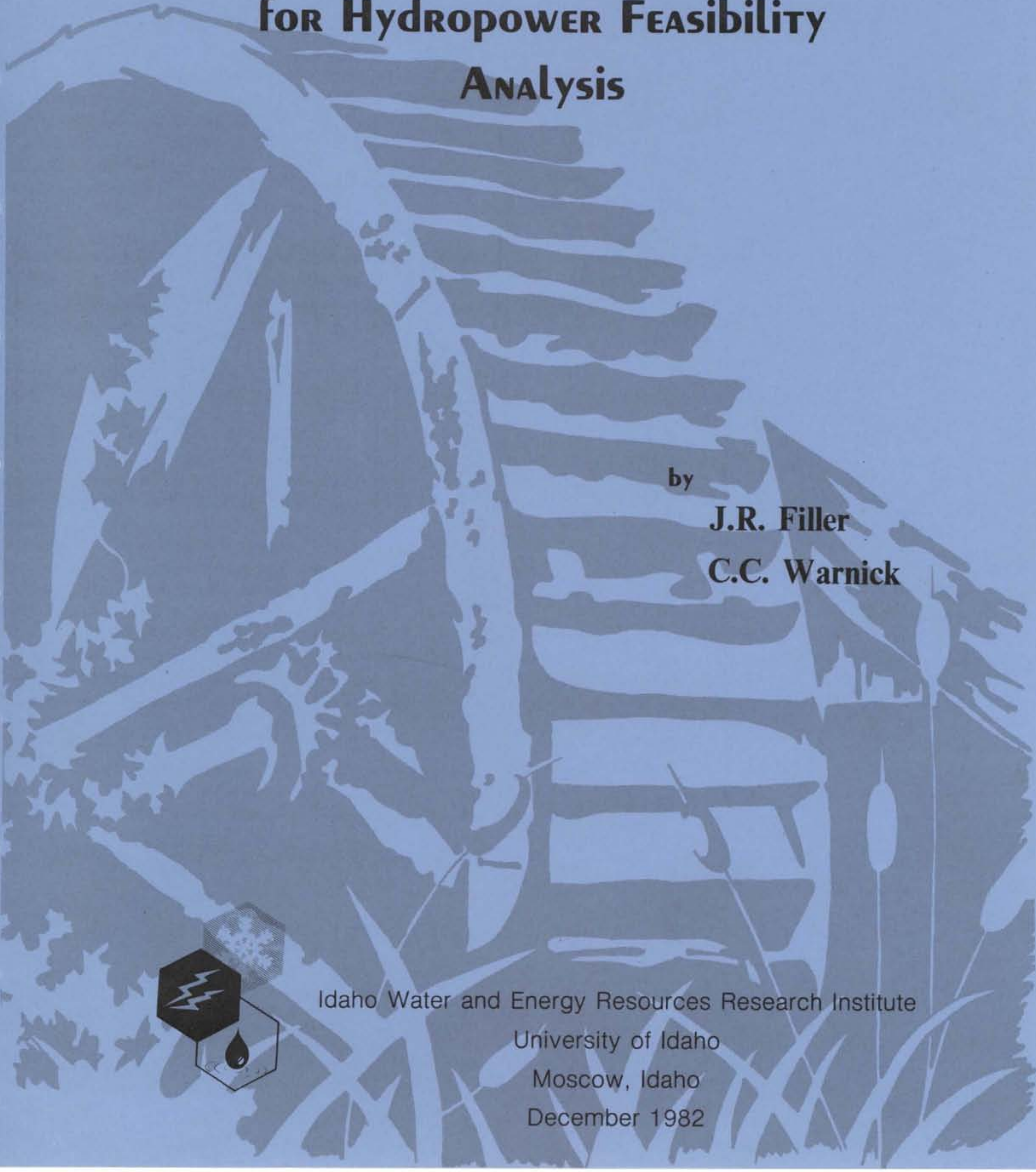
Research Technical Completion Report   Project A-068-IDA

Hydrologic Flow Determination for Hydropower Feasibility Analysis



by

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Moscow, Idaho

December 1982

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Supplemental Research Technical Completion Report

A-068-IDA

HYDROLOGIC FLOW DETERMINATION

FOR HYDROPOWER FEASIBILITY ANALYSIS

by

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Submitted to
United States Department of the Interior
Washington, D.C. 20242

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ABSTRACT

This report presents comparisons of different methods of estimating average annual discharge of ungaged streams. The primary purpose of the estimates being for making hydropower feasibility investigations that utilize flow duration curves. The published methods of McDonald (1948), Rosa (1968), Heitz (1980, 1981) and Hawley-McCuen (1982) were used on selected streams in Idaho to make the comparisons. The methods have been developed over a considerable period of time and have used different periods of record but all have used normal annual precipitation estimates as the basis for prediction. Reasonable agreement was obtained in the comparisons but inconsistencies do appear on some drainages.

Several additional approaches to improving the estimates and hopefully correcting the inconsistencies have been postulated and techniques for study recommended.

FOREWARD

The Idaho Water and Energy Resources Research Institute has provided administrative coordination for this study and organized the team in the Department of Civil Engineering at the University of Idaho that conducted the research. It is the Institute policy to make available the results of significant research related to the water and energy resources within Idaho and for possible application in a national and international realm. The Institute neither endorses nor rejects the findings of the authors. In this study a strong effort has been made to utilize earlier findings of research and to compare different hydrologic techniques in the field of hydropower engineering and to determine limitations that must be accounted for in using data drawn from hydrologic measurements that are frequently very limited in geographic coverage and often of limited historical length. The Institute does encourage careful consideration of techniques recently developed for extending the usefulness of limited hydrologic measurements.

INTRODUCTION

An earlier report entitled, "Assessment of the Usefulness of Hydrologic Data for Hydropower Feasibility Analysis" defined some general limits for the extrapolation of flow data for input in the computation of hydropower design capacity. That earlier study treated specifically the use of flow duration curves and utilized techniques of using parametric duration curve developed by Heitz (1981). An important parameter to make effective use of parametric flow duration curves is the determination of an accurate estimate of the average flow at an ungaged stream site. A recent paper by Hawley and McCuen (1982) has presented regression equations for determining average flow based on measurements of parameters such as precipitation, mean elevation, and percent cover density. The earlier work of the writers of this report has relied on extrapolation from existing streamgage records and qualitative evaluation along with qualitative judgments to temper runoff coefficients on ungaged watersheds such that they are compatable with the runoff coefficients at existing gaged watersheds.

PURPOSE AND OBJECTIVES

The purpose of this supplemental research was to develop a better method or methods for determining average flow at ungaged streamflow sites where hydropower potential exists. The specific objectives were to:

1. Study Hawley-McCuens approach and compare their approach with data developed in earlier research by Heitz and others.
2. Study ways of improving the accuracy of estimating the average flow of ungaged sites in relation to flow duration expressions.

DESCRIPTION OF HYDROLOGIC AREA

The area of principal interest for this research was the drainages in the Pacific Northwest wherein there is considerable topographic relief and a definite orographic effect on storms moving into the continental land masses. This region experiences considerable variation in the normal annual precipitation and the geology and topography make it difficult to generalize runoff characteristics of the streams. The work of Hawley and McCuen covered a major section of the western United States and subdivided the area into five regions as shown in Figure 1. The earlier work of this project concentrated on two major stream drainages in Idaho, the Clearwater River basin and the Salmon River basin. These basins are delineated in a general way on the generalized map adopted for the study by Hawley and McCuen (Figure 1). This study has concentrated most of the research on those basins mentioned but has made comparisons on a sampling basis on other basins in Idaho to compare results obtained in using the regression equations of Hawley and McCuen with earlier estimates of runoff characteristics as developed in the studies by Heitz, et. al (1980) and Warnick, et. al (1981). Particular samplings were made of a further comparison with some unpublished work of Johnson (1982) in the upper portions of Snake River drainage in Idaho.

METHODOLOGIES FOR ESTIMATION OF FLOW

Much research has been done on relating yield of storm runoff from the input parameter of precipitation. Most of the work has been done on short-term precipitation events and is characterized by such studies as those of Linsley and Ackerman (1942), Kohler and Linsley (1951) and the U.S. Soil Conservation Service (1955). Longer-term periods of

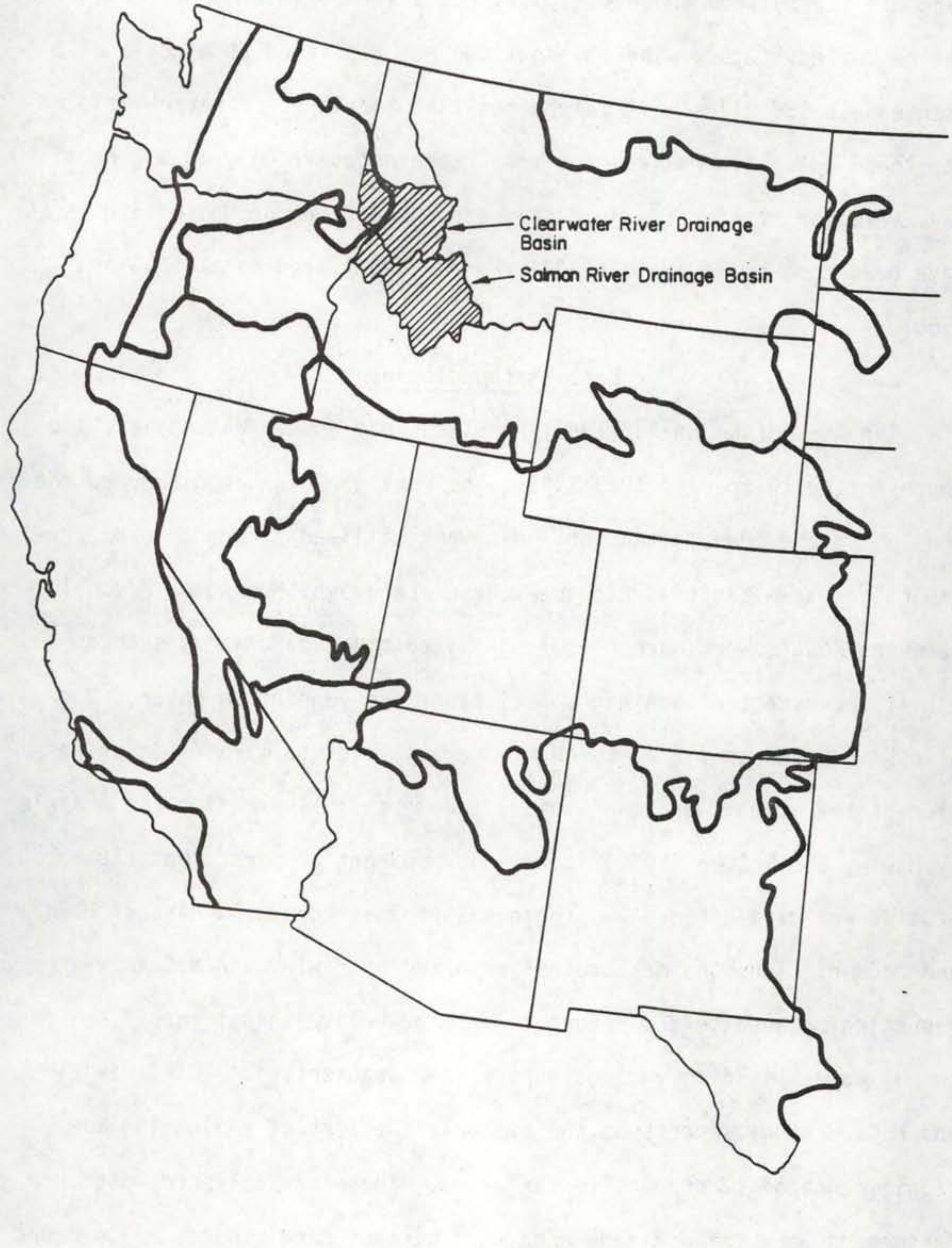

Figure 1. Map of Areas Involved in Study and Areas Studied by Hawley and McCuen.

annual runoff resulting from annual precipitation has been studied by Langbein (1949) from which was published a water yield map covering the entire United States. The original map was published at a scale of 1 inch equals 150 miles. It is obvious that the lines of water yield had to be quite generalized and were representative only in a general way. Similar studies for just the western part of the United States have been done by McDonald (1948), Munns (1952), and Rosa (1956 and 1968).

Early Methodologies

The work of McDonald (1948) resulted in a annual water yield map representing the period 1929-1945. The work of Rosa has pioneered the problem in the Idaho situation. His work utilized information on precipitation as a basis as did the work of Langbein, Munns and McDonald. However, Rosa's work more closely analyzed other parameters such as elevation, aspect of drainage, soil types and vegetative cover. Much of his work was confirmed through numerous trips to make field inspection of the streams and the various parameters. In reading the article by Hawley and McCuen (1982) it was not apparent at first that the studies and data of Rosa was the basis of the regression data of Hawley and McCuen. Thus the methodology reported by Hawley and McCuen was reporting on an extended effort to relate average annual runoff or annual water yield to various watershed characteristics. The Hawley and McCuen study reports on the systematic effort of evaluating the significance of 17 predictive variables. These variables or watershed parameters were (1) drainage area, (2) percent bare ground, (3) percent cover density, (4) mean elevation, (5) minimum elevation, (6) elevation at temperature station, (7) maximum elevation, (8) latitude, (9) longitude, (10) mean annual precipitation, (11) minimum average annual precipitation, (12) maximum average annual precipitation, (12) 60-minute, 25-year precipitation, (14) soil group, (15) mean annual temperature, (16) mean annual temperature at station, (17) percent vegetation and litter, and the dependent variable, water yield. The conclusion showed that the most significantly important parameters were mean annual precipitation, mean elevation, and percent cover density. In fact, the lone variable of precipitation tended to given just as good of results for a predictive evaluation of water yield as did including the other parameters. This work was done on mostly small gaged watersheds and appeared to have used no common historical time period.

Heitz, et. al. Methodology

The work of Heitz, Warnick, and Emmert (1979) approached the problem by attempting to use relations of average annual runoff or flow as related to input mean annual precipitation utilizing comparisons between gaged streams in a given hydrologically similar area. A certain amount of subjective engineering judgement was used to choose the appropriate runoff coefficients. Figure 2 taken from Emmerts' (1979) thesis shows how some of the projections were made. Runoff coefficients were developed for all the reaches of rivers studied under an inventory of potential hydropower energy in the streams of Idaho; Heitz, et. al. 1980. This information is best catalogued in a report by Warnick, Heitz, Kirkland and Burke (1981). The subjective technique of determining runoff coefficients was guided by the fact that at gaged sites the accumulated effect had to equal the ratio of the measured average annual runoff to the calculated mean annual precipitation as determined from long-time isohyetal maps of normal annual precipitation.

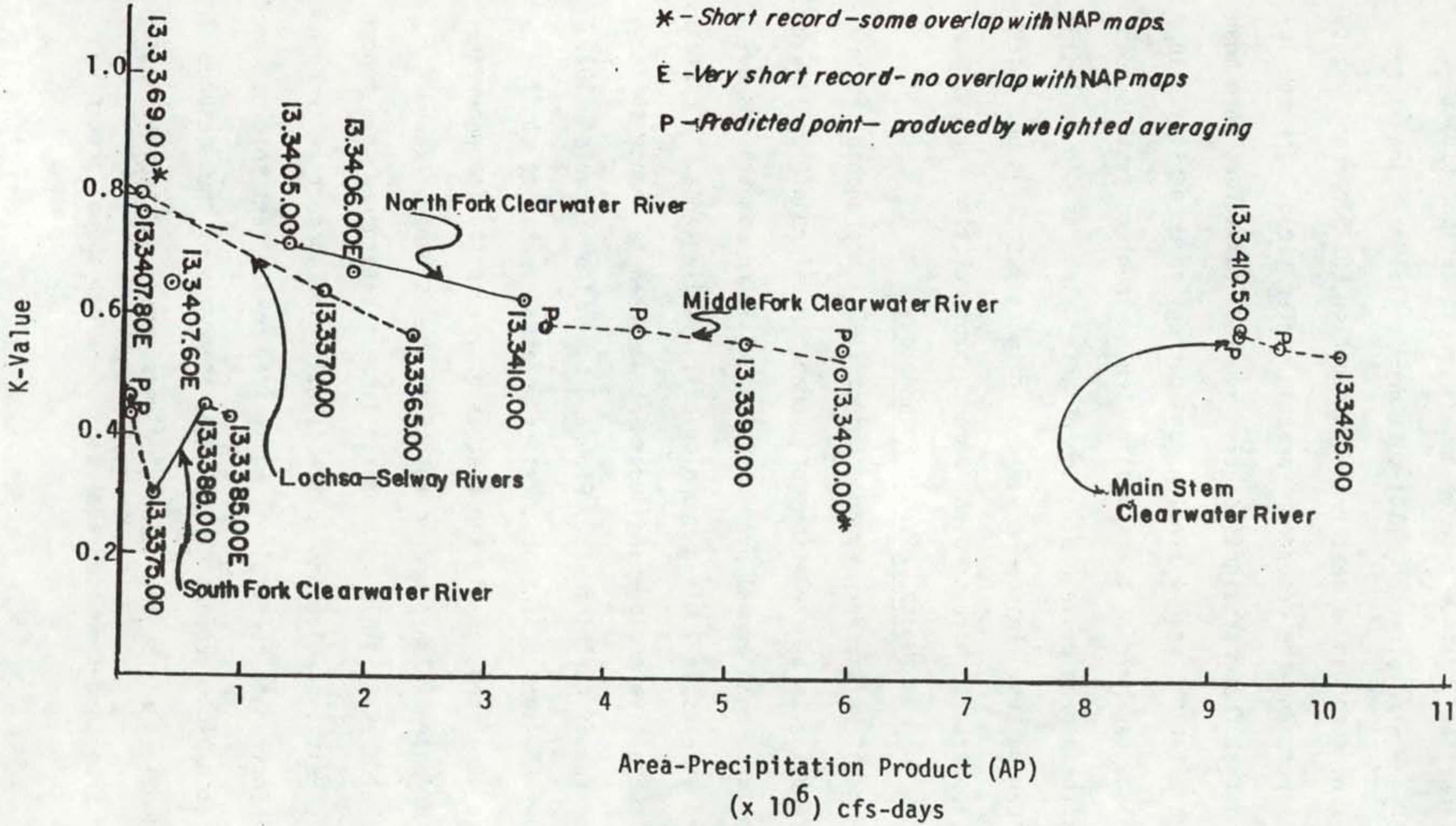

Figure 2. Relationship Between K-Values and Area-Precipitation Product for the Clearwater River, Idaho Method. *Source: Emmert (1979)*

Other Methodologies

In the research work of Gary Johnson (1982) there is reported another approach to determining average annual runoff. This is the unpublished work of Kjelstrom of the Boise Office of the U.S. Geological Survey and is for regions of the Upper Snake River drainage in Idaho. The particular equation for estimating average annual runoff was:

$$Q = 0.000903\ A^{0.9}\ P^{1.83}\ (F)^{0.29} \qquad \text{Eq. (1)}$$

where Q = average annual runoff in CFS

A = watershed area in square miles

P = mean or normal annual precipitation in inches

F = percentage of the watershed forested as indicated by 1:250,000 scale U.S.G.S. maps

The work of Rosa (1968) represents an earlier methodology than the work of Hawley and McCuen. Therefore, the work of McDonald (1948), the work of Rosa (1968), the work of Hawley and McCuen (1982) and the studies of Warnick, et. al. (1981) all represent different approaches. The research results reported here then are an effort to compare these various methodologies on some hydrologic situations in Idaho that have particular importance in feasibility studies of hydropower.

COMPARISON AND ANALYSIS OF METHODS

Hawley and McCuen Analysis

Analyses of the work of Hawley and McCuen was conducted on only the region they called Idaho-Montana-Wyoming and really covering the area that is cross-hatched in Figure 3. This actually involved 211 watersheds that had measured data for which analysis was possible. An

Figure 3. Idaho, Montana, and Wyoming Region Outlined by Hawley and McCuen.

appraisal of those sites revealed several gaged watersheds that the writers question as having good records applicable to this study. One site appears to have been recorded twice. A decision was made to utilize only 43 watersheds that were considered representative of good stations involving Idaho-type conditions. With the original data from the Hawley and McCuen report a regression study was made to see whether the selected group of 43 watersheds revealed different regression relations than the original 211 watersheds and if there was evidence that a better correlation might be obtained. Results of this analysis are presented in Table 1. The base data for these results are presented in the Appendix.

An alternative method of utilizing the same basic factors as the Hawley and McCuen data was also considered. This involved introducing parameters that were easily calculated from the basic data that were identified in the Hawley and McCuen information which were considered to have an influence on the runoff-precipitation relationship. The first new parameter was a relative relief term, ΔE, the difference between maximum elevation and minimum elevation of the basin. This was considered because with relatively large differences in elevation within a watershed it was considered that one might expect increased precipitation and more runoff coming off the watershed in a shorter period of time thus, allowing less loss of water from the annual precipitation input. This parameter was used in two regression analysis with both the original 211 sets of data and with the selected 43 watersheds data. One used normal annual precipitation, P_a, ΔE, and cover density, C, as the parameters to relate to average annual runoff. The other analysis used normal annual precipitation, P_a, mean elevation, E_a, relative relief, ΔE, and cover density, C.

Table 1. Results of Regression Analysis of Relation Between Normal Annual Precipitation and Runoff for Original 211 Stations and for 43 Selected Stations

No. of Sites	Prediction Equation	R	R^2
211	$Y = -12.1721 + 0.91756\ P_a$	0.973	0.947
43	$Y = -12.801182 + 0.908355\ P_a$	0.939	0.882
211	$Y = 2.10 \times 10^{-5}\ P_a^{2.45458}\ E_a^{0.49269}\ C^{0.16526}$	0.926	0.857
43	$Y = 1.060183 \times 10^{-3}\ P_a^{2.263636}\ E_a^{0.093715}\ C^{0.222769}$	0.934	0.872

Y = runoff or water yield in inches
P_a = normal annual precipitation in inches
E_a = mean elevation of basin ft. msl.
C = percent cover density, %

A further inquiry was to consider two relative steepness terms, S_R, and S'_R. This was defined by two different methods as shown in the two equations below:

$$S_R = \frac{E_{max} - E_{min}}{\sqrt{A}} \qquad \text{Eq. (2)}$$

where S_R = relative steepness

E_{max} = maximum elevation in ft

E_{min} = minimum elevation in ft

A = drainage area in mi^2

and

$$S'_R = \frac{E_{max} - E_{min}}{A} \text{ or } \frac{S_R}{\sqrt{A}} S_R \qquad \text{Eq. (3)}$$

Regression analyses were made with these terms as additional parameters to the normal annual precipitation and cover density terms related to average annual runoff. The resulting equations for the regression relations of the new parameters and the correlation coefficients are shown in Table 2. Very little change in the correlation coefficients was obtained.

A comparison was then made between the historical mean annual discharge and the predicted mean annual discharge as computed from the empirical regression equation developed by Hawley and McCuen (1982), namely:

$$Y = -12.1721 + 0.91756\ P_a, \qquad \text{Eq. (4)}$$

where Y = runoff or water yield in inches, and

P_a = mean annual precipitation in inches.

Table 2. Regression Equations with Relative Relief and Relative Steepness as Parameters Influencing Runoff-Rainfall Relations Compared with Regression Equations Using Just Precipitation as a Parameter

No. of Sites	Prediction Equation	R	R^2
211	$Y = 2.215981 \times 10^{-4} P_a^{2.522908} \Delta E^{0.208204} C^{0.182155}$	0.921	0.848
43	$Y = 8.962455 \times 10^{-4} P_a^{2.271726} \Delta E^{0.111674} C^{0.240633}$	0.936	0.875
211	$Y = 1.147326 \times 10^{-5} P_a^{2.437664} E_a^{0.43686} \Delta E^{0.133735} C^{0.183498}$	0.927	0.859
43	$Y = 5.061742 \times 10^{-4} P_a^{2.256129} E_a^{0.071116} \Delta E^{0.108424} C^{0.249435}$	0.936	0.876
211	$Y = 5.318792 \times 10^{-4} P_a^{2.370810} S_R^{0.229934} C^{0.147793}$	0.926	0.857
43	$Y = 1.778558 \times 10^{-3} P_a^{2.293415} S_R^{0.037890} C^{0.209949}$	0.934	0.817
211	$Y = 1.264297 \times 10^{-3} P_a^{2.431168} S_R'^{0.093227} C^{0.138412}$	0.922	0.850
43	$Y = 2.446685 \times 10^{-3} P_a^{2.280049} S_R'^{0.00803996} C^{0.212218}$	0.933	0.871
Note:	$S_R = E/\sqrt{A}$ $\quad S_R' = \frac{S_R}{\sqrt{A}}$ $\quad$ A = drainage area in Mi^2		
211	$Y = 1.702990 \times 10^{-3} P_a^{2.6280989}$	0.914	0.835
43	$Y = 3.159716 \times 10^{-3} P_a^{2.434996}$	0.931	0.867

This was done for groups of stations that have gaged streamflows of a significant length and appear to be of importance in hydroelectric studies. The precipitation input values for each watershed were those obtained from the studies by Warnick, et. a. (1981). None of these stations used in the comparisons were included in the development of Hawley and McCuens's regression equation, (Equation 3). The results of the comparison are shown in Table 3.

It was possible to find a few measured streamflow stations that were common in the studies of Hawley and McCuen (1982) and Heitz, et. al. (1980) wherein data were available to compare the runoff coefficients determined with the aid of the two regression equations of Hawley and McCuen and those determined in the studies by Heitz. This comparison is shown in Table 4. Note, this has been done with different values of precipitation (normal annual precipitation) and with different methodologies for getting the runoff coefficient.

In the final effort using the regression equations of Hawley and McCuen an attempt was made to apply the appraoch to ungaged streams and to compare the results with results obtained by using the methodology developed in the hydropower inventory study of Heitz et. al. (1980). Results for these are shown in Table 5.

In addition to the comparison of values predicted by the Hawley and McCuen equation, water yield or average annual discharge values were predicted from other sources and compared with gaged-record data. Results of the comparison are shown in Tables 6, 7 and 8. It should be noted that in Table 8 the comparison was made with the mean annual discharge for water year 1963 for the three gages shown. Water year 1963 was selected as it represented fairly closely the long-term average condition for other gaged sites in Idaho.

Table 3. Comparison of Predicted Average Discharge With Actual Average Annual Discharge, Using the Hawley-McCuen Equation for Prediction ($Y = -12.1721 + 0.91756\ P_{NAP}$)

Gage No.	Gage Location	Area (mi^2)	Reach No.	P_{NAP} (in)	Y (m)	$\overline{Q}$ (cfs)	$\overline{Q}$ 1930-57 (cfs)
Salmon River Drainage							
13.2950.00	Valley Creek-Stanley	147	088R0080	27.5	13.06	141.11	199.37
13.2955.00	Salmon River-Stanley	535	000R0082 & 088R0080	34.78*	19.74	778.05	669.88
13.2965.00	Salmon River-Clayton	802	000R0078 & 085R0002	33.14*	18.24	1077.43	992.57
13.2985.00	Salmon River-Challis	1800	000R0062	31.2	16.46	2182.13	1464.06
13.3025.00	Salmon River-Salmon	3760	000R0050	27.9	13.43	3719.50	1902.94
13.3085.00	Middle Fork-Cape Horn	138	030R0056	31.9	17.10	173.83	239.30
13.3090.00	Bear Valley Creek-Cape Horn	180	030R0052	35.0	19.94	264.45	294.31
13.3105.00	South Fork-Knox	95	020S0015	41.4	25.81	180.67	146.57
13.3130.00	Johnson Creek-Yellow Pine	213	020R0020	36.2	21.04	330.21	343.56
13.3170.00	Salmon River-Whitebird	13,550	000R0008	28.9	14.35	14,319.97	10,762.84
Clearwater River Drainage							
13.3365.00	Selway River-Lowell	1910	020R0105	46.2	30.22	4252.13	3641.86
13.3370.00	Lochsa River-Lowell	1180	020R0010	50.6	34.26	2977.93	2752.61
13.3390.00	Clearwater River-Kamiah	4850	000R0028	39.9	24.44	8731.88	7755.90
13.3410.00	North Fork-Ahsahka	2440	Dworshak	50.2	33.89	6091.78	5533.21
13.3425.00	Clearwater River-Spalding	9570	002S0002 & 000R0010	41.48*	25.61	18,057.74	14,737.09
Other Gages in Idaho							
12.3055.00	Boulder Creek-Leonia	53	000R0003	42.6	26.92	105.09	116.12
12.4145.00	St. Joe River-Calder	1030	000R0008	50.6	34.26	2599.38	2295.81
12.4150.00	St. Maries River-Lotus	437	010R0004	39.6	24.16	779.91	517.34
13.1850.00	Boise River-Twin Springs	830	000R0013	40.9	25.36	1150.43	1169.56

*Weighted average for two reaches.

Table 4. Comparison of Runoff Coefficients Calculated from Hawley-McCuen Studies with Coefficients Calculated from Heitz Studies

Gage No.	Site Name	P_a	P_{NAP}	Y_{HM}	K_{HM}	$Y=f(P_a)$	$K=f(P_a)$	$Y=f(P_a,E_a,C)$	$K=f(P_a,E_a,C)$	Y_{HZ}	K_{HZ}
		(in)	(in)	(in)	(in/in)	(in)	(in/in)	(in)	(in/in)	(in)	(in/in)
13.3369.00	Fish Creek-Lowell R.S.	50.00	45.89	38.70	0.77	33.71	0.67	37.30	0.75	36.7	0.80
13.3165.00	Little Salmon-Riggins	30.00	31.12	20.00	0.67	15.35	0.51	11.64	0.39	18.4	0.59
13.3414.00	E.F. Potlatch-Bovill	40.00	42.97	20.30	0.51	24.53	0.61	20.21	0.51	20.2	0.47
13.2610.00	Little Weiser-Indian Valley	28.00	34.85	17.00	0.61	13.52	0.48	10.33	0.37	17.6	0.48
13.3115.00	E.F.S.F. Salmon-Stibnite	35.00	35.56	16.10	0.46	19.94	0.57	20.24	0.58	20.3	0.57
13.3125.00	Johnson Creek-Landmark	45.00	40.83	22.50	0.50	29.12	0.65	36.67	0.81	20.4	0.50
13.2005.00	Robie Creek-Arrowrock	25.00	22.32	7.10	0.28	10.77	0.43	6.58	0.26	6.9	0.31

P_a = Precipitation Data from Hawley-McCuen Studies (in)

P_{NAP} = Precipitation Data from Heitz Studies (in)

Y_{HM} = Runoff or Water Yield Data from Hawley-McCuen Studies (in)

K_{HM} = Calculated Runoff Coefficient, Y_{HM}/P_a (in/in)

$Y=f(P_a)$ = Predicted Runoff or Water Yield Using $Y=12.1721 + 0.91756\ P_a$

$K=f(P_a)$ = Runoff Coefficient Calculated Using Predicted Runoff, $K=[y=f(P_a)]/P_a$

$Y=f(P_a,E_a,C)$ = Predicted Runoff Using $Y=2.1\text{x}10^{-5}\ P_a^{2.45458}\ E_a^{0.49269}\ C^{0.16526}$

$K=f(P_a)$ = Runoff Coefficient Calculated Using Predicted Runoff, $K=[Y=f(P_a,E_a,C)]/P_a$

Y_{HZ} = Runoff Calculated Using Precipitation Data from Heitz Studies

K_{HZ} = Runoff Coefficient from Heitz Studies

Table 5. Results of Applying Hawley-McCuen Equation to Ungaged Watersheds in Northern Idaho.

Site	$\overline{P}$	$\overline{Y}=f(\overline{P})$	$\overline{Q}=f(\overline{P})$	$\overline{Q}_{EST}$
	(in)	(in)	(cfs)	(cfs)
Elk Creek at Elk Creek Falls	47.10	31.04	108.59	94.33
Hell Roaring Creek above Mouth	46.10	30.13	24.95	29.80
Bedrock Creek above Mouth	22.55	8.59	21.20	22.44

$\overline{P}$ = Predicted Normal Annual Precipitation by Warnick-Filler (in)

$Y=f(\overline{P}) = -12.1721 + 0.91756\,\overline{P}$

Q = Average Annual Discharge (CFS)

$\overline{Q} = f(\overline{P}) = C \times A \times Y = f(\overline{P}) = C \times A \times [-12.1721 + 0.91756\overline{P}]$
Where A = Area in mi^2 and C = conversion factor 0.07367 cfs-year/in-mi^2

$\overline{Q}_{EST}$ = Average Annual Discharge as predicted by Warnick-Filler (CFS)

Table 6. Water Yield at Sample Stations Using The McDonald Study

Gage No.	Site Name	Y_{MC} (in)	$\overline{Q}_{MC}$ (cfs)	$\overline{Q}_{1963}$ (cfs)	$\overline{Q}_{1930-57}$ (cfs)
12.3923.00	Pack River - Colburn	17.50	159.86	302	---
13.1170.00	Birch Creek - Reno	1.00	23.57	70	---
13.3165.00	Little Salmon - Riggins	13.00	551.64	876	---
13.3370.00	Lochsa River - Lowell	30.00	2607.92	---	2752.61

Y_{MC} = Runoff or Water Yield Calculated Using McDonald Method (in)

Table 7. Water Yield at Sample Stations Using The Rosa Study

Gage No.	Site Name	Y_R (in)	$\overline{Q}_R$ (cfs)	$\overline{Q}_{1963}$ (cfs)	$\overline{Q}_{1930-57}$ (cfs)
12.3923.00	Pack River - Colburn	28.74	262.54	302	---
13.1170.00	Birch Creek - Reno	3.64	85.81	70	---
13.3165.00	Little Salmon - Riggins	15.16	643.30	876	---
13.3370.00	Lochsa River - Lowell	30.18	2623.57	---	2752.61

Y_R = Runoff or Water Yield Calculated Using the Rosa Study (in)

Table 8. Average Annual Runoff Using the Kjelstrom Study

Gage No.	Site Name	P_a	P_{NAP}	Q_j	$\overline{Q}_{1963}$
		(in)	(in)	(cfs)	(cfs)
13.0757.00	South Fork Pocatello Cr.	14.50	---	0.83	0.219
13.1170.00	Birch Creek - Reno	---	28.90	187.63	70.00
13.2070.00	Spring Valley Creek	17.00	---	4.02	1.08

Q_j = Average annual runoff predicted using Kjelstrom method (cfs)

Note:

$\overline{Q}_{1963}$ representative of long-term average conditions

NEW CONCEPTS

During the progress of this research several valuable ideas came to mind on which time was spent but a complete analysis was not possible. The first was the recognition that in including the mean elevation of a watershed was very time consuming to obtain. Several ideas were proposed for obtaining the mean elevation quickly and a brief listing of the approaches was tried. Figure 4 shows several ideas for making these determinations. A more detailed analyses of the value of these techniques is needed but is beyond the scope of this project. In asessing the relative steepness term it was likewise recognized that using the square root of the area of the waterhsed was a very arbitrary way of getting a characteristic length of the watershed. Other ideas for making this determination were explored. Some of the various ideas put forth are presented in Figure 5.

As the ultimate uses of these estimates of average discharge were often used without actual measurements in streams it was recognized that a single actual stream measurement at a ungaged site might be a very good check on whether a projection from empirical equations is reasonable. This is especially true in locations where the water flowing in the channel at a gage may not represent the entire flow discharging out of a particular basin. Estimates of the duration curves for an ungage stream location based on flow records of two nearby gaged are shown in Figure 6. This prompted the idea that it would be good to know what single date in the year represents a date when a single measurement will be most consistent in representing a nearly constant relation to the average annual flow and a flow from which to project flow duration curve estimates. This idea needs further research.

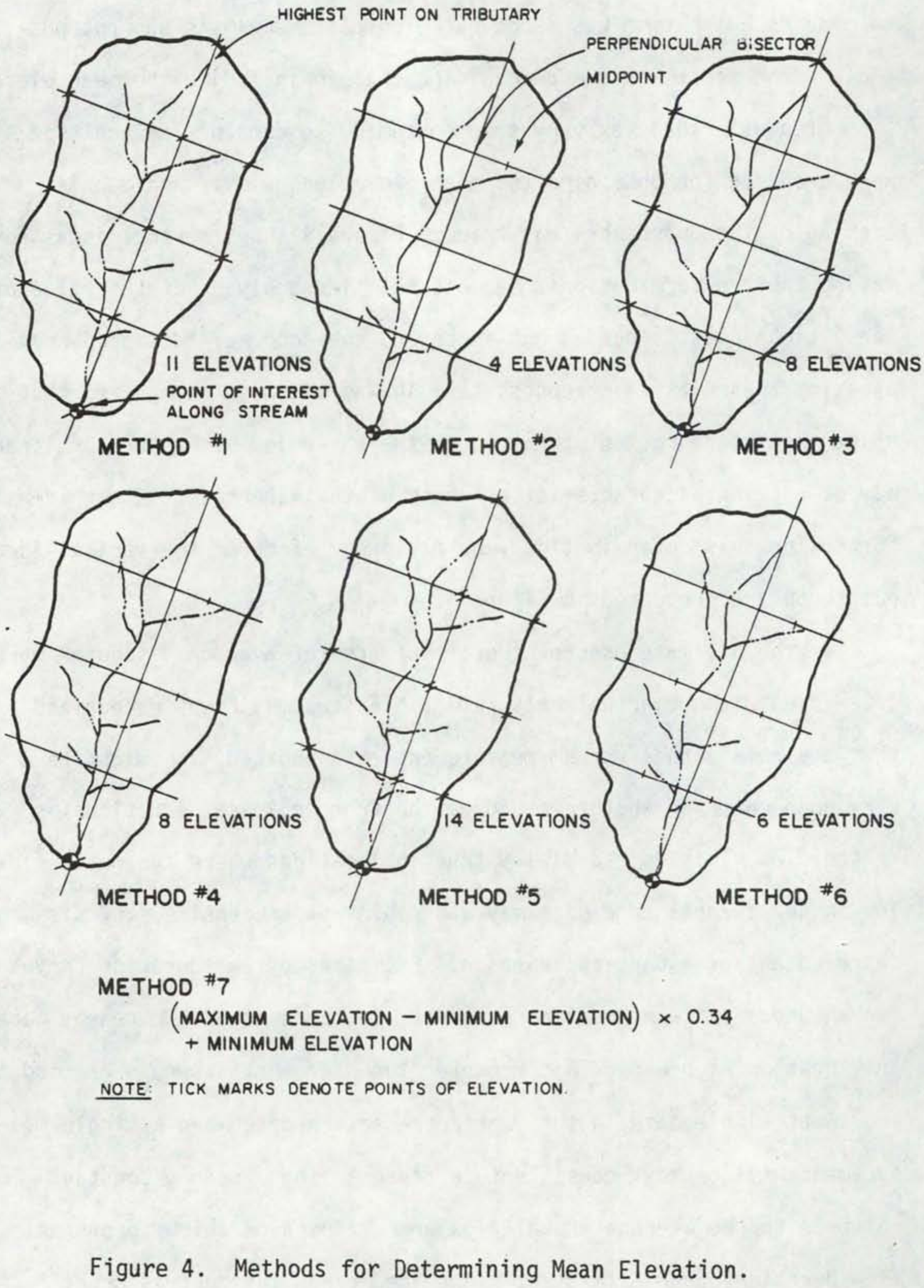

Figure 4. Methods for Determining Mean Elevation.

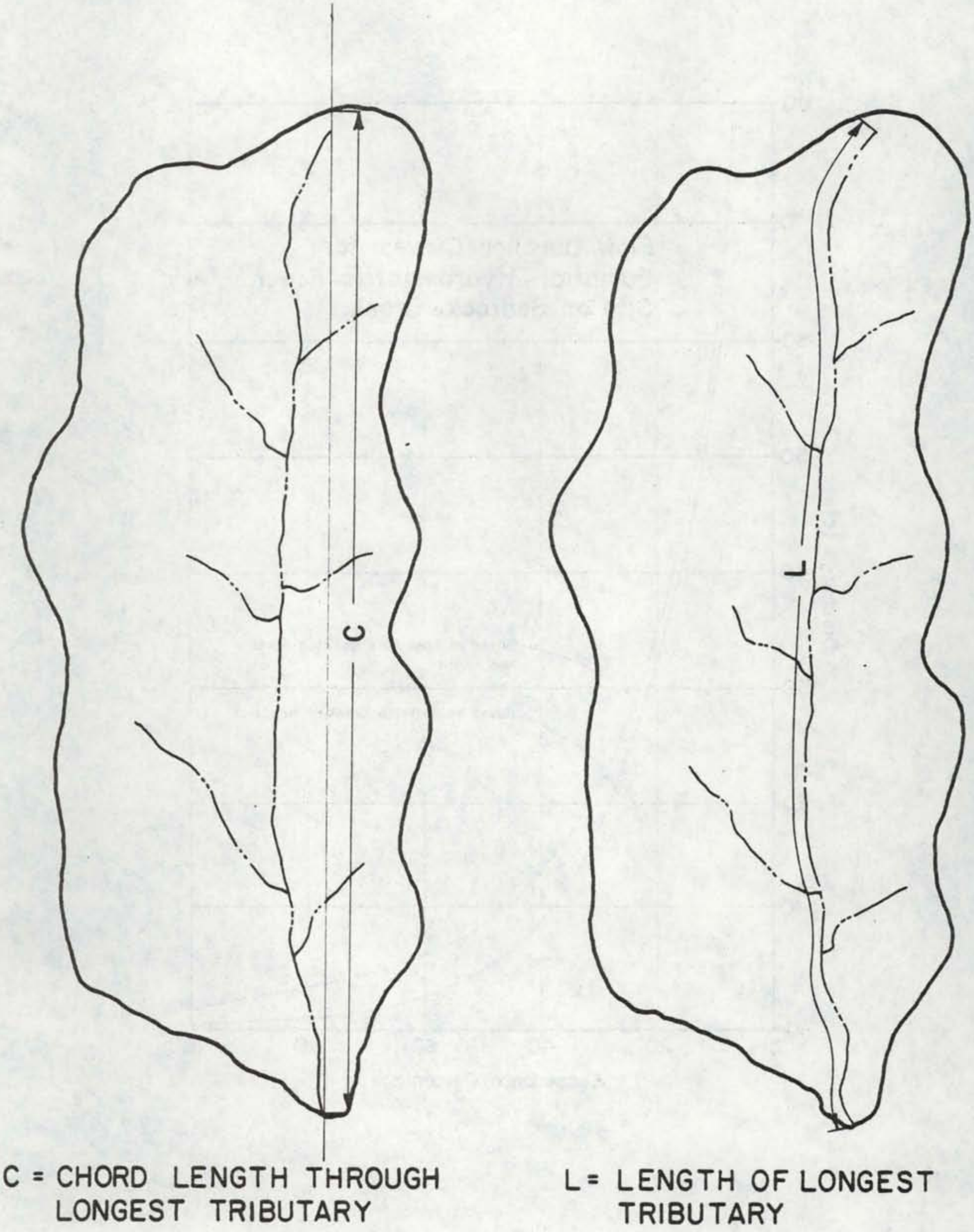

Figure 5. Methods for Determining
Characteristic Length of Watersheds.

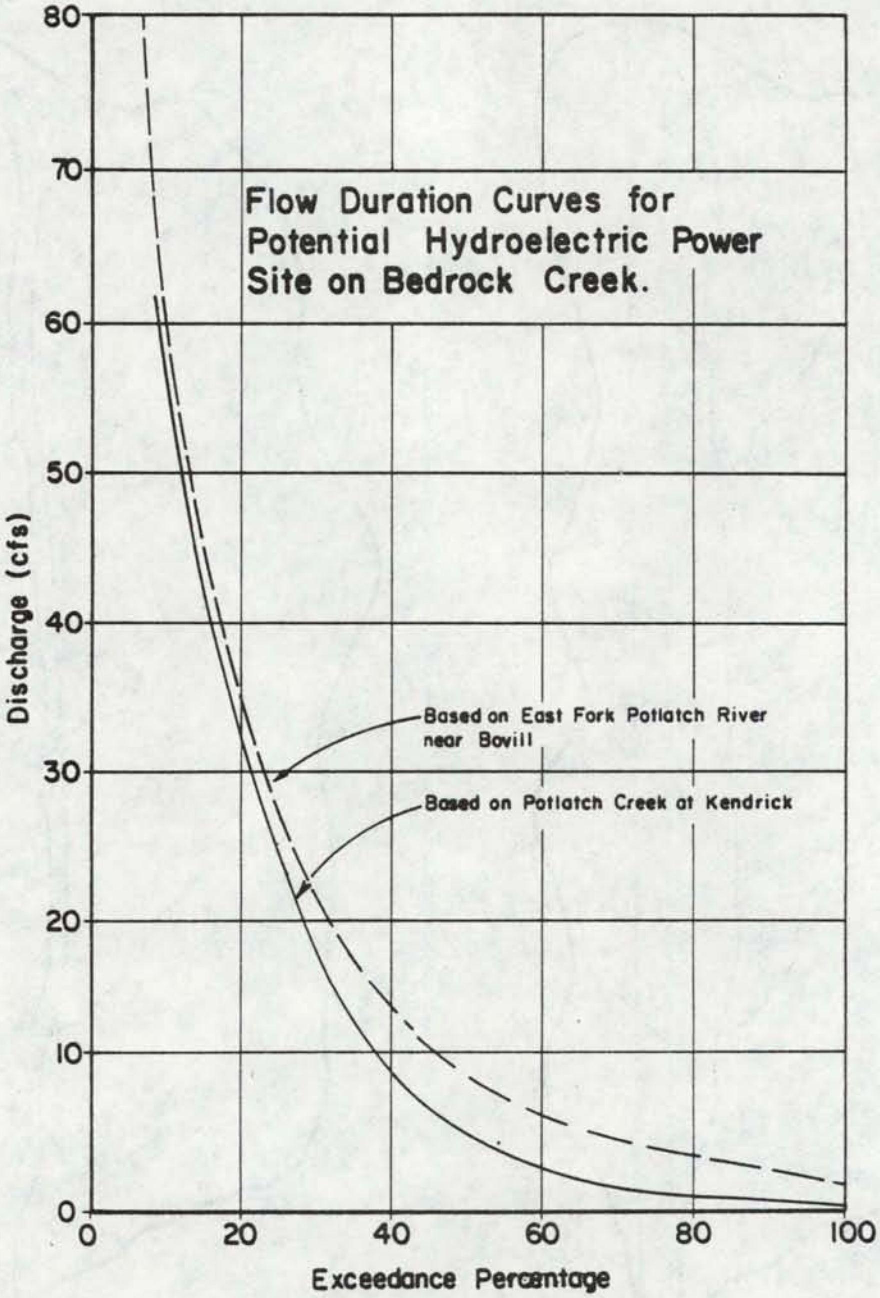

Figure 6. Flow Durations Based on Two Different Gaged Stream Records for Extrapolation.

CONSEQUENCES OF USING DIFFERENT AVERAGE ANNUAL DISCHARGE ESTIMATES IN PREDICTING FLOW DURATION CURVES FOR HYDROPOWER FEASIBILITY STUDIES

Because the original research of the project was centered on determining better methods on extrapolating flow duration curves for hydropower studies, it was considered important to project from this research the consequences of using the different methods of estimating average annual discharge and what the actual impact is on an estimate of the flow duration curve for a particular situation. In Figure 7, the dimensionless flow duration curve for the Pack River at Colburn was used to develop the flow duration curve of the Hell Roaring Creek using the several different methods for estimating average annual runoff from an ungaged basin.

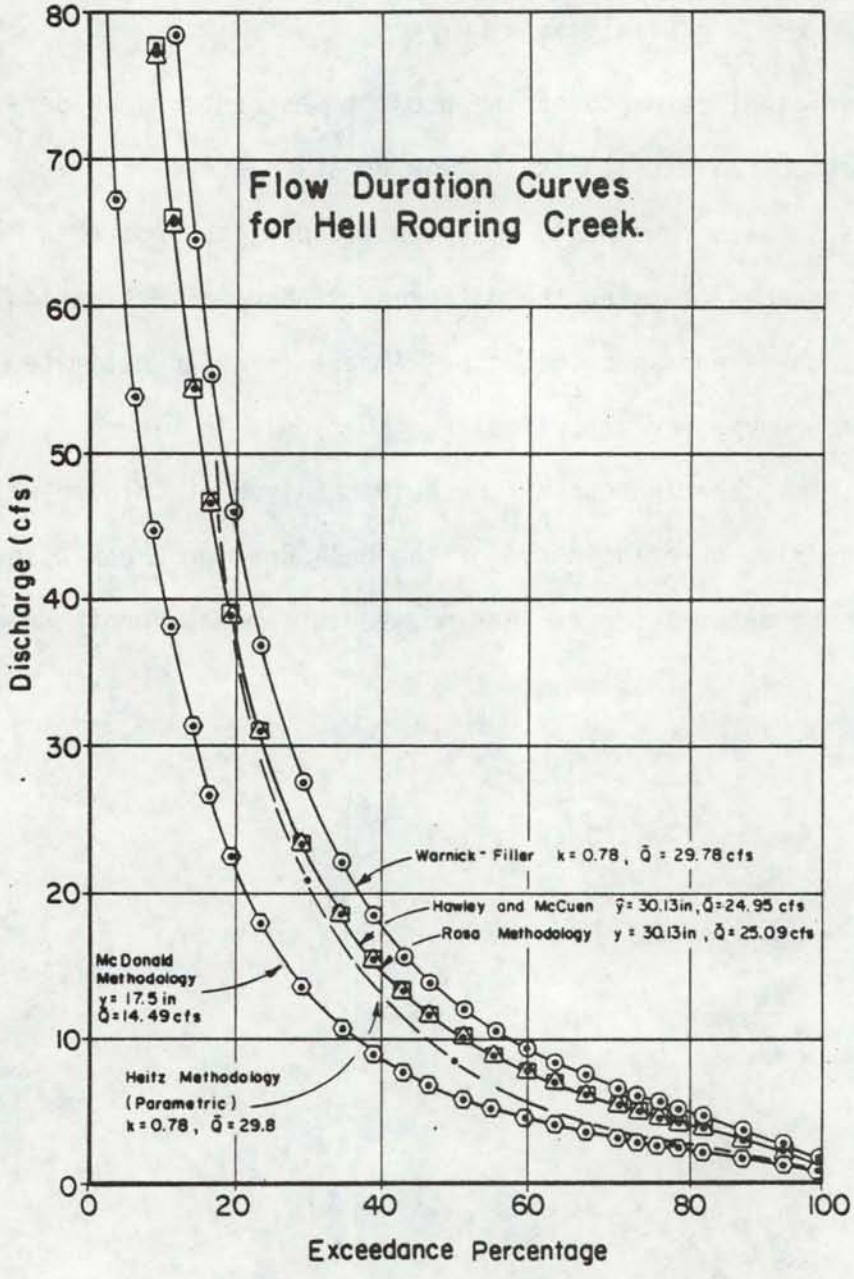

Figure 7. Flow Duration Curves Based on the Gaged Record of Pack River At Colburn Utilizing Different Methods of Predicting Mean Annual Discharge.

CONCLUSIONS AND RECOMMENDATIONS

This research has shown that the single parameter of normal annual precipitation offers the simplest factor to use in estimating average annual discharge from a watershed. Brief study of the work of Langbein, McDonald, Rosa, and Hawley and McCuen has provided methods of determining average annual discharge or annual water yield for Idaho watersheds. However, the earlier studies of Langbein and McDonald were so generalized that the accuracy on small waterhseds is not very good. Comparisons utilizing the studies of Rosa, Hawley and McCuen, and of Heitz show reasonable consistency.

These various water yield maps or equations presented by Langbein, McDonald, Rosa, and Hawley and McCuen do represent possible data and methods for making determinations of average annual discharge. The fact that these studies have been developed over a considerable period of time (1948 to 1982) and are based on hydrologic record periods that are of differing duration make it evident that a high degree of consistency cannot be expected. The brief check utilizing an equation suggested by Kjelstrom did not give very satisfactory predictions at the three sample gaged watersheds.

Study of Hawley-McCuen water yield regression equations has revealed that a method of obtaining a plant cover density term is not readily available throughout the state. Needed is a method/s that can be quickly done with consistent and reproducible results.

The comparative result of using different methods of estimating average annual runoff to make predictions of flow duration curves for an ungaged stream, Hell Roaring Creek, shows that the methods do give different results as shown in Figure 7. The results based on the subjective estimates made by the writers give the highest values. The use of the Heitz, Hawley-McCuen and Rosa approaches show rather close agreement. The use of McDonald's estimates of average annual runoff are apparently too conservative.

The study of predictions of a flow duration curve for a stream based on two nearby gages wherein different extrapolations were obtained as shown in Figure 6 makes it important that measurements of flow be made to attempt to verify the correct flow duration characteristics. A recommendation is made that more research be conducted to determine when measurements should be made that will provide the best data for projecting what the flow duration curve is at the site being investigated.

Because some improvement was observed in the R^2 values for regression equations using additional parameters than just precipitation, it is recommended that additional research be conducted with multiparameters such as relative relief and relative steepness in an attempt to get the best method for making estimates of average annual discharge at ungaged sites.

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APPENDIX

Basic Data for 43 Selected Watersheds as Extracted
from the Original Information of the Hawley-McCuen Study

43 Stations as Selected by J.R. Filler

SELECTED HAWLEY AND MCCUEN SITES

OBS	SITE	LOCATION	MEANELEV	MEANTEMP	P	SCILGRUP	COVERDEN	AREA	MINELEV	MINP	BAREGROD	VEGLITTR	LATITUDE	MAXELEV	MAXIMUMP	LONGITUD	ELEVTEMP	TEMPTEMP	PREC6025	Y	YPERSQMI
1	GROUSE	ARROWRK	4450	44.8	20.5	2.0	15	8.00	3400	18	40	25	43.35	5400	22	115.55	3239	49.0	0.7	4.65	0.5812
2	COTN G	BOISE	4200	46.2	16.0	2.0	20	16.00	2790	15	35	30	43.37	5500	20	116.11	2841	51.0	0.7	2.50	0.1563
3	S FORK	POCATELLO	5770	42.4	14.5	3.0	38	4.30	4835	14	29	59	42.53	6790	15	112.23	4444	47.0	1.0	0.65	0.1512
4	SALMON	OBSIDIAN	8110	31.2	30.5	1.5	40	94.70	6950	16	18	57	43.58	10175	45	114.48	6870	35.4	0.8	10.40	0.1098
5	ELK	IRWIN	7800	34.6	35.0	1.5	40	7.00	5800	20	18	57	43.24	9770	50	111.01	5397	43.0	1.1	15.20	2.1714
6	PEBBLE	MCCAM	7500	36.5	26.5	1.5	47	27.50	6000	18	14	75	42.50	9271	35	112.10	4774	46.0	1.0	14.00	0.5091
7	ROCK	HOLLISTER	6330	41.6	20.0	3.0	36	80.00	4347	10	34	57	42.21	7060	30	114.18	4550	47.8	0.8	5.70	0.0712
8	REYNOLDS	*****	4600	44.5	16.3	3.0	33	90.20	3600	12	51	49	43.15	7200	30	116.45	2841	50.7	0.7	2.90	0.0322
9	TOLLGATE	*****	5950	39.8	22.9	3.0	39	21.00	4600	18	42	58	43.10	7200	29	116.45	2841	50.7	0.7	10.00	0.4762
10	SALMON	*****	4600	44.5	16.1	3.0	30	13.70	3675	12	61	39	43.15	6200	22	116.45	2841	50.7	0.7	3.20	0.2336
11	MACKS	*****	4400	45.2	14.6	2.0	30	12.20	3728	11	55	45	43.15	6200	17	116.45	2841	50.7	0.7	2.60	0.2131
12	RABBIT	*****	5500	41.4	16.0	2.0	25	3.70	4480	13	65	35	43.10	6620	20	116.45	2841	50.7	0.7	2.00	0.5405
13	W MTN	*****	6625	37.5	27.2	2.0	50	0.20	6600	16	32	68	43.05	7000	34	116.50	2841	50.7	0.7	12.40	62.0000
14	TRAPER	OAKLEY	6360	42.5	18.0	2.0	36	53.70	4820	12	33	45	42.10	7795	24	113.59	4600	48.7	0.8	3.70	0.0689
15	COTN	OAKLEY	6500	42.0	26.0	2.5	23	38.00	4700	12	35	39	42.10	8765	40	114.10	4600	48.7	0.8	5.00	0.1316
16	GEORGE	YOST	8570	30.8	25.0	3.0	43	7.80	7000	20	31	61	41.55	9892	30	113.29	4550	44.9	1.0	11.60	1.4872
17	MONT-	PELIER	7500	37.3	25.0	2.0	51	50.90	6210	15	24	72	42.20	9200	35	111.14	5960	42.7	1.0	5.70	0.1120
18	COTNWD	ARROWRK	4900	43.2	21.5	2.0	50	21.40	3090	20	20	60	43.38	7300	25	115.49	3239	49.0	0.7	5.15	0.2407
19	ROBIE	ARROWRK	4960	43.0	25.0	2.0	30	15.80	3080	20	35	50	43.37	6453	30	115.59	3239	49.0	0.7	7.10	0.4494
20	PORTER	GARDEN	4500	41.5	25.0	1.5	46	21.20	3000	20	13	71	43.57	6700	30	116.11	3890	43.6	0.7	7.80	0.3679
21	CABIN	SMITHS	5090	40.0	30.0	3.0	67	0.42	4610	29	5	93	44.21	6000	31	115.47	4865	40.8	0.7	12.80	30.4762
22	L SALM	RIGGINS	5430	40.2	30.0	2.0	48	576.00	1760	15	6	88	45.25	9390	45	116.19	1801	52.9	0.8	20.00	0.0347
23	TYGHEE	HENRY	7500	32.8	25.0	2.0	52	7.30	6800	20	30	66	44.30	8710	30	111.24	6300	37.0	1.1	6.60	0.9041
24	MANN	WEISER	4860	41.7	21.0	1.5	50	56.00	2750	12	31	58	44.24	7640	30	116.54	2120	51.3	0.7	9.80	0.1750
25	JOHNS	PARK	7000	34.2	40.0	2.5	57	5.00	6000	38	6	88	44.45	7940	42	116.45	2935	48.4	0.7	27.80	5.5600
26	WEISER	INDIAN	5300	39.3	28.0	3.0	70	81.90	3250	16	5	90	44.30	7813	40	116.24	4865	40.8	0.7	17.00	0.2076
27	MUD	TAMARACK	4660	38.4	33.0	2.5	65	15.80	3990	26	10	80	45.00	6246	40	116.21	3871	41.2	0.8	16.50	1.0443
28	BOULD	TAMARACK	6500	32.0	36.0	2.5	67	5.90	5000	30	15	80	45.05	8048	42	116.27	3871	41.2	0.8	22.00	3.7288
29	WEISER	TAMARACK	4690	38.3	35.0	2.5	60	36.50	4080	30	16	80	44.57	6000	40	116.23	3871	41.2	0.8	16.20	0.4438
30	S FORK	KNOX	6630	33.9	42.5	2.0	70	92.00	5090	35	11	83	44.39	8696	50	115.42	5375	38.3	0.7	21.40	0.2326
31	E FORK	STIBNITE	7420	31.8	35.0	2.0	50	104.00	5049	30	22	72	44.58	8846	40	115.27	5686	37.9	0.7	17.60	0.1692
32	JOHNSON	YELLOW P	7170	32.7	40.0	2.0	50	213.00	4658	30	13	76	44.58	9169	60	115.30	5686	37.9	0.7	22.20	0.1042
33	E WEISER	COUNCIL	6900	34.1	45.0	3.0	70	2.00	6275	40	10	85	44.46	7180	50	116.16	2936	48.0	0.8	28.80	14.4000
34	MORES	IDA CITY	5000	40.4	25.0	2.0	50	119.00	3550	20	25	65	43.46	8141	50	115.55	3965	44.0	0.7	7.10	0.0597
35	FISH	LOCHSA	4470	39.6	50.0	2.0	50	89.20	1997	40	5	70	46.20	6580	55	115.21	1580	49.7	0.8	38.70	0.4339
36	POTLATCH	BOVILL	3550	42.8	40.0	2.0	70	3.15	2950	35	5	95	46.51	4000	45	116.17	2910	45.0	0.8	21.60	6.8571
37	POTLATCH	ELK R	3900	41.5	45.0	2.0	70	18.20	3000	40	5	90	46.52	5000	55	116.16	2910	45.0	0.8	25.00	1.3736
38	POTLATCH	BOVILL	3500	42.9	40.0	2.0	70	42.50	2800	30	5	90	46.50	5000	50	116.23	2910	45.0	0.8	20.30	0.4776
39	W WEISER	TAMARACK	4940	37.3	30.0	3.0	70	4.00	4200	25	10	85	45.01	6000	40	116.26	3871	41.0	0.8	17.90	4.4750
40	ELK	IDA CITY	6200	36.2	26.5	2.0	50	13.10	4570	20	20	65	43.54	8141	40	115.47	3965	44.0	0.7	13.60	1.0382
41	MORES	IDA CITY	6000	36.9	27.5	2.0	50	37.00	3990	25	20	70	43.50	8141	50	115.47	3965	44.0	0.7	12.30	0.3324
42	PACIFIC	MORAN	8160	29.6	40.0	1.5	48	160.00	6720	20	16	77	43.51	10400	60	110.31	6798	34.4	1.1	22.50	0.1406
43	LA BARGE	R STA	8970	27.7	40.0	2.0	35	6.30	8410	38	21	0	42.30	11418	42	110.40	6115	37.7	1.1	31.50	5.0000

Basic Data for the Original 211 Watersheds Utilized

in the Idaho-Montana-Wyoming Portion of the

Hawley-McCuen Study

Source: R.H. McCuen, Department of Civil Engineering
University of Maryland, College Park, MD

ORIGINAL HAWLEY AND MCCUEN DATA

OBS	SITE	LOC	MEANEL	MEANTMP	NAP	SOILGP	CODEN	AREA	MINELE.V	MINNAP	BARGD	VEGLIT	LAT	MAXEL	MAXNAP	LONG	TEMPEL	ELTEMP	PR6025	Y	YPRSQMI
1	CLOVER	BLISS	4700	45.1	15.0	2.5	13	140.00	3120	10	31	62	43.02	6806	20	115.00	3269	50.1	0.8	2.90	0.0207
2	BENNETT	MT HOME	5000	43.8	17.5	3.5	29	21.30	3000	10	33	57	43.13	7300	25	115.31	3180	50.2	0.8	4.00	0.1878
3	CRANE	MIDVALE	3700	44.5	20.5	3.0	25	242.00	3140	16	19	67	44.21	5190	25	116.37	2650	48.2	0.7	4.20	0.0174
4	KING	HILL	4500	45.6	17.0	2.5	22	83.60	3000	10	32	41	43.01	6000	25	115.14	3180	50.2	0.8	2.80	0.0335
5	MALHEUR	DREWSEY	4700	42.0	17.5	3.5	39	910.00	3479	10	19	50	43.47	9052	25	118.20	3277	47.0	0.8	2.60	0.0029
6	N FORK	BEULAH	5100	40.6	20.0	3.5	18	355.00	3351	10	20	40	43.57	7883	25	118.11	3277	47.0	0.8	4.70	0.0132
7	BURNT	HEREFORD	5700	40.8	18.0	3.0	35	309.00	3758	10	30	50	44.30	7883	25	118.11	2120	53.3	0.8	3.50	0.0113
8	FISH	CAREY	6000	39.2	14.0	2.0	35	56.00	5200	12	24	54	43.20	7200	16	113.50	4306	45.1	1.0	2.00	0.0357
9	W FISH	CAREY	6500	37.4	15.0	2.0	36	68.50	5200	12	29	60	43.21	8000	18	113.51	4306	45.1	0.9	2.90	0.0423
10	CAMAS	BLAINE	5600	38.7	18.5	2.5	35	648.00	4870	12	32	48	43.20	10095	25	114.32	5000	40.8	0.7	4.00	0.0062
11	GROUSE	ARROWRK	4450	44.8	20.5	2.0	15	8.00	3400	18	40	25	43.35	5400	22	115.55	3239	49.0	0.7	4.65	0.5812
12	COTN G	BOISE	4200	46.2	16.0	2.0	20	16.00	2790	15	35	30	43.37	5500	20	116.11	2841	51.0	0.7	2.50	0.1563
13	SILVIES	BURNS	5200	43.0	17.5	4.0	32	934.00	4195	15	33	0	43.43	6180	20	119.11	4140	46.7	0.8	2.30	0.0025
14	SILVER	RILEY	5180	43.1	17.5	4.0	30	228.00	4450	15	20	0	43.41	7190	20	119.39	4140	46.7	0.8	2.40	0.0105
15	BEAVER	PAULINA	4500	41.3	17.0	3.0	50	450.00	3690	15	30	0	44.10	6520	20	119.55	3979	43.1	1.0	2.70	0.0060
16	*S FORK	POCATELLO	5770	42.4	14.5	3.0	38	4.30	4835	14	29	59	43.53	6790	15	112.23	4444	47.0	1.0	0.65	0.1512
17	JACK	BRUNEAU	5020	42.9	10.0	1.5	15	100.00	2800	8	60	15	42.47	6160	12	115.59	2360	52.2	0.7	0.36	0.0036
18	E FORK	HOT SPRS	5500	43.4	15.0	3.0	30	620.00	3865	10	39	59	42.33	9050	20	115.30	5420	43.7	0.7	0.66	0.0011
19	*GOOSE	OAKLEY	6030	43.7	15.0	3.5	35	633.00	4770	10	37	59	47.07	8153	20	113.56	4600	48.7	0.8	1.00	0.0016
20	DRY	BOISE	4050	46.8	18.0	2.0	26	59.40	2693	16	20	74	43.44	6736	25	116.18	2841	51.0	0.6	1.70	0.0286
21	CASTLE	MURPHY	4700	44.0	15.0	3.0	23	160.00	2770	10	29	50	42.58	6670	20	116.21	2360	52.2	1.0	1.60	0.0100
22	WICKA	GRANDVIEW	5150	42.4	10.0	2.0	34	253.00	2810	8	46	43	42.47	5800	18	115.59	2360	52.2	0.7	0.04	0.0002
23	SPR VAL	EAGLE	3990	47.0	17.0	2.0	25	20.90	2722	16	20	75	43.46	5880	18	116.20	2841	51.0	0.6	1.70	0.0813
24	SALM F	JAC+NIO	6350	43.0	14.0	3.0	25	1450.00	5120	8	34	38	41.57	10185	40	114.41	5365	46.5	0.8	1.30	0.0009
25	BULLY	VALE	4200	43.4	15.0	2.6	20	539.00	2527	10	36	24	44.01	6780	20	117.27	2240	50.3	0.7	1.30	0.0024
26	WILLOW	MALHEUR	4400	45.5	14.0	2.7	30	100.00	3365	10	47	42	44.20	7820	18	117.40	3336	49.2	0.8	0.90	0.0090
27	COW	BROGAN	4500	41.2	12.5	3.0	19	10.00	4000	10	33	63	44.15	6200	15	117.30	3915	43.2	0.7	0.90	0.0900
28	SALMON	OBSIDIAN	8110	31.2	30.5	1.5	40	94.70	6950	16	18	57	43.58	10175	45	114.48	6870	35.4	0.8	10.40	0.1098
29	*T5XAS	LEADORE	7700	33.1	17.5	2.0	26	73.00	6280	10	31	36	44.35	9400	25	113.20	5066	42.3	0.8	4.00	0.0548
30	CHALLIS	CHALLIS	7830	34.8	24.0	2.0	37	85.00	5369	8	11	67	44.34	10340	40	114.18	5171	44.1	0.6	7.60	0.0894
31	HORSE	DRIGGS	7000	36.9	26.5	2.0	46	11.70	6200	18	14	75	43.44	7700	35	111.15	6097	40.1	1.0	13.70	1.1709
32	PACKS	TETONIA	7500	35.2	24.0	2.0	50	5.70	6600	18	8	85	43.45	8400	30	111.18	6097	40.1	1.0	11.30	1.9825
33	ELK	IRWIN	7800	34.6	35.0	1.5	40	7.00	5800	20	18	57	43.24	9770	50	111.01	5397	43.0	1.1	15.20	2.1714
34	PEBBLE	MCCAM	7500	36.5	26.5	1.5	47	27.50	6000	18	14	75	42.50	9271	35	112.10	4774	46.0	1.0	14.00	0.5091
35	BIRCH	DOWNEY	7240	37.4	30.0	2.0	42	6.56	5850	25	11	67	42.21	9095	35	112.15	4774	46.0	1.0	19.30	2.9421
36	WILLOW	RIRIE	6390	37.3	18.5	2.5	40	627.00	4940	12	23	61	43.35	7475	25	111.46	6200	38.0	1.0	3.80	0.0061
37	COTN	CLEVELAND	6500	40.1	22.5	2.0	40	61.70	5150	10	23	69	42.20	7600	35	111.46	4718	46.3	1.2	6.40	0.1037
38	HOUSE	ROSEWORTH	6700	41.3	20.0	3.0	41	40.00	5600	10	32	62	42.10	7765	30	114.59	4600	48.7	0.8	5.50	0.1375
39	ROCK	HOLLISTER	6330	41.6	20.0	3.0	36	80.00	4347	10	34	57	42.21	7060	30	114.18	4550	47.8	0.8	5.70	0.0712
40	SALM F	CONTACT	6760	41.6	16.5	3.0	30	461.00	5570	8	30	65	41.44	10185	40	114.53	5365	46.5	0.8	2.70	0.0059
41	CASSIA	ELBA	6560	39.2	20.0	3.5	39	84.00	4910	10	19	54	42.15	10550	55	113.39	4146	47.6	0.7	2.80	0.0333
42	JORDAN	VALLEY	5780	41.0	18.5	3.0	17	440.00	4500	12	38	43	42.52	8065	25	116.57	4600	45.1	0.6	5.90	0.0134
43	REYNOLDS	*****	4600	44.5	16.3	3.0	33	90.20	3600	12	51	49	43.15	7200	30	116.45	2841	50.7	0.7	2.90	0.0322
44	TOLLGATE	*****	5950	39.8	22.9	3.0	39	21.00	4600	18	42	58	43.10	7200	29	116.45	2841	50.7	0.7	10.00	0.4762
45	SALMON	*****	4600	44.5	16.1	3.0	30	13.70	3675	12	61	39	43.15	6200	22	116.45	2841	50.7	0.7	3.20	0.2336
46	MACKS	*****	4400	45.2	14.6	2.0	30	12.20	3728	11	55	45	43.15	6200	17	116.45	2841	50.7	0.7	2.60	0.2131
47	RABBIT	*****	5500	41.4	16.0	2.0	25	3.70	4480	13	65	35	43.10	6620	20	116.45	2841	50.7	0.7	2.00	0.5405
48	W MTN	*****	6625	37.5	27.2	2.0	50	0.20	6600	16	32	68	43.05	7000	34	116.50	2841	50.7	0.7	12.40	62.0000
49	TRAPER	OAKLEY	6360	42.5	18.0	2.0	36	53.70	4820	12	33	45	42.10	7795	24	113.59	4600	48.7	0.8	3.70	0.0689
50	CEDAR	ROSEWORTH	6400	42.4	17.0	2.0	11	130.00	5050	14	45	21	42.11	7765	20	114.55	4600	48.7	0.8	2.50	0.0192

ORIGINAL HAWLEY AND MCCUEN DATA

OBS	SITE	LOC	MEANEL	MEANTMP	NAP	SOILGP	COVDEN	AREA	MINELEV	MINNAP	BAREGD	VEGLIT	LAT	MAXEL	MAXNAP	LONG	TEMPEL	ELTEMP	P6025	Y	YPRSQMI
51	COTN	OAKLEY	6500	42.0	26.0	2.5	23	38.00	4700	12	35	39	42.10	8765	40	114.10	4600	48.7	0.8	5.00	0.1316
52	BLUE	RIDDLE	5500	45.3	15.0	2.5	33	77.00	5000	12	51	43	42.10	6200	18	116.10	5126	46.6	0.7	2.70	0.0351
53	JACKS	TUSCARE	7500	38.5	25.0	2.0	35	19.80	6361	20	32	44	41.30	10179	30	116.04	5396	45.9	0.6	14.70	0.7424
54	S FORK	OWYHEE	6400	42.1	15.0	3.0	28	330.00	5550	12	26	53	41.25	10179	30	116.11	5126	46.6	0.7	2.60	0.0079
55	JARBIDGE	THREE CR	7600	39.6	26.0	3.0	20	84.60	5150	20	21	35	42.02	10839	30	115.22	6150	44.7	0.7	9.00	0.1064
56	E OWYHEE	GOLD CR	7000	40.4	15.0	2.0	33	209.00	6130	10	26	53	41.41	8850	26	115.51	5400	46.0	0.6	2.70	0.0129
57	E OWYHEE	MIN CITY	7000	40.4	18.0	2.0	44	458.00	5425	10	33	53	41.55	8850	26	116.04	5400	46.0	0.6	4.10	0.0090
58	LAMOILLE	ELKO	9300	30.6	37.5	3.8	43	25.00	6240	20	27	0	40.40	11400	50	115.30	5075	45.4	0.7	23.30	0.9320
59	HUMBOLT	N FORK	7500	37.0	26.0	3.5	31	11.00	6700	12	21	0	41.34	8851	40	115.55	5585	43.7	0.7	13.80	1.2545
60	S FORK	LEE	8600	33.1	33.5	3.5	32	54.00	5500	15	22	0	40.35	10973	50	115.40	5075	45.4	0.7	16.90	0.3130
61	**SALM F	CONTACT	6760	41.6	16.5	3.0	30	461.00	5570	8	30	0	41.44	10185	40	114.53	5365	46.5	0.8	2.70	0.0059
62	OVERLAND	RUBY V	8600	37.6	34.6	4.0	55	9.00	6000	17	23	0	40.27	11076	50	115.23	6012	46.7	0.7	16.90	1.8778
63	FRANKLIN	ARTHUR	7500	38.2	25.0	4.0	40	10.30	6570	17	25	0	40.49	11100	50	115.08	5628	44.8	0.7	15.40	1.4951
64	GEORGE	YOST	8570	30.8	25.0	3.0	43	7.80	7000	20	31	61	41.55	9892	30	113.29	4550	44.9	1.0	11.60	1.4872
65	CLEAR	NAF	7870	33.3	20.0	2.5	33	20.20	5840	15	23	72	41.58	9160	25	113.17	4550	44.9	1.0	6.70	0.3317
66	DRY CR	BONNNEVILE	6000	43.2	14.0	2.0	17	52.60	5010	8	53	0	43.17	8272	20	107.55	5440	45.2	1.2	0.96	0.0183
67	FIFTEEN M	WORLAND	4940	41.5	7.2	2.5	15	518.00	4080	6	50	0	44.01	6725	12	108.01	4061	44.6	1.2	0.27	0.0005
68	S F OWL	THRMOPOLS	8000	33.4	18.0	2.5	50	133.00	6120	16	20	0	43.39	12496	20	108.47	4313	46.3	1.2	2.10	0.0158
69	BADWATER	LYSITE	7000	41.8	12.5	2.0	15	415.00	5240	5	50	0	43.16	9067	20	107.42	6060	45.1	1.2	0.78	0.0019
70	BRIDGER	LYSITE	7000	41.8	12.0	2.5	35	182.00	5200	8	35	0	43.17	8046	16	107.43	6060	45.1	1.2	1.32	0.0073
71	MONT-	PELIER	7500	37.3	25.0	2.0	51	50.90	6210	15	24	72	42.20	9200	35	111.14	5960	42.7	1.0	5.70	0.1120
72	MEDIC	ARGORA	7520	35.8	20.0	2.0	46	165.00	5710	10	31	59	44.17	11460	30	112.30	5462	43.0	1.0	3.40	0.0206
73	COTNWD	ARROWRK	4900	43.2	21.5	2.0	50	21.40	3090	20	20	60	43.38	7300	25	115.49	3239	49.0	0.7	5.15	0.2407
74	ROBIE	ARROWRK	4960	43.0	25.0	2.0	30	15.80	3080	20	35	50	43.37	6453	30	115.59	3239	49.0	0.7	7.10	0.4494
75	PORTER	GARDEN	4500	41.5	25.0	1.5	46	21.20	3000	20	13	71	43.57	6700	30	116.11	3890	43.6	0.7	7.80	0.3679
76	CABIN	SMITHS	5090	40.0	30.0	3.0	67	0.42	4610	29	5	93	44.21	6000	31	115.47	4865	40.8	0.7	12.80	30.4762
77	L SALM	RIGGINS	5430	40.2	30.0	2.0	48	576.00	1760	15	6	88	45.25	9390	45	116.19	1801	52.9	0.8	20.00	0.0347
78	TYGHEE	HENRY	7500	32.8	25.0	2.0	52	7.30	6800	20	30	66	44.30	8710	30	111.24	6300	37.0	1.1	6.60	0.9041
79	SQUAW	OLA	6500	35.5	30.0	2.0	50	21.00	4220	20	18	70	44.10	8340	40	116.20	2962	47.9	0.7	11.60	0.5524
80	MANN	WEISER	4860	41.7	21.0	1.5	50	56.00	2750	12	31	58	44.24	7640	30	116.54	2120	51.3	0.7	9.80	0.1750
81	JOHNS	PARK	7000	34.2	40.0	2.5	57	5.00	6000	38	6	88	44.45	7940	42	116.45	2935	48.4	0.7	27.80	5.5600
82	PINE	CAMBR	4730	40.9	25.0	2.5	60	54.00	2800	20	6	90	44.35	7800	30	116.44	2650	48.2	0.7	9.80	0.1815
83	WEISER	INDIAN	5300	39.3	28.0	3.0	70	81.90	3250	16	5	90	44.30	7813	40	116.24	4865	40.8	0.7	17.00	0.2076
84	MUD	TAMARACK	4660	38.4	33.0	2.5	65	15.80	3990	26	10	80	45.00	6246	40	116.21	3871	41.2	0.8	16.50	1.0443
85	BOULD	TAMARACK	6500	32.0	36.0	2.5	67	5.90	5000	30	15	80	45.05	8048	42	116.27	3871	41.2	0.8	22.00	3.7288
86	LOST	TAMARACK	5460	35.6	35.0	2.5	75	29.40	4730	30	3	95	44.57	7580	40	116.28	3871	41.2	0.8	18.00	0.6122
87	WEISER	TAMARACK	4690	38.3	35.0	2.5	60	36.50	4080	30	16	80	44.57	6000	40	116.23	3871	41.2	0.8	16.20	0.4438
88	PAYETTE	MCCALL	6520	34.7	43.0	2.0	65	144.00	4970	30	7	84	44.54	8755	56	116.07	5025	39.9	0.8	34.00	0.2361
89	LAKE	FORK	6950	33.2	46.0	2.0	60	48.90	5140	36	9	75	44.55	8744	56	115.59	5025	39.9	0.8	40.00	0.8180
90	S FORK	KNOX	6630	33.9	42.5	2.0	70	92.00	5090	35	11	83	44.39	8696	50	115.42	5375	38.3	0.7	21.40	0.2326
91	E FORK	STIBNITE	7780	30.6	35.0	2.0	50	19.50	6000	30	22	72	44.54	8846	40	115.19	5686	37.9	0.7	16.30	0.8359
92	E FORK	STIBNITE	7640	31.1	35.0	2.0	50	42.50	5912	30	22	72	44.56	8846	40	115.20	5686	37.9	0.7	16.10	0.3788
93	E FORK	STIBNITE	7420	31.8	35.0	2.0	50	104.00	5049	30	22	72	44.58	8846	40	115.27	5686	37.9	0.7	17.60	0.1692
94	JOHNSON	LANDMK	7300	31.6	45.0	2.0	50	54.70	6585	30	13	76	44.41	8433	60	115.33	5375	38.3	0.7	22.50	0.4113
95	JOHNSON	YELLOW P	7170	32.7	40.0	2.0	50	213.00	4658	30	13	76	44.58	9169	60	115.30	5686	37.9	0.7	22.20	0.1042
96	E WEISER	COUNCIL	6900	34.1	45.0	3.0	70	2.00	6275	40	10	85	44.46	7180	50	116.16	2936	48.0	0.8	28.80	14.4000
97	MORES	IDA CITY	5000	40.4	25.0	2.0	50	119.00	3550	20	25	65	43.46	8141	50	115.55	3965	44.0	0.7	7.10	0.0597
98	FISH	LOCHSA	4470	39.6	50.0	2.0	50	89.20	1997	40	5	70	46.20	6580	55	115.21	1580	49.7	0.8	38.70	0.4339
99	POTLATCH	BOVILL	3550	42.8	40.0	2.0	70	3.15	2950	35	5	95	46.51	4000	45	116.17	2910	45.0	0.8	21.60	6.8571
100	POTLATCH	ELK R	3900	41.5	45.0	2.0	70	18.20	3000	40	5	90	46.52	5000	55	116.16	2910	45.0	0.8	25.00	1.3736

ORIGINAL HAWLEY AND MCCUEN DATA

OBS	SITE	LOC	MEANEL	MEANTMP	NAP	SOILGP	CODVEN	AREA	MINELEV	MINNAP	BARGDT	VEGLIT	LAT	MAXEL	MAXNAP	LONG	TEMPEL	ELTEMP	PR6025	Y	YPRSQMI
101	POTLATCH	BOVILL	3500	42.9	40.0	2.0	70	42.5	2800	30	5	90	46.50	5000	50.0	116.23	2910	45.0	0.8	20.30	0.4776
102	W WEISER	TAMARACK	4940	37.3	30.0	3.0	70	4.0	4200	25	10	85	45.01	6000	40.0	116.26	3871	41.0	0.8	17.90	4.4750
103	ELK	IDA CITY	6200	36.2	26.5	2.0	50	13.1	4570	20	20	65	43.54	8141	40.0	115.47	3965	44.0	0.7	13.60	1.0382
104	MORES	IDA CITY	6000	36.9	27.5	2.0	50	37.0	3990	25	20	70	43.50	8141	50.0	115.47	3965	44.0	0.7	12.30	0.3324
105	N MUSSEL	DELPINE	6120	37.8	17.0	3.0	22	31.4	5380	16	31	0	46.38	8589	30.0	110.30	4820	42.4	1.2	5.30	0.1688
106	SWEETGRASS	MELVILLE	7630	31.8	30.0	3.3	50	63.8	5490	15	22	0	46.09	10737	60.0	110.05	5050	40.8	1.2	18.40	0.2884
107	WILLOW	HARRISON	7000	35.0	20.0	2.5	54	83.8	4750	12	12	0	45.43	9245	50.0	111.44	4598	43.4	1.1	6.10	0.0728
108	BRIDGER	BOZEMAN	6540	37.3	20.0	2.5	52	62.5	4960	18	13	0	45.22	9106	50.0	110.57	4856	43.2	1.1	7.80	0.1248
109	HYALITE	BOZEMAN	8500	29.7	30.0	2.5	64	48.2	5539	20	14	0	45.33	10196	50.0	111.04	5980	38.5	1.1	18.30	0.3797
110	CROW CR	RADERSBRG	7000	32.1	20.0	2.5	54	76.6	4870	14	12	0	46.14	9414	30.0	111.41	3833	43.2	1.1	8.60	0.1123
111	GRANITE	LIBBY	5260	33.7	50.0	2.5	50	23.6	2780	30	2	0	48.18	8500	100.0	115.35	2080	44.8	0.8	40.00	1.6949
112	FLOWER	LIBBY	5000	35.8	40.0	2.5	42	14.9	2870	32	2	0	48.20	7500	48.0	115.36	3600	40.7	0.8	25.00	1.6779
113	SULLIVAN	HUNGRY HS	5510	34.4	60.0	3.0	75	71.3	3630	30	2	0	48.01	7478	80.0	113.42	3160	42.6	1.0	42.00	0.5891
114	M ROCK	PHILLIPS	7180	34.0	30.0	2.0	45	123.0	5386	16	5	0	46.12	9624	50.0	113.30	5280	40.7	1.1	13.40	0.1089
115	E WALLOWA	JOSEPH	7890	28.9	47.0	3.0	75	10.3	5000	30	15	0	45.16	9702	65.0	117.13	3760	43.4	1.0	28.60	2.7767
116	HURRICANE	JOSEPH	7460	30.5	43.0	3.0	75	29.6	5000	30	10	0	45.20	9839	65.0	117.17	3760	43.4	1.0	34.10	1.1520
117	LOSTINE	LOSTINE	6820	31.6	50.0	3.0	80	70.9	4500	30	5	0	45.26	10033	80.0	117.26	2935	45.2	1.0	37.40	0.5275
118	BEAR	WALLAWA	5810	35.1	38.0	3.0	70	67.0	4000	20	15	0	45.32	8000	60.0	117.33	2935	45.2	1.0	22.90	0.3418
119	WALLOWA	JOSEPH	7000	32.1	50.0	3.0	75	50.9	4327	20	15	0	45.20	10033	80.0	117.14	3760	43.4	1.0	35.50	0.6974
120	CAMAS	UKIAH	4500	39.1	25.0	3.0	50	121.0	3588	20	30	0	45.09	5980	30.0	118.49	3340	43.2	1.0	10.90	0.0901
121	SNIPE	UKIAH	4000	40.9	22.0	3.0	50	37.0	3430	20	30	0	45.11	4840	25.0	118.56	3340	43.2	1.0	5.30	0.1432
122	UMATILLO	GIBBON	3890	42.1	35.0	3.5	50	131.0	1855	20	25	0	45.43	5830	45.0	118.19	1440	50.7	1.0	23.20	0.1771
123	STRAWBY	PRAIRE	6900	32.6	37.0	3.0	50	7.0	4910	35	50	0	44.20	9038	40.0	118.39	4333	41.6	1.0	24.80	3.5429
124	CAMAS	LEHMAN	4680	38.5	24.0	3.0	60	60.7	4000	20	25	0	45.10	6900	30.0	118.40	3340	43.2	1.0	9.70	0.1598
125	MCKAY	PENDLETON	3210	44.5	19.0	3.0	50	180.0	1200	15	50	0	45.33	5310	25.0	118.46	1440	50.7	1.0	7.40	0.0411
126	NESPELEM	OWHI	3100	42.9	20.0	2.0	50	122.0	1790	15	30	0	48.10	6774	30.0	118.59	1872	47.2	1.1	5.00	0.0410
127	CALISPELL	DALKENA	3650	39.6	32.0	2.0	90	68.3	2040	30	5	0	48.15	5740	40.0	117.20	2135	44.9	1.0	13.88	0.2032
128	MILL CR	COLVTLLE	3510	40.7	28.0	2.0	80	83.0	1878	15	10	0	48.35	5776	45.0	117.52	1862	46.5	1.1	8.00	0.0964
129	L SPOKANE	ELK	2800	46.2	28.0	2.0	70	115.0	2000	25	10	0	48.01	5256	35.0	117.16	2357	47.8	1.0	6.80	0.0591
130	E TOUCHET	WALLA	3750	44.4	34.0	2.5	65	102.0	2000	20	25	0	46.02	6250	50.0	118.44	949	54.2	1.0	16.50	0.1618
131	PACIFIC	MORAN	8160	29.6	40.0	1.5	48	160.0	6720	20	16	77	43.51	10400	60.0	110.31	6798	34.4	1.1	22.50	0.1406
132	CACHE	JACKSON	7900	32.2	35.0	2.5	56	40.0	6750	15	15	70	43.27	9000	55.0	110.42	6244	38.0	1.1	19.50	0.4875
133	STRAW	BEDFORD	8000	33.4	50.0	2.0	51	21.3	6500	20	26	63	42.57	10327	70.0	110.53	6325	39.3	1.0	39.80	1.8685
134	COTTON	SMOOT	8500	31.7	40.0	3.0	43	26.3	6800	20	14	61	42.37	10759	60.0	110.53	6325	39.3	1.0	21.60	0.8213
135	SWIFT	AFTON	8000	31.1	50.0	3.0	57	27.4	6420	30	11	80	42.43	10763	70.0	110.54	6115	37.7	1.0	43.00	1.5693
136	CROW	FAIRVW	7420	33.2	25.0	3.0	50	115.0	6230	20	9	81	42.40	9577	30.0	111.06	6115	37.7	1.0	7.20	0.0626
137	HORSE	DANIELS	8880	29.3	36.0	2.0	26	43.0	7700	32	35	0	42.57	10365	40.0	110.23	7665	33.6	1.1	19.80	0.4605
138	NEW FK	CORA	9200	23.7	36.0	2.0	23	36.2	7670	32	31	0	43.05	12222	40.0	110.01	6504	33.1	1.1	19.30	0.5331
139	FALL	NEWDALE	9320	28.1	28.0	2.0	32	37.2	7240	24	35	0	42.51	11850	32.0	109.43	7190	35.6	1.1	14.60	0.3925
140	SILVER	B SANDY	9580	26.1	28.0	2.0	21	45.4	7500	24	44	0	42.45	11490	32.0	109.31	6120	38.2	1.1	13.20	0.2907
141	LA BARGE	R STA	8970	27.7	40.0	2.0	35	6.3	8410	38	21	0	42.30	11418	42.0	110.40	6115	37.7	1.1	31.50	5.0000
142	LT SANDY	ELKHORN	9820	29.7	28.0	2.0	34	20.9	8000	20	35	0	42.32	13200	32.0	109.12	6934	39.8	1.1	13.70	0.6555
143	BOULDER	BOULDER	9700	26.5	35.0	2.0	32	130.0	7100	30	35	0	42.50	12900	40.0	109.43	7665	33.6	1.1	19.80	0.1523
144	POLE	PINEDALE	9600	26.8	33.0	2.0	26	87.5	7400	30	35	0	42.53	13007	40.0	109.43	7665	33.6	1.1	16.60	0.1897
145	SMITHS	BORDER	8200	30.9	30.0	2.0	38	165.0	6800	16	25	0	42.17	10000	50.0	110.52	6120	38.2	1.0	15.20	0.0921
146	DINWOODY	DUBOIS	11000	22.0	36.0	1.0	1	88.2	6500	32	1	0	43.21	13785	41.5	109.24	7665	33.6	1.1	21.90	0.2433
147	CROW CR	TIPPERARY	10000	29.7	22.0	1.5	70	30.0	8600	12	10	0	43.34	12236	32.0	109.16	6917	40.4	1.1	10.60	0.3533
148	POPO AGIE	ATLANTIC	10500	24.1	36.0	2.0	85	6.0	9780	32	5	0	42.35	11892	41.5	108.55	7190	35.6	1.1	20.20	3.3667
149	POPO AGIE	LANDER	8020	34.9	24.0	2.0	60	125.0	5436	16	15	0	42.43	11892	32.0	108.38	5563	44.4	1.1	8.60	0.0688
150	TENSLEEP	TENSLEEP	8190	30.1	22.0	2.5	44	247.0	4667	16	19	0	44.00	12281	28.0	107.18	4061	44.6	1.2	8.00	0.0324

ORIGINAL HAWLEY AND MCCUEN DATA

OBS	SITE	LOC	MEANEL	MEANTMP	NAP	SOILGP	CODEN	AREA	MINELEV	MINAGP	BAREGD	VEGLIT	LAT	MAXEL	MAXNAP	LONG	TEMPEL	ELTEMP	PR6025	Y	YPRSQMI
151	MEDICINE	*****	8070	31.7	20.00	2.0	18	87.000	4780	12	50	0	44.18	11578	28	107.32	3860	46.4	1.2	5.30	0.0609
152	SHELL	SHELL	10030	24.5	34.00	2.0	24	23.100	9050	28	29	0	44.30	11578	40	107.24	3860	46.4	1.3	20.80	0.9004
153	SHELL	SHELL	8810	29.1	24.00	2.5	23	145.000	4370	20	44	0	44.34	11578	28	107.43	3860	46.4	1.3	9.70	0.0669
154	S TOUNGE	DAYTON	8920	41.2	24.00	2.0	34	85.000	7622	20	34	0	44.47	10827	28	107.28	7863	44.9	1.4	12.30	0.1447
155	L TOUNGE	DAYTON	8000	31.0	20.00	2.0	22	25.100	4420	24	47	0	44.48	9492	16	107.17	3942	45.2	1.4	6.50	0.2590
156	WOLF CR	WOLF	7700	31.1	22.00	2.0	20	37.800	4525	20	49	0	44.46	10000	24	107.14	3800	44.8	1.4	10.40	0.2751
157	EF GOOSE	BIG HORN	9560	29.7	34.00	2.5	70	20.300	8270	28	15	0	44.33	11809	40	107.13	5240	44.8	1.4	21.40	1.0542
158	CROSS CR	BIG HORN	10000	28.1	34.00	2.5	70	9.300	8790	28	15	0	44.31	11809	40	107.12	5240	44.8	1.4	19.10	2.0538
159	WF GOOSE	BIG HORN	9500	25.7	34.00	2.5	70	24.400	8420	28	15	0	44.37	10250	40	107.18	3942	45.2	1.4	19.00	0.7787
160	MF POWDER	BARNUM	8500	31.6	24.00	2.0	19	46.000	7300	20	59	0	43.35	8880	28	107.08	4313	46.3	1.4	10.10	0.2196
161	MF POWDER	HAZELTON	9000	31.6	24.00	2.0	21	24.500	8180	20	56	0	44.02	10555	28	107.05	5240	44.8	1.4	8.00	0.3265
162	ROCK CR	BUFFALO	9000	31.6	21.50	2.5	21	60.000	5260	15	43	0	44.27	10968	28	106.52	5240	44.8	1.4	8.10	0.1350
163	PINEY	WILLOW	10000	28.1	28.00	2.5	22	33.600	8540	28	43	0	44.28	13175	30	107.02	5240	44.8	1.4	17.10	0.5089
164	PINEY	STORY	9000	31.6	26.00	2.5	70	69.400	5700	24	15	0	44.33	13175	30	106.56	5240	44.8	1.4	14.50	0.2089
165	NF PINEY	STORY	7920	35.4	24.00	2.5	70	36.800	5290	20	15	0	44.35	10800	28	106.56	5240	44.8	1.4	13.20	0.3587
166	ROCK CR	ATLANTIC C	9000	35.0	24.00	2.0	31	9.200	8330	16	27	0	42.33	10260	32	108.46	7270	41.1	1.1	13.20	1.4348
167	ROCK CR	ATLANTIC C	8500	34.1	24.00	2.0	31	21.300	7850	16	39	0	42.31	10260	32	108.45	5563	44.4	1.1	7.30	0.3427
168	SKALKAHO	HAMILTON	6800	34.3	30.00	2.0	70	87.800	4490	16	5	0	46.09	8532	50	113.57	3529	45.8	1.0	14.30	0.1629
169	GERMAN	PAMSAY	6930	38.1	18.00	2.0	43	40.600	5200	12	12	0	46.00	8910	24	112.47	5511	43.1	1.1	6.90	0.1700
170	RACETRACK	ANACONDA	7600	35.8	30.00	2.0	40	39.500	5420	24	2	0	46.16	9600	37	112.55	5511	43.1	1.1	20.30	0.5139
171	FLINT	S CROSS	7000	34.7	24.00	2.0	45	52.600	5630	16	5	0	46.14	9057	50	113.17	5280	40.7	1.1	7.30	0.1388
172	BOULDER	MAXVILLE	6980	29.8	25.00	2.0	43	71.300	4750	16	6	0	46.28	9294	50	113.14	4240	39.4	1.1	8.80	0.1234
173	TRAIL	WISDOM	7000	31.4	30.00	2.5	27	71.400	6249	16	31	0	45.39	8025	50	113.43	6058	34.7	1.0	16.20	0.2269
174	BIRCH CR	GLEN	7690	33.6	20.00	2.5	39	36.000	5860	12	24	0	45.22	10431	50	112.47	5218	42.3	1.0	10.90	0.3028
175	MICHIGAN	GOULD	9800	30.1	26.00	2.0	70	21.200	8793	20	15	0	40.33	12500	40	106.01	8100	36.1	1.5	10.90	0.5142
176	ST VRAIN	WARD	10500	35.4	40.00	2.5	85	14.400	9372	40	5	0	40.05	13200	50	105.31	5444	53.1	1.5	26.30	1.8264
177	FALL	PUSTIC	11000	30.8	35.00	2.0	85	3.640	9765	30	10	0	40.33	13000	40	105.37	8363	40.0	1.6	22.50	6.1813
178	S F POUDRE	RUSTIC	9900	31.2	22.00	2.0	65	90.300	7597	20	25	0	40.38	13300	40	105.29	5025	48.3	1.6	9.25	0.1024
179	WAGON	WHEEL	10133	30.3	20.83	3.0	50	0.313	8500	17	30	0	37.48	12000	24	106.50	8500	36.0	1.8	7.26	23.1949
180	WAGON	WHEEL	10209	30.0	21.16	3.0	70	0.347	8500	17	15	0	37.48	12000	24	106.50	8500	36.0	1.8	6.21	17.8963
181	FOOL	FRASER	9500	29.4	30.00	3.0	75	1.120	9300	20	10	0	39.52	9850	35	105.52	8560	32.7	1.6	13.20	11.7857
182	ST LOUIS	*****	10500	25.9	35.00	3.0	70	3.100	9300	20	15	0	39.52	12947	40	105.52	8560	32.7	1.6	19.50	6.2903
183	*DEAD HORSE	*****	9500	29.4	30.00	3.0	70	1.040	8980	20	30	0	39.52	12947	40	105.52	2560	32.7	1.6	16.40	15.7692
184	TENMILE	RIMINI	7000	32.0	20.00	2.5	43	32.700	4850	18	12	0	46.31	8150	30	112.15	3893	42.9	1.1	7.50	0.2294
185	SHEEP	WHITESULPR	6910	35.1	20.00	2.5	48	54.400	5820	18	25	0	46.46	8026	30	110.49	5187	41.1	1.2	7.80	0.1434
186	JUDITH	UTICA	6640	34.3	17.00	3.0	30	58.700	5300	16	24	0	46.45	8211	30	110.19	4300	42.5	1.2	4.90	0.0835
187	W ROSEBUD	ROSCOE	10000	29.4	50.00	3.0	60	52.100	6536	20	21	0	45.17	12800	80	109.43	6558	41.4	1.1	33.60	0.6449
188	BLUEWTR	PRYOR	5500	40.9	26.00	3.0	44	28.100	3910	20	27	0	45.19	6690	32	108.48	3680	47.3	1.2	13.30	0.4733
189	SOAP	XAVIER	4240	45.2	15.00	3.5	48	98.300	3250	14	40	0	45.19	5000	20	107.46	3650	47.3	1.3	3.90	0.0397
190	LODGEGR	WYOLA	6360	34.4	20.00	3.0	50	80.700	4360	16	37	0	45.07	9848	30	107.36	3030	46.1	1.3	7.90	0.0979
191	BEAUVAIS	XAVIER	4500	44.3	14.00	3.0	44	100.000	3350	14	31	0	45.29	6035	16	108.00	3650	47.3	1.3	3.72	0.0372
192	SILVERTIP	BELFRY	4500	46.4	22.00	3.0	34	87.600	3900	12	43	0	45.09	5145	32	108.58	5575	42.6	1.2	4.75	0.0542
193	S F OWL	THRMOPOLIS	9500	28.1	20.00	2.5	58	87.000	6504	16	17	0	43.39	12496	24	108.52	4313	46.3	1.2	5.50	0.0632
194	N F OWL	THRMOPOLIS	8500	31.6	20.00	2.5	50	61.000	6300	16	20	0	43.41	11298	24	108.50	4313	46.3	1.2	3.50	0.0574
195	GOOSEBERY	DICKIE	7100	39.1	13.10	2.0	58	95.000	5750	12	20	0	44.00	10900	20	108.45	5090	46.1	1.2	1.70	0.0179
196	LT SANDY	EDEN	9400	27.9	16.00	2.0	31	170.000	6750	12	41	0	42.14	13200	20	109.19	6321	38.7	1.1	1.56	0.0092
197	SKYLAND	GLACIER	5900	33.4	57.15	2.5	72	8.100	4500	40	10	0	48.19	7600	60	113.21	5213	35.8	1.0	31.60	3.9012
198	ARINNELL	GLACIER	6530	31.8	124.00	2.5	1	3.470	5000	98	1	0	48.46	9541	150	113.41	5900	34.0	1.0	100.00	28.8184
199	SWIFTCURNT	GLACIER	6460	31.2	80.00	2.5	10	31.400	4860	50	10	0	48.48	9954	120	113.39	5213	35.6	1.0	63.00	2.0064
200	SWIFTCURNT	SHERBURNE	7000	28.0	56.00	2.5	20	63.700	4720	50	20	0	48.50	9954	120	113.30	3154	41.5	1.0	42.00	0.6593

ORIGINAL HAWLEY AND MCCUEN DATA

OBS	SITE	LOC	MEANEL	MEANTMP	NAP	SOILGP	CODEVN	AREA	MINELEV	MINNAP	BAREGD	VEGLIT	LAT	MAXEL	MAXNAP	LONG	TEMPEL	ELTEMP	PR625	Y	YPRSQMI
201	WOOD R	KIRWIN	10500	24.5	40.00	2.0	70	7.66	9380	40	15	0	43.52	12435	54	109.18	4313	46.2	1.2	20.50	2.6762
202	NF CRAZY	BUFFALO	7830	35.7	19.50	2.5	20	51.70	5320	15	46	0	44.12	11686	24	106.46	5240	44.8	1.4	4.70	0.0909
203	NF CRAZY	BUFFALO	8010	35.1	19.50	2.5	22	82.70	5190	15	44	0	44.04	10555	24	106.48	5240	44.8	1.4	3.70	0.0447
204	SWEETWATR	STH PASS	8500	34.1	22.00	2.0	28	177.00	7420	12	29	0	42.22	12450	32	108.53	5563	44.4	1.1	5.00	0.0282
205	PRYOR	PRYOR	6000	38.7	18.00	3.5	54	39.60	4440	16	19	0	45.20	7065	20	108.34	3567	47.2	1.2	2.83	0.0715
206	WILLOW	GLASGOW	2536	40.0	13.26	3.0	27	5.00	2500	12	44	0	48.05	2800	14	107.08	2068	40.6	1.4	0.98	0.1960
207	BIG COULEE	LAVINA	4000	43.7	13.00	3.0	19	232.00	3480	12	18	0	46.16	4890	14	108.57	3800	44.4	1.2	0.43	0.0019
208	BOX ELDER	WINNETT	3470	44.5	15.00	3.5	20	684.00	2720	13	22	0	47.01	5585	20	108.09	2887	46.5	1.4	0.45	0.0007
209	BIG MUDDY	*****	2510	37.8	14.00	3.0	30	279.00	2120	12	43	0	48.55	2870	14	105.57	2400	38.2	1.8	0.79	0.0028
210	BOX CR	BILL	4700	45.7	13.07	3.0	50	109.00	4694	12	20	0	43.06	5500	14	105.15	4415	46.7	1.6	0.35	0.0032
211	BOX CR	BILL	5000	44.7	12.54	3.0	50	158.00	4997	12	20	0	43.07	5500	14	105.02	4415	46.7	1.6	0.16	0.0010

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16. Abstract

This report presents comparisons of different methods of estimating average annual discharge of ungaged streams. The primary purpose of the estimates being for making hydropower feasibility investigations that utilize flow duration curves. The published methods of McDonald (1948), Rosa (1968), Heitz (1980, 1981) and Hawley-McCuen (1982) were used on selected streams in Idaho to make the comparisons. The methods have been developed over a considerable period of time and have used different periods of record but all have used normal annual precipitation estimates as the basis for prediction. Reasonable agreement was obtained in the comparisons but inconsistencies do appear on some drainages.

Several additional approaches to improving the estimates and hopefully correcting the inconsistencies have been postulated and techniques for study recommended.

17a. Descriptors

Hydrologic Data, Hydropower Feasibility, Parametric Hydrology Streamflow, Runoff Coefficient, Rainfall-Runoff Relationship

17c. COWRR Field & Group

07C

18. Availability

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