RESEARCH TECHNICAL COMPLETION REPORT

Project A-062-IDA

A QUANTITATIVE ANALYSIS OF STREAMFLOW: THE IMPORTANCE OF PRECIPITATION AND GEOMORPHIC FACTORS IN DETERMINING YIELDS FROM SMALL WATERSHEDS

by

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ABSTRACT

Stream flow data from 12 drainage basins located in the rocky mountains in Northern Idaho that covered 12.43 square miles were statistically analyzed and related to factors such as basin length, basin area, square miles, relief ratio, and precipitation levels. The resulting linear regression (R-square value of .87) indicates that geomorphic factors as well as precipitation play a dominant role in explaining variations in streamflow. The regression model was then applied to the much larger Meadow Creek watershed (approximately 243 square miles). The Thiessen method, which assumes linear variation of precipitation between stations and assigns each segment of area to the nearest station, was used to determine precipitation values for the Meadow Creek basin. The regression model, on a number of occasions produced a prediction that was similar to actual yield from the larger basin.

ABSTRACT

Stream flow data from [illegible] drainage basins located in the rocky mountains in [illegible], Idaho, and Colorado [illegible] square miles) were statistically analyzed and related to [illegible] factors by basin length, basin area, square miles, [illegible] of [illegible]. The data [illegible] regression (R-square value of .97) [illegible] that geomorphic factors [illegible] as precipitation [illegible] in explaining variations in the [illegible]. The regression models were then applied to the [illegible] Creek [illegible] and [illegible] (R-square [illegible]). The [illegible] method, which assumes linear [illegible] of precipitation between [illegible] and [illegible] each segment of area to the [illegible] station, was used to [illegible] precipitation [illegible] Creek basin. The regression models, in a number of cases, [illegible] prediction that was similar to actual yield from the [illegible].

INTRODUCTION

Demands made upon the water that comes from mountain watersheds for power generation, irrigation, to recharge aquifers, and maintain streamflows is increasing. These demands, coupled with increased watershed uses such as logging, roadbuilding, backcountry recreation, and mining may mean the water yielding ability of a watershed is compromised (Rich & Gottfried 1967). This suggests some of these uses may have to be assigned to different areas.

Most mountain watersheds in the intermountain west have not been evaluated (gauged) to determine their water yielding capacity. Thus a methodology is needed to generate this data before attempts are made to allocate various uses to watersheds. Such knowledge will help planners to objectively designate compatible uses for "prime" water yielding watersheds, as well as assist them in designating areas where other land use demands can be accommodated.

Since watersheds along with their inherent drainage basin characteristics such as basin area, basin length, basin shape, basin relief, and basin elevation have been evolving for thousands of years, they undoubtedly best represent the impact that climate/precipitation has had on the environment (geology, soils, vegetation, streamflow, etc.). The approach in this study suggests this is the area to be investigated if one is to develop a predictive basin characteristic/water yield model.

THE LITERATURE

Current methodologies dealing with drainage basin characteristics add credibility to the concept that the water yielding ability of watersheds is predictable via reconnaissance level studies. Specifically, Trainer (1969) concluded that base flow from a basin is inversely proportional to drainage density. The argument for this relationship is true because the streams in his study were "well adjusted" to the terrain, thus they should be reliable indicators of the geohydrologic character of the terrain. Unfortunately, in other study areas where two or more unlike groups of geologic processes have been recently active, one might expect the streams may not yet reflect the character of the terrain, thus the drainage density/base flow relationship previously stated may not be true.

Carlston (1963) concluded that drainage density, surface water runoff, and the movement of groundwater are controlled by the transmissibility of the bedrock and its overlying soil mantle. He maintains the rejected or surface-water component increases with decreasing transmissibility. Therefore, as surface water runoff increases, an increase in the proliferation of stream channels is required for efficient removal of the runoff. The close relationship of drainage density to mean annual flood per unit area indicates the drainage network is adjusted to the mean flood runoff. Thus, it seems logical to assume that if one has bedrock with similar transmissibility characteristics over relatively large mountain areas, an increase in drainage density may reflect an increase in precipitation.

Thomas and Benson (1975), in studying streamflows in four widely separated regions of the United States, concluded that those basin characteristic variables most highly correlated with streamflow characteristics were drainage basin size and mean annual precipitation. However, they also stated that, "In general, it was found that the method produces more accurate relations for the humid Eastern and Southern regions than for the more arid Central and Western regions."

Mustonen (1967) found that "climatologic variables, especially seasonal precipitation and mean annual temperature, are found to be more important than basin characteristics such as soil type and vegetation". However, the basin characteristics he investigated involved such variables as winter, summer, and fall precipitation, frost depth, percentage of peat land, and the percentage of cultivated land rather than geomorphic variables such as basin shape, elevation, and drainage density.

In conclusion, no model presently exists which is widely accepted in the resource planning field that can predict streamflows/water yields using geomorphic characteristics and precipitation data.

OBJECTIVES

The main objective of this study is to develop a methodology that would demonstrate a correlation exists between water yields of mountain watersheds, drainage basin characteristics, and climate (precipitation). To do this, studies like the ones previously mentioned were reviewed, and basin characteristics (stream length, relief ratio, square miles, basin shape, basin length, average basin elevation, and drainage density) were selected for application via multiple regression modeling to the 12.43 square mile portion of the Horse Creek drainage, which is a relatively small basin within the larger 241.54 square mile Meadow Creek watershed.

DESCRIPTION OF STUDY AREA

The Meadow Creek watershed is a major tributary drainage to the Selway River and is located some 35 air miles east of Grangeville, Idaho. It consists of approximately 155,550 acres (241.545 square miles) which varies in elevation from 1800 to 7800 feet, with a computed mean basin elevation of 5400 feet. The slope gradients average 60 to 70% on terrain below the 4000 foot elevation, and 30 to 50% above 4000 feet with a mean slope gradient for the basin of 43%. Precipitation usually ranges from 35 to 50 inches annually, with an average basin precipitation of 40 inches.

Geology of the Horse Creek drainage (primary study area) is in the Precambrian Belt Supergroup, which includes most of Northern Idaho and much of the Northern Rocky Mountains. The area studied (Figure 1) covers 7,955 acres (12.43 square miles), and is relatively homogeneous in land form characteristics. The basin is a fifth order basin, which is the highest order found in the Meadow Creek drainage.

METHODS

The intent was to select geomorphic factors that could be quantified from U.S.G.S. maps along with gauged precipitation data and incorporate them into a model explaining streamflow:

Streamflow = f (geomorphic factors, precipitation) [1]

Data for the dependent variable or streamflow per acre of basin area were computed by dividing the gauged annual flow (in acre feet) from the basin by the area of the basin measured in acres.

Using 1:24000 scale maps the Meadow Creek drainage area was delineated by topographic divide. Within the Meadow Creek basin all streams above a

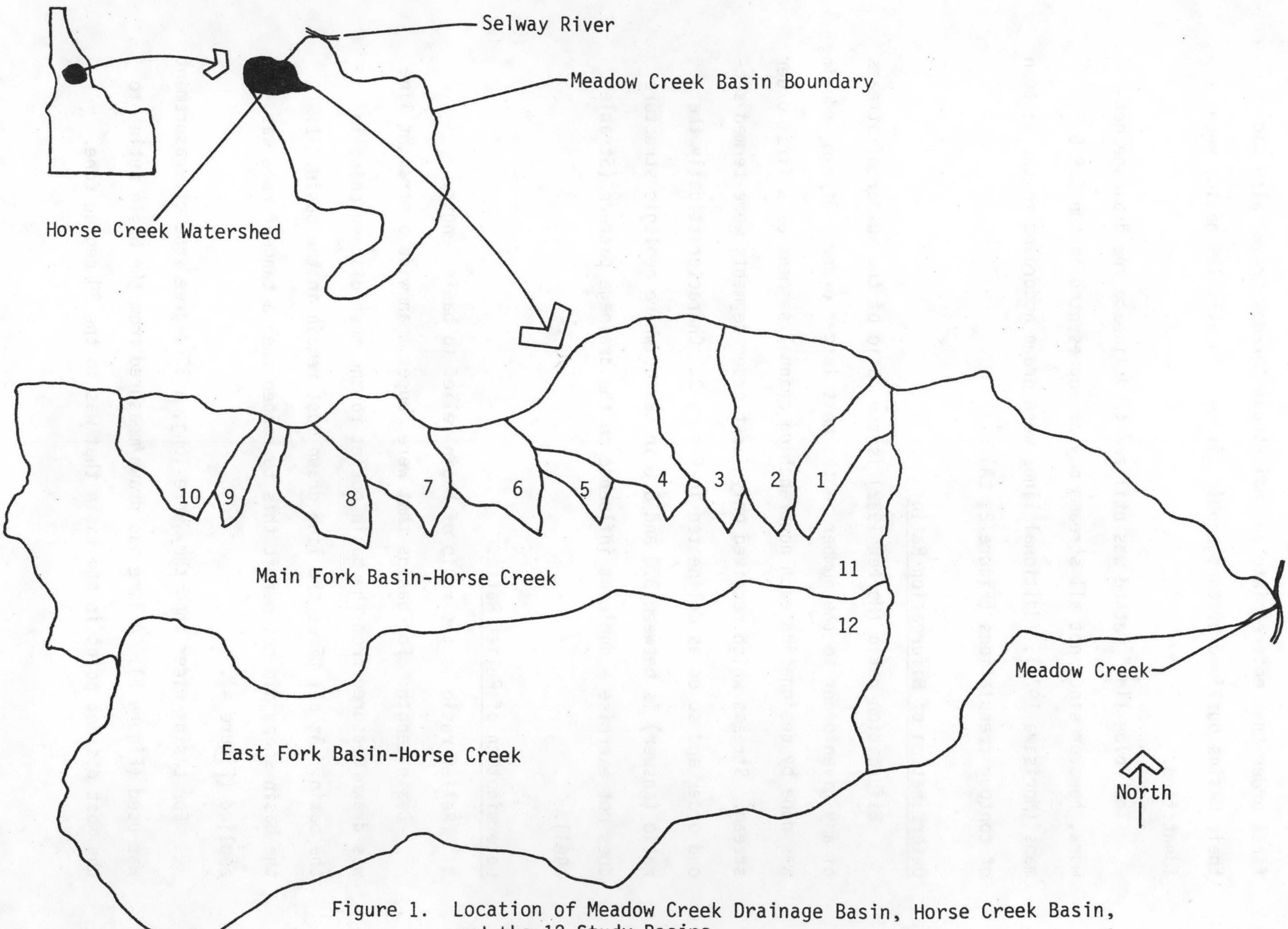


Figure 1. Location of Meadow Creek Drainage Basin, Horse Creek Basin, and the 12 Study Basins.

first order that entered into the mainstream (Meadow Creek) also had their basins outlined by topographic divide. In all, 129 basins were identified.

The "blue line" method was utilized to delineate the drainage network, however since not all streams may be represented on the U.S.G.S. maps (Morisawa 1975), additional lines were drawn according to the pattern of contour crenulations (Figure 2, 2A).

Determination of Bifurcation Ratio:

Bifurcation ratio (Horton 1932) is the ratio of the number of streams of any given order to the number in the next larger order. Stream ordering was done by designating each nonbranching channel segment as a first order stream. Streams which received only first order segments were termed second order and so on as delineated in Figure 3. Characteristically the ratio (answer) is between 3.0 and 5.0 in basins where geologic structure does not exercise a dominant influence on the drainage pattern (Strahler 1964).

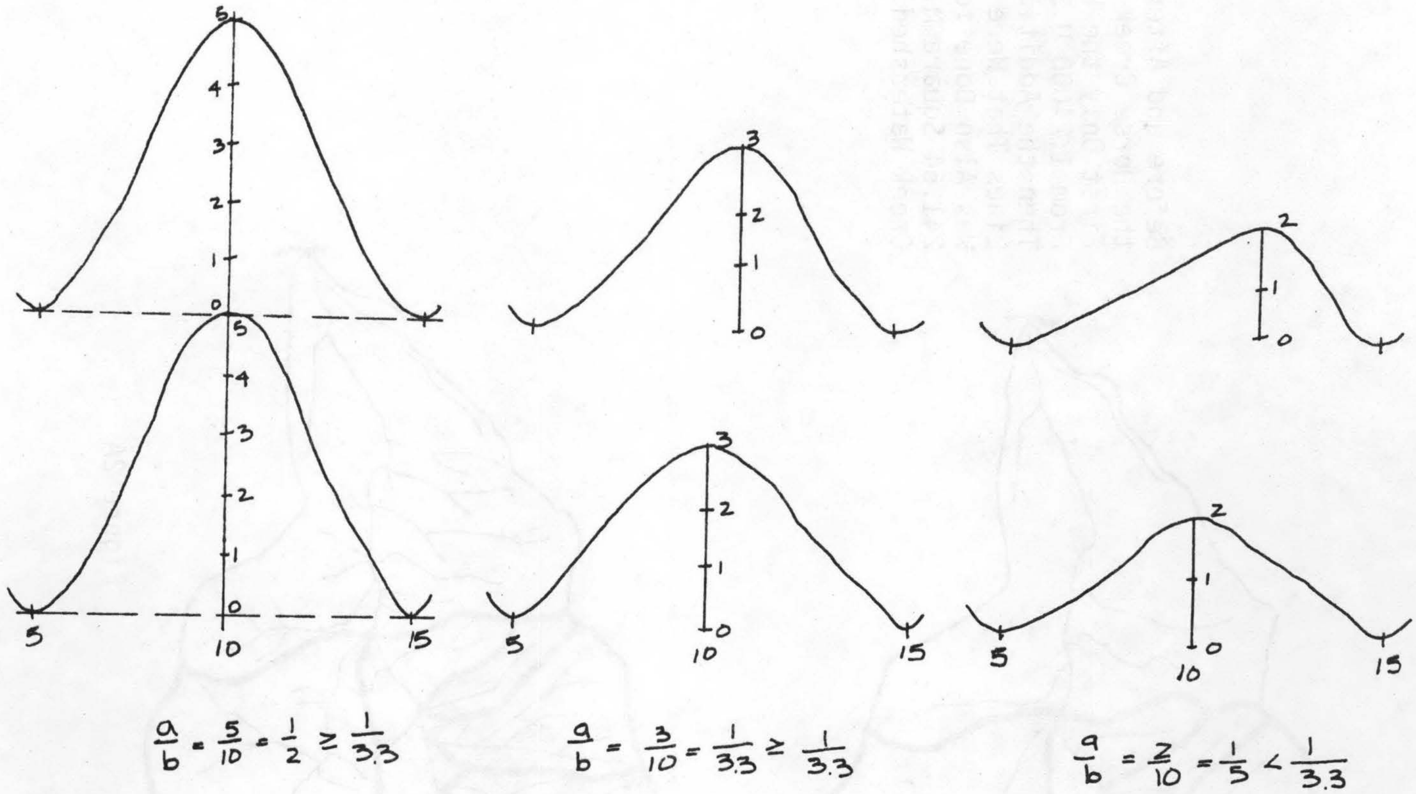
Determination of Relief Ratio:

Relief ratio is the ratio of basin relief to basin length.

Basin Length: For basins that were longer than wide a straight line was drawn/measured from the basin outlet to the most distant point in the basin. At all times the line drawn must remain in the basin. If the basin shape did not permit this to happen then a tangent rule was applied (Figure 4).

For basins wider than they were long, a 30 degree cone of measurement was used (Figure 5). A line was drawn/measured from the basin outlet to the most distant point in the basin that was in the 30 degree cone.

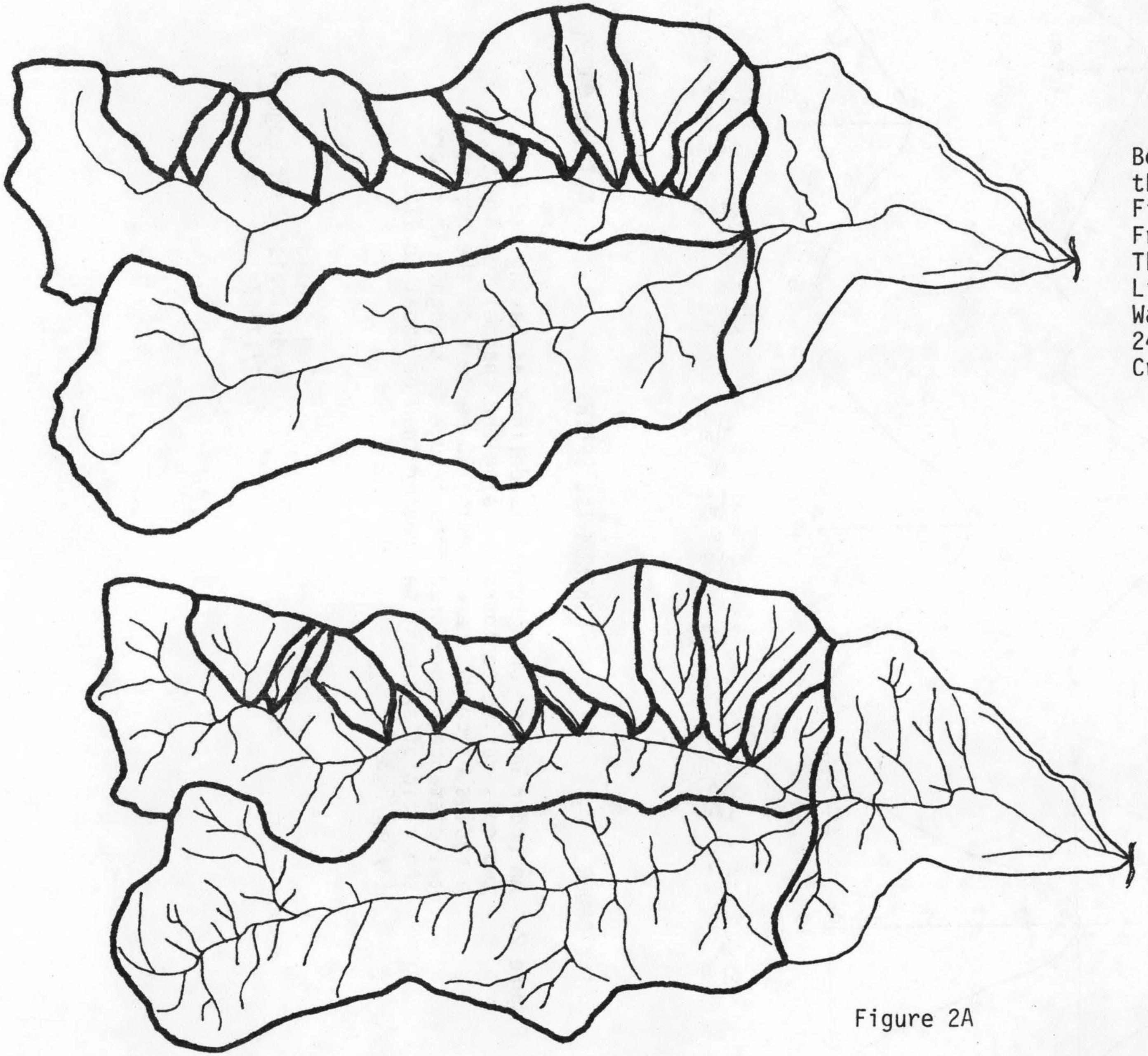
A METHOD FOR DETERMINING 1st ORDER STREAMS



1st ORDER | MINIMUM 1st ORDER | NOT 1st ORDER

Figure 2. An order number one channel is defined as having at least two consecutive contours crossing the channel, each with a radius of curvature exceeding 33 percent of the horizontal distance as measured from trough to trough. Therefore the ratio of a/b must be greater than or equal to 1/3.3 ($a/b \geq 1/3.3$).

Tom Schmidt
Hydrologist-Deerlodge N.F.
3/17/77



Before and After Drawing of the Horse Creek Basin Showing First Only the Blue Lines Taken From 1:24000 U.S.G.S. Maps and Then the Additional Drainage Lines That Were Added. This Was Also Done for the Entire 241.54 Square Mile Meadow Creek Watershed.

Figure 2A

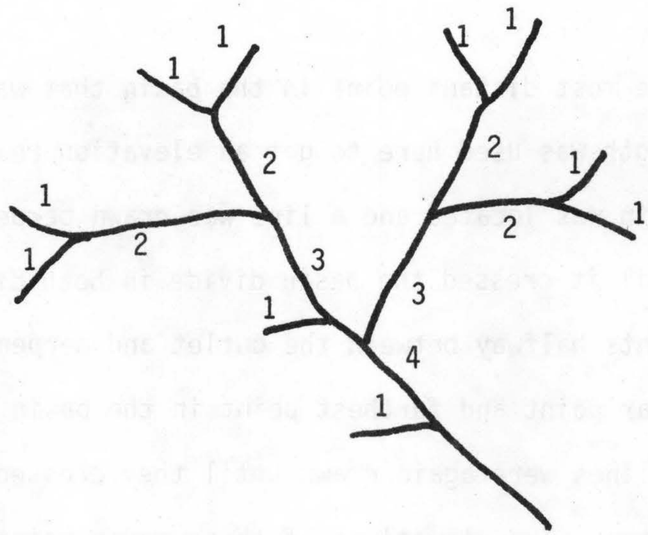


Figure 3. Stream ordering method used where each nonbranching segment is designated as a first order. When two first order streams meet the stream becomes a second order. This stream eventually became a fourth order stream/basin.

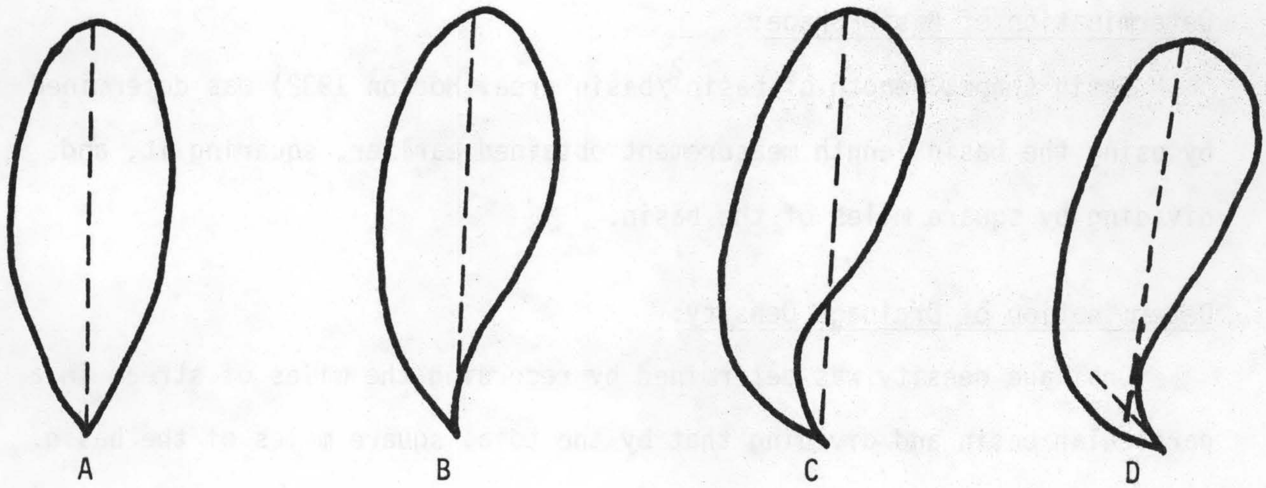


Figure 4. Figure A shows the basin length line drawn straight from basin outlet to most distant point in basin. Figure B shows the same thing except that the line almost is outside of the basin at one point. Figure C shows a basin where the straight line is out of the basin, thus the tangent rule is applied as shown in figure D. The measurement is then taken from the outlet to where the two lines cross, then from that point to the furthest point in the basin.

Basin Relief: The most distant point in the basin that was located to determine basin length was used here to get an elevation reading. The widest part of the basin was located and a line was drawn perpendicular to the length line until it crossed the basin divide in both directions (Figure 6). Next, points halfway between the outlet and perpendicular point, and perpendicular point and furthest point in the basin were determined. Perpendicular lines were again drawn until they crossed the basin divide in both directions. The elevations of these seven points were recorded.

The relief ratio was then determined by adding up the seven elevations, averaging them, subtracting the outlet elevation, and then dividing by the basin length.

Determination of Basin Shape:

Basin shape, length of basin^2/basin area,(Horton 1932) was determined by using the basin length measurement obtained earlier, squaring it, and dividing by square miles of the basin.

Determination of Drainage Density:

Drainage density was determined by recording the miles of stream in a particular basin and dividing that by the total square miles of the basin.

Determination of Average Basin Elevation:

Average basin elevation was established by adding the seven elevations discussed previously in the "Basin Relief" section of this report, adding the outlet elevation, and dividing by eight.

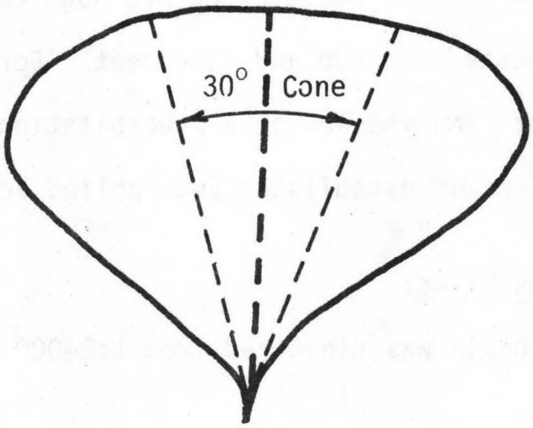


Figure 5. When a basin was wider than it was long, a 30 degree cone was drawn (dashed line) and within it a line was drawn from the outlet to the most distant point within that cone. The measurement was then taken along that line.

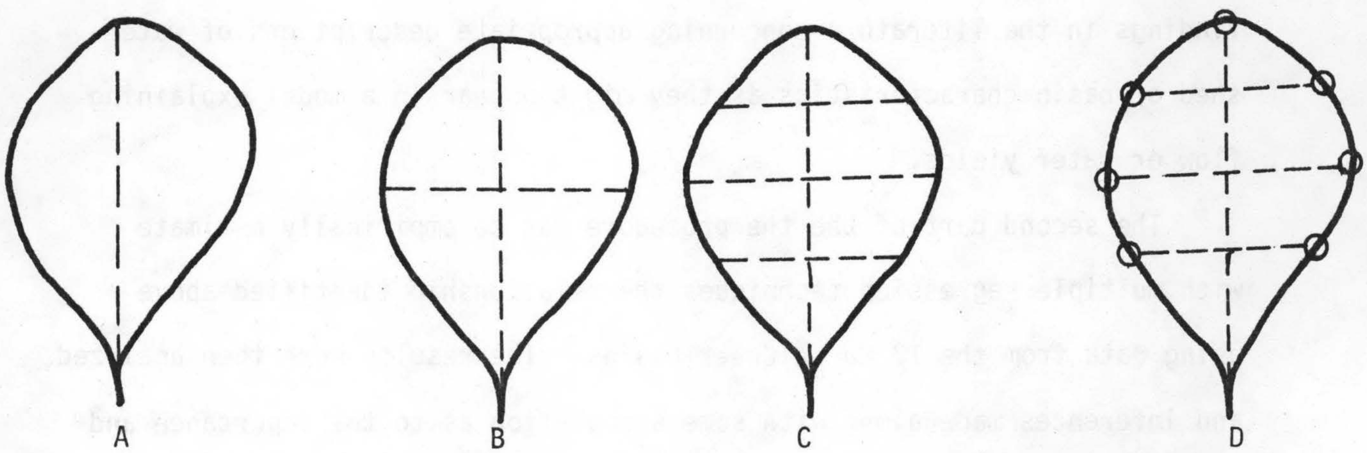


Figure 6. Diagrams A,B,C, & D show the steps taken to get the elevation readings per basin needed in the relief ratio computations. Diagram A shows how the most distant point elevation was designated. In diagram B, the widest part of the basin was located and a perpendicular line was drawn till it crossed the basin divide in both directions. Next, points halfway between the outlet and perpendicular point, and perpendicular point and most distant point in the basin were determined (Diagram C). Perpendicular lines were again drawn till they crossed the basin divide in both directions. Diagram D illustrates where the elevations were taken from (circled areas).

Determination of Precipitation:

Precipitation data for the Horse Creek drainage came from two precipitation stations located at 5600 and 4100 feet. For basins that were at elevations different from the above, a precipitation multiplier for per foot change in elevation was established and applied accordingly.

Determination of Square Miles:

Square miles per basin was digitized from 1:24000 U.S.G.S. maps.

STATISTICAL PROCEDURE AND FINDINGS

First, relationships among geomorphic factors and climate (indexed by precipitation data) were analyzed by computation of correlation coefficients with data for 129 basins. These results were then compared with findings in the literature concerning appropriate descriptions of watershed or basin characteristics as they might appear in a model explaining flow or water yields.

The second part of the the procedure was to empirically estimate with multiple regression techniques the relationship identified above using data from the 12 Horse Creek basins. The results were then analyzed, and inferences made along with some speculation as to the importance and usefulness of the estimation results.

The final step of the procedure was to statistically examine the controversial and important issue of whether a model developed to forecast run-off in small watersheds can be directly applied to forecast run-off for what is the aggregation of small watersheds--a large watershed. Clearly, one approach to forecasting water flow per acre of basin area for a large watershed would be to apply the model individually to all of the small watersheds constituting the large watershed, and then appropriately incorporate the individual results into one forecast.

The alternatives examined here are to forecast directly the flow per acre of basin area for the large watershed using the small basin model with the independent variables measured by using: 1) the actual values for the large basin, 2) the mean values for the 129 small basins that comprise the large watershed.

The forecasts were then compared to the metered runoff of the large watershed which provided the basis to determine the accuracy of the model.

RESULTS: RELATIONSHIPS AMONG GEOMORPHIC FACTORS AND CLIMATE

Correlation data for the one hundred twenty nine basins within the Meadow Creek watershed indicate strong relationships between square miles, stream length, and basin length which is consistent with Anderson (1957) where he stated that almost every watershed characteristic is correlated with area (Table 1).

Drainage density and relief ratio is inversely correlated with basin area which is consistent with what Gregory and Walling (1973) found in seventy six small drainage basins in south-east Devon. Drainage density "ideally" tells one much about a basin because it can reflect the response to input (precipitation) and output (streamflow). However, due to possible local variation by other basin characteristics such as rock type, vegetation, soils, and aspect, drainage densities often times have a wide range of values which can reduce their usefulness about characterizing a basin. For the Meadow Creek area the drainage density correlations imply the basin is not homogeneous in the strict sense of the word.

TABLE I

STATISTICAL ANALYSIS SYSTEM
14:07 Tuesday, August 1, 1978

VARIABLE	N	MEAN	STD DEV	SUM	MINIMUM	MAXIMUM
SHAPFACT	129	4.61247038	1.82795400	595.00867845	1.11172007	15.22080667
DENSITY	129	4.59876009	2.19011116	593.24005194	0.33333333	18.00000000
RELRAT	129	1401.22475448	769.17744611	180757.99332822	323.40561224	7693.61308238
SQM	129	1.55829457	4.34027327	201.02000000	0.02000000	32.49000000
STRL	129	5.34217054	14.12790661	689.14000000	0.01000000	85.41000000
BASINLT	129	1.52695349	1.49508956	196.97700000	0.33200000	10.18500000
BIFRRI	59	3.57694915	1.61811326	211.04000000	1.10000000	8.00000000
BIFRR2	20	3.44350000	1.11255644	68.87000000	2.00000000	6.20000000
BIFRR3	11	2.95454545	1.17163445	32.50000000	2.00000000	6.00000000
BIFRR4	3	2.00000000	0	6.00000000	2.00000000	2.00000000

CORRELATION COEFFICIENTS / PROB > (R) UNDER HO:RHO=0 / NUMBER OF OBSERVATIONS

	SHAPFACT	DENSITY	RELRAT	SQM	STRL	BASINLT
SHAPFACT	1.00000	0.42488	0.28287	-0.33510	-0.34170	-0.30798
	0.0000	0.0001	0.0012	0.0001	0.00001	0.0004
	129	129	129	129	129	129
DENSITY	0.42488	1.00000	0.16161	-0.19339	-0.16681	-0.32357
	0.0001	0.0000	0.0673	0.0281	0.0588	0.0002
	129	129	129	129	129	129
RELRAT	0.28287	0.16161	1.00000	-0.33837	-0.34667	-0.45755
	0.0012	0.0673	0.0000	0.0001	0.0001	0.0001
	129	129	129	129	129	129
SQM	-0.33510	-0.19339	-0.33837	1.00000	0.97332	0.89812
	0.0001	0.0281	0.0001	0.0000	0.0001	0.0001
	129	129	129	129	129	129
STRL	-0.34170	-0.16681	-0.34667	0.97332	1.00000	0.88526
	0.0001	0.0588	0.0001	0.0001	0.0000	0.0001
	129	129	129	129	129	129
BASINLT	-0.30798	-0.32357	-0.45755	0.89812	0.88526	1.00000
	0.0004	0.0002	0.0001	0.0001	0.0001	0.0000
	129	129	129	129	129	129
BIFRR1	-0.11960	-0.14029	-0.46260	0.33638	0.35333	0.45912
	0.3669	0.2892	0.0002	0.0092	0.0060	0.0003
	59	59	59	59	59	59

STATISTICAL ANALYSIS SYSTEM
CORRELATION COEFFICIENTS / PROB > (R) UNDER HO:RHO=0 / NUMBER OF OBSERVATIONS
14:07 Tuesday, August 1, 1978

	SHAPFACT	DENSITY	RELRAT	SQM	STRL	BASINLT
BIFRR2	-0.15039	-0.08147	-0.66160	0.42236	0.53968	0.59844
	0.5268	0.7328	0.0015	0.0636	0.0140	0.0053
	20	20	20	20	20	20
BIFRR3	-0.25354	-0.19102	-0.72283	0.87209	0.73850	0.70765
	0.4519	0.5737	0.0120	0.0005	0.0094	0.0148
	11	11	11	11	11	11
BIFRR4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	3	3	3	3	3	3

The bifurcation ratio's are (Table I) inversely correlated to relief ratio, in other words as the relief of a basin increases the bifurcation ratio decreases (example 12/1=2 or a high ratio, 12/4=3 or a decreasing ratio). Bifurcation ratios are also directly correlated to stream length, square miles, and basin length.

Strahler (1964) demonstrated that bifurcation ratios between three and five are found in watersheds where geologic structure does not exercise a dominant influence on the drainage pattern. The average ratio for first to second order basins in the Meadow Creek drainage is 3.6, for second to third order basins 3.4, and for third to fourth order basins 3.0. The implication is that possibly aspect, elevation, vegetation, or some other variable(s) is causing drainage density not to correlate well with other variables.

Using data from the 12 basins delineated within the Horse Creek watershed simple correlations were again made (Table 2). Basin length, square miles, and stream length are again strongly correlated. The density/relief ratio, square miles, stream length and basin length correlations are also quite similar between the two basins, however, the relief ratio/square mile, stream length, basin length correlations are much stronger for the small twelve basin area. This suggests a degree of similarity exists between the smaller Horse Creek basin and the larger 129 basin Meadow Creek area.

Table 2

STATISTICAL ANALYSIS SYSTEM
15:18 Friday, August 11, 1978

Variable	N	Mean	Std. Dev.	Sum	Minimum	Maximum
SHAPFACT	12	3.66320486	1.12966823	43.95845828	1.97507812	5.61125000
DENSITY	12	5.20161371	1.08678775	62.41936453	3.93750000	7.12962963
RELRAT	12	744.57667891	229.43686506	8934.92014695	296.26754083	983.00323079
SQM	12	1.28416667	2.31887300	15.41000000	0.08000000	6.74000000
STRL	12	6.22416667	10.91723779	74.69000000	0.44000000	32.43000000
BASINLT	12	1.60641667	1.54624545	19.27700000	0.63000000	4.96800000
ELZ	12	5194.08333333	193.51251819	62329.00000000	4887.00000000	5457.50000000

CORRELATION COEFFICIENTS / PROB > (R) UNDER HO:RHO=0 / N = 12

	SHAPFACT	DENSITY	RELRAT	SQM	STRL	BASINLT	ELZ
SHAPFACT	1.00000 0.0000	0.24543 0.4420	0.13364 0.6788	0.02834 0.9303	0.02585 0.9364	0.03644 0.9105	-0.17123 0.5947
DENSITY	0.24543 0.4420	1.00000 0.0000	0.13295 0.6804	-0.19721 0.5390	-0.16100 0.6172	-0.17381 0.5890	-0.50165 0.0966
RELRAT	0.13364 0.6788	0.13295 0.6804	1.00000 0.0000	-0.91050 0.0001	-0.91161 0.0001	-0.91432 0.0001	-0.41374 0.1812
SQM	0.02834 0.9303	-0.19721 0.5390	-0.91050 0.0001	1.00000 0.0000	0.99887 0.0001	0.99354 0.0001	0.36766 0.2397
STRL	0.02585 0.9364	-0.16100 0.6172	-0.91161 0.0001	0.99887 0.0001	1.00000 0.0000	0.99263 0.0001	0.35011 0.2646
BASINLT	0.03644 0.9105	-0.17381 0.5890	-0.91432 0.0001	0.99354 0.0001	0.99263 0.0001	1.00000 0.0000	0.32945 0.2957
ELZ	-0.17123 0.5947	-0.50165 0.0966	-0.41374 0.1812	0.36766 0.2397	0.35011 0.2646	0.32945 0.2957	1.00000 0.0000

RESULTS: ESTIMATION OF WATER FLOW MODEL

The model, equation [1] previously described, was specified with the functional form below:

$$FLOW = B_0 + B_1\ SQM + B_2\ BASINLT + B_3 ELZ + B_4\ RELRAT + B_5\ PRECIP + B_6\ (PRECIP)^2 + B_7\ PMOD + B_8\ ELZ \times PRECIP + \quad [2]$$

The estimation results using data for the 12 Horse Creek basins are displayed in Table 3. The relationship estimated is statistically significant with an F value of 38 and an adjusted R^2 statistic of .87. Excluding the constant term there are 8 variables in the model and the data employed provided 54 observations. The interaction term with average basin elevation (ELZ) and precipitation (Precip) was included as it was thought the effect of precipitation on runoff might itself depend on elevation since one might expect that among other things vegetation and/or soil type might systematically vary with elevation resulting in differential watershed properties.

PMOD, which is, "if PRECIP < 4.6 area feet then PMOD = 0, if PRECIP > = 4.6 then PMOD = PRECIP - 4.6," was created because a plot of YIELD versus PRECIP (Table 4) revealed that yield increased greatly after precipitation increased past the 4.6 level. One might hypothesize that around the 4.6 precipitation level the soil became saturated, therefore any additional amounts of water contributed greatly to yield.

The "T" values reported in Table 3 indicate that each variable is statistically significant at the 5% level of significance.

Table 3

STATISTICAL ANALYSIS SYSTEM

General Linear Models Procedure
11:52 Friday, August 18, 1978

Dependent Variable: Yield

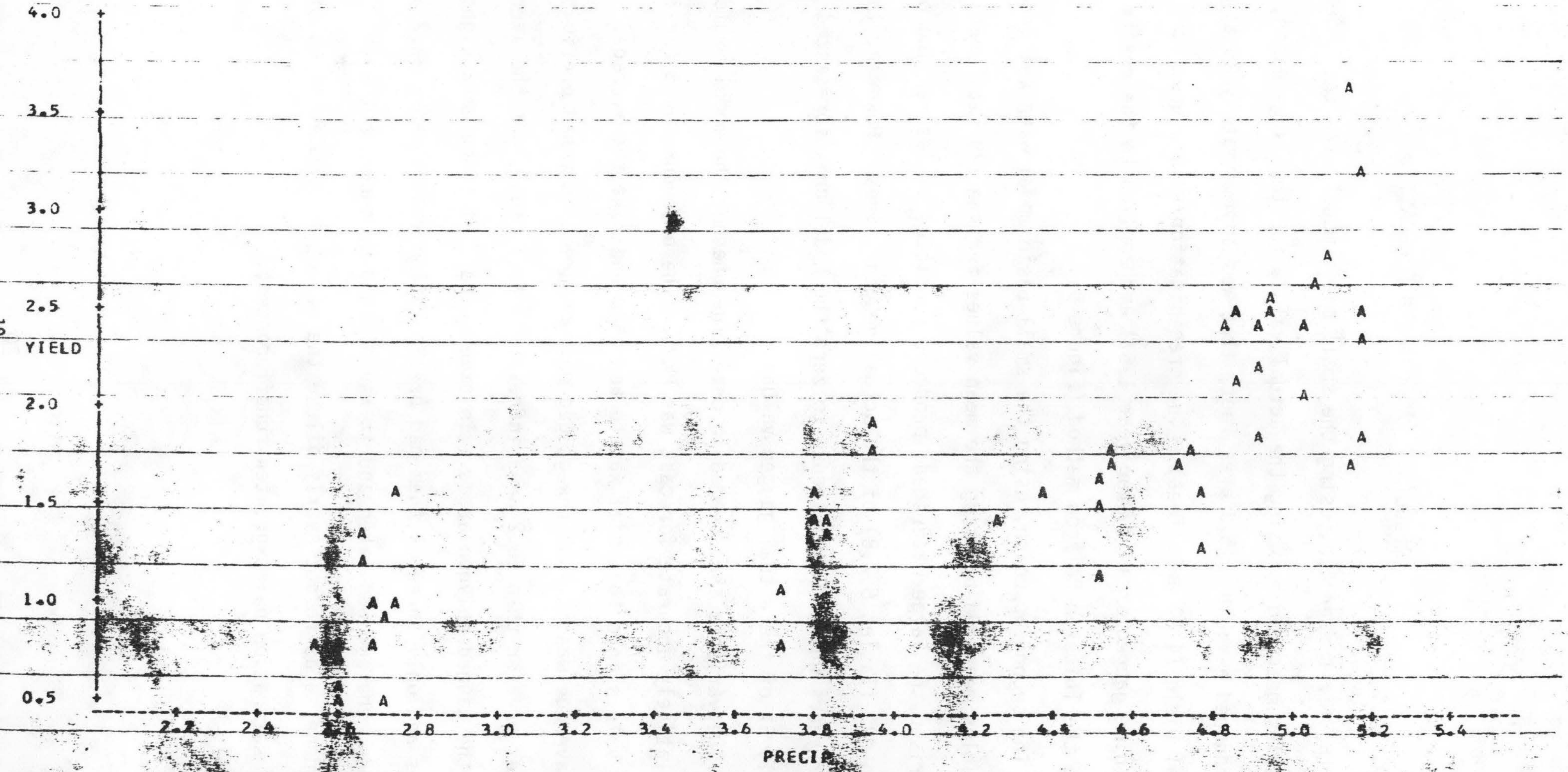
Source	DF	Sum of Squares	Mean Square	F Value	PR > F	R-Square	C.V.
Model	8	24.15125535	3.01890692	38.17	0.0001	0.871558	17.3411
Error	45	3.55917695	0.07909282		STD DEV		Yield Mean
Corrected Total	53	27.71043230			0.28123446		1/62177830

Source	DF	Type I SS	F Value	PR > F	DF	Type IV SS	F Value	Pr > F
SQM	1	0.71897064	9.09	0.0042	1	0.33813576	4.28	0.0445
BASINLT	1	0.89704242	11.34	0.0016	1	1.07793775	13.63	0.0006
ELZ	1	1.73764263	21.97	0.0001	1	0.28740454	3.63	0.0630
RELRAT	1	1.13753088	14.38	0.0004	1	1.11348665	14.08	0.0005
PRECIP	1	17.83939027	225.55	0.0001	1	0.82949613	10.49	0.0023
P2	1	0.52699120	6.66	0.0132	1	0.39369697	4.98	0.0307
PMOD	1	1.01959909	12.89	0.0008	1	1.09505625	13.85	0.0006
ELZ x PRECIP	1	0.27408824	3.47	0.0692	1	0.27408824	3.47	0.0692

Parameter	Estimate	T for H0 Parameter = 0	PR > (T)	STD Error of Estimate
INTERCEPT	-12.44949970	-2.30	0.0262	5.41498844
SQM	0.26238099	2.07	0.0445	0.12689817
BASINLT	- 0.76292173	-3.69	0.0006	0.20665774
ELZ	0.00191996	1.91	0.0630	0.00100720
RELRAT	- 0.00207236	-3.75	0.0005	0.00055232
PRECIP	5.60868231	3.24	0.0023	1.73189752
P2	- 0.40760685	-2.23	0.0307	0.18269597
PMOD	2.89045174	3.72	0.0006	0.77681221
ELZ x PRECIP	- 0.00044917	-1.86	0.0692	0.00024129

Table 4

PLOT OF YIELD*PRECIP   SYMBOL USED IS A



NOTE: 90 OBS HAD MISSING VALUES   4 OBS HIDDEN

RESULTS: LARGE BASIN FORECAST

The first approach, using the small basin model with the independent variables measured by using the actual values for the large basin, (Table 5) produced a yield (46.3 area feet) that was approximately 25 times the actual yield (1.97 area feet). The precipitation values used were taken from nine gauged areas (water year 1967) and applied to the entire basin using the Thiessen Polygon method (Figure 8).

The second approach, using the small basin model with the independent variables measured by using the mean values for the 129 small basins that comprised the large watershed, produced predicted yields ranging between 77 to 98% (Tables 6,7,8) of the actual gauged values. However, in the water years when PMOD was equal to zero the model only forecasted approximately 5% of the actual gauged values.

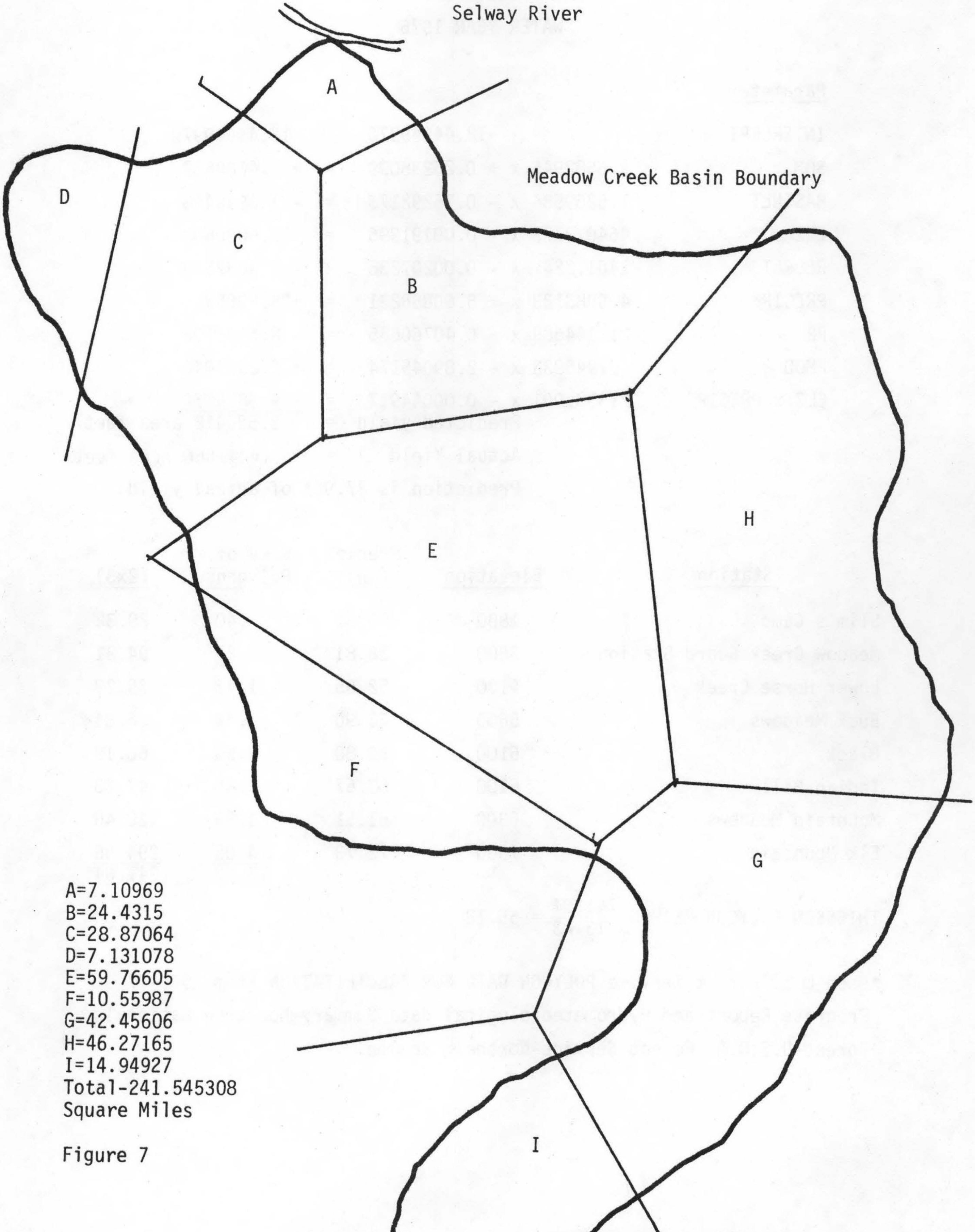
The variable that seemed to determine whether the model would produce a relatively accurate forecast was PMOD. The procedure used for inserting PMOD values into the model was to add them and take the average. However, the average was only of the gauged polygon areas that had precipitation values greater than 55.2 area inches (4.6 area feet), not the average of all the gauged polygon areas. In other words, if there were eight gauged areas and only three of them had precipitation values above 55.2 area inches, the sum was taken and it was divided by three, not eight. This was done so as to not overly dilute the effect of PMOD in terms of the soil saturation point-greater runoff concept.

Table 5

DATA FOR MEADOW CREEK DRAINAGE BASIN

Polygon % Of Total Area		Yearly Precipitation in Inches - 1967		Area Feet Of Water	Elevation Data	
Slims Camp	A-2.9434%	x 36.53 = 1.075224	÷ 12 =	.089602	Furthest Point Elevation	6480
Indian Hill	B-10.1147%	x 37.33 = 3.7758175	÷ 12 =	.3146514	Elevation A	7421
Lower Horse Creek	C-11.9525%	x 39.70 = 4.7451425	÷ 12 =	.3954285	Elevation B	7440
Buck Meadows	D-2.9523%	x 45.40 = 1.3403442	÷ 12 =	.1116953	Elevation C	6844
Meadow Creek Guard Station	E-24.7432%	x 27.29 = 6.7524192	÷ 12 =	.5627016	Elevation D	6020
BlackHawk Mountain	F-4.3716%	x 43.35 = 1.8950886	÷ 12 =	.157924	Elevation E	5700
Green Mountain	G-17.5769%	x 46.68 = 8.2048969	÷ 12 =	.6837414	Elevation F	6570
Elk Mountain	H-19.1565%	x 50.40 = 9.654876	÷ 12 =	.804573	Outlet Elevation	1736
Mountain Meadows	I-6.1890%	x 46.28 = 2.8642692	÷ 12 =	.2386891		
				3.3590063 area feet of water		

Model Key	Model	Estimate			=
Intercept	Intercept	-12.44949970			= -12.449499
SQM (square miles of basin)	SQM	0.26238099	x	241.54530	= +63.376873
BasinLt (length of basin)	Basinlt	-0.76292173	x	27.438	= -20.933045
ELZ (FUREL-ELA-ELB-ELC-ELD-ELE-ELF-OUTEL)/8	ELZ	-0.00191996	x	6026.375	= +11.570037
RELRAT (FUREL-ELA-ELB-ELC-ELD-ELE-ELF - OUTEL)/BASINLT	RELRAT	-0.00207236	x	178.70419	= -.3703286
PRECIP	PRECIP	5.60868231	x	3.3590063	= +18.839599
P2 (PRECIP*PRECIP)	P2	-0.40760685	x	11.282923	= -4.5989961
PMOD (IF PRECIP < 4.6 THEN PMOD = 0.; IF PRECIP > = 4.6 THEN PMOD = PRECIP-4.6;	PMOD	2.89045174	x	0.0000000	= 0.0000000
ELZ*PRECIP	ELZ*PRECIP	-0.00044917	x	20242.631	= -9.0909655
					+46.343676



A=7.10969
B=24.4315
C=28.87064
D=7.131078
E=59.76605
F=10.55987
G=42.45606
H=46.27165
I=14.94927
Total-241.545308
Square Miles

Figure 7

Table 6

WATER YEAR 1976

Parameter		
INTERCEPT	-12.44949970	-12.44949970
SQM	1.5582945 x + 0.26238099	= + .4088667
BASINLT	1.5269534 x - 0.76292173	= - 1.1649458
ELZ	4640.3773 x + 0.00191996	= + 8.9090603
RELRAT	1401.2247 x - 0.00207236	= - 2.9037579
PRECIP*	4.5983333 x + 5.60868231	= +25.79059
P2	21.144669 x - 0.40760685	= - 8.6187108
PMOD	.7945833 x - 2.89045174	= + 2.2967046
ELZ x PRECIP	21338.001 x - 0.00044917	= - 9.5828962
	Predicted yield	= 2.685412 area feet
	Actual Yield	= 3.4441666 area feet

Prediction is 77.96% of actual yield

Station	Elevation	Precip (in)	Area of Polygons	(2x3)
Slim's Camp	1800	50.80	.40	20.32
Meadow Creek Guard Station	3000	28.81	3.27	94.21
Lower Horse Creek	4100	52.65	1.43	75.29
Buck Meadows	5600	63.90	.42	26.84
Black	6100	60.80	.99	60.18
Indian Hill	6100	53.67	.88	47.23
Mountain Meadows	6300	61.51	1.99	122.40
Elk Mountain	7500	72.73	4.05	294.56
			13.43	741.04

THIESSEN POLYGON METHOD $\frac{741.04}{13.43} = 55.18$

*Used U.S. Forest Service POLYGON DATA FOR PRECIPITATION From 1976-77 Progress Report and Hydrometeorological Data Summary-Nezperce National Forest-U.S.D.A. Forest Service-Northern Region.

Table 7

WATER YEAR 1974

Parameter	Value		Estimate		Area Feet
INTERCEPT			-12.44949970	=	-12.44949970
SQM	1.5582945	x	+ 0.26238099	=	+ .4088667
BASINLT	1.5269534	x	- 0.76292173	=	- 1.1649458
ELZ	4640.3773	x	+ 0.00191996	=	+ 8.9090603
RELRAT	1401.2247	x	- 0.00207236	=	- 2.9037579
PRECIP*	3.75	x	+ 5.60868231	=	+21.032558
P2	14.0625	x	- 0.40760685	=	- 5.7319706
PMOD	.9527777	x	- 2.89045174	=	+ 2.7539579
ELZ x PRECIP	17401.414	x	- 0.00044917	=	- 7.814975
			Predicted Yield	=	3.039295 area feet
			Actual Yield	=	2.8241666 area feet

Prediction is 7.6% more than actual yield

Station	Elevation	Precip(LOC)	Area of Polygons	(2x3)
Slim's Camp	1800	36.72	.40	14.69
Meadow Creek Guard Station	3000	34.98	5.07	177.35
Lower Horse Creek	4100	42.90	1.43	61.35
Buck Meadows	5600	64.90	.42	27.26
Black Hawk	6100	49.16	.71	34.90
Indian Hill	6100	46.23	.88	40.68
Mountain Meadows	6300	65.04	.95	61.79
Elk Mountain	7500	69.69	2.60	181.896
			12.46	562.14

THIESSEN POLYGON METHOD $\frac{562.141}{12.46} = 45.115569$

*Used U.S. Forest Service Polygon Data for Precipitation from 1974 Progress Report and Hydrometeorological Data Summary - Nezperce National Forest - U.S.D.A. Forest Service - Northern Region.

Table 8

WATER YEAR 1972

Parameter	Value	Estimate	Area Feet
INTERCEPT		-12.44949970	-12.44949970
SQM	1.5582945	+ 0.26238099	+ .4088667
BASINLT	1.5269534	- 0.76292173	- 1.1649458
ELZ	4640.3773	+ 0.00191996	+ 8.9090603
RELRAT	1401.2247	- 0.00207236	- 2.9037579
PRECIP*	4.0899345	+ 5.60868231	+22.939143
P2	16.727564	- 0.40760685	- 6.8182688
PMOD	5916666	- 2.89045174	+ 1.7101837
ELZ x PRECIP	18978.839	- 0.00044917	- 8.5233965
		Predicted yield =	2.1073860
		Actual Yield =	2.1458333
		Prediction is	98% of actual yield

Station	Elevation	Precip(in)	Area of Polygons	(2x3)
Slim's Camp	1800	42.78	.40	17.11
Meadow Creek Guard Station	3000	34.71	5.07	175.98
Lower Horse Creek	4100	52.30	1.43	74.79
Buck Meadows	5600	61.90	.42	26.00
Black Hawk	6100	51.10	.71	36.28
Indian Hill	6100	50.19	.88	44.17
Mountain Meadows	6300	50.73	.95	48.19
Green Mountain	7200	49.45	2.99	147.86
Elk Mountain	7500	62.70	2.60	163.02
			15.45	733.40

Thiessen Polygon Method $\frac{733.40}{15.45} = 47.47$

* Used U.S. Forest Service Polygon Data for Precipitation from 1972 Progress Report and Hydrometeorological Data Summary - Nezperce National Forest - U.S.D.A. Forest Service - Northern Region.

CONCLUSIONS

1) Blue lines on 1:24000 topography maps supplemented by a consistently applied contour crenulation system to identify additional streams can be used as a base from which to conduct basin yield studies.

2) Where correlations between basin characteristics for a large watershed are relatively similar to those for a smaller watershed located within it, the data from the smaller basin should be able to apply to the larger basin.

3) Regression analysis of morphometric basin characteristics along with gauged precipitation data which is prorated according to elevation can be used to predict yield for a relatively small (12.43 square mile) forested watershed.

4) A model for a relatively small basin (12.43 square miles) can be used to predict yield from a larger basin (241.5 square miles) by using the mean values of the small basins that comprise the larger one.

5) PMOD values, which are an indication of yield increasing rapidly after a certain amount of precipitation, is probably the result of the soil becoming saturated, therefore infiltration is minimized which contributes to a greater increase in runoff. This value would probably vary from one basin to another if the type of soil in the area being studied was dramatically different.

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