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GEOLOGICAL SURVEY

AN EVALUATION OF IDAHO STREAM-GAGING NETWORKS

by E. W. Quillian and W. A. Harenberg

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CONTENTS

ILLUSTRATIONS

CONTENTS

ILLUSTRATIONS--Continued

TABLES

APPENDIX

CONVERSION FACTORS

For the convenience of those who prefer SI (International System of Units) rather than the inch-pound system of units, conversion factors for terms used in this report are listed below.

Multiply inch-pound unit	By	To obtain SI unit
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
foot (ft)	0.3048	meter
inch (in.)	25.4	millimeter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer

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ABSTRACT

Network Analysis for Regional Information (NARI) and the Cost-Effectiveness Procedure were tested by applying them to stream-gaging networks in Idaho. NARI was used to determine network design strategies that would maximize the value of additional data. Value of data was measured as the decrease in the probable true standard error of regional regression equations. NARI indicated that no significant decrease in regression error can be achieved by the collection of additional data and that better models should be sought. No major modifications to NARI are necessary to make it widely applicable. The Cost-Effectiveness Procedure was used to determine optimal network operation strategies. It showed network uncertainty can be reduced when six- or one-visit per year minimum constraints are in force. Sensitivity to various cost factors was examined. Attempts to model networks that included sites for collection of ground-water and water-quality data were unsuccessful.

INTRODUCTION

An evaluation of the Idaho stream-gaging program was undertaken as a pilot project by the Idaho District at the request of the Surface Water Branch. The purpose of the project was to help determine the feasibility of undertaking a nationwide evaluation of surface-water gaging programs similar to that made in the early 1970's (Benson and Carter, 1973). The project also would help to evaluate the Idaho program and to give district personnel experience in some of the latest network design techniques.

Techniques used were NARI (Network Analysis for Regional Information) and the Cost-Effectiveness Procedure. NARI was devised by Moss and Karlinger in 1974 and applied to the surface-water program in Washington (Moss and Haushild, 1978) and a flood network in Arizona (Tasker and Moss, 1979). The Cost-Effectiveness Procedure was devised by Moss and Gilroy (1980) and applied to a surface-water network on the Lower Colorado River.

The first step in the project was to identify different types of networks that exist in the Idaho stream-gaging program and determine to which type each gaging station belonged. Four networks were identified: (1) the flood network, (2) the general hydrologic network, (3) the management network, and (4) the long-term trend network. Table 1 contains a list of current (July 1981) Idaho stream-gaging stations and the networks to which they are assigned. Some stations were assigned to more than one network.

The flood network includes all crest-stage gage stations and other gaging stations that have peak discharges that are not affected by regulation or diversion. The general hydrologic network consists of gaging stations that are not affected by regulation or diversion and can be used to estimate mean flows and high- or low-flow parameters. The management network is composed of all gaging stations presumed to be used by water-management agencies. The long-term trend network is composed of stations identified by Thomas and Harenberg (1970) as those needed to track long-term hydrologic trends.

The flood and general hydrologic networks were analyzed using the NARI procedure. Part of the NARI procedure involves computing regression equations and standard errors. Not all stations listed in table 1 met criteria for inclusion in a regression analysis. These criteria include a period of record equaling or exceeding 5 years and insignificant regulations or diversions for the dependent variable being analyzed. Gaging stations used in the regression analyses included both active and discontinued stations that met the criteria.

The management and long-term trend networks were to be analyzed using the Cost-Effectiveness Procedure if time and funding permitted. There was time to analyze only a small part of the management network. The part of the management network used in the Cost-Effectiveness analysis was a field trip that had been run from the Boise Hydrologic Records section for many years. This trip recently had been divided into two trips because of an increase in the number of data-collection points. These data-collection points included not only the surface-water data sites being analyzed in this study, but also ground-water and water-quality measurement sites. Only the surface-water sites were included in the Cost-Effectiveness Procedure, although this report makes recommendations to include the other kinds of data-collection sites in the Cost-Effectiveness Procedure to make it more useful to the districts of the WRD (Water Resources Division).

Table 1.--Current Idaho stream-gaging stations showing operating networks

Station number - Gaging-station downstream order number.
Sta. loc. - Station location: St, State; Co, County; Di, USGS District.
Rec typ - Type of gage: cmb - combination of two or more gages
csg - crest-stage gage
ind - indirect measurement
obs - observer reads staff gage
rec - water-stage recorder
Reg div - Record affected by regulation (reg) or diversion (div).
Network - Network(s) under which the gaging station is operated:
fld - Flood network
gen - General hydrologic network
mgt - Management network
ltt - Long-term trend network
Sta. location - Latitude (Lat) and longitude (Long) of gaging station, in degrees, minutes, and seconds.
Notation -- Does not apply.

Station number	Station name	Sta. loc. St	Co	Di	Drainage area (mi^2)	Rec typ	Period of record	Reg div	Network Fld	Gen	Mgt	Ltt	Sta. location Lat	Long
	GREAT BASIN													
10039500	Bear River at Border, WY	16	007	49	2,486	rec	1937–	reg	—	—	—	—	421240	1110311
10041000	Thomas Fork near WY-ID State line	56	063	49	113	rec	1949–	—	—	—	—	—	422410	1110130
10044000	Bear River at Harer, ID	16	007	49	2,839	rec	1913–	reg	—	—	—	—	421150	1111005
10046000	Rainbow Inlet Canal near Dingle, ID	16	007	49	——	rec	1922–	reg	—	—	—	—	421348	1111743
10046500	Bear River below Stewart Dam near Montpelier, ID	16	007	49	2,853	rec	1922–	reg	—	—	—	—	421514	1111735
10055500	Bear Lake at Lifton near St. Charles, ID	16	007	49	435	rec	1903-06	reg	—	—	—	—	420716	1111852
						rec	1921–	reg	—	—	—	—		
10058600	Bloomington Creek at Bloomington, ID	16	007	49	24	rec	1960–	—	—	—	—	—	421105	1112530
10059500	Bear Lake Outlet Canal near Paris, ID	16	007	49	——	rec	1922–	reg	—	—	—	—	421300	1112035
10068500	Bear River at Pescadero, ID	16	007	49	3,705	rec	1921-54	reg	—	—	—	—	422406	1112122
						rec	1969–	reg	—	—	—	—		
10072800	Eightmile Creek near Soda Springs, ID	16	007	49	22.6	rec	1960–	—	—	—	—	—	423215	1113420
10075000	Bear River at Soda Springs, ID	16	029	49	3,972	obs	1896	reg	—	—	—	—	423650	1113458
						obs	1898	div	—	—	—	—		
						rec	1953–	reg	—	—	—	—		
10076400	Soda Creek at Fivemile Meadows near Soda Springs, ID	16	029	49	51.7	rec	1964–	—	—	—	—	—	424345	111365
10079000	Soda Reservoir at Alexander, ID	16	029	49	——	obs	1944–	reg	—	—	—	—	423945	1114645
10079500	Bear River at Alexander, ID	16	029	49	4,099	rec	1911–	reg	—	—	—	—	423842	1114151
10084500	Cottonwood Creek near Cleveland, ID	16	041	49	61.7	rec	1938–	div	—	—	—	—	421957	1114627
10086500	Bear River below Utah Power and Light tailrace at Oneida, ID	16	041	49	4,456	rec	1921–	reg	—	—	—	—	421600	1114504
10090500	Bear River near Preston, ID	16	041	49	4,545	obs	1889–	—	—	—	—	—		
							1916	reg	—	—	—	—	421005	1115059
						obs	1917	reg	—	—	—	—		
						rec	1943–	reg	—	—	—	—		
10091130	Swan Lake Creek near Swan Lake, ID	16	041	16	6.35	csg	1973–	—	fld	—	—	—	422031	1115905
10092700	Bear River at ID-UT State line	16	041	49	4,881	rec	1970–	reg	—	—	—	—	420047	1115514
10093000	Cub River near Preston, ID	16	041	49	31.6	rec	1940-52	—	—	—	—	—	420828	1114119
						rec	1955–	—	—	—	—	—		
10125500	Malad River at Woodruff, ID	16	071	16	485	rec	1938–	reg	—	—	mgt	—	420181	1121345
	UPPER COLUMBIA RIVER BASIN													
12305000	Kootenai River at Leonia, ID	30	053	16	11,740	rec	1928-72	div	—	—	—	—	483704	1160247
						rec	1972–	reg	—	gen	mgt	—		
12306550	Moyie River at Eastport, ID	16	021	16	570	rec	1929–	—	fld	gen	—	ltt	485958	1161043
12309500	Kootenai River at Bonners Ferry, ID [1]	16	021	16	13,000	rec	1928-60	reg	—	—	mgt	—	484200	1161845
							1960	reg	—	—	mgt	—		
12314000	Kootenai River at Klockmann Ranch near Bonners Ferry, ID	16	021	16	13,300	rec	1928–	—	—	—	mgt	—	484738	1162251
12316800	Mission Creek near Copeland, ID	16	021	16	23	rec	1958–	—	fld	gen	mgt	—	485554	1162000
12318500	Kootenai River near Copeland, ID	16	021	16	13,400	rec	1929–	—	—	gen	mgt	—	485443	1162459
12321500	Boundary Creek near Porthill, ID	16	021	16	97.0	rec	1928–	div	fld	gen	mgt	—	485950	1163405
12322000	Kootenai River at Porthill, ID	16	021	16	13,700	rec	1928–	reg	—	gen	mgt	—	490000	1163010
12322500	Kootenay Lake at Kuskonook, B.C.	—	—	—	——	rec	1936–	reg	—	—	mgt	—	491756	1163931
12392000	Clark Fork at Whitehorse Rapids near Cabinet, ID	16	017	16	22,073	rec	1928–	reg	—	gen	mgt	—	480518	1160416
12392300	Pack River near Colburn, ID	16	017	16	124	rec	1958–	—	fld	gen	—	ltt	482512	1163002
12392500	Pend Oreille Lake near Hope, ID [2]	16	017	16	22,900	rec	1914–	reg	—	—	mgt	—	481635	1162047
12392895	Blanchard Creek above Reservoir near Blanchard, ID	16	017	16	31.5	obs	1979–	—	fld	gen	mgt	—	475958	1170151
12393000	Priest Lake at Outlet near Coolin, ID [3]	16	017	16	572	obs	1911-13	—	—	—	—	—	482936	1165258
						obs	1928-39	—	—	—	—	—		
						rec	1940-50	—	—	—	—	—		
						rec	1951–	reg	—	—	mgt	—		
12394000	Priest River near Coolin, ID	16	017	16	611	rec	1948–	reg	—	—	mgt	—	482707	1165358
12395000	Priest River near Priest River, ID	16	017	16	902	obs	1903-05	reg	—	—	—	—	481231	1165449
						obs	1910	reg	—	—	—	—		
						obs	1923	reg	—	—	—	—		
						rec	1929–	reg	—	—	mgt	—		
12395500	Pend Oreille River at Newport, WA	16	017	16	24,200	obs	1903-12	—	—	—	—	—	481056	1170200
						obs	1928-41	—	—	—	—	—		
						rec	1952–	reg	—	—	mgt	—		
12411000	Coeur d'Alene River above Shoshone Creek near Prichard, ID	16	079	16	335	rec	1950–	—	fld	gen	mgt	—	474230	1155835
12413000	Coeur d'Alene River at Enaville, ID	16	079	16	895	obs	1911-12	—	—	—	—	—	473420	1161510
						rec	1939–	—	—	gen	mgt	—		

Table 1.--Current Idaho stream-gaging stations showing operating networks--Continued

Station number	Station name	Sta. loc. St	Sta. loc. Co	Sta. loc. Di	Drainage area (mi²)	Rec typ	Period of record	Reg div	Network Fld	Network Gen	Network Mgt	Network Ltt	Sta. location Lat	Sta. location Long
	UPPER COLUMBIA RIVER BASIN--Continued													
12413140	Placer Creek at Wallace, ID	16	079	16	14.9	rec	1967-	div	fld	gen	mgt	---	472750	1155610
12413150	South Fork Coeur d'Alene River at Silverton, ID	16	079	16	103	obs	1967-	---	fld	gen	mgt	---	472929	1155712
12413250	South Fork Coeur d'Alene River at Kellogg, ID	16	079	16	194	rec	1974-	---	fld	gen	mgt	---	473249	1160809
12414350	Big Creek above East Fork near Calder, ID	16	079	16	38.83	rec	1981-	---	fld	gen	---	---	471821	1160659
12414400	East Fork Big Creek near Calder, ID	16	079	16	15.4	csg	1973-	---	fld	---	---	---	471807	1160705
12414500	St. Joe River at Calder, ID	16	079	16	1,030	obs	1911-12	---	---	---	---	---	471630	1161115
						rec	1920-	---	fld	gen	mgt	---		
12414900	St. Maries River near Santa, ID	16	009	16	275	rec	1965-	---	fld	gen	mgt	---	471035	1162930
12415500	Coeur d'Alene Lake at Coeur d'Alene, ID [1]	16	055	16	3,700	rec	1903-	reg	---	---	mgt	---	473955	1164605
12416000	Hayden Creek below North Fork near Hayden Lake, ID	16	055	16	22	rec	1948-53	---	---	---	---	---	474922	1163910
						rec	1958-59	---	---	---	---	---		
						rec	1965-	---	fld	gen	---	ltt		
12417000	Hayden Lake at Hayden Lake, ID [1]	16	055	16	62.3	obs	1920-	---	---	---	mgt	---	474602	1164512
12418000	Rathdrum Prairie Canal at Huetter, ID	16	055	16	-----	rec	1946-	---	---	---	mgt	---	474235	1165205
12419000	Spokane River near Post Falls, ID	16	055	16	3,840	rec	1912-	reg	---	---	mgt	---	474210	1165840
12422950	Hangman Creek near Tensed, ID	16	009	16	125	rec	1981-	---	fld	gen	mgt	---	471124	1170101
	SNAKE RIVER BASIN													
13011000	Snake River near Moran, WY	56	039	16	807	rec	1903-	reg	---	gen	mgt	---	435131	1103509
13011500	Pacific Creek at Moran, WY	56	039	16	169	rec	1917-18	---	---	---	---	---	435104	1103059
						rec	1944-75	---	---	---	---	---		
						rec	1978-	---	fld	gen	mgt	ltt		
13011900	Buffalo Fork above Lava Creek near Moran, WY	56	039	16	323	rec	1965-	---	fld	gen	---	---	435014	1102621
13018300	Cache Creek near Jackson, WY	56	039	16	10.6	rec	1962-	---	fld	gen	---	ltt	432708	1104212
13018750	Snake River below Flat Creek near Jackson, WY	56	039	16	2,627	rec	1975-	reg	---	---	mgt	---	432200	1104300
13022500	Snake River above Reservoir near Alpine, WY	56	023	16	3,465	rec	1937-39	reg	---	---	---	---	431147	1105318
						rec	1953-	reg	fld	gen	mgt	---		
13023000	Greys River above Reservoir near Alpine, WY	56	023	16	448	rec	1937-39	div	---	---	---	---	430835	1105834
						rec	1953-	div	fld	gen	mgt	---		
13027500	Salt Creek above Reservoir near Etna, WY	56	023	16	829	rec	1953-	div	---	gen	mgt	---	430447	1110212
13032500	Snake River near Irwin, ID	16	019	16	5,225	rec	1935-36	reg	---	---	---	---	432103	1111306
						rec	1939-41	reg	---	---	---	---		
						rec	1949	reg	gen	mgt	---	---		
13037500	Snake River near Heise, ID	16	019	16	5,752	rec	1910-	reg	---	gen	mgt	---	433645	1113933
13038000	Dry Bed near Ririe, ID	16	051	16	-----	rec	1923-27	reg	---	---	---	---	433821	1124255
						rec	1976-	reg	---	---	mgt	---		
13038380	Dry Bed near Lewisville, ID	16	051	16	-----	rec	1976-	reg	---	---	mgt	---	434241	1120219
13038410	Lyons Creek near Ririe, ID	16	065	16	18.8	csg	1973-	---	fld	---	---	---	434054	1114450
13038500	Snake River at Lorenzo, ID	16	051	16	5,810	rec	1924-27	reg	---	---	---	---	434406	1115233
						rec	1978-	reg	---	---	mgt	---		
13039000	Henrys Lake near Lake, ID [3]	16	043	16	99	rec	1923-	---	---	---	mgt	---	443551	1112110
13039500	Henrys Fork near Lake, ID	16	043	16	99.3	rec	1920-	reg	---	---	mgt	---	443542	1112057
13042500	Henrys Fork near Island Park, ID	16	043	16	481	rec	1933-	reg	---	---	mgt	---	442459	1112341
13046000	Henrys Fork near Ashton, ID	16	043	16	1,040	obs	1890-91	reg	---	---	---	---	440430	1112958
						rec	1902-09	reg	---	---	---	---		
						rec	1920-	reg	---	---	mgt	---		
13047500	Falls River near Squirrel, ID	16	043	16	326	obs	1904-09	---	---	---	---	---	440407	1111425
						rec	1918-	reg	fld	gen	mgt	---		
13049500	Falls River near Chester, ID	16	043	16	520	rec	1920-	div	---	gen	mgt	---	440106	1113357
13050500	Henrys Fork near St. Anthony, ID	16	043	16	1,770	rec	1919-	reg	---	gen	mgt	---	435800	1114020
13052200	Teton River above Leigh Creek near Driggs, ID	16	081	16	335	rec	1961-	div	fld	gen	mgt	---	434654	1111230
13055000	Teton River near St. Anthony, ID	16	043	16	890	obs	1890-93	div	---	---	---	---	435538	1113655
						obs	1903-09	div	---	---	---	---		
						rec	1920-76	div	---	---	---	---		
						rec	1977-	div	---	gen	mgt	---		
13055198	North Fork Teton River at Teton, ID	16	043	16	-----	rec	1977-	div	---	---	mgt	---	435353	1114038
13055319	Moody Creek near Rexburg, ID	16	065	16	-----	obs	1979-	---	---	---	mgt	---	434648	1113721
13056500	Henrys Fork near Rexburg, ID	16	065	16	2,920	rec	1909-	reg	---	---	mgt	---	434934	1115415
13057150	Snake River near Lewisville, ID	16	051	16	-----	rec	1978-	reg	---	---	mgt	---	433735	1120356
13060000	Snake River near Shelley, ID	16	011	16	9,790	rec	1915-	reg	---	---	mgt	---	432450	1120805
13061800	Aberdeen-Springfield Canal near Springfield, ID	16	011	16	-----	rec	1980-	---	---	gen	---	---	430630	1123906
13062500	Snake River at Blackfoot, ID	16	011	16	9,950	rec	1924-32	reg	---	---	---	---	431150	1122205
						rec	1978-	reg	---	---	mgt	---		
13062650	Snake River Tributary No. 9 near Rockford, ID	16	011	16	17.6	csg	1973-	---	fld	---	---	---	431335	1123424

Table 1.—Current Idaho stream-gaging stations showing operating networks—Continued

Station number	Station name	Sta. loc. St	Sta. loc. Co	Sta. loc. Di	Drainage area (mi²)	Rec typ	Period of record	Reg div	Network Fld	Network Gen	Network Mgt	Network Ltt	Sta. location Lat	Sta. location Long
	SNAKE RIVER BASIN—Continued													
13063000	Blackfoot River above Reservoir near Henry, ID	16	029	16	350	obs	1914-25	div	—	—	—	—	424900	1113035
						rec	1967-	div	fld	gen	mgt	ltt		
13065000	Blackfoot Reservoir near Henry, ID [3]	16	029	16	581	obs	1912-25	—	—	—	—	—	430020	1114300
						obs	1929-	—	—	—	mgt	—		
13065940	Wolverine Creek near Goshen, ID	16	011	16	----	obs	1979-	div	—	—	mgt	—	431502	1120057
13065950	Blackfoot River Tributary near Goshen, ID	16	011	16	2	csg	1973-	—	fld	—	—	—	431530	1120206
13066000	Blackfoot River near Shelley, ID	16	011	16	909	rec	1909-25	reg	—	—	—	—	431546	1120248
						rec	1975-	reg	—	gen	mgt	—		
13068495	Blackfoot River Bypass near Blackfoot, ID	16	011	16	----	rec	1978-	reg	—	—	mgt	—	431016	1122313
13068500	Blackfoot River near Blackfoot, ID	16	011	16	1,295	rec	1913-	reg	—	gen	mgt	—	430750	1122835
13068501	Blackfoot River and Bypass Channel near Blackfoot, ID	16	011	16	----	cmb	1975-	reg	—	gen	mgt	—	430750	1122835
13069500	Snake River near Blackfoot, ID	16	011	16	11,310	rec	1910-	reg	—	gen	mgt	—	430731	1123106
13069540	Danielson Creek near Springfield, ID	16	011	16	----	rec	1932-77	—	—	—	—	—	430232	1124124
						rec	1980-	—	—	gen	—	—		
13070300	Portneuf Reservoir near Chesterfield, ID	16	005	16	100	obs	1980-	reg	—	—	mgt	—	425242	1115638
13072890	Dempsey Creek near Lava Hot Springs, ID	16	005	16	37	csg	1973-	—	fld	—	—	—	423557	1120112
13073000	Portneuf River at Topaz, ID	16	005	16	570	obs	1913-15	reg	—	—	—	—	423730	1120520
						obs	1919-	reg	—	gen	mgt	—		
13075000	Marsh Creek near McCammon, ID	16	005	16	335	rec	1954-	div	—	gen	mgt	—	423750	1121330
13075090	Inman Creek near Inkom, ID	16	005	16	8.2	csg	1973-	—	fld	—	—	—	424917	1121257
13075100	Rapid Creek near Inkom, ID	16	005	16	57.2	obs	1980-	div	—	gen	—	—	424802	1121346
13075500	Portneuf River at Pocatello, ID	16	005	16	1,250	obs	1897-99	reg	—	—	—	—	425220	1122805
						rec	1911-	reg	—	gen	mgt	—		
13075900	Fort Hall Michaud Canal near Pocatello, ID	16	077	16	----	rec	1964-	div	—	—	mgt	—	425610	1123245
13075983	Spring Creek at Sheepskin Road near Pocatello, ID	16	011	16	----	rec	1980-	—	—	gen	—	—	430236	1123315
13076125	Bannock Creek Tributary near Pocatello, ID	16	077	16	4.9	csg	1975-	—	fld	—	—	—	424427	1123646
13076400	Michaud Canal at American Falls, ID	16	077	16	----	rec	1958-	reg	—	—	mgt	—	424645	1125220
13077000	Snake River at Neeley, ID	16	077	16	13,600	obs	1907-09	reg	—	—	—	—	424606	1125242
						rec	1912-	reg	—	gen	mgt	—		
13077600	East Fork Rock Creek near Rockland, ID	16	077	16	13.7	rec	1960-64	—	—	—	—	—	423340	1124720
						rec	1978-	—	fld	gen	—	—		
13077650	Rock Creek near American Falls, ID	16	077	16	320	rec	1978-	div	—	gen	—	—	423910	1130100
13078205	Raft River below Onemile Creek near Malta, Id	16	031	16	417	rec	1975-	div	—	gen	mgt	—	420400	1132700
13081500	Snake River near Minidoka, ID (at Howells Ferry)	16	067	16	15,700	rec	1911-	reg	—	gen	mgt	—	424023	1132958
13082500	Goose Creek above Trapper Creek near Oakley, ID	16	031	16	633	rec	1911-16	div	—	—	—	—	420730	1135620
						rec	1919-	div	—	gen	mgt	—		
13083000	Trapper Creek near Oakley, ID	16	031	16	53.7	obs	1911-16	div	—	—	—	—	421010	1135820
						rec	1919-	div	fld	gen	mgt	—		
13083500	Oakley Reservoir near Oakley, ID [3]	16	031	16	729	obs	1912-	reg	—	—	mgt	—	421150	1135450
13084400	Birch Creek above diversions near Oakley, ID	16	031	16	33.9	csg	1973-	—	fld	—	—	—	421040	1134905
13084850	"F" Man Drain near Rupert, ID	16	067	16	62.1	csg	1973-	div	fld	—	—	—	424214	1134045
13087900	Lake Milner at Milner Dam, ID [3]	16	031	16	----	rec	1974-	reg	—	—	mgt	—	423126	1140040
13088000	Snake River at Milner, ID	16	083	16	17,180	rec	1909-	reg	—	gen	mgt	—	423141	1140104
13090000	Snake River near Kimberly, ID	16	083	16	----	rec	1923-	reg	—	gen	mgt	—	423528	1142134
13091000	Blue Lakes Spring nr Twin Falls, ID	16	053	16	----	rec	1950-	—	—	gen	mgt	—	423653	1142806
13093095	Rock Creek near mouth near Twin Falls, ID	16	083	16	300	rec	1975-	reg	—	gen	mgt	—	423725	1143158
13093500	Cedar Draw near Filer, ID	16	083	16	----	rec	1955-58	div	—	—	—	—	423725	1143905
						rec	1980-	div	—	gen	—	—		
13094000	Snake River near Buhl, ID	16	083	16	----	rec	1946-	reg	—	gen	mgt	—	423958	1144241
13095500	Box Canyon Spring near Wendell, ID	16	047	16	----	rec	1950-	—	—	gen	—	—	424229	1144835
13105000	Salmon Falls Creek near San Jacinto, NV	32	007	16	1,450	obs	1910-16	div	—	—	—	—	415640	1144115
						rec	1918-	div	—	gen	mgt	—		
13106000	Salmon River Canal Company Canal near Rogerson, ID	16	083	16	----	rec	1937-	reg	—	—	mgt	—	421310	1144420
13106500	Salmon River Canal Company Reservoir near Rogerson, ID	16	083	16	1,610	obs	1922-	reg	—	—	mgt	—	421240	1144400
13106535	Soldier Creek near Rogerson, ID	16	083	16	5.23	csg	1973-	—	fld	—	—	—	421324	1141448
13108150	Salmon Falls Creek near Hagerman, ID	16	047	16	2,120	rec	1970-	reg	—	gen	mgt	—	424147	1145115
13112000	Camas Creek near Camas, ID	16	033	16	440	rec	1925-	div	—	gen	mgt	—	440010	1121312
13113000	Beaver Creek at Spencer, ID	16	033	16	120	obs	1940-52	div	—	—	—	—	442120	1121045
						rec	1968-	div	fld	gen	mgt	—		
13113500	Beaver Creek at Dubois, ID	16	033	16	220	rec	1924-	div	—	gen	mgt	—	441110	1121408
13114000	Beaver Creek near Camas, ID	16	051	16	510	rec	1921-	div	—	gen	mgt	—	440027	1121325
13115000	Mud Lake near Terreton, ID [3]	16	051	16	1,130	rec	1921-	reg	—	—	mgt	—	435325	1122128
13117020	Birch Creek at Blue Dome Inn near Reno, ID	16	033	16	380	rec	1967-	div	—	gen	mgt	—	440914	1125424

Table 1.--Current Idaho stream-gaging stations showing operating networks--Continued

Station number	Station name	Sta. loc. St	Co	Di	Drainage area (mi²)	Rec typ	Period of record	Reg div	Network Fld	Gen	Mgt	Ltt	Sta. location Lat	Long
	SNAKE RIVER BASIN--Continued													
13117030	Birch Creek at Eightmile Canyon Road near Reno, ID	16	033	16	400	rec	1967-	div	—	gen	mgt	—	440449	1125230
13118700	Little Lost River below Wet Creek near Howe, ID	16	023	16	440	rec	1958-	div	—	gen	mgt	—	440819	1131439
13119000	Little Lost River near Howe, ID	16	023	16	703	rec	1921-	div	—	gen	mgt	—	435310	1130600
13120000	North Fork Big Lost River at Wild Horse near Chilly, ID	16	037	16	114	rec	1944-	div	fld	gen	mgt	ltt	435559	1140647
13120500	Big Lost River at Howell Ranch near Chilly, ID	16	037	16	450	obs	1904-14	div	—	—	—	—	435954	1140112
						rec	1920-	div	fld	gen	mgt	—		
13126000	Mackay Reservoir near Mackay, ID [3]	16	037	16	788	obs	1919-	reg	—	—	mgt	—	435705	1134028
13127000	Big Lost River below Mackay Reservoir near Mackay, ID	16	037	16	813	obs	1903-06	reg	—	—	—	—	435620	1133850
						obs	1912-15	reg	—	—	—	—		
						rec	1919-	reg	—	gen	mgt	—		
13128900	Lower Cedar Creek above diversions near Mackay, ID	16	037	16	8.26	obs	1920-22	—	—	—	—	—	435757	1133440
						csg	1963-66	—	—	—	—	—		
						rec	1967-73	—	—	—	—	—		
						rec	1980-	—	fld	gen	mgt	—		
13132500	Big Lost River near Arco, ID	16	023	16	1,410	rec	1946-61	reg	—	—	—	—	433500	1131610
						rec	1966-	reg	—	gen	mgt	—		
13132555	Big Lost River Tributary No. 2 near Idaho Falls, ID	16	011	16	6.29	csg	1973-	—	fld	—	—	—	433302	1123737
13135000	Snake River below Lower Salmon Falls near Hagerman, ID	16	047	16	-----	rec	1937-	reg	—	gen	mgt	—	425055	1145402
13139500	Big Wood River at Hailey, ID	16	013	16	640	obs	1889	div	—	—	—	—	433105	1141910
						rec	1915-	div	fld	gen	mgt	—		
13141000	Big Wood River near Bellevue, ID	16	013	16	823	rec	1911-	div	—	gen	mgt	—	431940	1142025
13141500	Camas Creek near Blaine, ID	16	025	16	648	rec	1912-21	reg	—	—	—	—	431959	1143227
						rec	1923-	reg	—	gen	mgt	—		
13142000	Magic Reservoir near Richfield, ID[3]	16	013	16	1,600	obs	1909-	reg	—	—	mgt	—	431519	1142125
13142500	Big Wood River below Magic Dam near Richfield, ID	16	013	16	1,600	rec	1911-	reg	—	gen	mgt	—	431500	1142130
13147900	Little Wood River above High Five Creek near Carey, ID	16	013	16	248	rec	1958-74	div	—	—	—	—	432930	1140330
						rec	1980-	div	fld	gen	mgt	—		
13148200	Little Wood Reservoir near Carey, ID[3]	16	013	16	279	obs	1955-	reg	—	—	mgt	—	432530	1140130
13148500	Little Wood River near Carey, ID	16	013	16	312	obs	1904-05	reg	—	—	—	—	432320	1140000
						rec	1926-	reg	—	gen	mgt	—		
13150430	Silver Creek at Sportsman Access near Picabo, ID	16	013	16	70	rec	1974-	—	—	gen	mgt	—	431922	1140629
13152500	Big Wood River near Gooding, ID	16	047	16	2,990	rec	1916-	reg	—	gen	mgt	—	425312	1144808
13153777	Snake River Tributary No. 10 near King Hill, ID	16	047	16	.52	csg	1973-	—	fld	—	—	—	425334	1150839
13154500	Snake River at King Hill, ID	16	039	16	35,800	rec	1909-	reg	—	gen	mgt	—	430008	1151206
13157005	Pot Hole Creek Tributary near Winter Camp Butte, ID	16	073	16	5.73	csg	1973-	—	fld	—	—	—	423630	1152125
13157150	Browns Creek at Highway 78 crossing near Hammett, ID	16	073	16	108	csg	1980-	—	—	gen	—	—	425559	1153335
13168500	Bruneau River near Hot Springs, ID	16	073	16	2,630	obs	1909-15	div	—	—	—	—	424616	1154310
						rec	1943-	div	—	gen	mgt	—		
13169500	Big Jacks Creek near Bruneau, ID	16	073	16	253	rec	1938-49	—	—	—	—	—	424706	1155900
						rec	1965-	—	fld	gen	—	ltt		
13170200	Sugar Creek near Bruneau, ID	16	073	16	33.6	csg	1973-	—	fld	—	—	—	424036	1155330
13171700	Poison Creek near Grand View, ID	16	073	16	11.6	csg	1973-	—	fld	—	—	—	424505	1161820
13172500	Snake River near Murphy, ID	16	073	16	41,900	rec	1913-	reg	—	gen	mgt	—	431730	1162512
13176100	Blue Creek near Grasmere, ID	16	073	16	24	csg	1975-	—	fld	—	—	—	422729	1161503
13184500	Middle Fork Boise River near Twin Springs, ID	16	015	16	382	rec	1976-	—	fld	gen	mgt	—	434245	1153750
13185000	Boise River near Twin Springs, ID	16	015	16	830	rec	1911-	—	—	gen	mgt	—	433922	1154334
13186000	South Fork Boise River near Featherville, ID	16	039	16	635	rec	1945-	div	fld	gen	mgt	—	432940	1151820
13190000	Anderson Ranch Reservoir at Anderson Ranch Dam, ID	16	039	16	980	rec	1945-	reg	—	—	mgt	—	432130	1152640
13190500	South Fork Boise River at Anderson Ranch Dam, ID	16	039	16	982	rec	1943-	reg	—	gen	mgt	—	432030	1152840
13194000	Arrowrock Reservoir at Arrowrock Dam, ID	16	039	16	2,210	obs	1917-	reg	—	—	mgt	—	433540	1155519
13200000	Mores Creek above Robie Creek near Arrowrock Dam, ID	16	015	16	399	rec	1950-	div	fld	gen	mgt	—	433853	1155920
13201500	Lucky Peak Lake near Boise, ID	16	001	16	2,680	obs	1955	reg	—	—	—	—	433131	1160315
						rec	1956-	reg	—	—	mgt	—		
13202000	Boise River near Boise, ID	16	001	16	2,680	obs	1895-1916	reg	—	—	—	—	433633	1161227
						rec	1952-	reg	—	gen	mgt	—		
13204500	Diversions from Boise River between near and at Boise gaging station, ID	16	001	16	-----	cmb	1966-	reg	—	gen	mgt	—	433200	1160400
13204800	Cottonwood Creek near Boise, ID	16	001	16	11.7	ind	1959	—	—	—	—	—	433659	1160930
						csg	1973-	—	fld	—	—	—		
13205500	Boise River at Boise, ID	16	001	16	2,760	rec	1940-	reg	—	gen	mgt	—	433633	1161227

Table 1.--Current Idaho stream-gaging stations showing operating networks--Continued

Station number	Station name	Sta. loc. St	Co	Di	Drainage area (mi^2)	Rec typ	Period of record	Reg div	Network Fld	Gen	Mgt	Ltt	Sta. location Lat	Long
	SNAKE RIVER BASIN--Continued													
13205633	Crane Creek at 1206 Ranch Road at Boise, ID	16	001	16	7.21	csg	1979-	—	fld	gen	—	—	433848	1161201
13206000	Boise River at Strawberry Glen near Boise, ID	16	001	16	—	obs	1938-40	reg	—	—	—	—	433950	1161710
						rec	1981-	reg	—	gen	mgt	—		
13206400	Eagle Drain at Eagle, ID	16	001	16	—	obs	1981-	reg	—	—	mgt	—	434138	1162111
13209450	Thurman Drain near Eagle, ID	16	001	16	—	obs	1981-	reg	—	—	mgt	—	434018	1162229
13210050	Boise River near Middleton, ID	16	027	16	—	rec	1974-	reg	—	—	mgt	—	434106	1163422
13210810	Fivemile Creek Drain near Middleton, ID	16	027	16	—	obs	1981-	reg	—	—	mgt	—	434027	1163504
13210824	North Middleton Drain at Middleton, ID	16	027	16	—	obs	1981-	reg	—	—	mgt	—	434224	1163702
13210831	South Middleton Drain near Middleton, ID	16	027	16	—	obs	1981-	reg	—	—	mgt	—	434208	1163702
13210835	Willow Creek at Highway 44 at Middleton, ID	16	027	16	—	obs	1981-	reg	—	—	mgt	—	434224	1163747
13210849	Mason Slough near Caldwell, ID	16	027	16	—	obs	1981-	reg	—	—	mgt	—	434119	1163910
13210983	Mason Creek near Caldwell, ID	16	027	16	—	rec	1981-	reg	—	—	mgt	—	434100	1163955
13210986	West Hartley Drain near Caldwell, ID	16	027	16	—	obs	1981-	reg	—	—	mgt	—	434159	1164105
13210987	East Hartley Drain near Caldwell, ID	16	027	16	—	obs	1981-	reg	—	—	mgt	—	434156	1164038
13211345	Indian Creek at Lone Tree Lane Crossing near Nampa, ID	16	027	16	—	csg	1979-	reg	fld	—	—	—	483803	1163811
13211445	Indian Creek at mouth near Caldwell, ID	16	027	16	—	rec	1981-	reg	—	—	mgt	—	434026	1164205
13212550	Conway Gulch at Notus, ID	16	027	16	—	csg	1981-	reg	—	—	mgt	—	434336	1164727
13212890	Dixie Drain near Wilder, ID	16	027	16	—	rec	1981-	reg	—	—	mgt	—	434351	1155415
13212995	Boise River diversions from at Boise to near Parma gaging station, ID	16	027	16	—	cmb	1973-	reg	—	gen	mgt	—	434654	1165817
13213000	Boise River near Parma, ID	16	027	16	3,970	rec	1971-	reg	—	gen	mgt	—	434654	1165817
13213072	Sand Run Gulch near Parma, ID	16	027	16	—	rec	1979-	div	—	—	mgt	—	434759	1165829
13213100	Snake River at Nyssa, OR	41	045	16	58,700	rec	1974-	reg	—	gen	mgt	—	435234	1165902
13235000	South Fork Payette River at Lowman, ID	16	015	16	456	rec	1941-	—	fld	gen	mgt	ltt	440505	1153710
13236000	Deadwood Reservoir near Lowman, ID [1]	16	085	16	112	rec	1935-	reg	—	—	mgt	—	441738	1153841
13236500	Deadwood River below Deadwood Reservoir near Lowman, ID	16	085	16	112	rec	1926-	reg	—	gen	mgt	—	441730	1153833
13238500	Payette Lake at McCall, ID[1]	16	085	16	144	rec	1921-	reg	—	—	mgt	—	445450	1160710
13239000	North Fork Payette River at McCall, ID	16	085	16	144	rec	1909-	reg	—	gen	mgt	—	445430	1160710
13240000	Lake Fork Payette River above Jumbo Creek near McCall, ID	16	085	16	48.9	rec	1945-	reg	fld	gen	mgt	—	445450	1155910
13244500	Cascade Reservoir at Cascade, ID	16	085	16	620	obs	1948-58	reg	—	—	—	—	443130	1160300
						rec	1959-	reg	—	—	mgt	—		
13245000	North Fork Payette River at Cascade, ID	16	085	16	626	rec	1941-	reg	—	gen	mgt	—	443044	1160152
13246000	North Fork Payette River near Banks, ID	16	015	16	933	rec	1947-	reg	—	gen	mgt	—	440650	1160625
13247500	Payette River near Horseshoe Bend, ID	16	015	16	2,230	obs	1906-16	reg	—	—	—	—	435633	1161145
						rec	1919-	reg	—	gen	mgt	—		
13248970	Johnson Creek near Montour, ID	16	045	16	3.44	csg	1974-	—	fld	—	—	—	435508	1162121
13249500	Payette River near Emmett, ID	16	045	16	2,680	rec	1925-	reg	—	gen	mgt	—	435550	1162630
13250000	Payette River near Letha, ID	16	045	16	2,760	rec	1952-53	reg	—	—	—	—	4353	11637
						rec	1980-	reg	—	gen	mgt	—		
13250600	Big Willow Creek near Emmett, ID	16	075	16	47.4	rec	1961-	—	fld	gen	mgt	ltt	440425	1162910
13251000	Payette River near Payette, ID	16	075	16	3,240	rec	1935-	reg	—	gen	mgt	—	440233	1165527
13254000	Lost Valley Reservoir near Tamarack, ID	16	003	16	29.4	obs	1924	reg	—	—	—	—	445730	1162800
						obs	1926-66	reg	—	—	—	—		
						obs	1981-	reg	—	—	mgt	—		
13254500	Lost Creek near Tamarack, ID	16	003	16	29.4	obs	1910-14	reg	—	—	—	—	445720	1162755
						rec	1920-21	reg	—	—	—	—		
						rec	1924-69	reg	—	—	—	—		
						rec	1980-	reg	—	—	mgt	—		
13255050	West Fork Weiser River near Fruitvale, ID	16	003	16	—	rec	1981-	reg	—	—	mgt	—	444910	1162734
13255060	Weiser River near Fruitvale, ID	16	003	16	—	rec	1981-	div	—	—	mgt	—	444709	1162626
13257020	Middle Fork Weiser River near Mesa, ID	16	003	16	—	rec	1981-	div	—	—	mgt	—	443935	1162714
13258500	Weiser River near Cambridge, ID	16	087	16	605	rec	1939-	reg	—	gen	mgt	—	443447	1163820
13260500	Little Weiser River near Indian Valley, ID	16	003	16	—	rec	1981-	div	—	—	mgt	—	442922	1162323
13261100	C Ben Ross Feeder Canal near Indian Valley, ID	16	003	16	—	obs	1981-	reg	—	—	mgt	—	443052	1162518
13261150	C Ben Ross Reservoir near Indian Valley, ID	16	003	16	—	obs	1981-	reg	—	—	mgt	—	443118	1162656
13261200	C Ben Ross Irrigation Canal near Indian Valley, ID	16	003	16	—	obs	1981-	reg	—	—	mgt	—	443139	1162649
13261650	Weiser River below Little Weiser River near Cambridge, ID	16	087	16	—	obs	1981-	reg	—	—	mgt	—	443306	1164144
13261670	Dixie Creek near Cambridge, ID	16	087	16	10.9	csg	1973-	—	fld	—	—	—	442956	1163626
13264000	Crane Creek Reservoir near Midvale, ID	16	087	16	242	obs	1924-69	reg	—	—	—	—	442130	1163700
						obs	1980-	reg	—	—	mgt	—		
13265500	Crane Creek at mouth near Weiser, ID	16	087	16	288	rec	1920-73	reg	—	—	—	—	441728	1164648
						rec	1981-	reg	—	—	mgt	—		

Table 1.--Current Idaho stream-gaging stations showing operating networks--Continued

Station number	Station name	Sta. loc. St	Sta. loc. Co	Sta. loc. Di	Drainage area (mi^2)	Rec typ	Period of record	Reg div	Network Fld	Network Gen	Network Mgt	Network Ltt	Sta. location Lat	Sta. location Long
	SNAKE RIVER BASIN--Continued													
13266000	Weiser River near Weiser, ID	16	087	16	1,460	obs	1897-1904	div	---	---	---	---	441623	1164623
						obs	1910-14	reg	---	---	---	---		
						rec	1921-	reg	---	---	mgt	---		
13269000	Snake River at Weiser, ID	16	087	16	69,200	rec	1910-	reg	---	gen	mgt	---	441444	1165848
13289700	Brownlee Reservoir at Brownlee Dam, ID	16	087	16	72,590	rec	1965-	reg	---	---	mgt	---	445008	1165358
13289960	Wildhorse River at Brownlee Dam, ID	16	003	16	177	rec	1979-	div	fld	gen	mgt	---	445108	1165324
13290190	Pine Creek near Oxbow, OR	16	001	16	230	rec	1966-	reg	---	gen	mgt	---	445713	1165221
13290450	Snake River at Hells Canyon Dam, ID-OR State line	16	087	16	73,300	rec	1967-	reg	---	gen	mgt	---	451505	1164150
13290460	Snake River at Johnson Bar, OR[1]	41	063	16	-----	rec	1959-	reg	---	---	mgt	---	452750	1163316
13296500	Salmon River below Yankee Fork near Clayton, ID	16	037	16	802	rec	1921-	div	---	gen	mgt	---	441606	1144355
13297330	Thompson Creek near Clayton, ID	16	037	16	29.1	rec	1972-	---	fld	gen	mgt	---	441536	1143050
13297350	Bruno Creek near Clayton, ID	16	037	16	6.29	rec	1971-	---	fld	gen	mgt	---	441756	1142850
13297355	Squaw Creek below Bruno Creek near Clayton, ID	16	037	16	79	rec	1972-	---	fld	gen	mgt	---	441726	1142815
13297450	Little Boulder Creek near Clayton, ID	16	037	16	18.4	rec	1970-	---	fld	gen	mgt	---	440557	1142656
13297597	Herd Creek below Trail Gulch near Clayton, ID	16	037	16	110	rec	1980-	div	fld	gen	mgt	---	440856	1141722
13298000	East Fork Salmon River near Clayton, ID	16	037	16	532	obs	1928-39	div	---	---	---	---	441329	1141706
						rec	1973-	div	fld	gen	mgt	---		
13302500	Salmon River at Salmon, ID	16	059	16	3,760	obs	1912-16	div	---	---	---	---	451100	1135340
						rec	1919-	div	---	gen	mgt	---		
13305000	Lemhi River near Lemhi, ID	16	059	16	890	obs	1938-39	div	---	---	---	---	445624	1133816
						obs	1955-63	div	---	---	---	---		
						rec	1967-	div	---	gen	mgt	---		
13307000	Salmon River near Shoup, ID	16	059	16	6,270	rec	1944-	div	---	gen	mgt	---	451920	1142623
13309220	Middle Fork Salmon River near Yellow Pine, ID	16	085	16	770	rec	1973-	---	---	gen	mgt	---	444311	1150048
13310700	South Fork Salmon River near Krassel Ranger Station, ID	16	085	16	330	rec	1966-	---	fld	gen	mgt	---	445930	1154330
13313000	Johnson Creek at Yellow Pine, ID	16	085	16	213	rec	1928-	div	fld	gen	mgt	ltt	445744	1152958
13316500	Little Salmon River at Riggins, ID	16	049	16	576	rec	1951-	div	fld	gen	mgt	ltt	452447	1161929
13317000	Salmon River at White Bird, ID	16	049	16	13,550	obs	1910-17	div	---	---	---	---	454501	1161923
						rec	1919-	div	---	gen	mgt	---		
13334300	Snake River near Anatone, WA	53	003	16	92,960	rec	1958-	reg	---	gen	mgt	---	460550	1165836
13336300	Gedney Creek near Selway Falls, ID	16	049	16	48.2	rec	1981-	---	fld	gen	---	---	460327	1151848
13336450	Rackcliff Creek at O'Hara Guard Station, ID	16	049	16	8.44	csg	1973-	---	fld	---	---	---	460505	1152938
13336500	Selway River near Lowell, ID	16	049	16	1,910	obs	1911	div	---	---	---	---	460512	1153046
						rec	1929-	div	---	gen	mgt	---		
13337000	Lochsa River near Lowell, ID	16	049	16	1,180	rec	1910-12	---	---	---	---	---	460902	1153511
						rec	1929-	---	---	gen	mgt	---		
13337540	Leggett Creek near Golden, ID	16	049	16	7.78	csg	1973-	---	fld	---	---	---	454936	1153735
13338500	South Fork Clearwater River at Stites, ID	16	049	16	1,150	obs	1910-12	---	---	---	---	---	460512	1155832
						rec	1964-	---	---	gen	mgt	---		
13339500	Lolo Creek near Greer, ID	16	049	16	243	obs	1911-12	---	---	---	---	---	462220	1160940
						rec	1980-	---	fld	gen	mgt	---		
13340000	Clearwater River at Orofino, ID	16	035	16	5,580	obs	1930-38	---	---	---	---	---	462843	1161523
						rec	1964-	---	---	gen	mgt	---		
13340600	North Fork Clearwater River near Canyon Ranger Station, ID	16	035	16	1,360	rec	1967-	---	---	gen	mgt	---	465026	1153711
13340950	Dworshak Reservoir near Ahsahka, ID	16	035	16	2,440	rec	1972-	reg	---	---	mgt	---	463100	1161730
13341050	Clearwater River near Peck, ID	16	069	16	8,040	rec	1964-	reg	---	gen	mgt	---	463000	1162330
13341128	Long Hollow Creek near Nez Perce, ID	16	061	16	17.7	obs	1980-	---	fld	gen	mgt	---	461403	1161410
13342450	Lapwai Creek near Lapwai, ID	16	069	16	235	rec	1974-	div	fld	gen	mgt	---	462536	1164815
13342500	Clearwater River at Spalding, ID	16	069	16	9,570	obs	1910-13	div	---	---	---	---	462655	1164935
						rec	1925-	reg	---	gen	mgt	---		
13343010	Lindsay Creek Tributary No. 4 near Lewiston, ID	16	069	16	2.96	csg	1973-	---	fld	---	---	---	462210	1165328
13345000	Palouse River near Potlatch, ID	16	057	16	317	rec	1915-19	reg	---	---	---	---	455455	1165700
						rec	1966-	reg	fld	gen	mgt	---		
13346750	Paradise Creek at Moscow, ID	16	057	16	14	csg	1973-	---	fld	---	---	---	464327	1165845
13346800	Paradise Creek at University of Idaho at Moscow, ID	16	057	16	17.7	rec	1978-	---	fld	gen	mgt	---	464355	1170124
13350448	Cow Creek at Genesee, ID	16	057	16	34.3	obs	1980-	---	---	gen	mgt	---	463248	1165537

[1]Gage height only
[2]Elevation only
[3]Contents only

NETWORK ANALYSIS FOR REGIONAL INFORMATION

Information concerning streamflow characteristics is necessary to design hydraulic structures such as culverts, dams, and bridges. Often, such information is not available from data collected systematically at the site of interest and must be transferred from sites in the same region that have streamflow data. Regression analysis is a method of accomplishing this transfer. NARI is a tool that helps the network designer determine how best to deploy available stream-gaging resources to achieve maximum information content in a stream-gaging network. The following is a description of the application of NARI to evaluate the U.S. Geological Survey stream-gaging networks in Idaho.

Regression Analysis

Multivariate regression analysis is used to develop equations to transfer streamflow information from gaged sites to ungaged sites. The regression equations use drainage basin characteristics to provide estimates of streamflow characteristics at locations where no data have been collected. Typical streamflow characteristics to be estimated are 10-year peak discharge, 100-year peak discharge, and average discharge. Typical drainage basin characteristics used are drainage area, mean annual precipitation, percentage forest cover, and mean basin elevation.

A form of regression equation recommended for use in hydrology (Benson and Matalas, 1967) is

$$Y=b_0 X_1^{b_1} X_2^{b_2} \ldots X_k^{b_k}$$

where Y, the dependent variable, is the streamflow characteristic of interest; X_1, X_2, ..., and X_k, the independent variables, are characteristics of the drainage basin at the site being considered; and b_0, b_1, b_2, ..., and b_k are regression coefficients. The least-squares regression coefficient values derived are those that give the regression equations with minimum variance for a group of gaged basins in a region (Haan, 1977). Regions, subareas within a study area, are established by an iterative process that involves successive runs through the regression programs. Generally, one or more regressions are run through the entire data base to compute regression equations and residuals, the differences between the actual and estimated values for the dependent variable. The residuals are plotted and the plots examined to determine if patterns exist that indicate whether some regional relations are present. Successive regression runs are then made to refine the region boundaries. To do this, gaging stations are moved in and out of regions to lower standard errors in all regions. Constraints other than standard error may be given consideration. For example, to make the resulting regression equations easier to use, it may be desirable to require that, if possible, region boundaries fall on hydrologic unit boundaries (U.S. Geological Survey, 1975).

A regional regression equation for each dependent variable is fitted to a sample of hydrologic events on the basis of data that have been collected using the stream-gaging network in the region. Time-sampling and space-sampling errors are present in the sample. The observed standard error, S_0, is a measure of how well the regression equation fits the sample. If the fit of the regression equation, with coefficients estimated from the sample, could be measured using the entire population of events in the region, the result would be the true standard error, S_T. The model error, γ, is the standard error of a regression equation fitted to the population having the goodness of fit measured using the population. The smaller the magnitude of the standard error, the greater the information content of the stream-gaging network is considered to be.

The NARI Package

The NARI package of computer programs (Moss and others, 1982) describes the value of S_T probabilistically by producing probability distribution functions of S_T given various network designs. NARI first calculates the joint probabilities of C_v and ρ_c, where C_v is the average coefficient of variation of a streamflow parameter in the region of interest, and ρ_c is the regional average cross-correlation coefficient between pairs of stations. NARI then calculates joint probabilities of a number of combinations of γ, C_v, and ρ_c values. Finally, it computes cumulative probability functions of the form

$$P(S_T \leq S_T\alpha \mid S_0, NB, NY)=\alpha,$$

where $S_T\alpha$ is a reference value of true standard error; α is the reliability associated with that value; NB is the adjusted number of gaged basins in the network being considered and is equal to the unadjusted number of stations, plus 1, minus the number of independent variables in the regression equation; and NY is the harmonic mean record length.

Application of NARI in Idaho

Earlier studies divided the State of Idaho into two different sets of regions for the purpose of making regression analyses for the transfer of streamflow information (Thomas and Harenberg, 1970; and Thomas and others, 1973). These two sets of regions were considered, and a third set of regions was derived during this study, on the basis of the behavior of the residuals of a statewide regression equation for the 10-year peak discharge. In addition, divisions along hydrologic unit boundaries (U.S. Geological Survey, 1975) for this study were favored. Some difficulty was encountered in choosing region boundaries so that the condition $10 \leq NB \leq 50$ was satisfied, as required by NARI.

Each stream gage that contributed data to the sample of hydrologic events was included in the flood-frequency network and/or the general hydrologic network. Also, each gaged basin was assigned to a region in each of the three sets of regions being considered. Data from gages in the flood-frequency network were used to develop regression equations for peak discharges at the 2-, 10-, 50-, and 100-year recurrence intervals. These peak discharges are herein referred to as P2, P10, P50, and P100, respectively. Basins in the general hydrologic network were used to develop regression equations for the average discharge, QA, and the standard deviation of average discharge, SDA.

The regions (fig. 1) chosen in this study were based on the networks with minimum standard error (table 2).

Basin characteristics used in the regression analysis as independent variables were drainage area, stream length, main channel slope, mean basin elevation, percentage lake area, percentage forest cover, latitude of the stream gage, longitude of the stream gage, mean annual precipitation, 24-hour rainfall intensity at the 2-year recurrence interval, mean air temperature in January, and mean air temperature in July. Only the basin characteristics that were significant at the 5 percent level were used in the final regression equations (table 2).

For each of six dependent variables, P2, P10, P50, P100, QA, and SDA, a regression equation was developed for each region. The observed standard error, in percent, S_0, was calculated in each case. The median, minimum, and maximum standard errors for each dependent variable are shown in table 3. Median standard errors ranged from 30 percent for the QA regressions to 83 percent for the P100

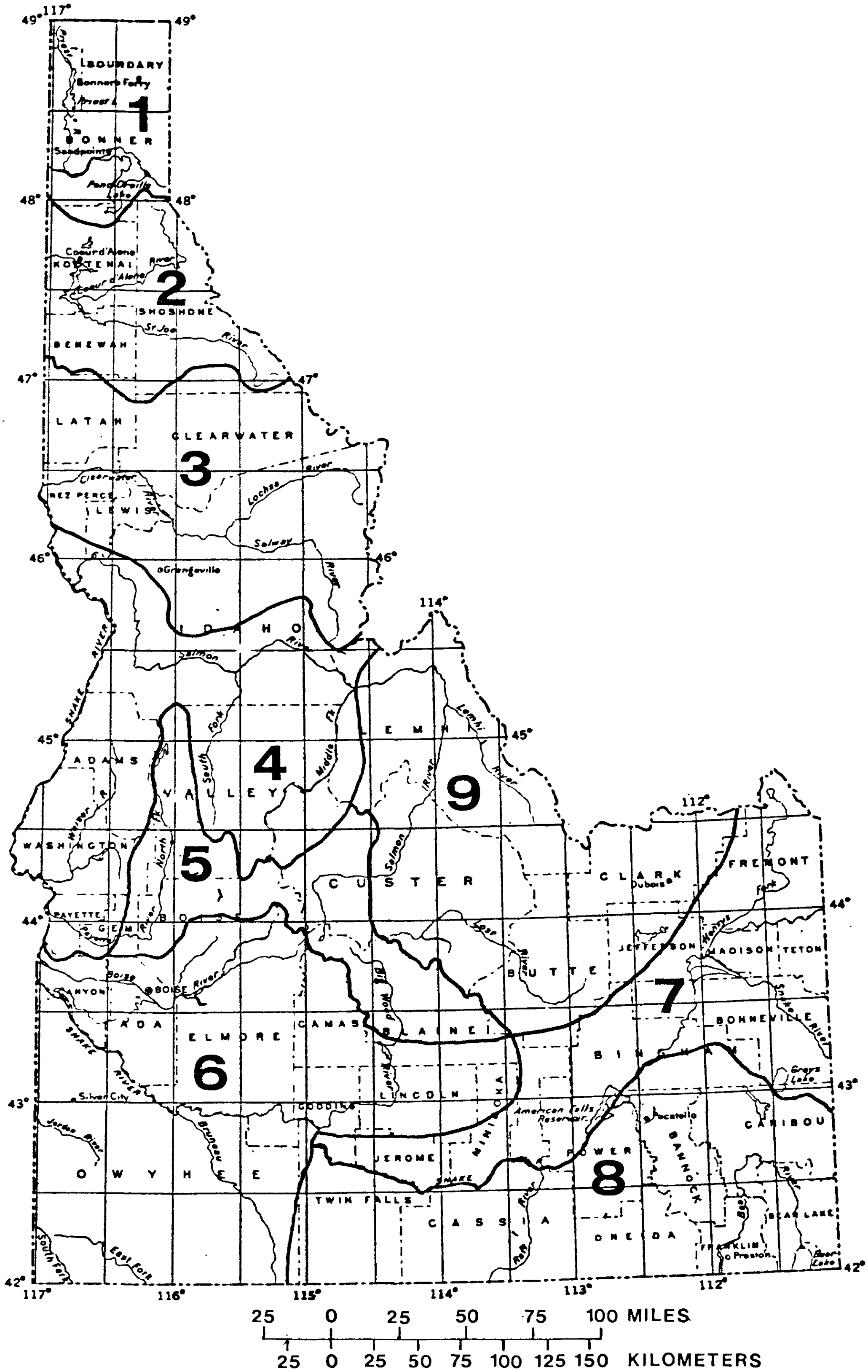

FIGURE I. -- Regions for which regression equations were developed.

Table 2.--Regression equations for regions of Idaho

Region: Refers to regions delineated in figure 1.

Number of Stations in Network: The number of stations in the regional stream-gaging network used to develop the regression equation.

Regression Equation: The predictive equation developed by multiple-regression analysis with logarithmic (base 10) transformation. Dependent variables are P2, 2-year peak discharge; P10, 10-year peak discharge; P50, 50-year peak discharge; P100, 100-year peak discharge; QA, average discharge; and SDA, standard deviation of mean annual discharge. Independent variables are A, drainage area, mi^2; P, mean annual precipitation, in.; F, percentage of forest cover plus 1 percent; Lng, longitude of the gaging station, decimal degrees minus 110°; E, mean basin elevation, ft minus 1,000; La, percentage of lake area plus 1 percent; and Le, stream length measured along main channel from gaging station to basin divide, mi.

Observed Standard Error: Observed standard error, in percent, as calculated by Riggs (1968, p. 15).

Region	Number of of stations in region	Regression equation	Observed mean	Standard (plus)	Error (minus)
1	34	$P2 = 0.0402\ A^{0.972}\ P^{1.551}$	--	76	43
	34	$P10 = 0.199\ A^{0.919}\ P^{1.320}$	--	59	37
	34	$P50 = 0.711\ A^{0.890}\ P^{1.102}$	--	56	36
	34	$P100 = 1.20\ A^{0.882}\ P^{1.006}$	--	59	37
	19	$QA = 0.299\ A^{0.929}\ P^{0.565}$	26	--	--
	19	$SDA = 0.635\ A^{0.875}$	--	74	42

Table 2.--Regression equations for regions of Idaho--Continued

Region	Number of of stations in region	Regression equation	Observed mean	Standard (plus)	Error (minus)
2	18	$P2 = 22.3\ A^{0.893}$	--	68	41
	18	$P10 = 53.6\ A^{0.863}$	--	72	47
	18	$P50 = 87.6\ A^{0.859}$	--	91	48
	18	$P100 = 103\ A^{0.858}$	--	99	50
	12	$QA = 1720\ A^{0.857}\ F^{-3.270}\ P^{2.307}$	19	--	--
	11	$SDA = 0.509\ A^{1.002}\ La^{3.295}$	28	--	--
3	31	$P2 = 13.9\ A^{0.950}$	--	58	37
	31	$P10 = 40.3\ A^{0.843}$	--	74	57
	31	$P50 = 76.7\ A^{0.779}$	--	100	50
	31	$P100 = 96.3\ A^{0.756}$	--	112	53
	20	$QA = 0.968\ A^{1.102}\ Lng^{-2.958}\ P^{1.354}$	26	--	--
	20	$SDA = 0.0328\ A^{1.093}\ F^{0.421}$	--	76	43
4	44	$P2 = 12.4\ A^{0.956}$	--	68	41
	44	$P10 = 34.3\ A^{0.852}$	--	77	44
	44	$P50 = 62.4\ A^{0.793}$	--	99	50
	44	$P100 = 76.9\ A^{0.773}$	--	108	52
	23	$QA = 0.506\ A^{0.951}\ E^{0.650}$	30	--	--
	22	$SDA = 0.312\ A^{0.990}$	34	--	--

Table 2.--Regression equations for regions of Idaho--Continued

Region	Number of of stations in region	Regression equation	Observed mean	Standard (plus)	Error (minus)
5	28	$P2 = 0.0525\ A^{0.814}\ P^{1.632}$	--	87	46
	28	$P10 = 0.387\ A^{0.770}\ P^{1.263}$	--	76	43
	28	$P50 = 45.5\ A^{0.769}$	--	79	44
	28	$P100 = 52.9\ A^{0.760}$	--	79	44
	25	$QA = 0.00125\ A^{1.006}\ P^{0.996}\ Lng^{2.057}$	30	--	--
	21	$SDA = 0.0221\ A^{0.951}\ Lng^{1.898}$	24	--	--
6	49	$P2 = 3.91\ A^{1.010}$	--	281	74
	49	$P10 = 29.0\ A^{0.765}$	--	96	49
	49	$P50 = 70.4\ A^{0.697}$	--	115	53
	49	$P100 = 97.9\ A^{0.669}$	--	132	57
	25	$QA = 6.82 \times 10^{-6}\ A^{1.147}\ P^{3.256}$	--	377	79
	24	$SDA = 1.29 \times 10^{-4}\ A^{1.091}\ P^{2.156}$	--	212	68
7	30	$P2 = 0.125\ A^{0.757}\ P^{1.559}$	--	82	45
	30	$P10 = 4.06\ A^{0.783}\ P^{0.681}$	--	91	48
	30	$P50 = 50.5\ A^{0.731}$	--	109	52
	30	$P100 = 62.6\ A^{0.707}$	--	119	54
	25	$QA = 0.00553\ A^{1.138}\ F^{1.068}$	32	--	--
	20	$SDA = 4.13 \times 10^{-4}\ Le^{2.083}\ F^{1.088}$	--	83	45

Table 2.--Regression equations for regions of Idaho--Continued

Region	Number of of stations in region	Regression equation	Observed mean	Standard (plus)	Error (minus)
8	51	$P2 = 4.34\ A^{0.873}$	--	178	64
	51	$P10 = 13.5\ A^{0.785}$	--	133	57
	51	$P50 = 27.7\ A^{0.722}$	--	144	59
	51	$P100 = 36.0\ A^{0.698}$	--	156	61
	28	$QA = 9.67 \times 10^{-4}\ A^{0.748}\ F^{0.540}\ P^{1.681}$	--	105	51
	27	$SDA = 22.2 \times 10^{-4}\ A^{0.665}\ P^{2.380}$	--	129	56
9	30	$P2 = 0.0377\ A^{0.826}\ P^{1.535}$	--	117	54
	30	$P10 = 16.8\ A^{0.766}$	--	139	58
	30	$P50 = 35.8\ A^{0.676}$	--	156	61
	30	$P100 = 46.3\ A^{0.645}$	--	164	62
	20	$QA = 0.00261\ A^{0.916}\ P^{1.712}$	--	54	35
	20	$SDA = 2.13 \times 10^{-4}\ A^{0.877}\ P^{2.105}$	--	90	48

Table 3.--Summary of observed standard errors

Dependent Variable: Streamflow characteristics for which regional regression equations were developed. P2, 2-year peak discharge; P10, 10-year peak discharge; P50, 50-year peak discharge; P100, 100-year peak discharge; QA, average discharge; and SDA, standard deviation of mean annual discharge.

Observed Standard Error: Observed standard error, in percent, as calculated by Riggs (1968, p. 15).

Region: The region in which the median, minimum, or maximum standard error was determined. (See figure 1.)

Median: The median observed standard error for a given dependent variable.

Minimum: The minimum observed standard error for a given dependent variable.

Maximum: The maximum observed standard error for a given dependent variable.

	Median		Minimum		Maximum	
Dependent variable	Observed standard error (percent)	Region	Observed standard error (percent)	Region	Observed standard error (percent)	Region
P2	64	7	48	3	178	6
P10	66	3	48	1	98	9
P50	75	3	46	1	108	9
P100	83	3	48	1	113	9
QA	30	5	19	2	228	6
SDA	60	3	24	5	140	6

regressions. Minimum standard errors ranged from 19 percent for the QA regressions to 48 percent for the P2, P10, and P100 regressions; maximums ranged from 98 percent for the P10 regressions to 228 percent for the QA regressions.

Ranges of values for the variables used in the regression equations for each region are given in table 4 for the flood-frequency network and table 5 for the general hydrologic network. Data from these tables can be used as a guide when applying the regression equations for estimating values for the dependent variables. Using values of independent variables that are outside the ranges shown may result in erroneous estimates. When using the regression equations, it should be noted that the equations are statistical in nature and that some combinations of data values may result in standard errors significantly larger than those given in table 2. For this reason, all such estimates should be checked for reasonableness.

Regression equations developed for regions in northern Idaho tended to have smaller observed standard errors than those developed for regions in southern Idaho. Except for Region 6, regression equations for dependent variables QA and SDA had smaller observed standard errors than those for dependent variables P2, P10, P50, and P100.

The cataloged procedures of the NARI package, BBPEAK, BBFLOW, and BBPOSPRI (Moss and others, 1982) were operated for the flood-frequency and general hydrologic networks in each region. These procedures retrieve data and calculate joint probabilities of C_v and ρ_c and values of NY. Accuracy of the $P(C_v, \rho_c)$ and NY values was adversely affected by the following factors:

(1) BBPEAK and BBFLOW retrieve data from the Peak Flow File and Daily Values File, respectively, and format data for input to BBPOSPRI. Networks used in the regression analysis included stations not listed in the files summoned by BBPEAK and BBFLOW.

(2) BBPEAK and BBPOSPRI use only peak-discharge data having no qualifying footnotes. In some basins, peak-discharge data having qualifying footnotes were used to compute flood-frequency statistics that were subsequently used in the regression analysis.

Table 4.--Ranges of variables used in flood network

Region	Area (mi^2)		Precipitation (in.)	
	Minimum	Maximum	Minimum	Maximum
1	1.12	575	20	76
2	.59	437	--	--
3	.88	425	--	--
4	.90	622	--	--
5	.42	640	21	48
6	.05	648	--	--
7	2.60	622	8	45
8	.30	360	--	--
9	1.00	529	--	--

Table 5.--Ranges of variables used in general hydrologic network

Region	Area (mi^2)		Precipitation (in.)		Forest cover (percent)		Longitude (degrees)		Mean elevation (ft)	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
1	23.0	13,700	22	76	--	---	--	--	--	--
2	22.0	3,840	35	54	83	100	--	--	--	--
3	2.41	9,640	19	58	--	---	114.886	117.272	--	--
4	2.00	2,230	--	--	--	---	--	--	3,720	7,780
5	.59	2,230	23	48	--	---	113.842	116.200	--	--
6	.05	2,680	12	42	--	---	--	--	--	--
7	6.80	3,940	--	--	15	95	--	--	--	--
8	4.30	633	11	40	1	93	--	--	--	--
9	6.30	6,270	17	39	--	---	--	--	--	--

(3) Many of the streamflow statistics used in the regression analysis were retrieved from the Streamflow and Basin Characteristics File. The periods of record for which these statistics had been computed were unknown and probably different than periods for which data were retrieved by BBPEAK and BBFLOW.

Differences between data used in the regression analysis and data used by BBPEAK, BBFLOW, and BBPOSPRI may have had a negligible effect on values of $P(C_v, \rho_c)$; however, the effect on NY was probably significant. For the flood-frequency network in each region, the value of NY calculated by BBPOSPRI was not used as input to procedure MODLVALU, which calculates cumulative probability functions of S_T; instead, an NY value calculated by hand was used. For the general hydrologic network in each region, the value of NY calculated by BBPOSPRI was used. Joint probabilities input to MODLVALU were those calculated by BBPOSPRI.

The output of the MODLVALU procedure is a table of S_T values for various values of reliability, α, at requested values of NB and NY. A separate table was generated for each regression equation associated with a specified dependent variable and region. For reliability of α=0.50, plots of S_T contours as a function of NB and NY were constructed. These plots indicate the effect that various network designs, as defined by NB and NY, have on the probable value of S_T. Figures 2 and 3 show selected production plots for various regions and dependent variables. Other plots are given in the appendix. Production plots (figs. 2 and 3) for Regions 4 and 7 indicate that, even if the time and resources were available to move the networks to NB=50, NY=50, improvement in S_T would be less than 10 percent. Improvements should be greater than 10 percent to be considered significant. Most of the cases where feasible S_T improvements were greater than 10 percent still did not bring S_T below 100 percent (see plots in appendix).

A perfect model scenario was developed for P10, P100, and QA in Region 4. A perfect model scenario is where $\gamma = 0$. It was developed by running the MODLVALU procedure and manually inputting the value of γ as 0. Results are shown in figure 4. A comparison (table 6) between S_T for the present network as given in figure 2, where γ is estimated on the basis of S_0, C_v, ρ_c; and S_T for the present network as given in figure 4, where γ is assumed to be 0. Improvement in S_T that would result from a perfect model is considerably greater than any improvement that is expected from collecting additional data for use with the present model.

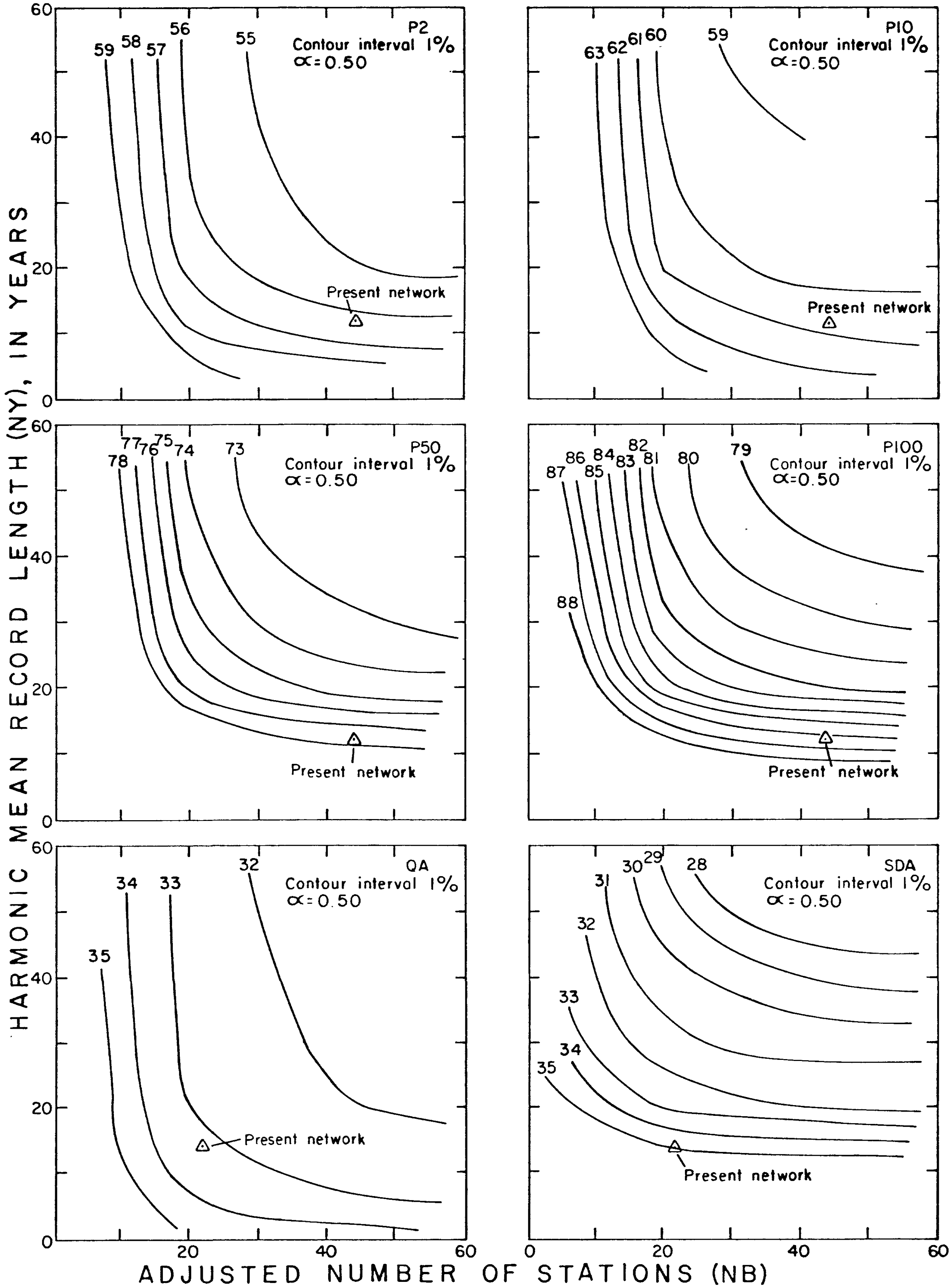

Figure 2.-- True standard error, S_T, in percent, as a function of NY and NB Region 4.

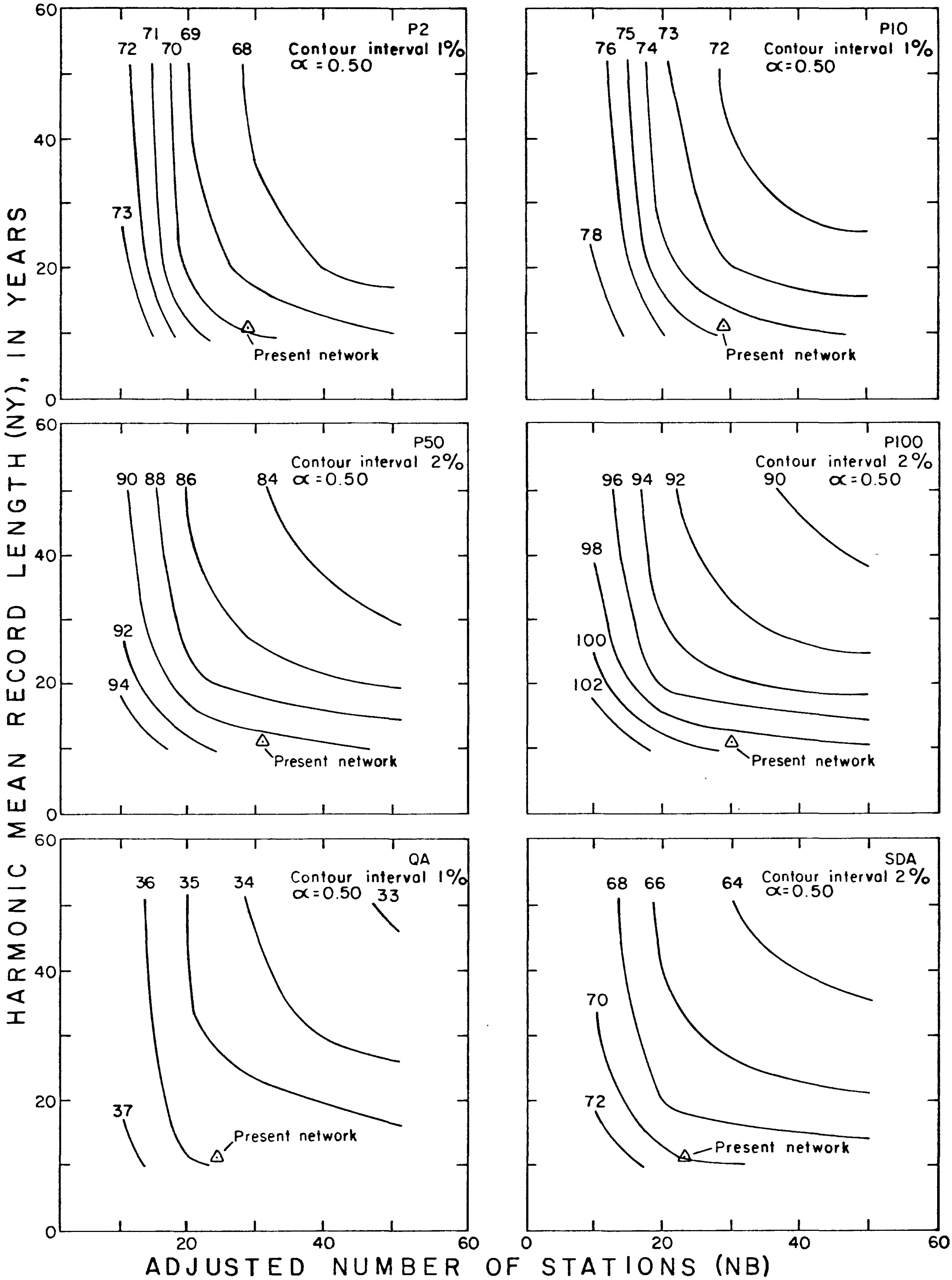

Figure 3.-- True standard error, ST, in percent, as a function of NY and NB, Region 7.

Table 6.--Comparison of observed scenario and perfect model scenario in Region 4

Dependent variable: Streamflow characteristic estimated by the regression model. P10, 10-year peak discharge; P100, 100-year peak discharge; and QA, average discharge.

Standard error: Median probable true standard error of the regression model in percent, given the present stream-gaging network.

Observed scenario: Both the model error and the true standard error are estimated.

Perfect model scenario: The model error is assumed to be zero and the true standard error is estimated.

	Standard error	
Dependent variable	Observed scenario	Perfect model scenario
P10	61	12
P100	86	28
QA	33	6

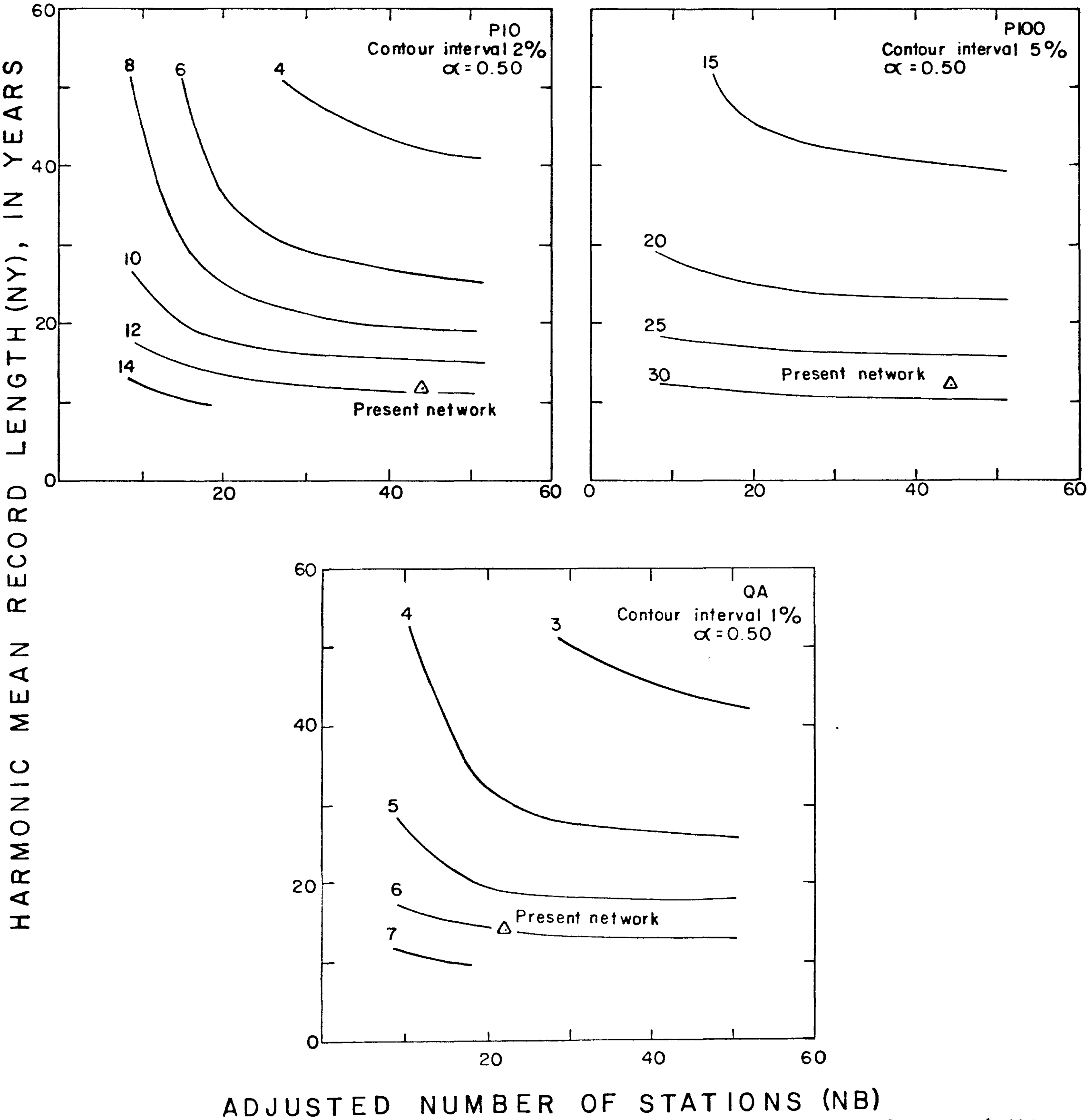

Figure 4. -- True standard error, S_T, in percent, as a function of NY and NB, given a perfect model, Region 4.

NARI indicates that collection of more streamflow data solely for purposes of improving regional regression equations would be futile, because any improvements in predictive accuracy would not be significant. Improving accuracy in the transfer of regional streamflow information to ungaged sites can be accomplished only by developing better methods of transfer.

The HARMEAN Computer Program

In an attempt to improve predictive accuracy of the regression equation, additional streamflow data could be collected. An aid in evaluating alternative strategies for collection of additional data is the HARMEAN computer program (Moss, 1979). HARMEAN calculates the maximum possible NY that can be expected as a result of operating a given number of gages during an n-year planning horizon. Tasker and Moss (1979) described three strategies considered for improving regression equations for peak discharges in northwestern Arizona. These strategies were used as a guide for developing the following strategies for future data collection in Idaho.

Strategy I uses gaging stations at which data already have been collected. The network designer is constrained to operate, during the planning horizon, those stations that are currently operating. Beginning with the station having the shortest period of record and continuing in order of increasing record length, noncurrent stations are reactivated and added to the group of stations operated during the planning horizon. In this way, priority is given to extending the length of record of those stations where record length is shortest. Data from all stations having record are used in the regression analysis, regardless of whether they are operated during the planning horizon. By using Strategy I, NY will be increased and NB will remain constant.

Strategy II deals with X new stations, plus those stations for which some data already have been collected. As a minimum, the X new stations are operated during the planning horizon, and the previously operated stations are added one at a time, in order of increasing record length, to those operated during the planning horizon. At the end of the planning horizon, all stations having record are used in the regression analysis. By using Strategy II, NB will be increased by X and NY may or may not be increased.

Strategy III uses stations for which data previously have been collected. Beginning with the station having the longest record, stations are added one at a time, in order of decreasing record length, to those operated during the planning horizon. Only stations operated during the planning horizon are used in the regression analysis. In this way, priority is given to maximizing NY even at the expense of NB. By using Strategy III, NY will increase and NB will be less than or equal to its present value.

Region 4 was chosen to demonstrate the evaluation of Strategies I, II, and III using HARMEAN. Strategies were studied in the context of both 10- and 20-year planning horizons. Information-cost curves, presented in figure 5, show the relation between increased information in the network, as indicated by lower values of S_T, and increased cost, as indicated by the number of stations operated during the planning horizon. For all strategies and dependent variables, the more stations that are operated during the planning horizon, the more S_T is decreased. For a constant number of stations operated during the n-year planning horizon, S_T is always smaller at the end of the 20-year planning horizon than at the end of the 10-year planning horizon. Even if up to 25 stations were operated for 20 years, the decrease in S_T would be less than 10 percent, which is not significant. Information-cost curves for Region 7 given in the appendix show similar results.

Summary of Problems and Recommendations

Some problems encountered in using NARI and some suggested solutions for its use and improvement follow:

1. Problem.--Insuring that the same data are used in each phase of network evaluation from computation of streamflow statistics through operation of the NARI package.

   Suggestions to users:

   A. Users should use BBREVISE procedure to revise the files created by BBPEAK and BBFLOW, so that these files will contain the same data as were used to compute streamflow characteristics.

      No modifications to the NARI package regarding this problem are suggested.

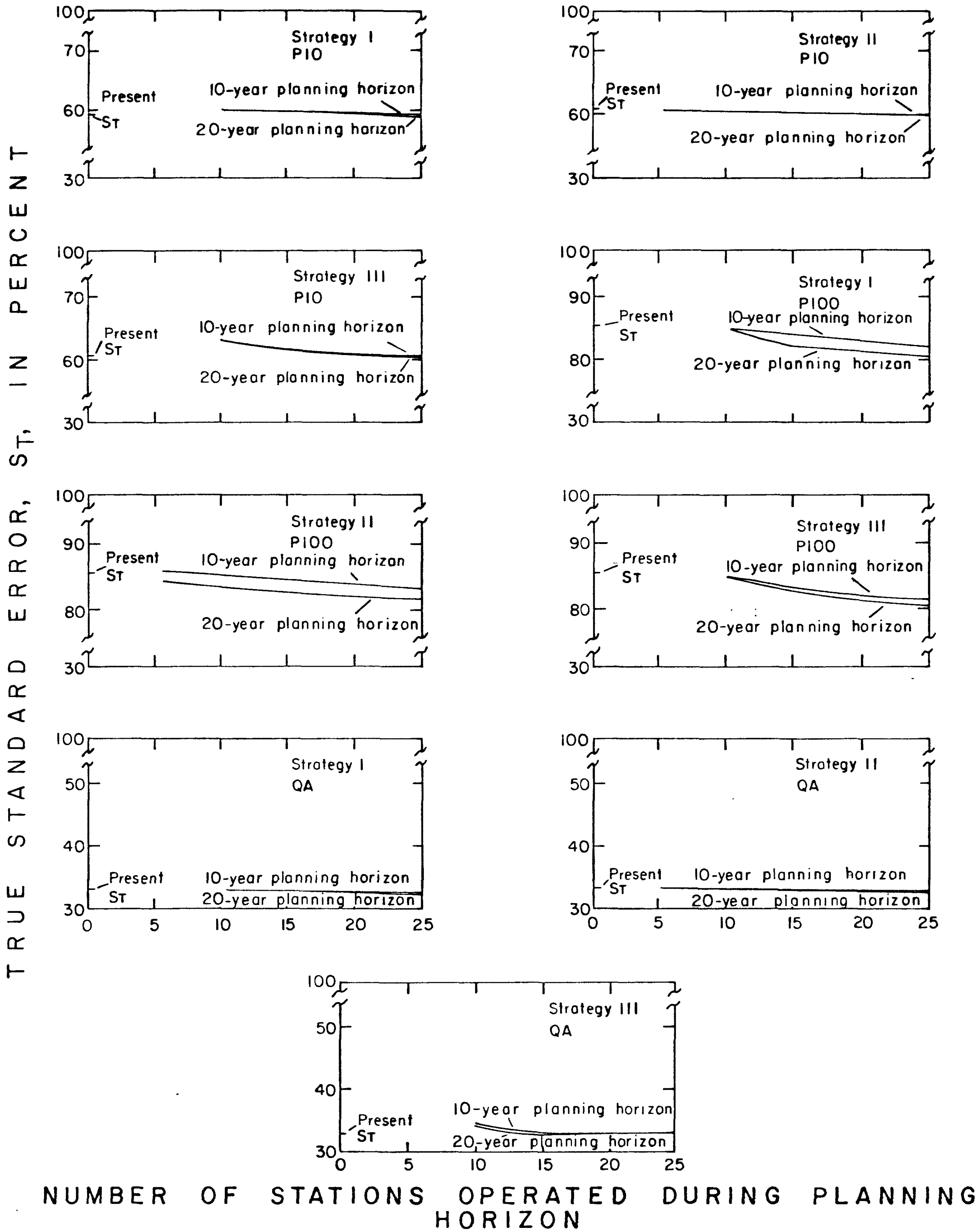

Figure 5.--True standard error as a function of planning horizon and number of stations operated, Region 4.

2. Problem.--MODLVALU does not run if S_0 for the regression equation is too large.

Suggestions to users:

A. Input prior probabilities manually for values of γ less than or equal to 2.00 (in $\log_e$ units). The resulting output probably will be a questionable value.

B. Use small regions. Small regions tend to have regression equations with small S_0 values because of more homogeneous hydrologic conditions.

Suggested modification of NARI package:

A. Modify MODLVALU to allow for larger values of S_0.

The NARI package, including the HARMEAN computer program, operated satisfactorily on stream-gaging networks in Idaho and would be useful in making decisions concerning network design. A difficulty encountered was in matching the periods of record of data used to estimate streamflow characteristics of the gaged basins with the periods of record of data retrieved and used by NARI. Another problem encountered was that one of the regression equations had an observed standard error whose magnitude was greater than NARI was capable of handling. Suggestions are made for increasing the ease of using NARI to obtain accurate information helpful in designing stream-gaging networks.

THE COST-EFFECTIVENESS PROCEDURE

Whereas NARI concerns itself with cost-effective allocation of resources in the design of stream-gaging networks, the Cost-Effectiveness Procedure is concerned with allocation of resources in the operation of stream-gaging networks. The Cost-Effectiveness Procedure seeks to minimize uncertainty in the estimate of the mean annual discharge of the network by choosing how often to visit various stream-gaging stations.

The Cost-Effectiveness Procedure is applied in five steps: (1) Determine a stage-discharge rating on the basis of discharge measurements, and calculate the residual (measured discharge minus rated discharge) associated with each measurement. (2) Estimate the respective contributions of measurement and rating errors to the variance of the residuals. (3) Compute uncertainty functions that are relations between variance of estimated mean annual discharge and number of visits (measurements) per year. (4) Determine the costs (fixed, visit, travel, and overhead) of operating the network. (5) Minimize uncertainty in estimated mean annual discharge in the network, given a specific budget, by using the Traveling Hydrographer program.

The Cost-Effectiveness Procedure, as presented and applied by Moss and Gilroy (1980), uses a measure of uncertainty, the variance of the estimate of mean annual discharge at a stream-gaging station. The sum of variances at stations in the network is the measure of uncertainty in the entire network.

Description of Network

The network to which the procedure was applied in this study was the group of stream gages in the Weiser-McCall area of west-central Idaho. Presently, each of these gages is visited on one of three field trips that operate out of the Idaho District office in Boise. One is a NASQAN (National Stream Quality Accounting Network) trip that is run 12 times per year with a measurement being made at each station only 6 times per year; that is, stations are sometimes visited without a discharge measurement being made. The other two trips, labeled the Weiser trip and the McCall trip, are operated nine times per year and include visits to nonsurface-water sites, such as ground-water wells, and visits to crest-stage gages, at which measurements normally are not made. Table 7 lists all the sites in the Weiser-McCall area, including nonsurface-water and crest-stage gage sites.

Application of Procedure to Network

Stage-discharge ratings were developed for the stream-gaging stations in the Weiser-McCall area. These ratings were based on the discharge measurements made during water years 1976 to early 1981. Procedure NLIN of the SAS (Statistical Analysis System) computer software system was used to fit the rating equation given below, in SAS notation:

Q=B1*(GH-B3)**B2,

where Q is discharge, in cubic feet per second; GH is gage height, in feet; and B1, B2, and B3 are parameters of the rating equation. Procedure NLIN also was used to calculate

Table 7.--Data-collection sites in Weiser-McCall area

[Type of site: lk, lake; sw, surface water; gw, ground water
Comments: EPA, U.S. Environmental Protection Agency;
RASA, Regional Aquifer Systems Analysis; NASQAN,
National Stream-Quality Accounting Network]

Station number	Station name or local identification number	Type of site	Current trip assignment	Comments
13236000	Deadwood Reservoir near Lowman, ID	lk	McCall	Visited with following station
13236500	Deadwood River below Deadwood Reservoir near Lowman, ID	sw	McCall	
13238500	Payette Lake at McCall, ID	lk	McCall	
13239000	North Fork Payette River at McCall, ID	sw	McCall	
13240000	Lake Fork Payette River above Jumbo Creek near McCall, ID	sw	McCall	Sometimes snowmobile in winter
	16N- 3E-14AAB1	gw	McCall	Measure semiannually
	18N- 3E-36BC1	gw	McCall	Measure semiannually
	Mud Creek near Donnelly, ID	sw	McCall	New crest-stage gage
13244500	Cascade Reservoir at Cascade, ID	lk	McCall	
13245000	North Fork Payette River at Cascade, ID	sw	McCall	
	13N- 4E-16BAD1	gw	McCall	Measure semiannually
13246000	North Fork Payette River near Banks, ID	sw	McCall	
13254000	Lost Creek Reservoir near Tamarack, ID	lk	Weiser	Read gage monthly
13254500	Lost Creek near Tamarack, ID	sw	Weiser	Measure monthly
	17N- 1W-15AAC1	gw	Weiser	Measure bimonthly
13255050	West Fork Weiser River near Fruitvale, ID	sw	Weiser	Measure monthly
13255060	Weiser River near Fruitvale, ID	sw	Weiser	Measure monthly
	16N- 1W-22BAA1	gw	Weiser	Measure bimonthly
	16N- 1W- 3DDD2	gw	Weiser	Measure bimonthly
13257000	Middle Fork Weiser River near Council, ID	sw	Weiser	
	14N- 1W-11CCC1	gw	Weiser	Measure semiannually
	15N- 1W-22BAD1	gw	Weiser	Measure bimonthly
13260500	Little Weiser River near Indian Valley, ID	sw	Weiser	
	Ben Ross Feeder Canal near Indian Valley, ID	sw	Weiser	Measure bimonthly
	Ben Ross Reservoir near Indian Valley, ID	lk	Weiser	Read gage bimonthly
	Ben Ross Canal near Indian Valley, ID	sw	Weiser	Measure bimonthly
	14N- 2W-10BCA1	gw	Weiser	Measure bimonthly
13258500	Weiser River near Cambridge, ID	sw	Weiser	Sediment samples monthly
13261570	Weiser River below Little Weiser River near Cambridge, ID	sw	Weiser	Sediment samples monthly
13261600	Dixie Creek near Cambridge, ID	sw	Weiser	Crest-stage gage
13264000	Crane Creek Reservoir near Midvale, ID	lk	Weiser	Read sloping gage monthly
	12N- 4W-31DBB1	gw	Weiser	Measure bimonthly
	13N- 1W-32ACD1	gw	Weiser	Measure bimonthly
	13N- 4W-12CDC1	gw	Weiser	Measure bimonthly
13265500	Crane Creek at mouth near Weiser, ID	sw	Weiser	Measure monthly, sediment samples monthly
13266000	Weiser River near Weiser, ID	sw	Weiser	Sediment samples monthly
	18S-47E-17BBB1	gw	Weiser	Measure bimonthly for RASA in Oregon
	16S-47E-17ABC1	gw	Weiser	Measure bimonthly for RASA in Oregon
	11N- 6W-25CAC1	gw	Weiser	Measure bimonthly
	Warm Springs Creek near Weiser, ID	sw	Weiser	New crest-stage gage
13269000	Snake River at Weiser, ID	sw	NASQAN	EPA site
13289700	Brownlee Reservoir near Oxbow, OR	lk	NASQAN	Not a NASQAN site
13289960	Wildhorse River near Brownlee Dam, ID	sw	NASQAN	Not a NASQAN site
13290000	Oxbow Dam spill gates	sw	NASQAN	Not a NASQAN site, miscellaneous measurement
13290190	Pine Creek near Oxbow, OR	sw	NASQAN	Not a NASQAN site
13290450	Snake River at Hells Canyon Dam, ID-OR	sw	NASQAN	NASQAN site
13310700	South Fork Salmon River near Krassel Ranger Station	sw	McCall	Sometimes fly in winter
13312300	Transmountain diversion near Landmark, ID	sw	McCall	Miscellaneous site, spring and fall
13313000	Johnson Creek near Yellow Pine, ID	sw	McCall	Sometimes fly in winter
13316500	Little Salmon River at Riggins, ID	sw	NASQAN	Not a NASQAN site
13317000	Salmon River at Whitebird, ID	sw	NASQAN	NASQAN site

residuals of the rating equation. NLIN was observed to be sensitive to the bounds put on the range of possible parameter values. For some stations, only measurements made toward the end of the 1976-81 period were used to develop the rating equation.

The Cost-Effectiveness Procedure models the uncertainty in computed discharge at a station at a point in time as the variance of the difference between true discharge and computed discharge. Uncertainty is considered to be the sum of the variance of measurement error and the variance of rating error. Measurement errors are assumed to be independent random events. Rating errors, such as those caused by shifting control, are considered to be a discrete time series with intervals of 1 day. This time series is assumed to be a realization of a first-order autoregressive process, the parameters of which are approximated from the estimated autocovariance function of the rating residuals. In the case of several stations in the Weiser-McCall network, inspection of the observed ACF (autocovariance function) indicated it was unlikely that the observed ACF could have been associated with a lag-1 autoregressive process, which implied that the model was structurally inadequate. In these cases, the model was "forced" to fit the data. Program XCOVMIS (Gilroy, E. J., U.S. Geological Survey, written commun., 1981) is used to calculate estimates of the variance of measurement error, the variance of rating error, and the lag-1 autocorrelation coefficient of rating error.

An uncertainty function was calculated for each station by using the program XVARSTO (Gilroy, E. J., U.S. Geological Survey, written commun., 1981). These uncertainty functions relate variance of the estimate of mean annual discharge at a station to the number of measurements per year at that station.

Various costs of operation were defined. For each station, annual fixed costs were determined, which included maintenance, equipment, and preparation of records for publication. Visit costs were identified, which included labor costs of man-hours spent at the station when it was visited and a discharge measurement was made. A number of feasible routes were defined along with the cost (mileage, man-hours, and per diem) incurred each time a route was used. Routes that were defined included those presently being used, a route for each station where that station is the only site visited, and a route that included a visit to every station. It was estimated that 38 percent of the budget is spent on overhead. District management and supervisors of field personnel participated in the determination of costs. This phase of the Cost-Effectiveness Procedure proved difficult and required a great deal of judgment to identify and classify various operating costs.

A key problem was encountered during definition of feasible routes and their costs. The Cost-Effectiveness Procedure was developed to evaluate strategies for operating a network that consisted solely of sites where surface-water data were collected. The problem is that networks serviced by field trips in the Idaho District are multidisciplinary, in that the networks include sites where data are collected concerning ground water and quality of water, as well as surface water. Efforts during this study to adapt the procedure to multidisciplinary networks have been unsuccessful. Possible methods of adaptation that were not tried because of time constraints are given later in this report. Because of this problem, it was decided to analyze the operation of the stream-gage network in the Weiser-McCall area as though the field trips represented by routes in the Cost-Effectiveness Procedure were solely for the purpose of collecting surface-water data.

The program TRAVEL, sometimes referred to as the Traveling Hydrographer program, was used to evaluate various scenarios. Present operation was assumed to be equivalent to using the following routes and frequencies:

NASQAN trip - six times per year
Weiser trip - nine times per year
McCall trip - nine times per year

Note that though in reality the NASQAN trip presently is run 12 times per year, a measurement is made at each station only 6 times per year; thus, in the present operation scenario, the NASQAN trip is treated as though it were run 6 times a year with a measurement being made at every station on every run. Program TRAVEL assumes that a discharge measurement is made each time a station is visited (unless there is no flow at the time of visit).

The annual cost of present operation was computed to be $73,884. Table 8 describes present operation and also how the uncertainty could be minimized given six-visits per year and one-visit per year minimum constraints, while holding the annual budget at $73,884. Uncertainty in the network is expressed by the Cost-Effectiveness Procedure as the sum of the variances of the estimate of mean annual discharge at each station; or, as in table 8, uncertainty can be expressed as the square root of the sum of the variances, which is referred to as standard deviation, in units of cubic feet per

Table 8.--Number of visits per year and network uncertainty under three constraint scenarios given an annual budget of $73,884, with estimation error expressed in cubic feet per second

Station No.: Gaging-station identification number.

Present operation: Network is constrained to be operated as it is at present.

6-visit minimum: Six-visit per year minimum constraint.

1-visit minimum: One-visit per year minimum constraint.

Network uncertainty: In cubic feet per second.

Station No.	Present operation	6-visit minimum	1-visit minimum
	Number of visits per year		
13236500	9	6	4
13239000	9	6	4
13240000	9	6	4
13245000	9	6	4
13246000	9	6	4
13254500	9	6	4
13255050	9	6	4
13255060	9	6	4
13258500	9	6	4
13265500	9	6	4
13266000	9	6	4
13269000	6	22	28
13289960	6	10	15
13290190	6	10	15
13290450	6	14	20
13310700	9	6	4
13313000	9	6	4
13316500	6	10	15
13317000	6	10	15
	Network uncertainty		
----	143.8	114.0	107.2

second. Program TRAVEL uses a direct search optimization technique (Moss and Gilroy, 1980, p. 10), which is sensitive to starting point or initial conditions of the optimization. If initial conditions are not specified by the program user, the program will select its own set of initial conditions. The scenarios in table 8 used present operation as initial conditions. Different results would have been obtained had no initial conditions been specified. Uncertainty in the accuracy of computed discharge in the network for present operation was observed to be 143.8 ft^3/s. With the budget held constant at $73,884 per year at a six-visit per year minimum constraint, uncertainty can be reduced to 114.0 ft^3/s. With a one-visit per year minimum, uncertainty can be reduced to 107.2 ft^3/s. With both a six- and one-visit per year minimum, program TRAVEL assigned the greatest number of visits to stations 13269000, Snake River at Weiser, and 13290450, Snake River at Hells Canyon Dam. This seems reasonable, because these two stations have the greatest mean annual discharges of all stations in the network; therefore, reductions in uncertainty at these two sites would contribute the most to reductions in uncertainty in the entire network.

Figure 6 shows the effects on uncertainty, expressed as standard deviation, of increasing the budget available for collecting surface-water data in the network. The smaller the minimum number of visits per year, the more flexibility there is. This flexibility is the reason that the 1-visit minimum allows for greatest reduction in network uncertainty and that uncertainty for the 6-visit minimum is less than that for the 12-visit minimum. Points to which these curves were fitted are from runs of program TRAVEL with no initial conditions specified; therefore, they do not directly correspond to results in table 8.

Figure 7 shows sensitivity of network uncertainty to fixed costs. Estimates of fixed costs mentioned earlier were multiplied by a factor between 0.2 and 2.0. The lowest achievable uncertainty then was calculated, using program TRAVEL, for each resulting set of fixed costs with a budget of $90,000, given 12-, 6-, and 1-visit per year minimum constraints. No initial conditions were specified. As indicated by the steepness of the curve, the uncertainty is most sensitive to fixed costs for a 12-visit per year minimum constraint. Sensitivity to fixed costs is expected to decrease if the budget is increased, because a smaller fraction of the budget would be consumed by fixed costs.

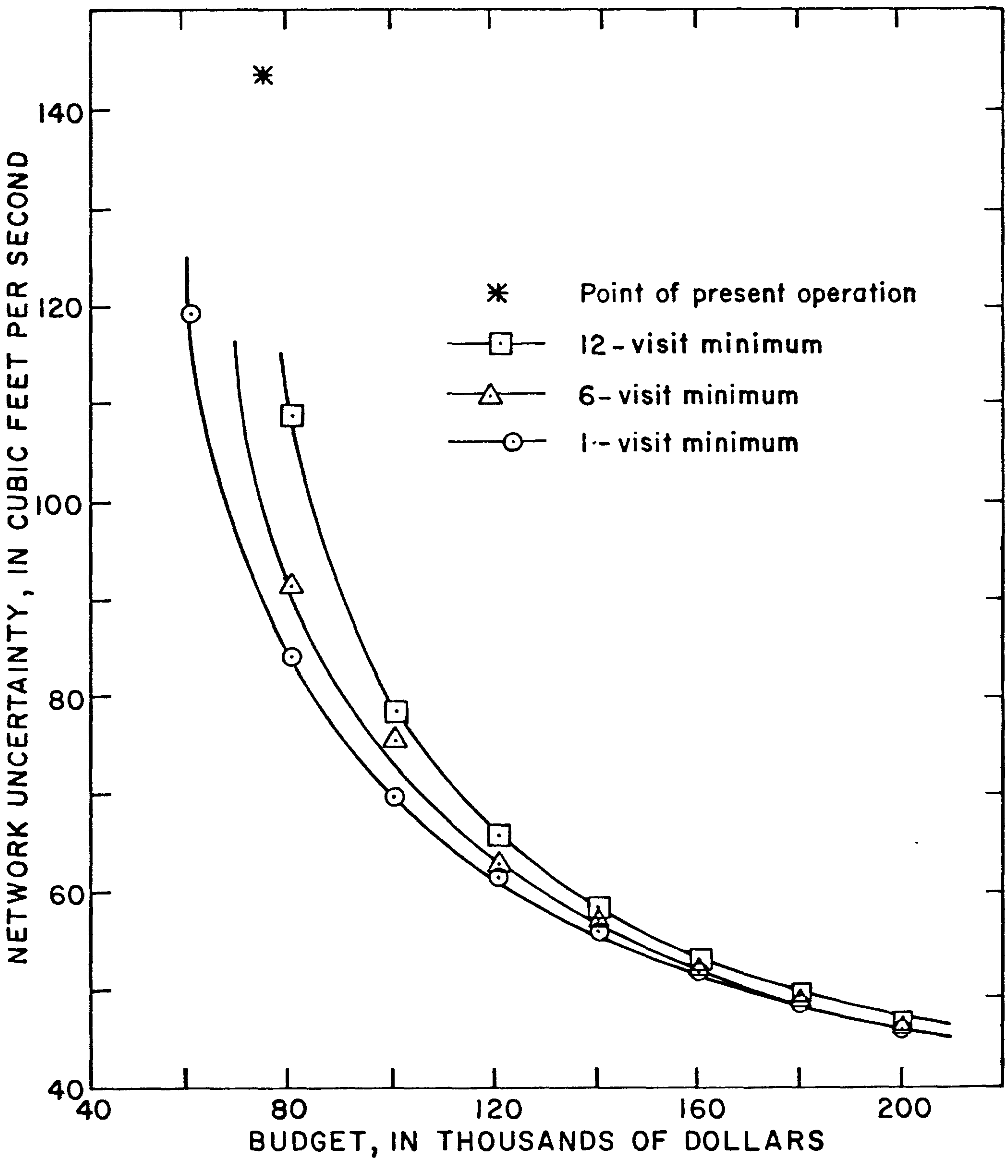

Figure 6.-- Network uncertainty versus budget.

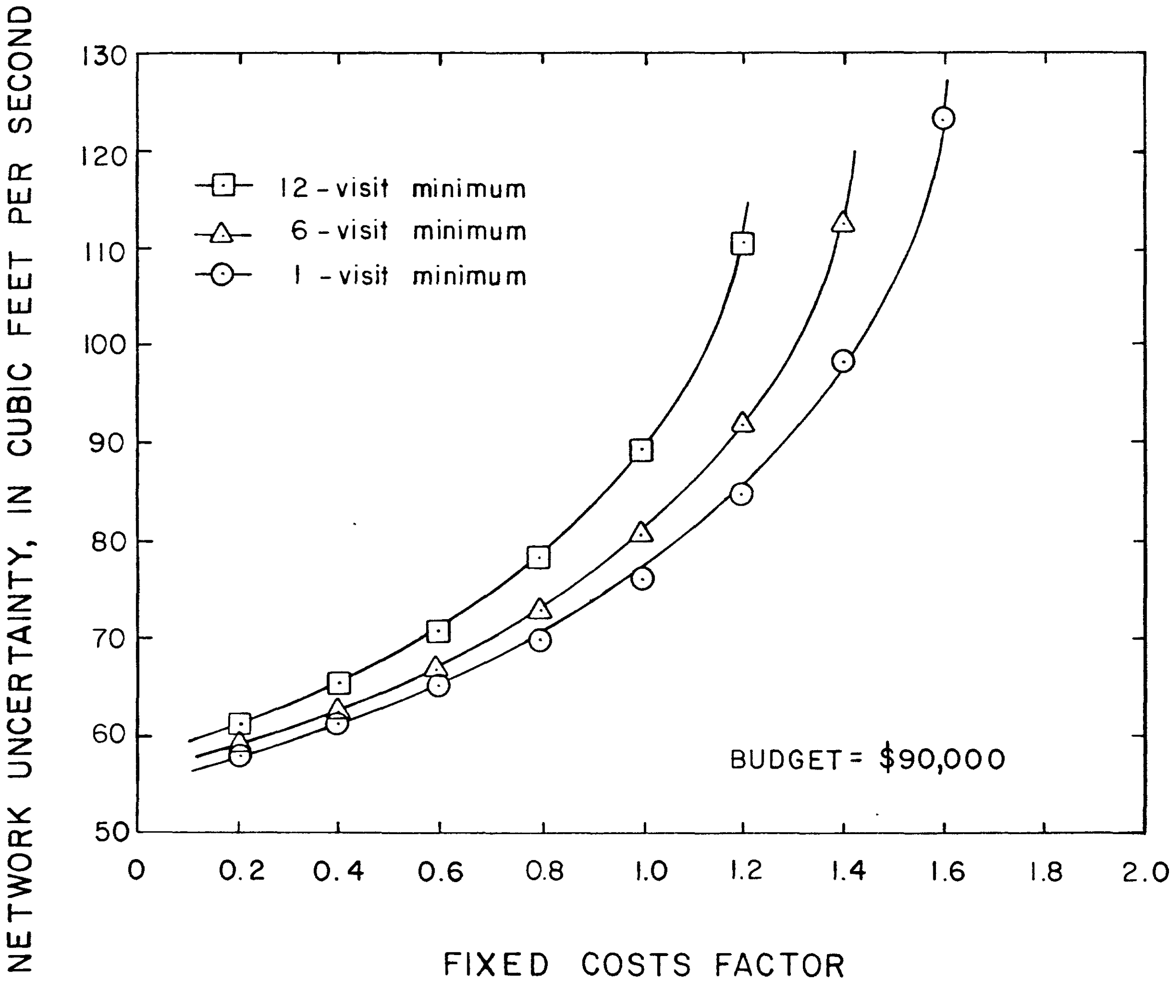

Figure 7. -- Analysis of sensitivity to fixed costs.

Sensitivity to visit costs is shown in figure 8. These curves were obtained in a manner similar to that applied for fixed costs; that is, visit costs were varied by multiplying them by factors between 0.2 and 2.0. As with fixed costs, uncertainty was most sensitive to visit costs for a 12-visit per year minimum constraint.

Figure 9 shows the sensitivity of uncertainty to route costs. Estimates of route costs were multiplied by factors ranging from 0.2 to 2.0, and the lowest achievable uncertainty in each case was calculated for a budget of $90,000, given 12-, 6-, and 1-visit per year minimum constraints. The curve associated with the 12-visit per year minimum was steepest, indicating the greatest sensitivity.

Curves for the six-visit per year minimum constraint, taken from figures 7, 8, and 9, are plotted together in figure 10. A cost factor greater than 1.0 results in an increase in the cost to which it applies, and a factor less than 1.0 results in a decrease. Increases in fixed costs caused a greater change in uncertainty than increases in route costs, which, in turn, caused a greater change than increases in visit costs. Decreases in fixed costs caused roughly the same magnitude of change in uncertainty as decreases in route costs, unless the decreases were drastic (greater than 50 percent). Decreases in visit costs caused less change in uncertainty than decreases in fixed and route costs. Sensitivity to fixed costs is expected to decrease if the budget is increased. Sensitivity to route costs is always expected to be greater than sensitivity to visit costs, as long as route costs contribute so much more than visit costs to the total cost of obtaining measurements, which is true according to cost estimates made herein. Plots of sensitivity curves for other minimum-number-of-visits constraints reveal situations similar to that shown in figure 10.

The Cost-Effectiveness Procedure uses the variance of the error of estimation of the mean annual discharge at a station as a measure of uncertainty. In the previous discussion, the error of estimate is expressed in cubic feet per second. This serves the needs of managers of some networks but results in having nearly all the "extra" measurements being done on streams with the largest discharges. In effect, the procedure is concerned with measuring the total water in the network with the greatest accuracy. Since this is not the primary function of surface-water networks in most WRD districts, an attempt was made to

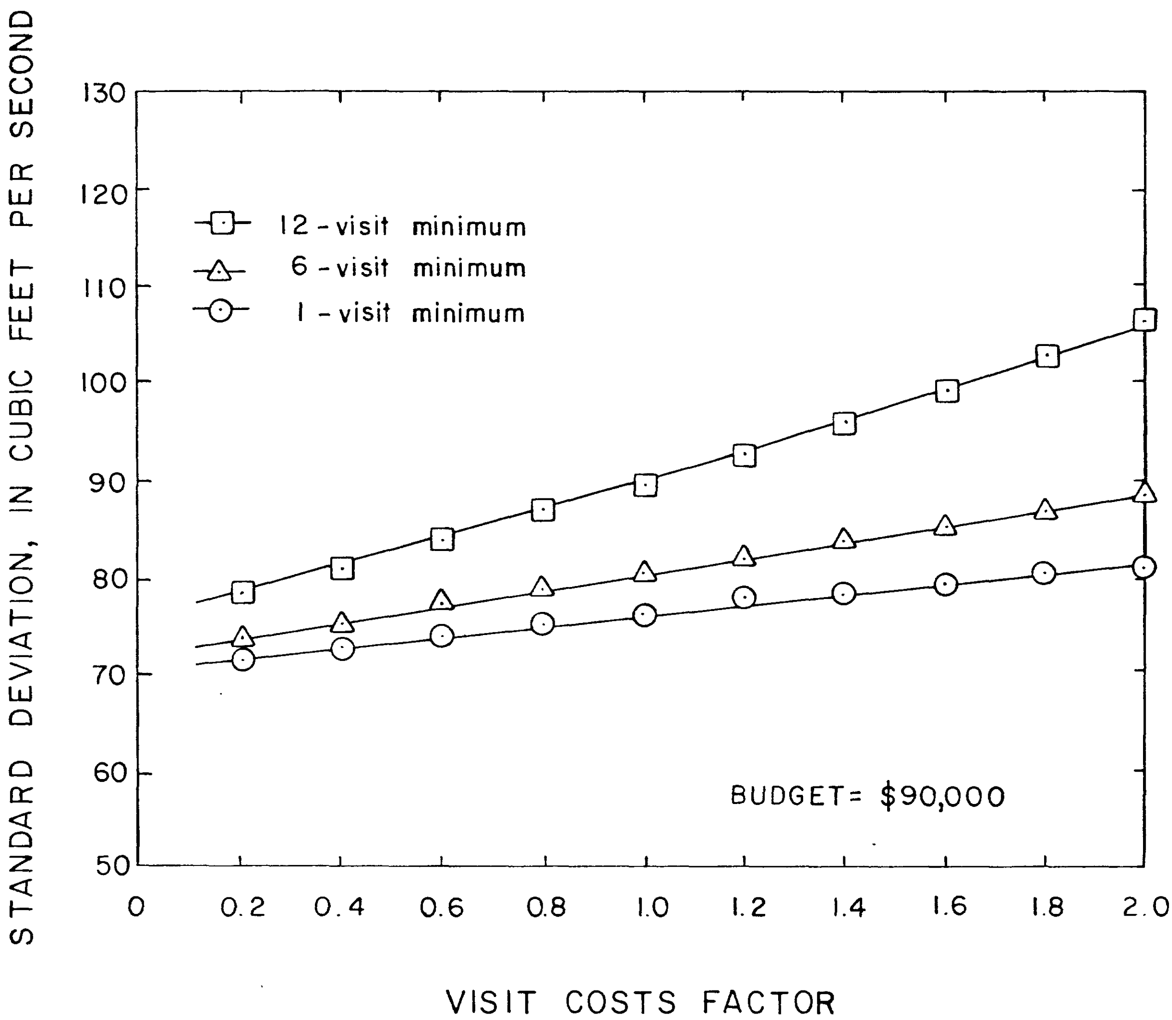

Figure 8. -- Analysis of sensitivity to visit costs.

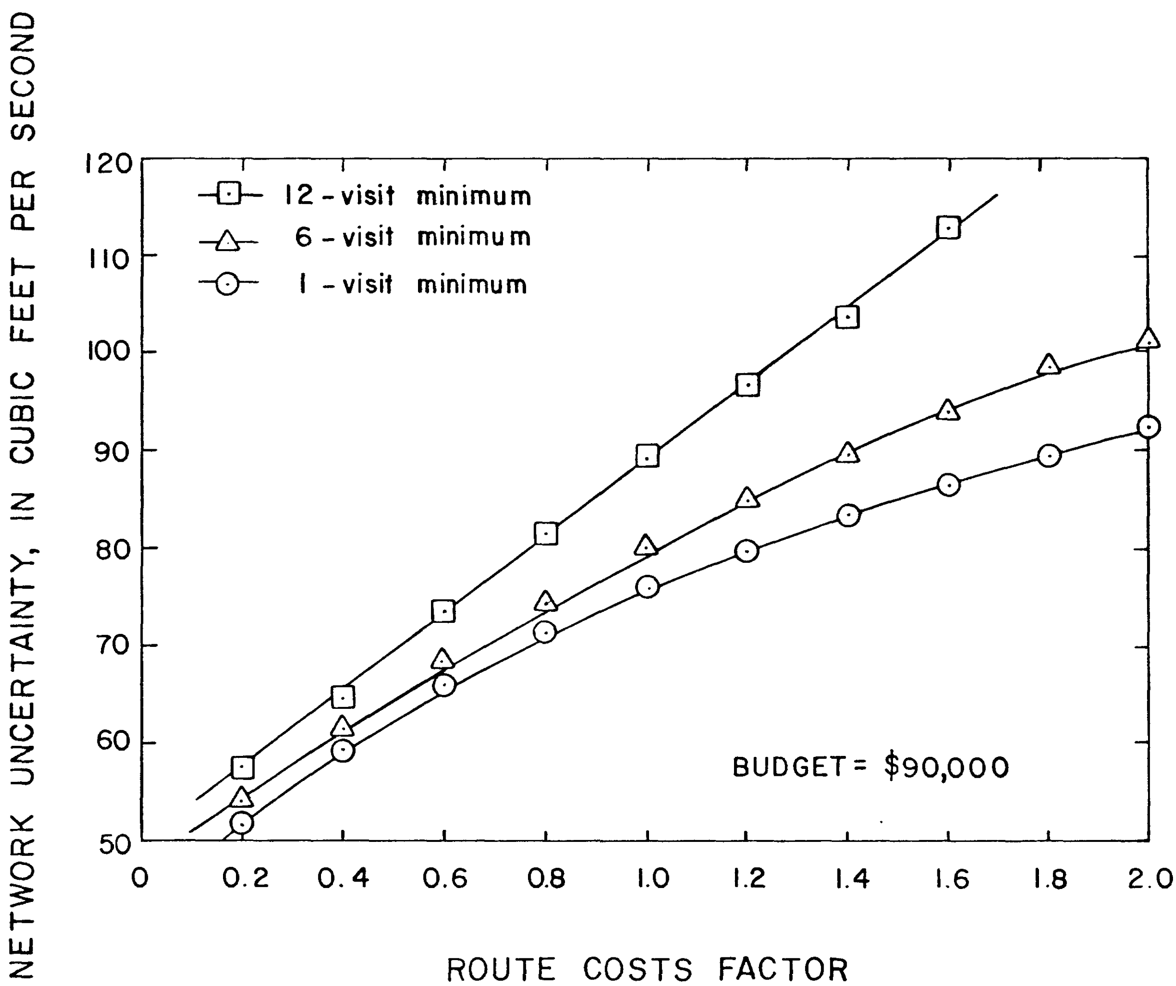

Figure 9.-- Analysis of sensitivity to route costs.

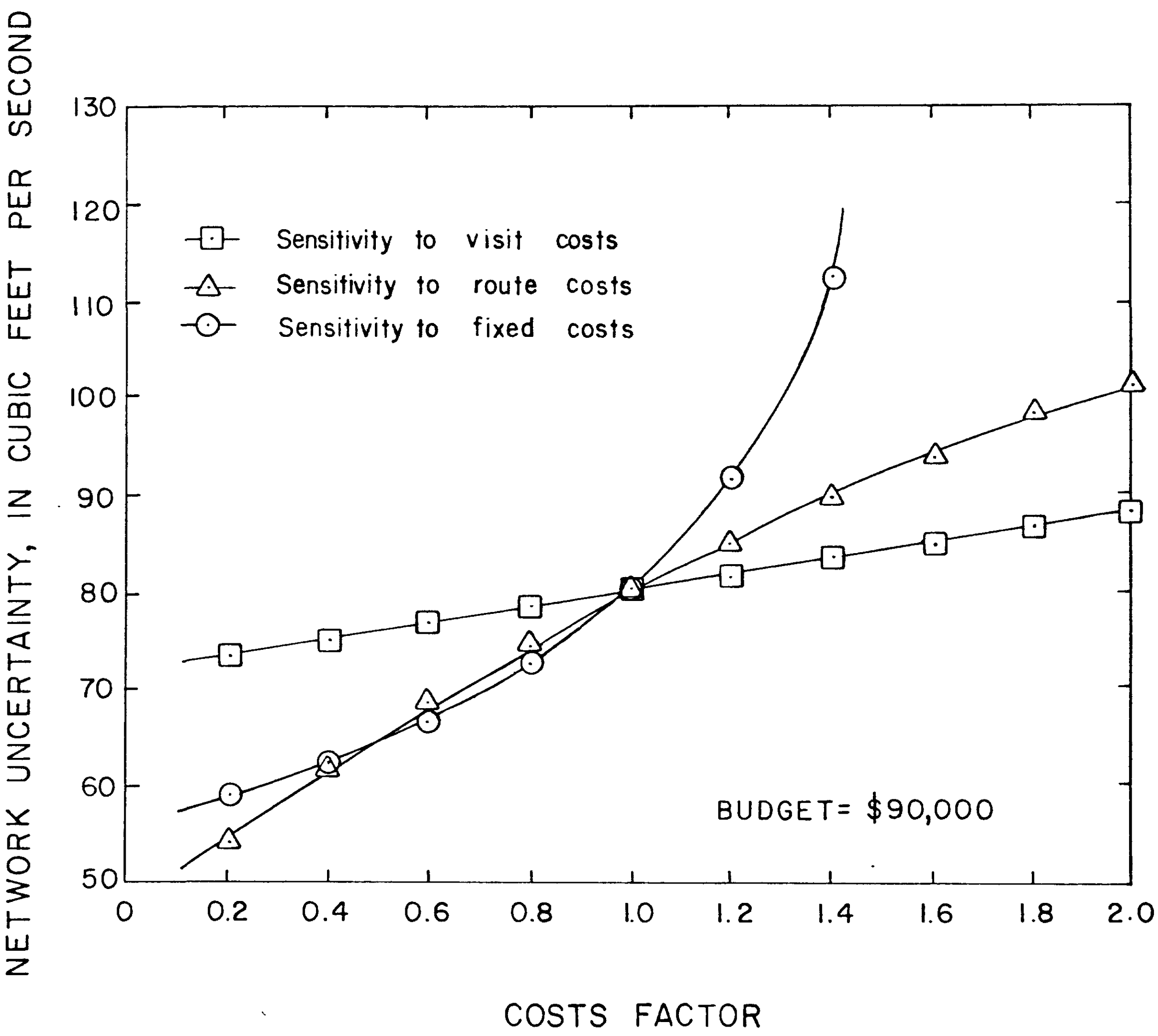

Figure 10.-- Sensitivity to fixed, visit, and route costs given a six-visit per year minimum constraint.

find ways to use the Cost-Effectiveness Procedure to minimize network uncertainty for all streams in a network, regardless of the magnitude of discharge. This can be done by expressing discharge and the error of the estimate as a percentage of, or as a ratio with, the mean annual flow.

In the following discussion, the measured discharge and thus the estimate of error is expressed as a ratio to the mean annual discharge. At each station in the Weiser-McCall area, measured discharges were divided by the most recently published average discharge, which approximates the mean annual flow. The resultant discharge ratios were used, beginning with development of rating equations, to apply the Cost-Effectiveness Procedure.

Rating equations were fitted on the basis of discharge ratios as calculated above. As before, the rating equation, in SAS notation, was:

Q=B1*(GH-B3)**B2.

When the discharge ratio was used, parameters B2 and B3 remained the same as when discharge in cubic feet per second was used. The value of parameter B1, however, was equal to the previous B1 value divided by the average discharge.

Program XCOVMIS was used to estimate variance of measurement error, variance of rating error, and lag-1 autocorrelation coefficient of rating error. The autoregressive model of the rating error often had to be "forced" to fit the data. The Cost-Effectiveness Procedure probably is more sensitive to structural inadequacy of the model when discharge is expressed as a discharge ratio than when discharge is expressed in cubic feet per second. The estimated autocorrelation coefficient tended to be the same as before. Estimated variances were similar to previous variance values divided by the square of average discharge.

Uncertainty functions relating total error variance to number of visits per year were calculated using program XVARSTO. When discharge was expressed as a ratio to average discharge, uncertainty (total error variance) values were similar to values calculated when discharge was in cubic feet per second divided by the square of average discharge.

Expressing discharge as a discharge ratio had no effect on estimated fixed, visit, and route costs and overhead percentage; therefore, it was not necessary to reestimate them for this analysis.

Table 9 shows number of visits per year to each station and network uncertainty for three scenarios. Network uncertainty is expressed as standard deviation (square root of the sum of station variances). Present operation was used as initial conditions for runs of program TRAVEL to obtain six- and one-visit minimum scenarios. Network uncertainty associated with present operation is 0.04202 and can be reduced to 0.03963 by using program TRAVEL with a six-visit per year minimum constraint. Uncertainty can be reduced even further for a one-visit per year constraint.

Patterns of visits to the stations are different from patterns given in table 8, where discharge was expressed in cubic feet per second. For instance, in table 8, the most visited station was 13269000, Snake River at Weiser, whereas in table 9, the most visited station was 13265500, Crane Creek at mouth near Weiser. The effect of changes in the budget when discharge is expressed as a discharge ratio is shown in figure 11. Note that different minimum number of visit constraints makes no difference in uncertainty when the budget is greater than $120,000.

Conclusions

The Cost-Effectiveness Procedure is a promising, innovative method for modeling uncertainties inherent in operation of stream-gaging networks. The procedure uses the model to choose an optimum allocation of resources to maximize accuracy. Given a network of stream gages, the model has provisions for both the independent error in discharge measurements and the time-related error due to shifts in rating curves. Cost considerations account for fixed costs and overhead, as well as route costs and visit costs.

The following weaknesses were observed. Suggested improvements are mentioned.

(1) Difficulty was encountered in determining costs associated with network operation. If the technique is to be applied nationwide, guidelines should be provided to help districts identify more clearly what are included in the various costs (fixed, visit, route, and overhead). It may be helpful if district personnel who have worked on estimating costs were to compile a list of items that should be included in each cost factor.

Table 9.--Number of visits per year and network uncertainty under three constraint scenarios given an annual budget of $73,884, with estimation error expressed as a discharge ratio

Station No.: Gaging-station identification number.

Present operation: Network is constrained to be operated as it is at present.

6-visit minimum: Six-visit per year minimum constraint.

1-visit minimum: One-visit per year minimum constraint.

Network uncertainty: In cubic feet per second *per* cubic feet per second.

Station No.	Present operation	6-visit minimum	1-visit minimum
	Number of visits per year		
13236500	9	6	5
13239000	9	6	8
13240000	9	6	5
13245000	9	6	5
13246000	9	6	5
13254500	9	12	17
13255050	9	12	17
13255060	9	12	17
13258500	9	12	17
13265500	9	16	18
13266000	9	12	17
13269000	6	6	6
13289960	6	6	6
13290190	6	9	8
13290450	6	6	6
13310700	9	6	5
13313000	9	6	5
13316500	6	6	6
13317000	6	6	6
	Network uncertainty		
----	0.04202	0.03963	0.03824

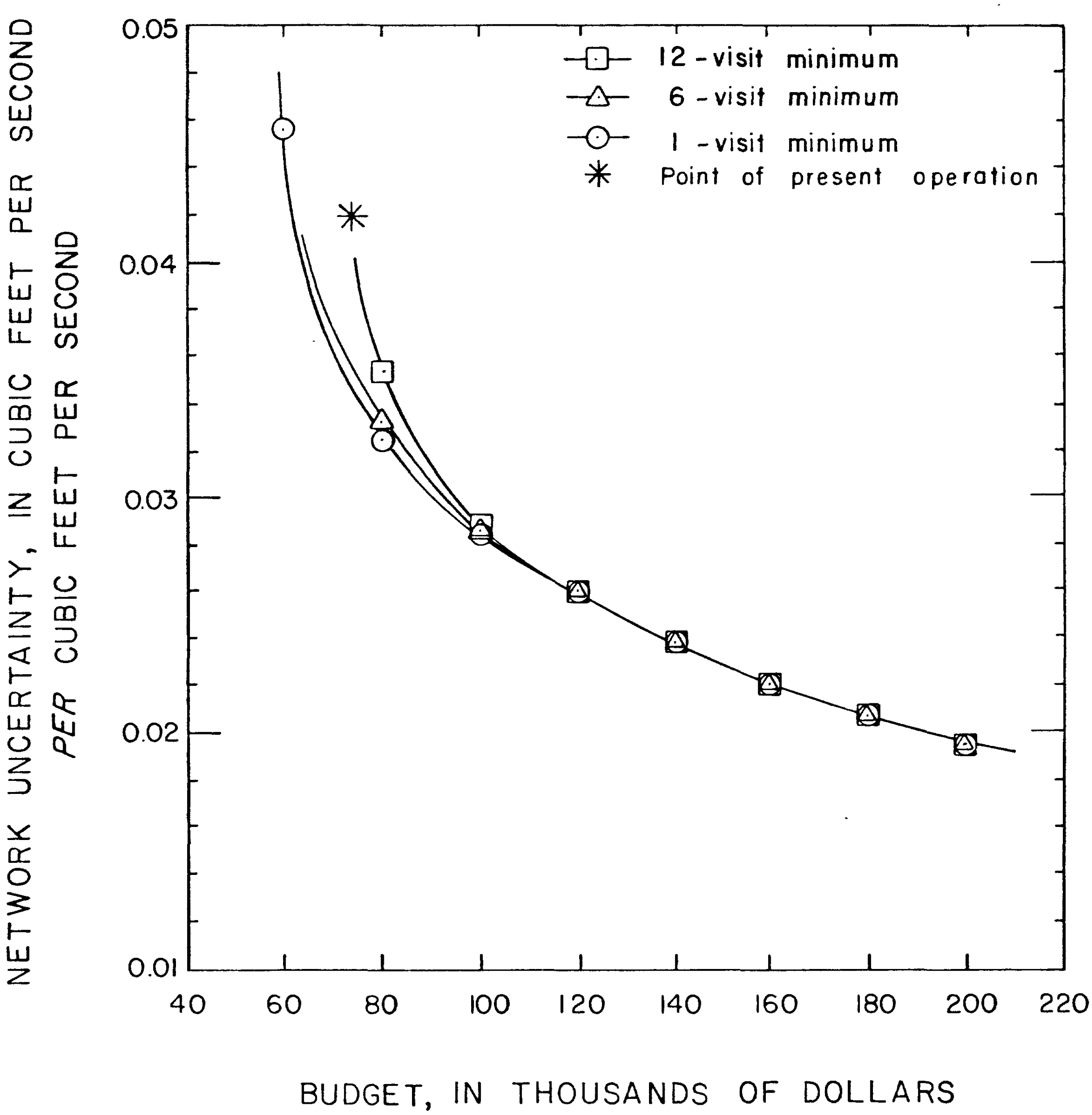

Figure 11. -- Network uncertainty versus budget; discharge ratio.

(2) The Cost-Effectiveness Procedure, as applied in this study, did not model the Idaho District's multidisciplinary field activities, where field trips often include visits to ground-water and quality-of-water sites, as well as to surface-water stations, and route costs are shared among several project accounts. A way to model these multidisciplinary activities would be to include the ground-water and quality-of-water sites as stations in the network. These sites would be assigned fixed and visit costs, and route costs would include the cost of traveling to them. The budget would include funding for collection of data in all three disciplines. Fictitious uncertainty functions would be assigned to ground-water and quality-of-water sites. Once this multidisciplinary network had been described, program TRAVEL would be run to obtain optimum operation strategies. Including sites from all disciplines would increase the size of the network in the Weiser-McCall area from 19 to 54 stations.

(3) The rating error was modeled as a lag-1 autoregressive process. The model often had to be forced to fit the data, which reduced confidence in the accuracy of results of the Cost-Effectiveness Procedure. It is recommended that choices between stream-gaging strategies with little difference in magnitude of uncertainty be made on the basis of considerations other than the magnitude of uncertainty.

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APPENDIX

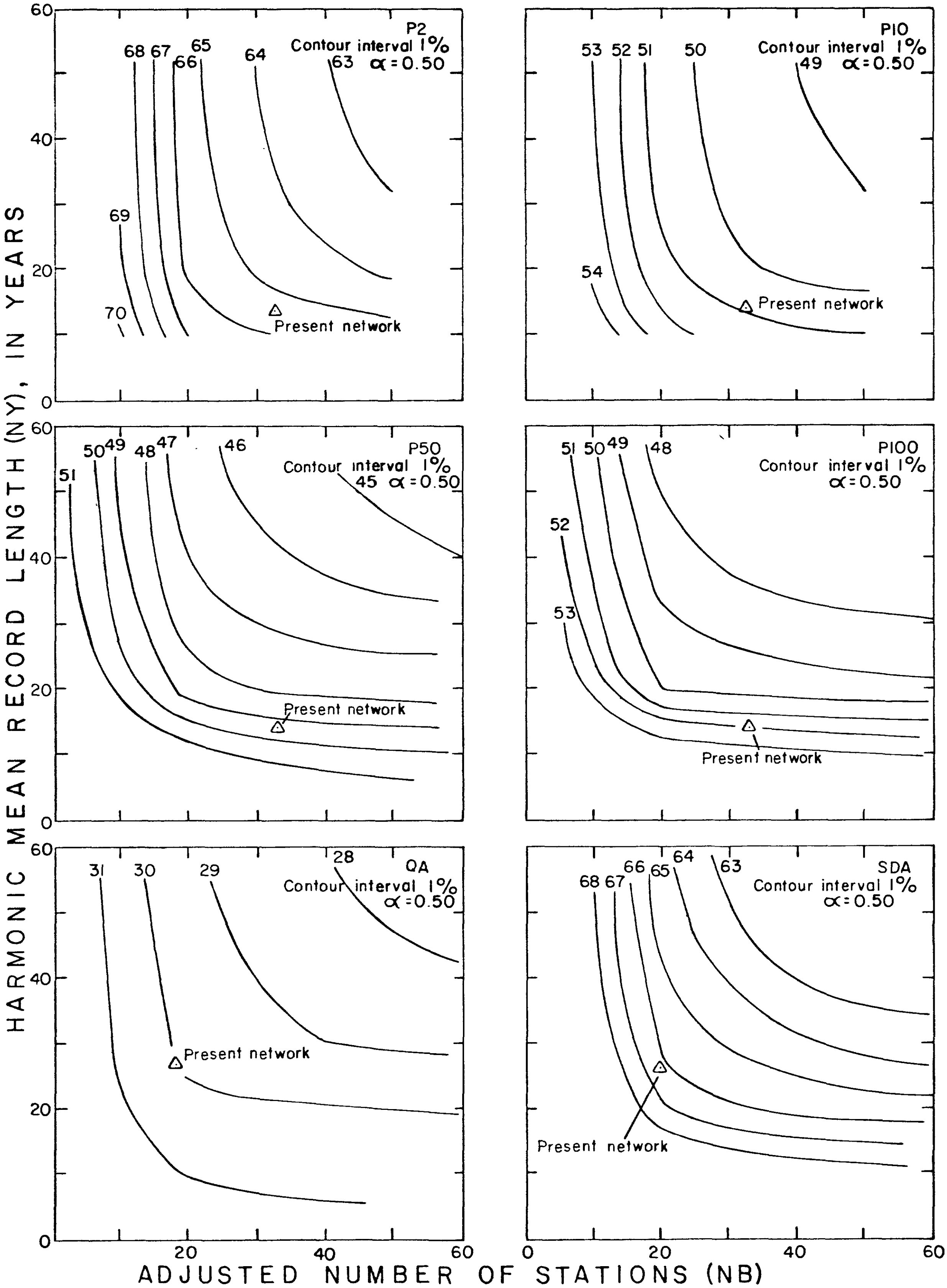

Figure 12.-- True standard error, ST, in percent, as a function of NY and NB, Region 1.

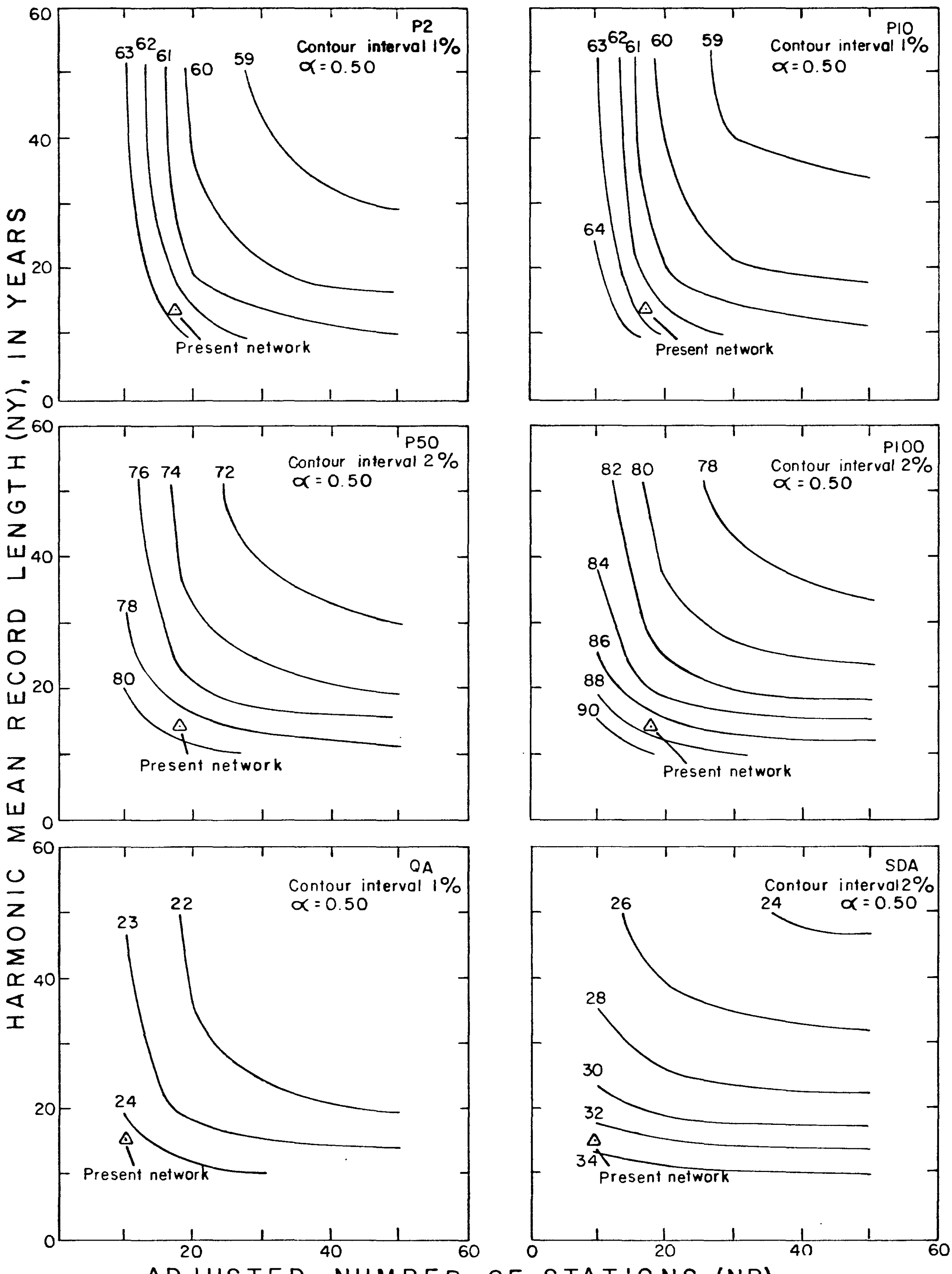

Figure 13.-- True standard error, ST, in percent, as a function of NY and NB, Region 2.

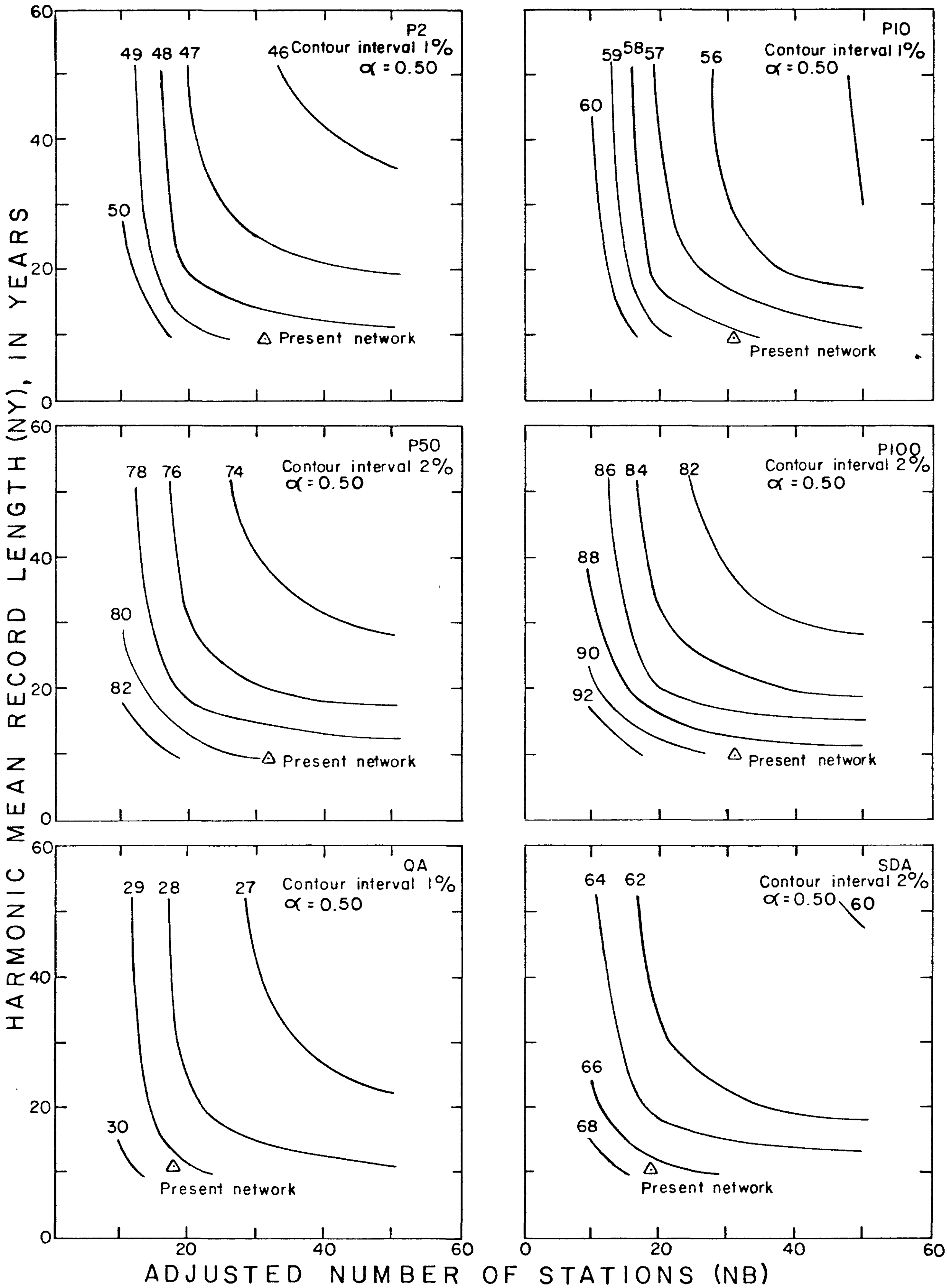

Figure 14.-- True standard error, S_T, in percent, as a function of NY and NB, Region 3.

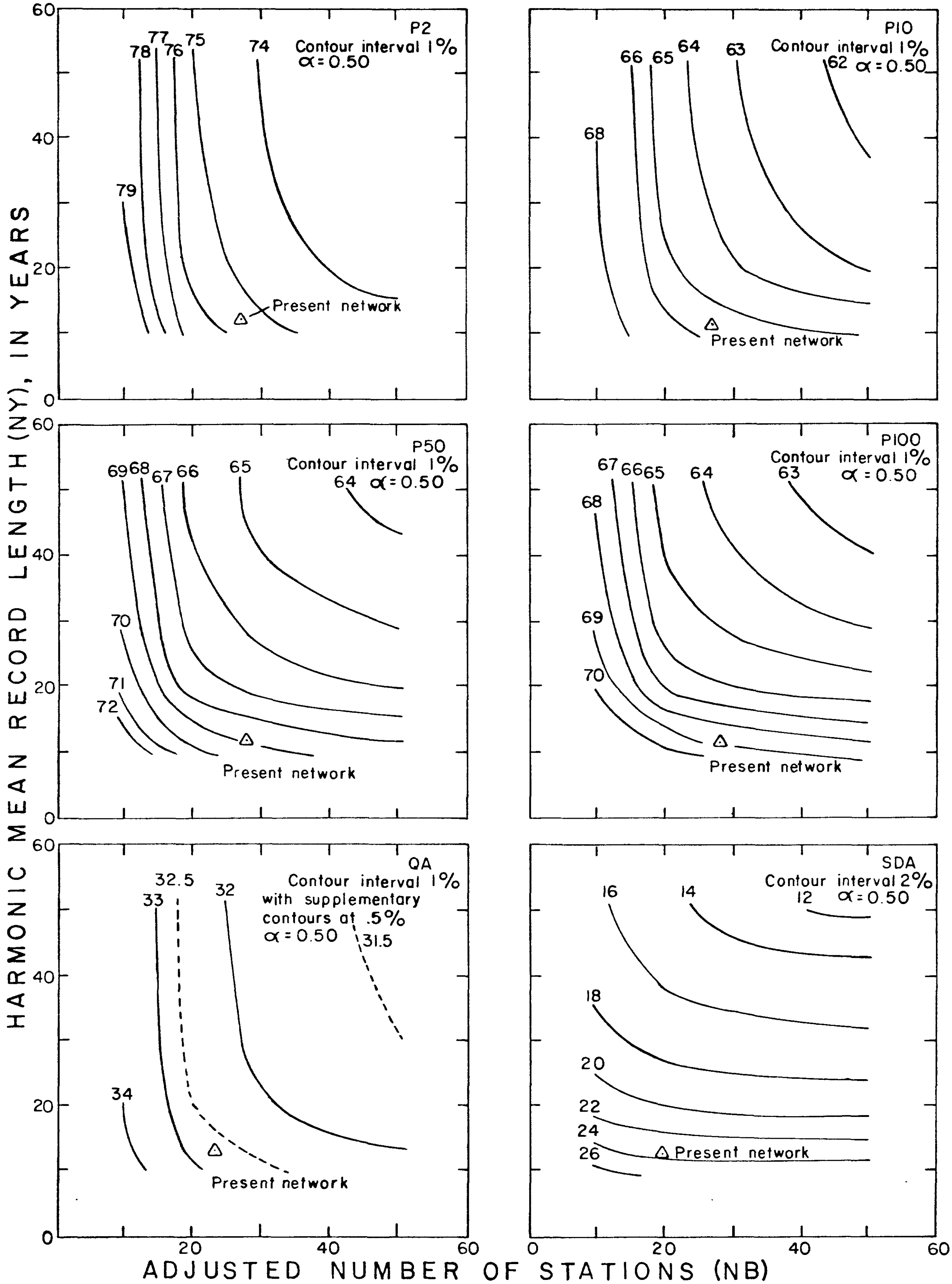

Figure 15.-- True standard error, ST, in percent, as a function of NY and NB, Region 5.

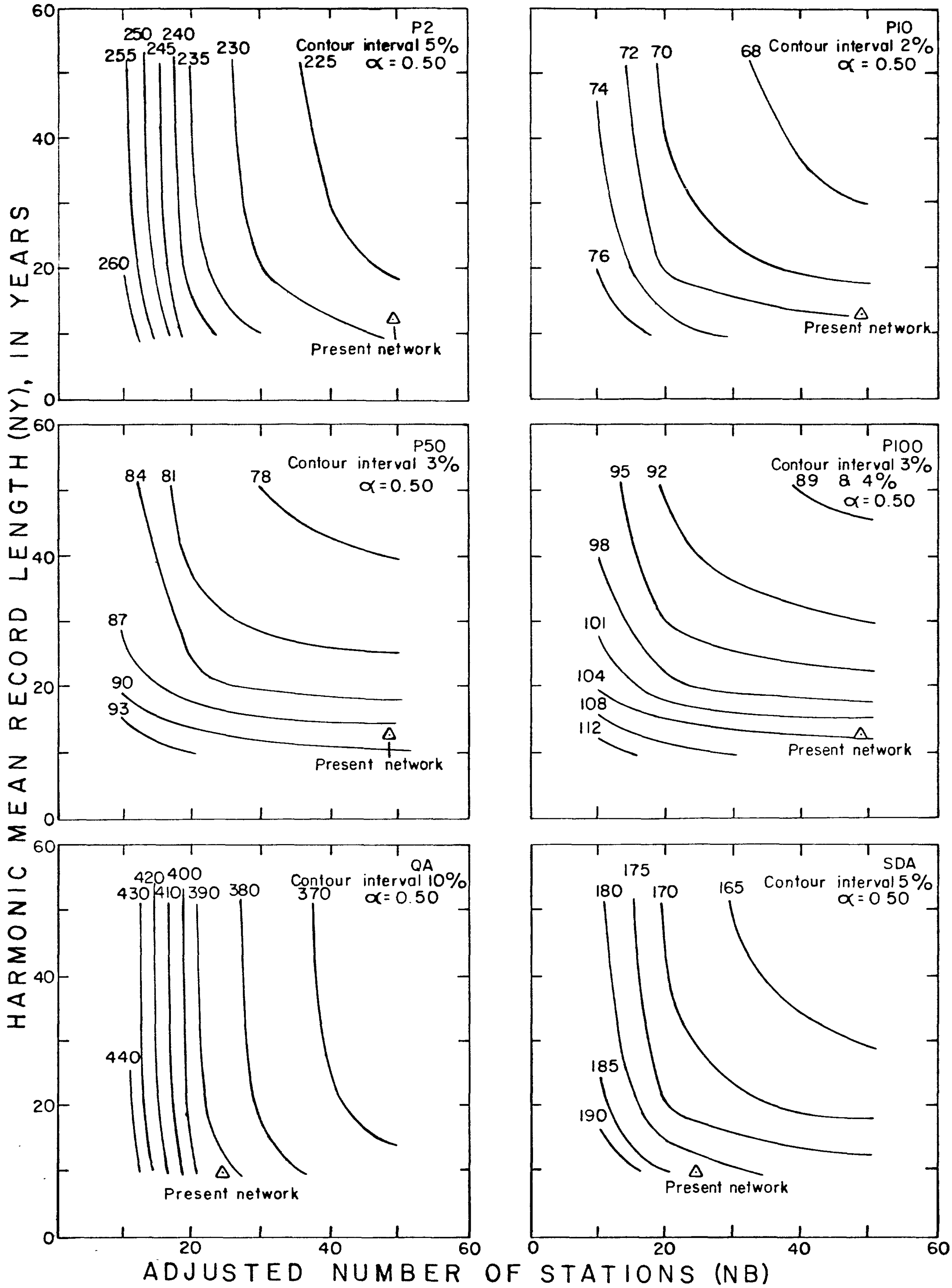

Figure 16.-- True standard error, S_T, in percent, as a function of NY and NB, Region 6.

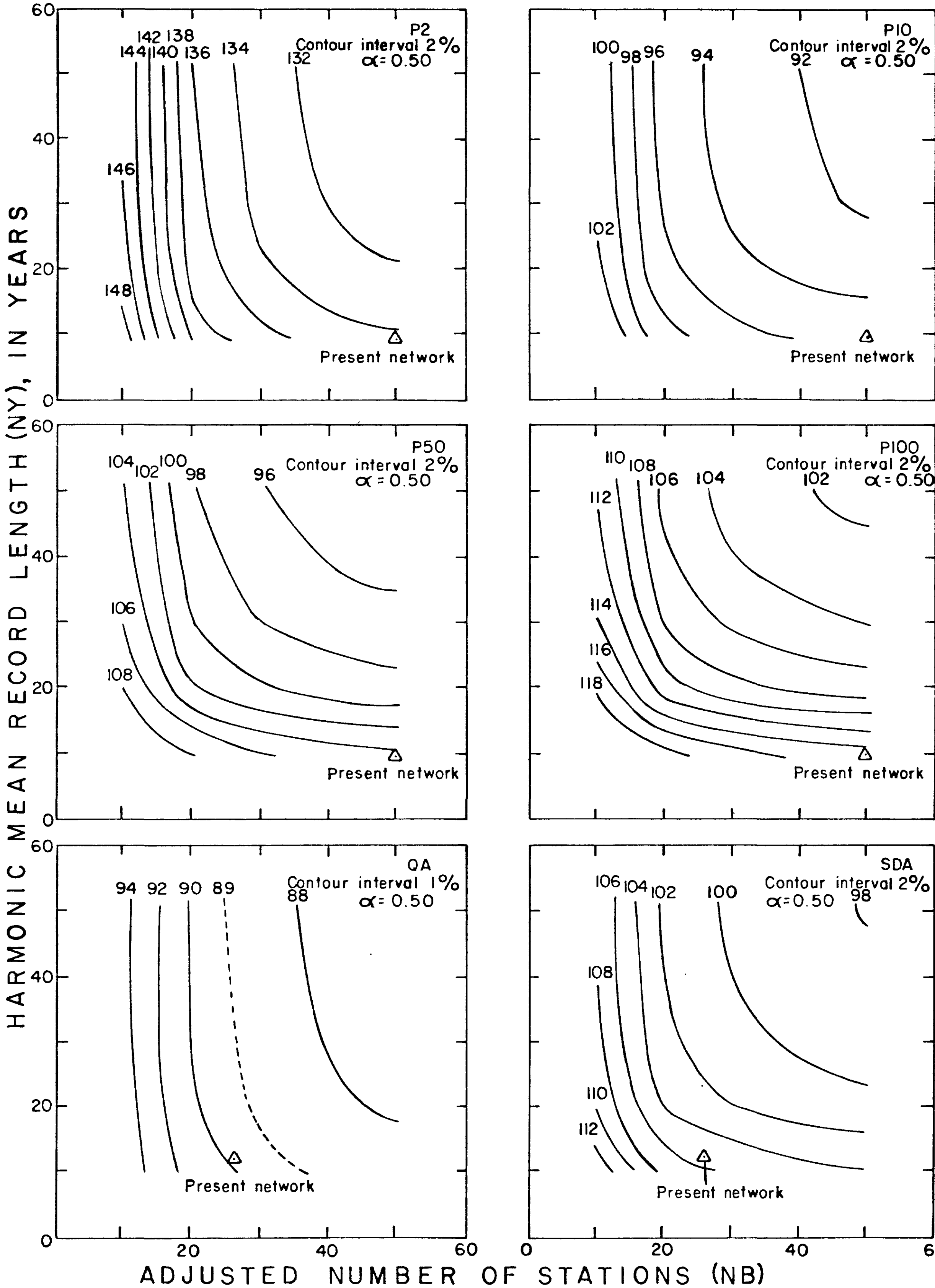

Figure 17.-- True standard error, ST, in percent, as a function of NY and NB, Region 8

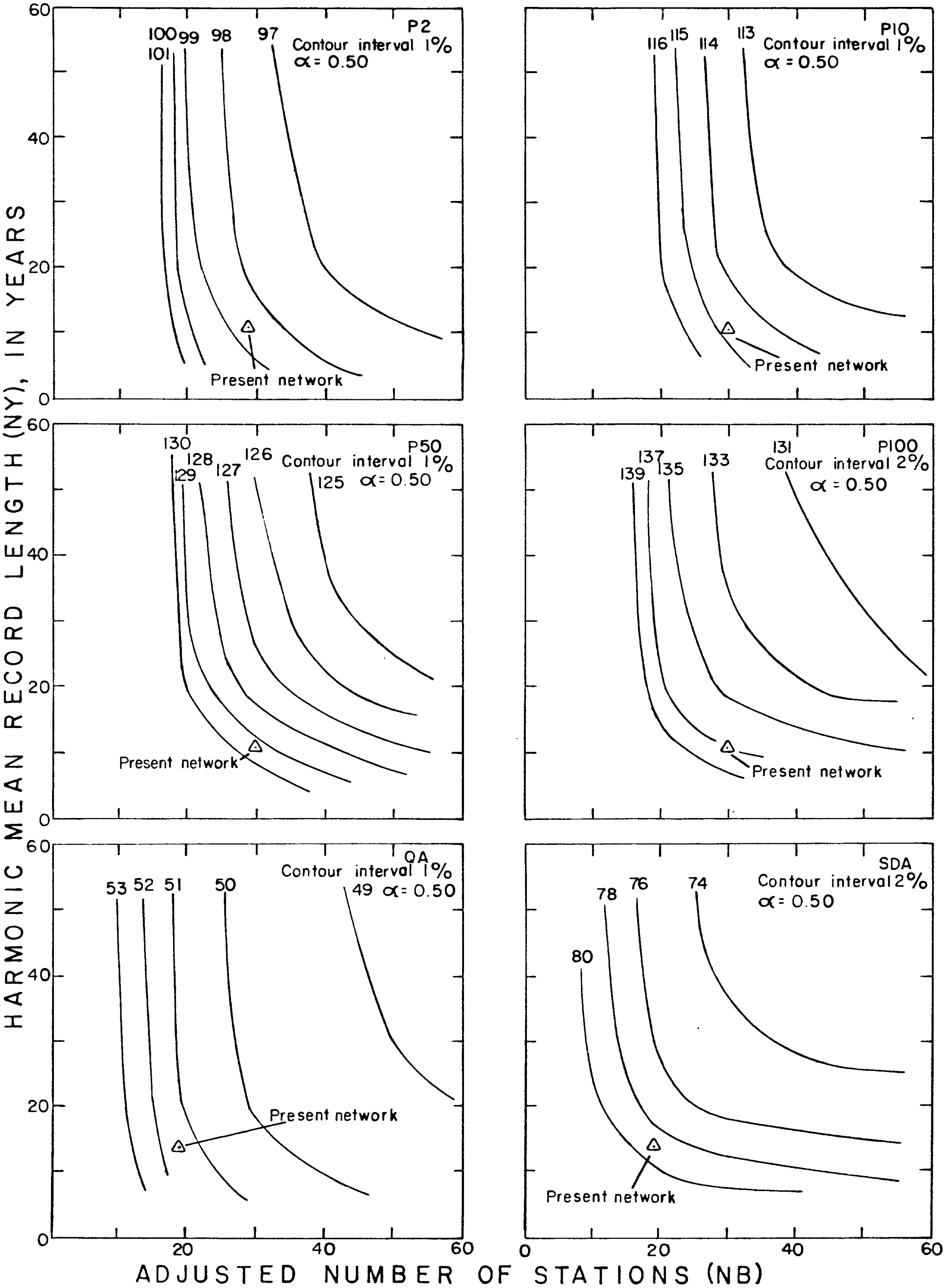

Figure 18.-- True standard error, ST, in percent, as a function of NY and NB, Region 9.

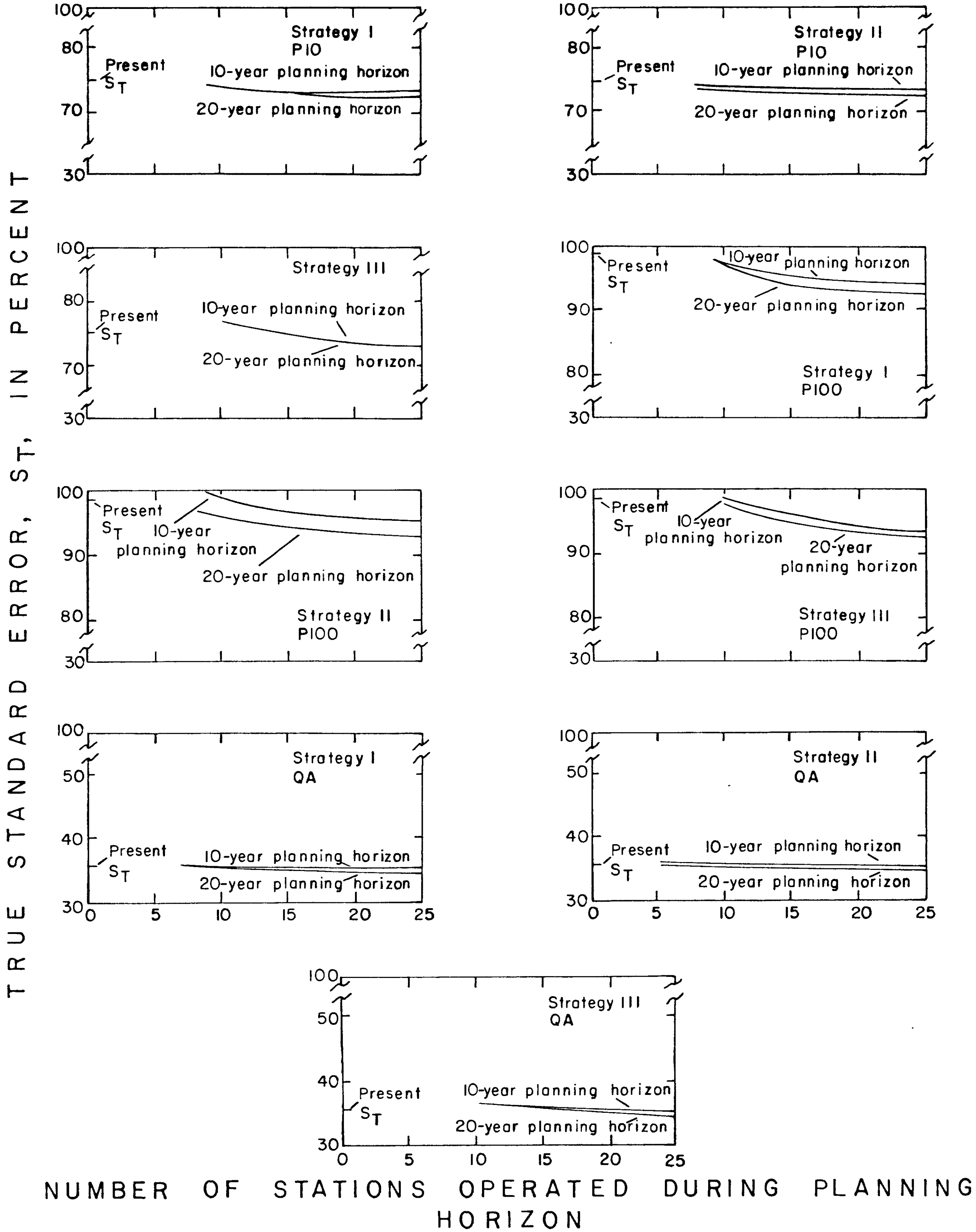

Figure 19.--True standard error as a function of planning horizon and number of stations operated, Region 7.