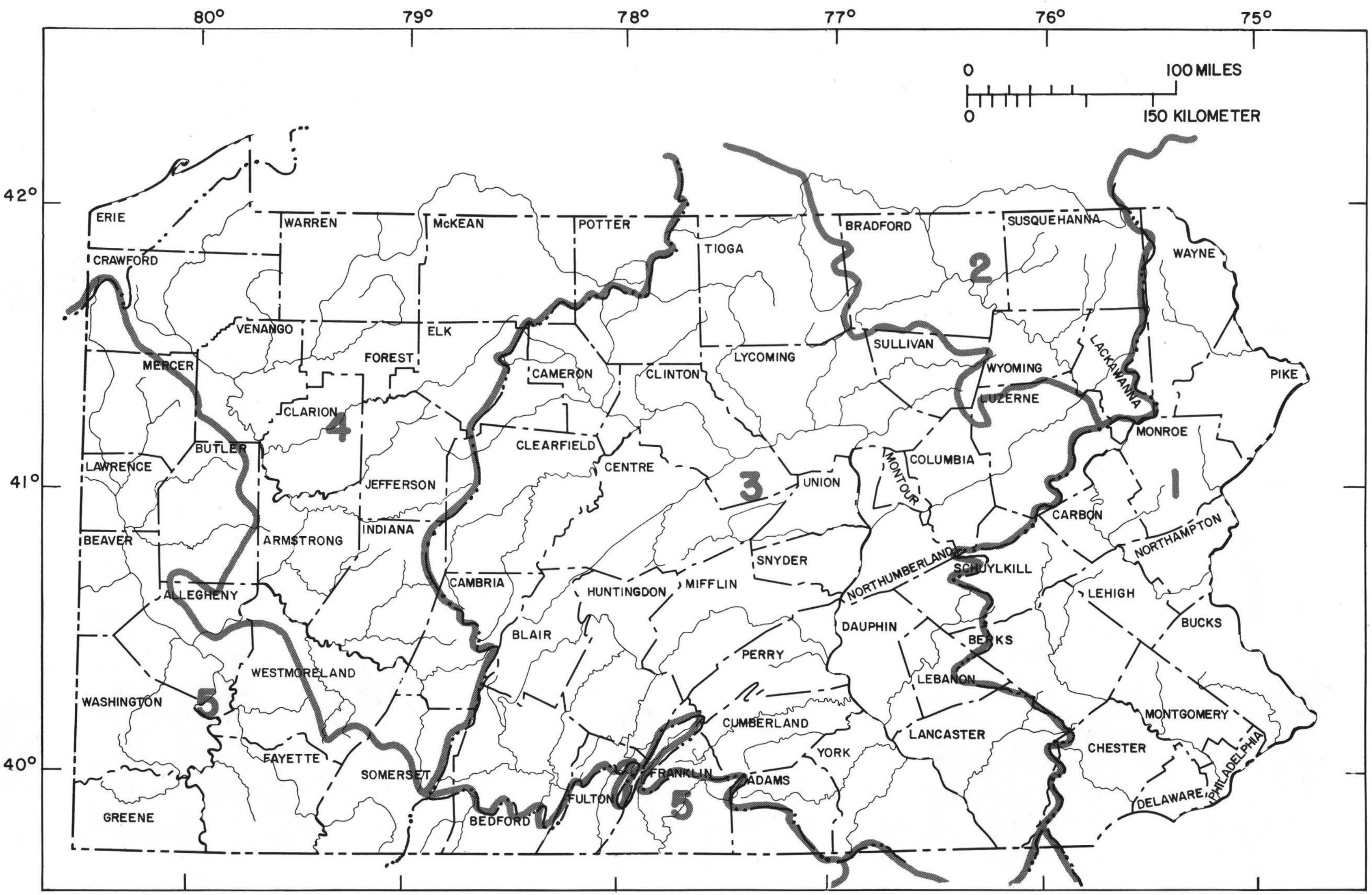
where Y is an estimate of a flow characteristic; A, E, F, G, Pi, S, and St are drainage-basin characteristics; and a through g are corresponding regression coefficients. No more than three basin characteristics are used in a single regression. Table 3 summarizes the regression equations used in the NARI evaluations. The regression constant (C) and coefficients are given for the common logarithmic form of equation 1, which is:

$$log\ Y = log\ C + a\ log\ A + ... + g\ log\ St. \qquad (2)$$

Homogeneous regions of mean-, low-, and flood-discharge characteristics, for which regression equations of this form were developed, are delineated in figures 2-4. Sequential numbers of the regions are in the same order as in the source references.

The standard errors of regression (s) shown in table 3 are those observed for the indicated regressions. They are a measure of how well the data fit the model. Also, they provide a rough estimate of true predictive accuracy. For a given regression equation, the observed values of (s) is partly dependent on the sample of observed values of the flow characteristic used in the regression analysis. Because flow records are of finite length, computed flow characteristics are subject to time-sampling errors. Such errors can be substantial for the extreme-flow characteristics of short-record stations. The space-sampling component of regression error is inversely related to station density.

The equations for 50- and 100-year flood discharges have been revised, from those presented by Flippo (1977), on the basis of recomputations using flood statistics developed by application of the techniques set forth in Water Resources Council Bulletin No. 17A (1977). Annual peak discharges observed through water year 1975 were used for these revisions. Flood region 5 (Flippo, 1977) has been subdivided into eastern and western parts. Observed standard errors for the revised 50- and 100-year equations of the western 70-station subgroup were 3 percent greater than those of the earlier regression analysis for 128 stations in flood region 5. However, corresponding standard errors for the eastern subgroup of 62 stations were 10 and 13 percent, respectively, greater than those of the earlier analysis. Standard errors for region 3, which has only 8 stations, were 12 percent greater than those of the earlier analysis. All other standard errors were within $\pm$ 6 percent of their previous values.

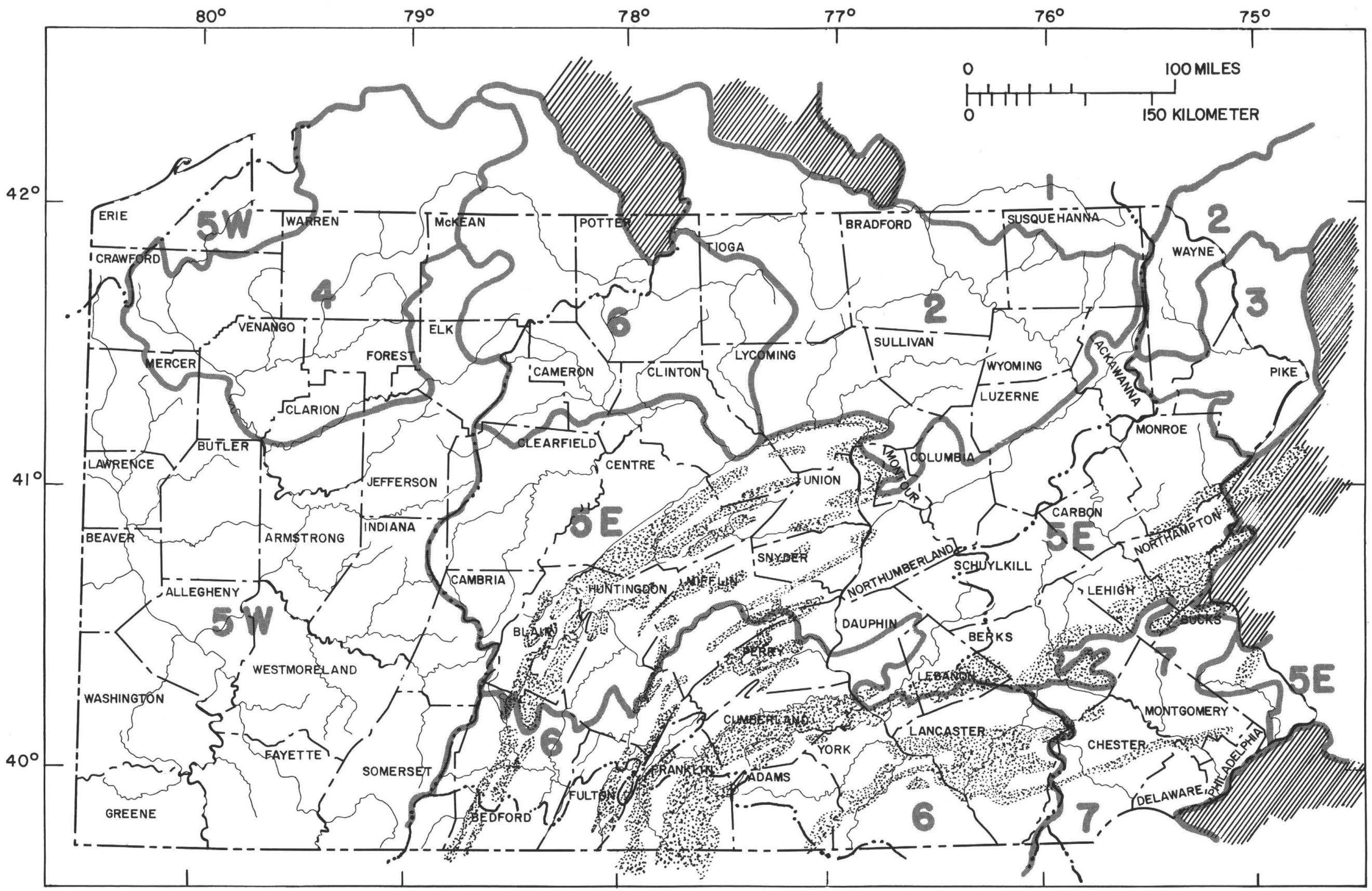


EXPLANATION

Regions of homogenous mean-discharge characteristics

Principal drainage basin boundary

Figure 2.--Mean-discharge regions (Herb, unpublished report).



EXPLANATION

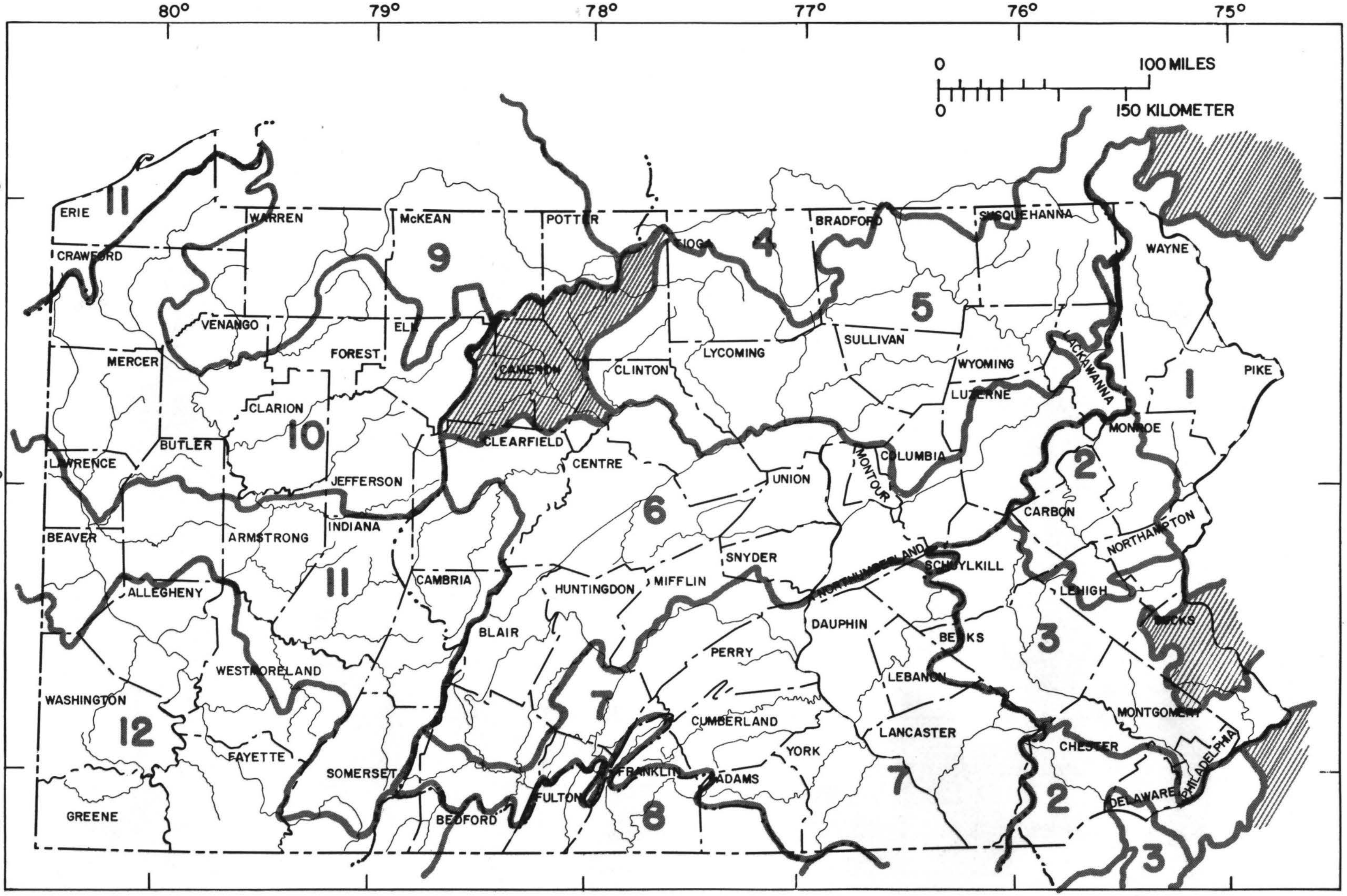
Regions I through 7 of homogenous flood-discharge characteristics

Region 8 of homogenous flood-discharge characteristics

Unmodeled area

Principal drainage-basin boundary

Figure 3.--Flood-discharge regions (Flippo, 1977).



EXPLANATION

Region of homogenous low-flow-discharge characteristics

Unmodeled areas and subregions not considered in program evaluation

Principal drainage-basin boundary

Figure 4.--Low-flow-discharge regions (Flippo, 1982).

Observed standard errors of regression can be used to assess how well the desired goals of a 10-year-record equivalency (Page, 1970) for small streams has been achieved. Table 4 presents, for selected flow characteristics, standard-error equivalents of this goal in conjunction with high, median, and low observed standard errors. Accuracy goals for mean-flow characteristics have been attained for about half of the regions delineated by Herb (in press). Goals for some flood-flow characteristics have been attained for about one-fourth of the regions (fig. 3). Goals for 7-day, low-flow characteristics have been met for only region 9 of figure 4.

NETWORK ANALYSIS FOR REGIONAL INFORMATION

The efficient design of a network for regional information requires knowledge of the information in the streamflow data base and an assessment of the potential for improving, through acquisition of additional data, the accuracy of data-transfer mechanisms. Accuracy of a regression equation as a data-transfer mechanism is a function of accuracy in the data, the number of streamflow records, the lengths of records used in the regression analysis, and model error.

The NARI technique devised by Moss and Karlinger (1974) uses the probability distribution of true regression error, SE_T, of the regression equation as a function of harmonic mean record length, NY, and the number of site records, NB, used in the regression analysis as the tool for objective, quantitative network design. NY is the reciprocal of the average reciprocal record length, in years, for the NB number of gaging-station records used to develop a particular regression equation. SE_T is the standard error of estimate that would be observed for the regression equation for an infinite number of sites, each having records of infinite length. Briefly, NARI is a procedure that partitions observed regression error into time-sampling, space-sampling, and model error--the error in the regression that is unrelated to sample errors of the dependent variable--in deriving the true regression error, SE_T. A Monte Carlo simulation involving a regression simulator and a multisite streamflow generator are used to derive the distribution of the standard error for each regression. These distributions are conditioned on computed values of average interstation correlation coefficient, ρ_c; coefficient of variation, C_v; model error, γ; NB; and NY. A Bayesian analysis is made of prior probabilities that are assigned to values of parameters γ, C_v, and ρ_c. In this way, probability distributions for these uncertain parameters are introduced to the analysis. Bayes' theorem is also used to introduce regression error in calculating the probabilistic relationship among SE_T, NY, and NB. Each such relationship has associated with it various confidence levels to appraise the uncertainty in SE_T derived from a generated regression.

Table 4.--Summary of proposed goals and observed standard errors of estimate for selected flow characteristics

Characteristics	Goals[1]	Standard error (percent) Observed High	Median	Low
Mean flow				
annual-	8.4	12	9	8
standard deviation of-	22.0	16	13	9
monthly-	24.4	41	18	8
Flood flow				
2 year-	16.4	42	30	20
10 year-	22.2	43	27	22
25 year-	26.3	50	29	24
50 year-	29.2	56	32	26
100 year-	32.3	62	34	28
Low flow (7 day)				
5 year-	20.2	53	30	17
10 year-	22.5	45	32	20
20 year-	25.8	56	34	20
50 year-	29.3	76	41	22

[1]For a 10-year-record equivalency, after Page (1970).

The calculation procedures of the NARI technique were performed by means of computer programs prepared by Moss and others (1982). Selections of streamflow records from those records used in derivation of the respective mean-, flood-, and low-flow regressions (table 3) were made so as to obtain a representative estimate of the probabilistic joint distribution of ρ_c and C_v. To achieve this, for each group of gages corresponding to one of the regression equations of table 3, all data in the period beginning with the earliest pair of concurrent records and ending in 1975 (1977 for the mean discharge groupings) were used in the computations. Minimum lengths of concurrent records considered for these computations were 15 years for mean flows, 10 years for annual peak discharges, and 14 years for low flows. These minima were chosen so as to maximize use of available records in calculating ρ_c and C_v. Annual mean discharges were used to compute joint probabilities of ρ_c and C_v for mean flow. For low flow, this joint-probability distribution was based on annual 7-day average minimum discharges. Methods have not been devised to estimate probability distributions of ρ_c for standard deviations (Moss, 1976); therefore, those prior probabilities computed from annual mean-, peak-, and low-flow averages were used as estimates of those for standard deviations.

For the network of gages operated in fiscal-year 1980, table 5 summarizes, by regression groupings for the selected streamflow characteristics, the period of concurrent records, the number of gage records (adjusted for degrees of freedom) used to estimate prior probabilities, harmonic mean record length, and true regression error, SE_T, of the regional equations. As figures 2-4 indicate, regional divisions are different for the three classes of regionalized flow characteristics.

Evaluation of Results

The NARI procedure was used to determine the relationship among NB, NY, and SE_T, at the 0.5 (50 percent) level of confidence for 88 regional equations that were developed for 38 gage groupings (tables 3 and 5). In addition, 11 similar relationships were calculated for 100-year peak discharge (Q_{100}) at the 0.95 level of confidence. Figures 5-7 show examples of these 99 probabilistic definitions of true regression error SE_T as a function of the regional number of gaging stations, NB, and record length, NY. Each curve in these figures is a line of constant SE_T, which signifies that all points on the curve specify networks of equal information content. Thus, a tradeoff of stations operated, NB, against a measure of the period of operation, NY, is possible for any attainable level of information content. These expressions of SE_T provide the basis for developing strategies for future gaging operations.

Several important features of these 99 SE_T relationships are easily determined from their plots. These features are:

1. Two-thirds of the SE_T's for the regression equations (present-network values), which are tabulated for the 0.5 level of confidence and to the nearest 0.1 percent in table 5, are within 4 percentage points, and all are within 11 percentage points, of observed standard errors of estimate (table 3). Observed standard errors are all within 8 percent of the SE_T's for the most commonly used streamflow characteristics--Q_A, Q_{50}, Q_{100}, and $Q_{7,10}$.

2. Observed standard errors of estimate are twice as likely to be less, rather than greater, than the SE_T.

3. Potential for improvement (reduction) of SE_T, at the 0.5 confidence level and within $NB \leq 50 \geq NY$ constraints, are generally less than 5 percentage points for existing regression models on Q_A, Q_{50}, Q_{100}, and $Q_{7,10}$ characteristics. For any SE_T, the ratio NY/NB diminishes as NB increases. Thus, the SE_T curves "flatten" with increasing values of NB. If the number of stations in each regional group (column 4 of table 5) was increased to 50, in order to reduce space-sampling errors, the value of SE_T for those characteristics would in no case be reduced from those values in table 5 by more than 4 percentage points while NY remained below its present value. Except for the 6 regional groups that presently equal or exceed the 50-station limit of programmed computational capability, 8 to 25 years of additional record, depending on the 50-station group being considered, would be needed to achieve the present NY value.

Table 5.--Number of gages, period of record, record length, and median true regression error for the 1980 stream-gaging program

Figure	Region	Period of record	No. of gage records[1]	Adjusted number of gages[2], NB	Harmonic mean record length (years), NY	Streamflow characteristic[3]	Median true regression error, SE_T at 0.50 confidence level: $\log_{10}$ units	Median true regression error, SE_T at 0.50 confidence level: percent
				MEAN-DISCHARGE REGIONALIZATION				
2	1[4]	1909-77	60	50[5]	25.2	Q_A	0.0479	11.0
						Q_S	.0544	12.7
2	2	1914-77	24	29	28.0	Q_A	.0454	10.5
						Q_S	.0464	10.7
2	3	1929-77	60	50[5]	34.4	Q^A	.0469	10.8
						Q_S	.0399	8.8
2	4	1921-77	31	31	32.3	Q_A	.0410	9.3
						Q_S	.0516	12.0
2	5	1916-77	47	47	33.5	Q_A	.0469	10.8
						Q_S	.0403	8.9
				FLOOD-DISCHARGE REGIONALIZATION				
3	1	1913-75	31	31	28.4	Q_{50}	.1169	27.4
						Q_{100}	.1278	30.0
3	2	1901-75	51	50	21.8	$\bar{x}$	.1005	23.2
						s	.1387	32.6
						Q_{50}	.1234	28.7
						Q_{100}	.1346	31.6
3	3	1940-75	7	8	21.3	$\bar{x}$	.2064	50.0
						s	.2581	64.2
						Q_{50}	.1538	36.0
						Q_{100}	.1549	36.5

Table 5.--Number of gages, period of record, record length, and median true regression error for the 1980 stream-gaging program--(continued)

Figure	Region	Period of record	No. of gage records[1]	Adjusted number of gages[2], NB	Harmonic mean record length (years), NY	Streamflow characteristic[3]	Median true regression error, SE_T at 0.50 confidence level: $\log_{10}$ units	Median true regression error, SE_T at 0.50 confidence level: percent
						FLOOD-DISCHARGE REGIONALIZATION--Continued		
3	4	1909-75	21	21	20.5	$\bar{x}$	0.1412	33.4
						s	.1954	47.5
						Q_{50}	.1361	32.3
						Q_{100}	.1413	33.1
3	5E	1901-75	63	50[5]	21.5	$\bar{x}$	.1161	27.1
						s	.2028	49.2
						Q_{50}	.1552	36.8
						Q_{100}	.1750	41.7
3	5W	1905-75	70	50[5]	23.8	$\bar{x}$	.1089	25.5
						s	.1431	33.7
						Q_{50}	.1266	29.6
						Q_{100}	.1280	30.0
3	6A[6]	1901-75	50	50	28.4	$\bar{x}$	.0873	20.2
						s	.1748	41.8
						Q_{50}	.1087	25.2
						Q_{100}	.1275	29.9
3	6B[7]	1938-75	24	23	16.0	$\bar{x}$	.1587	37.9
						s	.2752	69.9
						Q_{50}	.1858	44.6
						Q_{100}	.2089	50.5

Table 5.--Number of gages, period of record, record length, and median true regression error for the 1980 stream-gaging program--(continued)

Figure	Region	Period of record	No. of gage records[1]	Adjusted number of gages[2], NB	Harmonic mean record length (years), NY	Streamflow characteristic[3]	Median true regression error, SE_T at 0.50 confidence level: log_{10} units	Median true regression error, SE_T at 0.50 confidence level: percent
					FLOOD-DISCHARGE REGIONALIZATION--Continued			
3	7A[6]	1902-75	27	26	19.6	$\bar{x}$	0.1300	30.8
						s	.2094	51.1
						Q_{50}	.1864	45.0
						Q_{100}	.2100	51.2
3	7B[7]	1940-75	16	15	14.0	$\bar{x}$	.1848	44.0
						s	.2808	71.8
						Q_{50}	.2483	61.8
						Q_{100}	.2749	69.7
3	8	1910-75	15	13	23.1	$\bar{x}$	.1500	35.7
						s	.1864	45.1
						Q_{50}	.1277	30.2
						Q_{100}	.1415	33.7
					LOW-DISCHARGE REGIONALIZATION			
4	1	1910-75	18	18	22.3	$\bar{x}$	.1560	37.0
						s	.1670	39.8
						$Q_{7,10}$	.1756	42.3
4	2	1913-75	22	25	20.6	$\bar{x}$	.0921	21.4
						s	.1037	24.0
						$Q_{7,10}$	.1134	26.5
4	3	1929-75	14	16	16.4	$\bar{x}$	.1158	27.1
						s	.1389	33.0
						$Q_{7,10}$	.0947	22.0

Table 5.--Number of gages, period of record, record length, and median true regression error for the 1980 stream-gaging program--(continued)

Figure	Region	Period of record	No. of gage records[1]	Adjusted number of gages[2], NB	Harmonic mean record length (years), NY	Streamflow characteristic[3]	Median true regression error, SE_T at 0.50 confidence level: log_{10} units	Median true regression error, SE_T at 0.50 confidence level: percent
				LOW-DISCHARGE REGIONALIZATION--Continued				
4	4	1918-75	15	16	31.2	$\bar{x}$	0.1286	30.4
						s	.0885	20.6
						$Q_{7,10}$	.2144	52.5
4	5	1915-75	25	23	23.2	$\bar{x}$	.0934	21.7
						s	.0966	22.6
						$Q_{7,10}$	.1386	32.7
4	6	1913-70	20	19	27.0	$\bar{x}$	.1018	23.8
						s	.0936	22.2
						$Q_{7,10}$	.1351	31.9
4	7	1913-75	22	22	21.1	$\bar{x}$	.0896	20.9
						s	.1383	32.8
						$Q_{7,10}$	.1332	31.4
4	8	1930-75	17	16	21.2	$\bar{x}$	.1483	35.2
						s	.1567	37.5
						$Q_{7,10}$	.1660	39.5
4	9	1911-75	12	13	20.6	$\bar{x}$	.0673	15.4
						s	.1075	24.8
						$Q_{7,10}$	.1018	23.6
4	10	1911-75	18	18	23.8	$\bar{x}$	.1220	28.6
						s	.1316	31.1
						$Q_{7,10}$	.2049	49.8

Table 5.--Number of gages, period of record, record length, and median true regression error for the 1980 stream-gaging program--(continued)

Figure	Region	Period of record	No. of gage records[1]	Adjusted number of gages[2], NB	Harmonic mean record length (years), NY	Streamflow characteristic[3]	Median true regression error, SE_T at 0.50 confidence level: $\log_{10}$ units	Median true regression error, SE_T at 0.50 confidence level: percent
				LOW-DISCHARGE REGIONALIZATION--Continued				
4	11	1915-75	15	16	24.5	$\bar{x}$	0.1495	35.6
						s	.1332	31.5
						$Q_{7,10}$	.1569	37.2
4	12	1911-75	19	17	20.2	$\bar{x}$	.1129	26.8
						s	.1511	35.8
						$Q_{7,10}$	.2032	49.7

[1] Selected for estimation of probability distributions for coefficient of variation and interstation correlation coefficient.
[2] Number of gages used in regional regression, adjusted for degrees of freedom in regression.
[3] See description in table 3.
[4] No subdivision of region on basis of drainage area.
[5] Limit of computerized capability for design matrix.
[6] For streams draining more than 15 mi^2.
[7] For streams draining less than 15 mi^2.

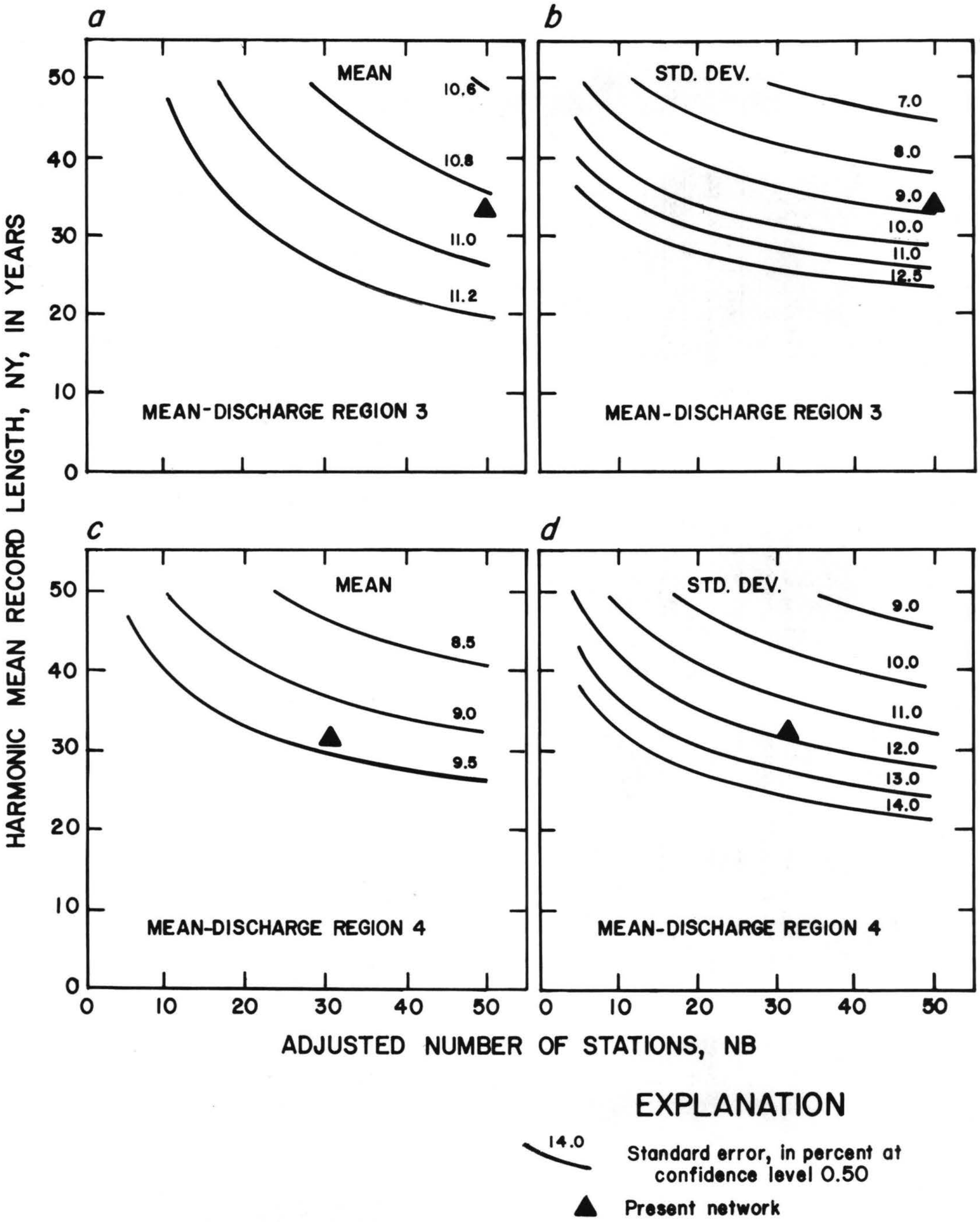


Figure 5.--True standard error SE_T for the (a,c) mean and (b,d) standard deviation of annual mean discharges, for streams in mean-discharge regions 3 and 4, as a function of NB and NY.

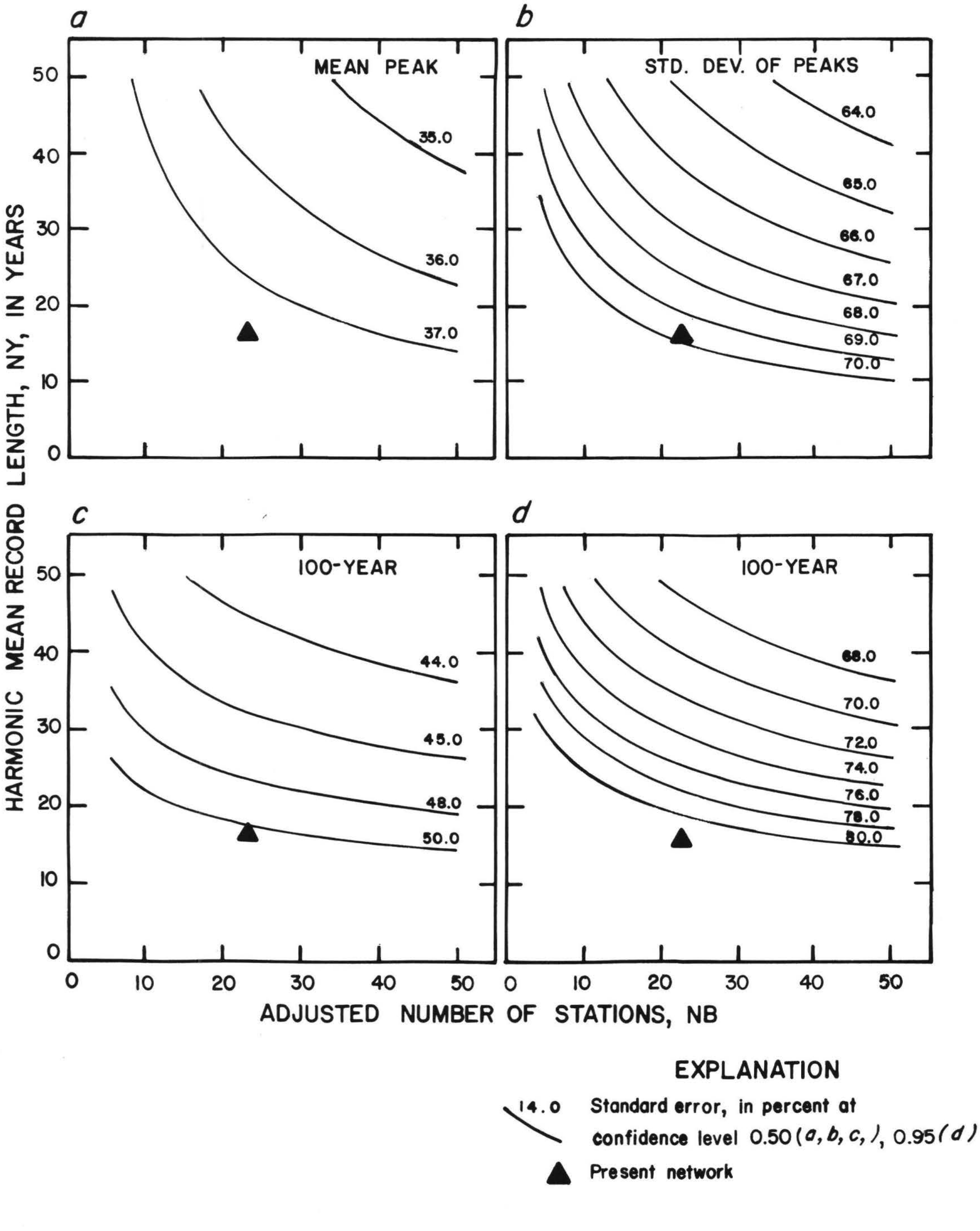


Figure 6.--True standard error SE_T for the (a) mean and (b) standard deviation of annual peak discharges, and the (c,d) 100-year peak discharge, for streams draining less than 15 mi^2 in flood region 6, as a function of NB and NY and confidence level.

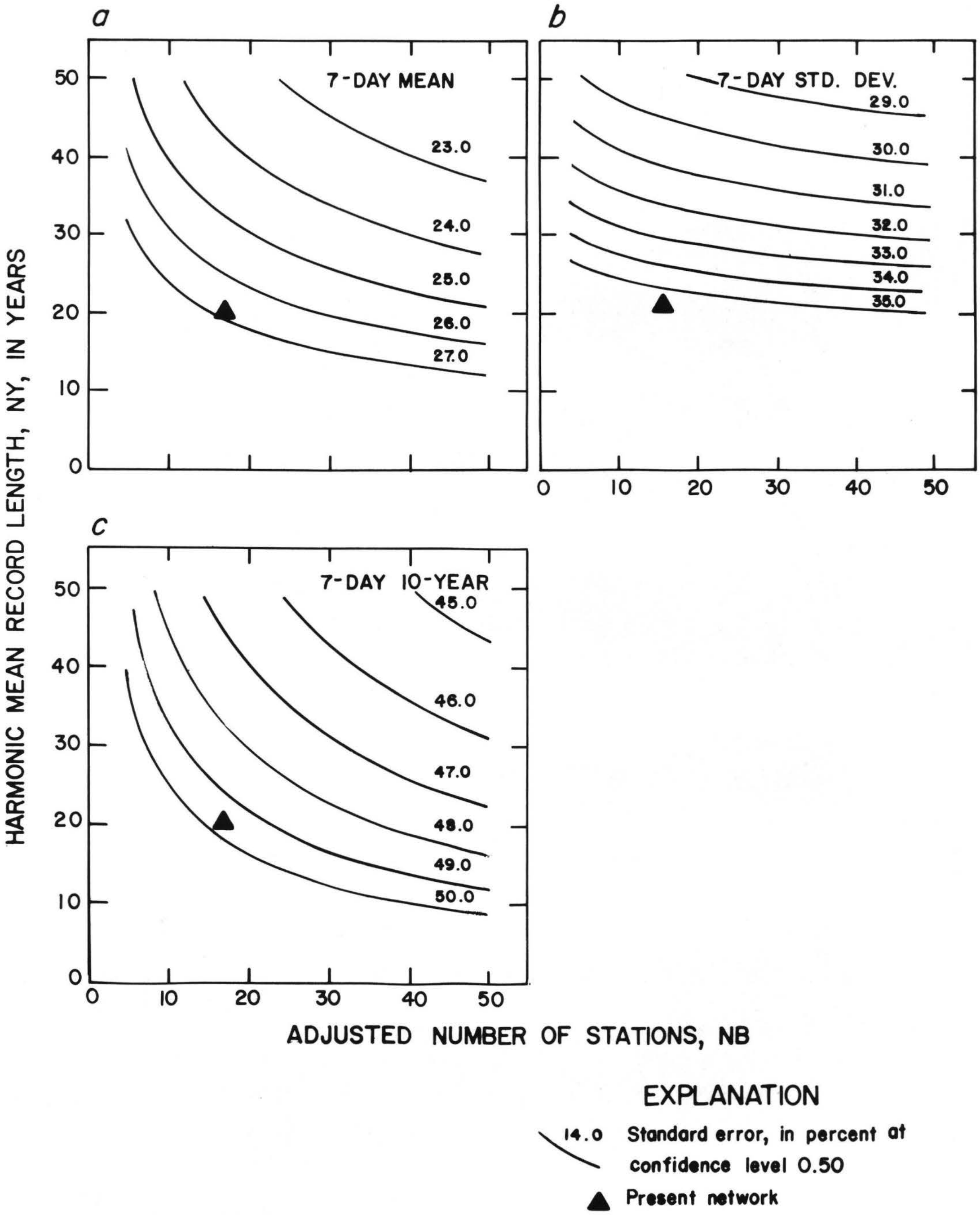


Figure 7.--True standard error SE_T for the (a) mean, (b) standard deviation, and (c) 10-year value of 7-day low discharges, for streams in low-flow region 12, as a function of NB and NY.

Slightly better improvments in SE_T's would result if time-sampling errors were reduced by continuing the present networks of stations in operation until NY=50 for all regional groups. An approximation of such improvements is given in table 6, which shows the expected reduction in SE_T, for each regression equation considered in this analysis, to be achieved by operation of gages for sufficient time (19 to 20 years) to increase NY by 20 years. The expected improvement in SE_T does not exceed 5.3 percentage points at the 0.5 confidence level for any regression equation. Expansion of the data base until NB=50 and NY=50 would result in slightly better improvements in SE_T than those in the example of table 6. The maximum, relative improvement to SE_T to be thereby achieved, at the 0.5 confidence level, for regression models of Q_A, Q_{50}, Q_{100}, and $Q_{7,10}$ would be about 20 percent. This improvement corresponds to reductions of 6-7 percentage points in the 30.2 and 33.7 SE_T percentages for the Q_{50} and Q_{100} equations of flood region 8. However, much of this potential improvement in SE_T could be attained merely by operating managerial gages for an additional 25 years. Nine gages in the part of region 8 within Pennsylvania were operated in 1980. Of these, seven are maintained for managerial purposes. If the other two (usage class P) gages in Pennsylvania are discontinued, SE_T's for Q_{50} and Q_{100} equations will, without further modification of the regional group of gages, decline about 4 percentage points in the next 25 years. Similarly, it can be shown that SE_T's for the flow-characteristic equations of the other regional groups can be reduced by as much as 4 percentage points over the next 25 years through operation of only managerial gages. Continued operation of those gages that are currently operated for nonspecific planning and design purposes will cause negligible additional reductions in SE_T's.

4. True standard errors at the 0.95 confidence level for Q_{100} regressions are 40 to 75 relative percent greater than those at the 0.5 confidence level. This feature is exemplified by frames c and d of figure 6. The SE_T relationships for the 0.95 confidence level are not comparable to observed standard errors of estimate. Comparison of SE_T plots for the 100-year peak discharge at this level of confidence with plots at the 0.5 level revealed a slightly greater potential for improvement, in terms of relative percentages, at the higher level of confidence.

On the basis of data-usage information summarized in table 2 and the four described features of SE_T relationships, particularly the third, the conclusion is drawn that continued operation of gages for regionalization of flow characteristics will result in minor improvements to the existing regression equations for these characteristics. Indeed, the large proportion of gages that are operated for managerial purposes, as well as the small improvements in SE_T to be achieved by operation of any feasible and practicable group of gages seems to obviate the need to operate gages for general planning and design purposes. However, gaging strategies should take into account a broader scope of hydrologic information than is encompassed in the presently adopted ensemble of log-linear regression equations--including their low potential for improvement by means of time-space tradeoffs, as indicated by the NARI results.

Table 6.--Reduction in true standard errors of estimate, for selected streamflow charcteristics, expected to be attained by operation of gages in the 1980 program for 20 additional years (1976-95)

Flow characteristics[1]		Confidence level	Expected reduction in true standard error SE_T, in percent, for indicated region[2]											
			1	2	3	4	5							
Mean discharge:	Q_A	0.50	0.4	0.2	0.3	0.8	0.3							
	Q_S	.50	5.1	4.1	3.0	3.1	3.5							
			1	2	3	4	5E	5W	6A	6B	7A	7B	8	
Flood discharge:	$\overline{x}$	.50	---	1.5	1.1	0.4	0.7	0.2	1.2	1.5	1.4	1.3	1.2	
	s	.50	---	2.5	2.6	2.4	2.1	1.8	2.1	3.7	2.1	4.2	3.1	
	Q_{50}	.50	1.1	2.3	2.3	1.7	2.7	1.9	2.3	4.6	1.6	3.7	3.4	
	Q_{100}	.50	1.8	3.4	3.2	1.7	3.0	2.0	2.6	5.3	1.8	4.7	4.3	
	Q_{100}	.95	5.0	8.8	5.5	4.1	6.8	3.6	6.6	11.0	3.5	6.5	8.0	
			1	2	3	4	5	6	7	8	9	10	11	12
Low-flow discharge:	$\overline{x}$	.50	0.6	0.5	0.8	1.2	0.9	0.8	0.6	1.1	0.2	0.8	1.2	2.7
	s	.50	2.4	3.2	4.0	3.2	4.2	3.1	3.0	3.2	3.3	2.8	3.2	5.3
	$Q_{7,10}$	.50	1.4	.6	1.0	.8	.8	.2	.6	.8	.8	.3	.7	2.3

[1]See descriptions in table 3.
[2]See figures 2-4 for delineations of regions.

Model improvement, which can only be measured in a statistical sense, cannot be quantitatively estimated prior to its achievement (Moss, 1979a). The previously discussed low potential for improvement of SE_T's for regression equations of Q_A, Q_{50}, Q_{100}, and $Q_{7,10}$ by means of space-time tradeoffs indicates that model errors are a substantial part of standard errors. Posterior probability distributions of model errors determined by NARI procedures are broad (probability varies over a wide range of model error), which shows model error as an uncertain quantity (Moss, 1979a). Measurement errors in quantitative independent variables used in the regression models are comparatively small; therefore, observed standard errors and SE_T's are largely controlled by the component of model error that stems from incorrect or insufficient specification of the model. Some improvement--as much as 3 or 4 percentage points in observed standard errors for some regression equations--could be readily achieved by adding 2 or 3 more independent variables to the equations. Such small improvements do not compensate for the added effort required to solve the equations. Evidently, an improved regionalization model or a better information-transfer technique of another type is needed if markedly improved accuracies in estimated flow characteristics for ungaged sites are desired.

Gaging Strategies

In consideration of the foregoing observations, two general strategies for future operation of a gaging network seem practicable: (I) continue to operate only those stream gages that serve on going programs in stream management, resource evaluation, and research, or which relate to specific stream developments; and (II) continue to operate those gages that qualify under Strategy I, as well as other selected gages whose records will or, at least, are expected to be useful in providing hydrologic knowledge in regions having recognized deficiencies in streamflow records, in improving the areal definition of statistical skew in flood discharges, or for testing and developing better mechanisms for transferring flow information to ungaged sites. Strategy I could be implemented on the basis of information in table 2 and knowledge of those gages for which data usage classed as P applies to a specific design problem or a planning-related need for detailed resource evaluation on the gaged stream. Effective implementation of Strategy II requires the network manager to have detailed knowledge of deficiencies in hydrologic information, an appreciation of possibilities for development of new data-transfer techniques, and an appraisal of the future worth of hydrologic data in meeting indefinite future needs for information.

Strategy II is the logical choice for optimization of the network. However, to be cost effective, the marginal worth of the data obtained must be no less than its marginal cost (Dawdy, 1979). Attainment of equivalency between worth and cost is extremely difficult, owing to uncertainties in: (1) the utility of data sequences in improving accuracy estimates of flow characteristics at ungaged sites, (2) those localities or streams for which more accurate data will be needed than can be obtained by developed data-transfer mechanisms, and (3) the economic value of data in specific applications.

The NARI results provide our best estimate of the utility of data sequences for estimating flow characteristics at ungaged sites. Analysis of SE_T curves in conjunction with record lengths can provide relationships between SE_T and the number of gages operated from which a cost-effective, regional network to meet a chosen planning horizon can be selected (Tasker and Moss, 1979). However, the noted low potential for improving SE_T's and the large proportion of gages operated for managerial purposes makes such analysis superfluous for the gaging program in Pennsylvania. Uncertainties surrounding the future utility of data obtained from gages operated on a contingency basis probably increases the worth of the data obtained, but selection of sites to obtain the most useful data is largely a matter of judgment. As Dawdy (1979) has pointed out, proposed theories and techniques for reducing the uncertainties associated with network design have been inadequate in dealing with the complexities of multi-objective gaging programs. The value of data for many uses is difficult to assess. Although techniques have been devised to determine the economics of streamflow records as they relate to some specific problems--for example, development of a water supply, there are no objective worth functions for determining the overall worth of various types of data.

SUMMARY AND CONCLUSIONS

The procedures for analysis of hydrologic networks developed by Moss and Karlinger (1974) have been used to determine the true standard errors of estimate of regional regression equations for flow characteristics. Results of this analysis are used to evaluate the potential for improvement of these equations by collecting additional streamflow data. Some of the regression equations already meet accuracy goals, but only minor improvements in them can be expected if all stations in the 1980 program are operated for 20 additional years. Expansion of the regional groups to 50, or so, stations would result in even smaller immediate improvements.

In keeping with the tenets of gaging Strategy II, gages operated for planning and design purposes (usage class P in table 2) for which additional records would have minimal value for enhancement of hydrologic knowledge were selected to be discontinued before April 1, 1981. These 11 continuous-record and 25 partial-record gages are listed by number and name in table 7. At least 6 of the other 29 continuous-record and 29 of the other 57 partial-record gages operated for planning and design purposes, which are not included in table 7, are expected to meet their operational objectives by the end of the 1985 water year. These gages, which are suggested for discontinuance at that time, are listed in table 8. Special-purpose gages that will be discontinued in the 1981-85 period, as the studies for which they were established are completed, are not included in this table. If gages are discontinued as suggested, each record will exceed the 10- or 15-year minimum length that was the objective when the gages were established.

Table 7.--Gaging stations selected for discontinuance before April 1, 1981[1]

Station Number	Station Name	Remarks
	Continuous-Record Stations	
01470720	Maiden Cr Trib at Lenhartsville	
01540200	Trexler Run nr Ringtown	
01547800	S Fk Beech Cr nr Show Shoe	
01553130	Sand Spring Run nr White Deer	
01565700	Little Lost Cr at Oakland Mills	
01568700	Stony Cr ab Res Site nr Dauphin	Discontinued 10-01-80
01573086	Beck Cr nr Cleona	
01578400	Bowery Run nr Quarryville	
01614090	Conococheague Cr nr Fayetteville	
03031950	Big Run nr Sprankle Mills	
03104760	Harthegig Run nr Greenfield	
	Partial-Record Stations	
01427650	N Br Calkins Cr nr Damascus	
01431000	Middle Cr nr Hawley	
01431680	Mill Brook nr Paupack	
01454600	Polk Valley Run at Hellertown	
01465780	Puquessing Cr ab Byberry Cr, Phila	
01465795	Byberry Cr at Grant Ave, Phila	
01467045	Pennypack Cr bl Verre Rd, Phila	

Table 7.--Gaging stations selected for discontinuance before April 1, 1981--(continued)

Station Number	Station Name	Remarks
	Partial-Record Stations	
01473100	Zacharias Cr nr Skippack	
01531250	N Br Sugar Cp Trib nr Columbia Crossroads	
01538800	Huntington Cr nr Pikes Creek	
01541248	Anderson Cr at Curwensville	
01541800	Alder Run nr Kylertown	
01542310	Mushannon Cr nr Mushannon	
01548020	Bull Run nr Logantown	
01555251	Mahonoy Cr nr Herndon	
01556400	Sandy Run nr Bellwood	
01565920	Lick Run nr East Waterford	
01572900	Reeds Cr nr Ono	
01638900	White Run nr Gettysburg	Discontinued 10-01-80
03015080	Akeley Run nr Russell	
03020440	W Br Caldwell Cr nr Grand Valley	
03026400	Richey Run at Emlenton	
03031780	Mill Cr nr Brockway	
03049100	Little Buffalo Cr at Cabot	
03083600	Gillespie Run nr Sutersville	

[1] Note--All were discontinued as of 4-1-81

Table 8.--Gaging stations suggested for discontinuance at close of 1985 water year

Station Number	Station Name	Remarks
	Continuous-Record Status	
01467050	Wooden Bridge Run at Philadelphia	
01473950	Wissahickon Cr at Bells Mill Rd	
01542810	Waldy Run nr Emporium	
01567500	Bixler Run nr Loysville	
01613050	Tonoloway Cr nr Needmore	
04213040	Raccoon Cr nr West Springfield	
	Partial-Record Stations	
01438300	Vandermark Cr at Milford	
01440300	Mill Cr at Mountainhome	
01446650	Martins Cr at Martins Creek	
01446900	Bushkill Cr nr Easton	
01471800	Pine Cr nr Manatawny	
01478150	E BR White Clay Cr at Landenberg	
01479700	W BR Red Clay Cr nr Kennett Square	
01480610	Sucker Run at Coatesville	
01530850	Bentley Cr at Ridgebury	
01532200	S BR Towanda Cr at New Albany	
01533250	Tuscarora Cr nr Silvara	
01542720	Wilson Run at Penfield	

Table 8.--Gaging stations suggested for discontinuance at close of 1985 water year--(continued)

Station Number	Stations Name	Remarks
	Partial-Record Stations	
01542950	Sinn. Portage Cr nr Emporium	
01543700	First Fk Sinnemahuning Cr at Wharton	
01551830	Loyalsock Cr nr Forksville	
01553050	White Deer Hole Cr nr Elimsport	
01555250	Mahanoy Cr at Dornsife	
01555570	Wisconisco Cr nr Elizabethville	
01569340	Newburg Run at Newburg	
01576320	Stony Run at Reamstown	
01578200	Conowingo Cr nr Buck	
01600700	Little Wills Cr at Bard	
03015390	Hare Cr nr Corry	
03017800	Minister Cr nr Truemans	
03029200	Clear Cr nr Sigel	
03045300	McCune Run at Keystone State Park	
03072880	Browns Cr nr Nineveh	
03083100	Jacobs Cr at Jacobs Creek	
04213200	Mill Cr at Erie	

No gages in usage classes other than P, except four gages that were used in a mine restoration study, are suggested to be discontinued. The remainder of the gages in usage class P are operated for current-purpose design objectives. The utility of each managerial gage, like that of current-purpose gages in usage class P, requires annual review to insure that data-collection activities are relevant to data needs. Such reviews can be made when cooperative gaging agreements are prepared. As funds become available to establish new gages for planning and design purposes, densely populated areas for which models of extreme-flow characteristics are relatively poor or nonexistent deserve priority consideration. Examples of such areas are flood regions 7 and 8 (fig. 3), and the unmodeled low-flow area in southeastern Pennsylvania (fig. 4).

Because low-flow models that might be developed in the future are unlikely to meet standard-error goals (table 4), operation of a large low-flow partial-record network throughout severe droughts would provide useful information on the spatial variability of low flows.

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