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Application of Multivariate Analysis in Predicting Water Yields in Utah

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APPLICATION OF MULTIVARIATE ANALYSIS
IN PREDICTING WATER YIELDS IN UTAH

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INTRODUCTION

The basic hydrologic data required to determine the water yield are usually unavailable for small basins and streams while increasing emphasis is being placed on their development. Therefore, some methods and techniques for estimating the amount of water available for development of these small units is needed.

The purpose of this study is to use the concepts and techniques of statistical analysis to develop equations which are useful in estimating the water yield of watersheds for which no stream flow records are available. The approach is an extension of earlier studies at Utah State University (1, 10) in which physiographic and topographic parameters were related to mean annual runoff of Utah watersheds. Previous studies used multiple regression techniques primarily. The work reported herein utilizes the same data as in the earlier work but analysis is based on the multivariate technique of principal component analysis. Results and evaluations derived from the principal component analysis are compared with those obtained from multiple regression analysis.

PREVIOUS WORK AND PRESENT STATUS

The increased use of statistical methods in hydrology in recent years has perhaps been most apparent in research papers reporting results based on multiple regression techniques. The hydrologist uses these techniques because he is working largely with uncontrolled experiments.

Nixon and Schwab (14) developed a rational approach for estimating the water yield for watersheds in southern Iowa, from five watershed characteristics, climate, land use, land slope, soil and management and conservation practices. To estimate the water yield for any watershed, the median annual water yield is multiplied by a rating factor of the watershed. Spreen (20) correlates the precipitation in western Colorado to elevation of the station, maximum land slope, exposure of the station to the inflow of air masses, and the orientation of this exposure. A study to develop simple equations for estimating mean annual runoff from Utah data was initiated in 1958. In this study, factors which are easily obtained from maps and published data were selected to correlate with the mean water yield of a watershed. Watersheds with gaging stations above all major diversions were used in the study and assumed the watersheds were representative of those to which the equations would be applied. Results of this work for the northern part of the state were reported in a thesis by Jeppson (10). Later Bagley, Jeppson and Milligan (1) extended the analysis to cover the entire state and applied the relation thus developed in obtaining regional runoff inventories.

Sharp, Gibbs, Owen and Harris (17) discuss the limitations of the multiple regression approach in water yield studies. They include in their presentation comments both on the association of errors and on the apparently erroneous results which may be obtained when the independent variables are highly correlated.

The premises upon which multiple regression and correlation analysis is based are as follows:

1. No errors exist in the independent variables, errors occur only in the dependent variable.

2. The independent variables are statistically independent.

3. The variance of the dependent variable (runoff) does not change with changes in magnitude of the independent variables.

4. The observed values of the dependent variable are uncorrelated events.

5. The population of the dependent variable (runoff) is normally distributed about the regression line for any fixed level of the independent variables under consideration.

The first two assumptions are obviously violated by hydrologic data, for measurements of all variables, both dependent and independent, contain certain amounts of error. A glance at the correlation matrix of nearly any hydrological data used in multiple regression reveals that most variables exhibit some and often high degrees of correlation. The fact that small values of precipitation are associated with low values of runoff which exhibit a low variance while large precipitation events generate runoff events with large variance cause doubt in the third assumption for at least this related physiographic parameter. The fourth assumption is violated in the case of runoff data because streamflow is often related to the antecedent flow. Studies on the distribution of runoff events reveal that they do not follow a normal distribution thus causing the last assumption to be violated.

Although many of the assumptions upon which multiple regression analysis are based are violated, it is widely used because it does provide an easy way to evaluate a large number of factors simultaneously and also the extent of the violations may not affect the results appreciably. However, with the wide availability of high speed computers, a much larger variety of procedures is available that may remove some of the uncertainties resulting from violations of the assumptions implicit in multiple regression analysis. These procedures involve a wide field of statistical analysis known as multivariate analysis. One of the procedures known as principal component analysis has been cited in recent literature (5, 21) as a possible improvement to the ordinary multiple regression approach of relating various hydrologic phenomena because it transforms the original independent variables which in reality may be highly correlated into a set of new factors called principal components which are truly orthogonal.

DESCRIPTION OF THE STATISTICAL PROCEDURES

Multiple Regression Analysis

When information is available on two or more related variables, it is natural to seek a way of expressing the form of the functional relationship, and to know the strength of the relationship. The regression method is used to determine the "best" functional relation among the variables. The criterion used to determine the "best" is that linear function which minimizes the sum of the squared deviations between the predicted and observed values of the dependent variable.

The general form of an ordinary multiple regression model is

$$Y = b_0 + b_1 X_1 + b_2 X_2 + \dots + b_m X_m + e \quad . \quad . \quad . \quad . \qquad (1)$$

Where

Y = observed value of water yield

X's are the factors related to the water yield

b_0 = constant term of the regression equation

$b_1, b_2, .., b_m$ = regression coefficients

e = error or amount of deviation between the predicted and observed Y. The procedure for obtaining the unknown coefficients may be found in most textbooks on statistics (15, 18).

An index to the "goodness of fit" of the derived expression is given by the fraction of the original deviation in the dependent variable eliminated by the regression equation and is represented by R^2 where

$$R^2 = \frac{\text{Sum of squares due to regression}}{\text{Total sum of squares}}$$

The closer R approaches 1 the more accurate the estimate of the regression equation will be.

Principal Component Analysis

Principal component analysis is a method by which the information (measured by statistical variance in the sample space) contained in the matrix of predictor variables (in this study the matrix of physiographic observations) is transformed into another matrix of factors which are linearly independent and are called orthogonal factors. The set of orthogonal factors which contain all of the significant information of the original data matrix are called principal components.

For example, if all the data are linear functions of one of the variates, then one variate expresses all of the information contained in the entire array or sample space and conversely if all of the data are linearly independent no amount of linear mathematical rearrangement can reduce the number of variates needed to express all of the information contained in the original array. Most hydrologic data lie between these two examples where it might be possible to eliminate a few of the original independent variates because they contribute little or nothing to the information contained in the remaining group.

The technique which yields the set of transformations which define the orthogonal factors has been discussed in recent books (3, 4, 9) and papers (5, 19, 21, 22) and is briefly outlined as follows:

First, it is necessary to solve the characteristic matrix equation

$$\left[r_{ij} - \lambda I \right] = 0 \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (2)$$

where r_{ij} represents the correlation matrix, I denotes the unit matrix and λ is an undetermined scalar multiplier.

Equation 2 yields an m-rooted polynomial in λ where m is the rank of the correlation matrix r_{ij}. If there are no linearly dependent variables in the original array then m also is the same as the number of original variates in the sample space. The roots of equation 2 are called characteristic roots or eigenvalues of the matrix. For each root, there exists a corresponding vector, ν_j, $(j = 1, 2, ..., m)$, called an eigenvector, whose elements comprise the solution to the simultaneous equations implied by Equation 2. That is

$$\begin{bmatrix} (1-\lambda_i) & r_{12} & r_{13} & \cdots\cdots & r_{1m} \\ r_{21} & (1-\lambda_i) & r_{23} & \cdots\cdots & r_{2m} \\ \cdot & \cdot & \cdot & \cdots\cdots & \cdot \\ \cdot & \cdot & \cdot & \cdots\cdots & \cdot \\ \cdot & \cdot & \cdot & \cdots\cdots & \cdot \\ r_{m1} & r_{m2} & & \cdots\cdots & (1-\lambda_i) \end{bmatrix} \cdot \begin{bmatrix} \nu_{1i} \\ \nu_{2i} \\ \cdot \\ \cdot \\ \cdot \\ \nu_{mi} \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ \cdot \\ \cdot \\ \cdot \\ 0 \end{bmatrix} \qquad (3)$$

If the original variates denoted by x_j are standardized, i.e. measured about their respective sample means and divided by their respective standard deviations, the principal components, D_i, are defined by

$$D_i = \sum_{j=1}^{m} v_j x_j \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (4)$$

The D_i are uncorrelated (by definition) and have variance λ_i where λ_i is the ith root of the characteristic equation. It can be shown that for the case in which r_{ij} is positive-definite, which all correlation matrices must be, that

$$\sum_{i=1}^{m} \lambda_i = m \quad . . . . \quad (5)$$

and

$$\frac{\lambda i}{m} (100) = P_i \quad . . . . \quad (6)$$

where P_i is the precentage of variation accounted for by the ith principal component. Therefore, the eigenvector corresponding to the largest eigenvalue defines the principal component that accounts for the largest percent of variation in the original sample space. The eigenvector corresponding to the next largest eigenvalue yields the principal component that accounts for the next largest percent of variation in the sample space. And so on until all variation is accounted for.

There are various ways of obtaining solutions to the above equations which are not discussed here, but most computer centers have library programs that will calculate eigenvalues and corresponding eigenvectors.

COLLECTION OF DATA

Runoff Data

Most of the runoff data were obtained from the publications of the U. S. Geological Survey. A few runoff records of selected watersheds were obtained from the files of the Salt Lake City Water Department. Names of the stream gaging stations which are used in this study are listed in Table 1. In this report, both the gaging station and the watershed are designated by the same name. The annual runoff refers to the water year beginning October 1 of the preceding year to September 30 of the current year.

Since the runoff records for various watersheds cover different periods of time, stations of short record were extended by correlating them with longer records from other stations in the area, in order to enable compatible analysis. The average annual runoff expressed as a uniform depth over the watershed for the 30 year period from 1931 to 1960 was selected for this study to conform to the precipitation data obtained from the Weather Bureau.

Precipitation and Physiographic Data

Precipitation and physiographic data were obtained from Special Report 18, Utah Agricultural Experiment Station with the exception that the drainage areas were revised according to the 1965 Surface Water Supply of Utah published by the U. S. Geological Survey and a

Table 1. Basic data used in the study

	Area	E	E_M	D	S_S	A_S	$S_{L(N-S)}$	$S_{L(E-W)}$	S_L	L	X	F_S	G	V	P_{AN}	P_{O-A}	Y
	sq mi	ft	ft	mi/mi^2	ft/ft	degrees	ft/ft	ft/ft	ft/ft			ft			in	in	in
(Great Salt Lake Div.)																	
Woodruff Cr.	65.00	7910	9050	.881	.0166	247	.220	.218	.315	111°24'	41°26'	.46	62.51	17.27	26.00	19.00	5.44
Farmington Cr.	10.00	7462	9070	.505	.1135	95	.385	.221	.306	111°50'	40°59'	.74	96.80	17.20	40.20	31.40	15.95
Holmes Cr.	2.49	7582	9400	1.480	.2660	85	.485	.425	.454	111°52'	41°03'	.86	99.99	14.56	32.10	26.70	19.11
Parrish Cr.	2.08	7049	9259	1.210	.2310	75	.225	.386	.306	111°50'	40°56'	.86	98.65	17.60	32.90	24.30	9.83
Rick Cr.	2.35	7351	8000	.425	.2780	75	.073	.363	.218	111°51'	40°57'	.91	97.75	18.20	32.70	24.50	12.17
Centerville Cr.	3.15	6944	8800	.620	.2980	85	.312	.287	.299	111°50'	40°56'	.73	97.75	17.91	33.40	24.70	10.42
City Cr.	19.20	7408	9200	.593	.0753	65	.356	.182	.272	111°49'	40°50'	.94	67.60	17.28	35.50	24.90	10.56
Blacksmith Fork	260.00	7068	9000	.537	.0189	125	.183	.187	.186	111°36'	41°36'	.65	69.64	17.11	23.60	16.90	6.04
E. Fk. Little Bear R.	50.00	7239	9000	.449	.0308	115	.195	.226	.210	111°40'	41°28'	.55	71.64	17.41	27.10	20.10	10.33
Hardscrabble Cr.	28.10	7188	8800	.620	.0403	180	.258	.287	.272	111°45'	40°54'	.61	78.43	16.70	29.70	24.70	13.50
Mill Cr. nr. Bountiful	8.79	7382	9248	.652	.1260	90	.372	.229	.308	111°48'	40°52'	.83	84.71	17.20	36.10	27.20	9.36
Stone Cr.	4.48	7084	8600	.819	.2500	90	.374	.265	.320	111°49'	40°54'	.73	98.84	17.63	32.50	23.40	9.31
South Fork Ogden R.	148.00	7225	8800	.830	.0410	75	.229	.264	.245	111°35'	41°20'	.79	60.38	17.32	19.00	13.10	3.06
Lost Cr.	133.00	7343	8400	.549	.0231	30	.212	.197	.205	111°21'	41°15'	.37	63.60	16.45	26.50	20.10	9.71
Big Cr.	52.20	7335	8800	.881	.0166	243	.379	.261	.315	111°21'	40°35'	.38	59.17	17.56	19.70	13.00	3.72
Birch Cr.	17.00	7719	9065	.601	.0271	270	.065	.080	.072	111°23'	41°30'	.34	64.22	17.92	21.70	14.20	4.87
Hobble Cr.	105.00	7036	11068	.570	.0225	45	.275	.335	.305	111°28'	40°14'	.50	71.34	14.57	26.20	20.90	4.57
American Fork	51.10	8459	11400	.755	.0525	40	.440	.391	.415	111°37'	40°29'	.84	70.31	12.95	40.30	32.60	14.00
Fort Cr.	6.55	7329	11000	1.050	.1890	0	.447	.099	.273	111°47'	40°30'	1.05	38.05	11.02	27.90	23.20	15.42
Dry Cr.	9.82	8789	11200	2.380	.1930	40	.397	.363	.380	111°43'	40°31'	1.28	68.06	11.71	37.40	32.70	26.62
Big Cottonwood Cr.	50.00	8586	11319	.710	.0587	80	.366	.412	.404	111°40'	40°38'	.69	75.55	12.29	41.80	32.70	17.36
Parleys Cr.	50.10	6950	8620	.614	.0281	60	.221	.280	.251	111°42'	40°45'	.74	65.13	17.04	30.20	21.70	6.21
Mill Cr. nr. SLC	21.70	7814	10242	.530	.0637	80	.453	.347	.397	111°42'	40°41'	.68	69.33	16.31	36.90	30.40	8.31
Emigration Cr.	18.00	6439	8600	.730	.0400	60	.323	.350	.336	111°45'	40°48'	.53	64.63	17.33	27.40	20.20	4.05
Little Cottonwood Cr.	27.40	8943	11319	.746	.0778	85	.544	.326	.434	111°41'	40°34'	1.38	70.17	5.62	45.20	33.90	29.12
Logan River	218.00	7542	9600	.600	.0200	20	.200	.200	.200	111°35'	41°52'	.86	68.78	15.57	32.20	24.50	14.49
(Uinta Division)																	
Little Brush Cr.	28.00	9140	10400	.370	.0237	328	.134	.117	.125	109°33'	40°45'	.379	88.51		25.80	14.00	7.33
Brush Cr.	23.00	9490	10600	.235	.0567	340	.163	.311	.232	109°33'	40°45'	.219	83.87		27.00	14.30	4.46
Ashley Cr.	101.00	9442	12020	.407	.0401	340	.146	.149	.147	109°42'	40°33'	.740	73.58		25.20	14.00	12.19
Ashley Cr. bel. T.C.	27.00	9968	10509	.222	.0198	300	.099	.070	.085	109°42'	40°46'	.300	73.87		29.80	14.80	10.24
South Fk. Ashley Cr.	20.00	10404	12020	.290	.0284	275	.175	.094	.133	109°48'	40°46'	.419	72.12		31.90	18.20	12.14
East Fk. Dry Fk.	12.00	9894	11200	.416	.0439	0	.092	.198	.142	109°46'	40°41'	.400	83.64		27.60	15.10	8.69
E. Fk. Dry Fk. at mouth	18.00	9468	11200	.412	.0622	0	.134	.214	.173	109°46'	40°40'	.700	81.34		26.10	14.70	5.13
N. Fk. Dry Fk.	12.00	9825	12200	.642	.1020	340	.160	.148	.154	109°50'	40°40'	.618	84.60		27.70	14.10	6.59
Dry Fork	48.00	10215	12200	.380	.0362	330	.155	.145	.150	109°54'	40°42'	.635	60.23		30.00	17.16	9.45
Whiterocks River	115.00	10215	12280	.561	.0357	330	.203	.198	.201	110°00'	40°42'	.994	72.77		32.80	20.00	12.68
Whiterocks R. ab. PC	90.00	10626	12280	.578	.0390	330	.194	.189	.191	110°00'	40°44'	.666	70.31		34.50	18.70	13.86
Carter Cr.	19.00	10080	12020	.290	.0622	225	.153	.130	.141	109°53'	40°51'	.631	68.07		28.10	18.40	5.50
Farm Cr.	22.00	9050	10200	.412	.0676	320	.252	.298	.276	110°00'	40°38'	.681	75.34		21.70	11.90	3.68
Clover Cr.	9.50	10449	12000	.722	.1370	0	.119	.188	.152	110°08'	40°40'	.706	64.58		38.90	15.20	3.00
Uinta R. ab. Clover Cr	132.00	10966	13400	.587	.0374	350	.302	.210	.256	110°15'	40°44'	.725	59.35		35.60	20.90	13.74

Uinta R. bel. Gilbert	33.00	11452	13400	.830	.0525	280	.222	.151	.187	110°18'	40°48'	483	64.77	39.40	22.50	16.67
Yellowstone Cr. bel. S. Cr.	99.00	10854	13498	.775	.0323	350	.234	.272	.254	110°26'	40°42'	.863	68.54	35.10	19.90	15.76
Yellowstone Cr.	131.00	10519	13498	.664	.0272	345	.219	.234	.227	110°26'	40°40'	1.130	50.07	32.80	18.40	13.88
Lake Fork	78.00	10809	13299	.770	.0442	350	.271	.220	.245	110°35'	40°41'	.788	56.49	35.90	21.60	17.43
Rock Cr. nr. Mt. Home	149.00	10163	12525	.640	.0232	330	.260	.276	.268	110°44'	40°37'	1.055	66.67	33.30	20.20	14.90
Rock Cr. nr. Hanna	120.00	10694	12525	.620	.0359	0	.261	.263	.262	110°45'	40°39'	.756	66.74	34.60	21.20	17.38
Duchesne River	39.00	9920	12400	.610	.0313	5	.203	.234	.218	110°52'	40°42'	.640	59.59	35.10	22.80	18.24
Provo River	29.60	9682	11800	1.970	.0357	40	.129	.113	.121	110°59'	40°39'	.470	59.46	34.40	23.10	22.64
Weber River	163.00	9063	11600	.633	.0248	80	.278	.294	.286	111°05'	40°45'	.906	61.30	33.00	21.40	16.15
Wolf Cr.	9.00	9030	9800	.600	.0525	300	.268	.108	.203	110°57'	40°29'	.542	51.63	24.70	21.00	11.34
W. Fk. Duchesne R.	61.00	8901	10400	.380	.0217	270	.194	.059	.114	110°00'	40°27'	.663	54.22	26.40	19.20	10.47
W. Fk. Duchesne R. below D.	47.00	9134	10400	.600	.0390	270	.199	.088	.141	111°06'	40°27'	.438	54.49	27.30	20.70	11.09
Water Hollow	15.00	8569	10600	.615	.0413	285	.234	.191	.213	110°04'	40°15'	.617	7.97	16.90	21.40	4.26
White River	53.00	8304	9400	.235	.0172	350	.196	.193	.195	111°02'	39°57'	.331	81.23	27.00	18.70	4.81
North Fk. White R.	23.00	8407	9800	.393	.0235	20	.146	.182	.164	110°58'	39°57'	.375	79.39	29.50	19.40	3.59
Minnie Maud Cr.	30.00	8456	9505	.382	.0314	245	.200	.359	.279	110°36'	39°48'	.450	70.62	18.40	11.60	2.76
Carter Cr. at Mouth	110.00	8866	12020	.320	.0994	258	.121	.158	.139	109°43'	40°51'	.844	69.15	24.20	13.20	6.33
Brown Duck Cr.	15.00	10370	11600	.714	.0770	290	.227	.165	.196	109°33'	40°35'	.580	72.85	31.30	21.80	8.22
Hades Cr.	7.50	9897	11400	.390	.1250	35	.446	.357	.401	110°50'	40°34'	.883	74.14	32.00	19.30	16.28
(Southern Division)																
Summit Cr.	14.60	8841	10913	1.200	.0897	160	.362	.403	.382	110°46'	39°35'	.740	75.60	26.50	16.70	10.34
Price River	62.00	8670	9680	.230	.0133	245	.194	.181	.188	111°10'	39°47'	.450	62.52	28.40	21.10	9.76
Gooseberry Cr.	16.40	8881	9680	.726	.0158	0	.248	.210	.222	111°18'	39°43'	.850	62.23	31.70	23.00	15.23
Pleasant Cr.	16.00	8830	10600	1.430	.0951	120	.291	.241	.266	111°23'	39°33'	.780	63.93	31.80	21.90	16.36
Huntington Cr.	188.00	8944	10760	.655	.0218	335	.293	.254	.273	111°20'	39°32'	.660	66.24	24.50	19.30	6.62
Cottonwood Cr.	205.00	8887	11300	.546	.0321	310	.226	.238	.232	111°16'	39°20'	1.000	58.43	24.70	17.40	6.11
Ferron Cr.	157.00	8736	10980	.513	.0322	305	.216	.214	.215	111°21'	39°10'	.900	62.98	21.50	15.70	4.98
Muddy Cr.	105.00	8850	11000	.474	.0370	295	.219	.137	.175	111°22'	39°02'	.850	65.28	27.80	17.30	4.40
Twin Creek	5.90	8482	10400	1.750	.0806	120	.404	.278	.341	111°18'	39°30'	.760	63.29	26.30	17.80	22.56
Ivie Creek	50.00	7650	11400	.672	.0431	260	.179	.250	.215	111°29'	38°44'	.480	58.48	18.20	11.00	1.03
Chalk Cr. nr. Fillmore	58.70	7807	10082	.778	.0632	110	.292	.274	.283	112°18'	38°58'	.540	60.37	22.10	16.50	7.83
Indian Creek	4.70	8915	11100	.770	.0769	180	.298	.218	.257	109°31'	37°50'	.350	79.97	27.50	21.00	7.26
Center Cr.	60.00	8109	11229	.464	.0493	180	.238	.256	.247	112°48'	37°46'	1.200	66.16	23.10	13.20	3.68
Beaver River	82.00	9146	12173	.688	.0487	85	.223	.186	.204	112°21'	38°17'	1.090	61.52	27.60	19.00	8.39
Sevier River	340.00	8295	11229	.671	.0093	250	.100	.109	.104	112°36'	37°36'	.850	57.13	22.00	13.70	4.17
Castle Cr.	7.58	7914	11150	.780	.0147	127	.261	.252	.256	110°15'	38°34'	.900	77.40	24.20	13.30	1.88
Mill Cr. nr. Moab	74.90	7478	12600	.411	.0408	120	.164	.151	.157	110°26'	38°34'	1.030	51.20	17.50	9.80	2.48
North Cr.	90.00	8130	10600	.537	.0351	325	.188	.198	.193	111°48'	37°53'	.870	38.19	22.30	13.40	1.10
Pine Cr.	78.00	7536	10400	.593	.0459	350	.159	.209	.184	111°39'	37°52'	.950	35.79	21.80	16.00	.80
Coal Creek	80.90	8959	10600	.532	.0356	120	.224	.246	.235	112°55'	37°39'	.980	59.37	25.70	18.00	4.99
E. Fk. Boulder Cr.	21.40	10536	11400	.381	.0498	350	.132	.084	.108	111°27'	38°05'	.700	65.72	32.10	19.50	15.77
E. Fk. Deer Cr.	1.90	9240	10000	1.380	.0963	5	.168	.060	.114	111°23'	38°01'	.450	45.07	31.00	19.50	10.65
Henrieville Cr.	29.00	7226	9196	.559	.0203	50	.230	.190	.210	111°52'	37°38'	.480	54.74	19.80	11.10	2.31
N. Fk. Virgin R.	350.00	7457	10200	.636	.0272	0	.193	.234	.214	112°53'	37°24'	.900	53.17	24.70	19.60	3.93

revised geology factor was obtained based on a new geology map of the State and new weighting coefficients assigned by James Milligan and Dr. Stewart Williams. The new weighting coefficients and the proportion of each watershed covered by the respective geologic formations based on the above are given in Appendix A and B respectively.

The various parameters and the symbols used to denote them are given as follows:

P_{wy}	Water year precipitation in inches
P_{oa}	October to April precipitation in inches
E	Mean elevation in feet
E_m	Maximum elevation in feet
D	Drainage density in mi/mi^2
S_s	Slope of the main stream in ft/ft
A_s	Aspect in degrees clockwise from south
$S_{1(n-s)}$	Average land slope in a north-south direction in ft/ft
$S_{1(e-w)}$	Average land slope in an east-west direction in ft/ft
S_1	Average land slope in ft/ft
L	Longitude of watersheds center in degrees
X	Latitude of watersheds center in degree
F_s	Slope factor in feet
G	Weighted geology factor in dimensionless units
V	Weighted vegetative factor in dimensionless units
Y	Annual watershed runoff in inches

Detailed definitions of and computational examples for obtaining the physiographic parameters may be found in Utah Agricultural Experiment Station Special Report 18. The basic data used for this study is given in Table 1.

The analysis of the data was done using the same segregation of the data into three hydrologic divisions, the Great Salt Lake, the Uinta, and the Southern, that are described in Special Report 18. This was done because preliminary analysis using statewide data gave results that indicated more homogeneous grouping of the data was required in order to be of acceptable precision.

RESULTS OF STATISTICAL ANALYSIS

Multiple Regression Analysis

The multiple regression analysis was done using the facilities of Western Data Processing Center. The praticular library program selected for this analysis was BMDO2R, "Stepwise Regression," prepared by the Health Aciences Computing Facility of the Department of Preventive Medicine and Public Health, School of Medicine, University of California, Los Angeles. This program computes a sequence of multiple linear regression equations in a stepwise manner. At each step one variable is added to the regression equation. The variable added is the one which will, in combination with those variables previously included in the regression, reduce the unexplained variance the most in a single step. Output from the computer contains the regression equation applicable at each step. The multiple correlation coefficients for various stepwise regression equations for the three divisions and the entire state are tabulated in Table 2, 3, 4, and 5 respectively. The stepwise multiple regression equations for the Great Salt Lake division are shown in Table 6, and those for the Uinta division, Southern division, and the entire state are shown in Table 7, 8 and 9 respectively.

Table 2. Summary of multiple correlation coefficients for various regression equations (stepwise) relating mean water yield to climatic and physiographic factors in the Great Salt Lake Division.

Equation number	Variable in regression equation	Correlation coefficient	Variable entered	Variable removed	No. of variables included
1	F_S	0.850	F_S		1
2	F_S, E	0.914	E		2
3	F_S, E, L	0.929	L		3
4	F_S, E, L, V	0.940	V		4
5	F_S, E, L, V, X	0.959	X		5
6	F_S, E, L, V, X, D	0.965	D		6
7	F_S, E, L, V, X, D, G	0.969	G		7
8	F_S, E, L, V, X, D, G, S_L	0.972	S_L		8
9	F_S, E, L, V, X, D, G, S_L, P_{O-A}	0.977	P_{O-A}		9
10	E, L, V, X, D, G, S_L, P_{O-A}	0.977		F_S	8
11	E, L, V, X, D, G, S_L, P_{O-A}, E_M	0.982	E_M		9
12	E, L, V, X, D, G, S_L, P_{O-A}, E_M, P_{WY}	0.985	P_{WY}		10
13	E, L, V, X, D, G, S_L, P_{O-A}, E_M, P_{WY}, A_S	0.986	A_S		11
14	E, L, V, X, D, G, S_L, P_{O-A}, E_M, P_{WY}, A_S, $S_{L(N-S)}$	0.986	$S_{L(N-S)}$		12
15	E, L, V, X, D, G, S_L, P_{O-A}, E_M, P_{WY}, A_S, $S_{L(N-S)}$, $S_{L(E-W)}$	0.987	$S_{L(E-W)}$		13
16	E, L, V, X, D, G, S_L, P_{O-A}, E_M, P_{WY}, A_S, $S_{L(N-S)}$, $S_{L(E-W)}$, F_S	0.987	F_S		14
17	E, L, V, X, D, G, S_L, P_{O-A}, E_M, P_{WY}, A_S, $S_{L(N-S)}$, $S_{L(G-W)}$, F_S, S_S	0.987			15

Table 3. Summary of multiple correlation coefficients for various regression equations (stepwise) relating mean water yield to climatic and physiographic factors in the Uinta Division.

Equation number	Independent variable in regression equation	Correlation coefficient	Variable entered	Variable removed	No. of variables included
1	P_{O-A}	0.676	P_{O-A}		1
2	P_{O-A}, E_M	0.782	E_M		2
3	P_{O-A}, E_M, D	0.806	D		3
4	P_{O-A}, E_M, D, S_S	0.830	S_S		4
5	P_{O-A}, E_M D, S_S, $S_{L(N-S)}$	0.862	$S_{L(N-S)}$		5
6	P_{O-A}, E_M, D, S_S, $S_{L(N-S)}$, X	0.895	X		6
7	P_{O-A}, E_M, D, S_S, $S_{L(N-S)}$, X, A_S	0.910	A_S		7
8	P_{O-A}, E_M, D, S_S, $S_{L(N-S)}$, X, A_S, $S_{L(E-W)}$	0.922	$S_{L(E-W)}$		8
9	P_{O-A}, E_M, D, S_S, $S_{L(N-S)}$, X, A_S, $S_{L(E-W)}$, G	0.931	G		9
10	P_{O-A}, E_M, D, S_S, $S_{L(N-S)}$, X, A_S, $S_{L(E-W)}$, G, L	0.938	L		10
11	P_{O-A}, E_M, D, S_S, $S_{L(N-S)}$, X, A_S, $S_{L(E-W)}$, G, L, F_S	0.939	F_S		11
12	P_{O-A}, E_M, D, S_S, $S_{L(N-S)}$, X, A_S, $S_{L(E-W)}$, G, L, F_S, S_L	0.939	S_L		12
13	P_{O-A}, E_M, D, S_S, $S_{L(N-S)}$, X, A_S, $S_{L(E-W)}$, G, L, F_S, S_L, E	0.939	E		13
14	P_{O-A}, E_M, D, S_S, $S_{L(N-S)}$, X, A_S, $S_{L(E-W)}$, G, L, F_S, S_L, E, P_{WY}	0.939	P_{WY}		14

Table 4. Summary of multiple correlation coefficients for various regression equations (stepwise) related mean water yield to climatic and physiographic factors in the Southern Division.

Equation number		Correlation coefficient	Variable entered	Variable removed	No. of variables included
1	P_{WY}	0.730	P_{WY}		1
2	P_{WY}, D	0.833	D		2
3	P_{WY}, D, X	0.867	X		3
4	P_{WY}, D, X, E	0.876	E		4
5	P_{WY}, D, X, E, A_S	0.882	A_S		5
6	P_{WY}, D, X, E, A_S, E_M	0.886	E_M		6
7	P_{WY}, D, X, E, A_S, E_M, $S_{L(E-W)}$	0.888	$S_{L(E-W)}$		7
8	P_{WY}, D, X, E, A_S, E_M, $S_{L(E-W)}$, S_L	0.892	S_L		8
9	P_{WY}, D, X, E, A_S, E_M, $S_{L(E-W)}$, S_L, L	0.900	L		9
10	P_{WY}, D, X, E, A_S, E_M, $S_{L(E-W)}$, S_L, L, P_{O-A}	0.900	P_{O-A}		10
11	P_{WY}, D, X, E, A_S, E_M, $S_{L(E-W)}$, S_L, L, P_{O-A}, $S_{L(N-S)}$	0.901	$S_{L(N-S)}$		11
12	P_{WY}, D, X, E, A_S, E_M, $S_{L(E-W)}$, S_L, L, P_{O-A}, $S_{L(N-S)}$, F_S	0.901	F_S		12

Table 5. Summary of multiple correlation coefficients for various regression equations (stepwise) related mean water yield to climatic and physiographic factors in the State.

Equation number	Independent variable in regression equation	Correlation coefficient	Variable entered	Variable removed	No. of variables included
1	P_{WY}	0.731	P_{WY}		1
2	P_{WY}, D	0.809	D		2
3	P_{WY}, D, E	0.824	E		3
4	P_{WY}, D, E, P_{O-A}	0.850	P_{O-A}		4
5	P_{WY}, D, E, P_{O-A}, X	0.858	X		5
6	P_{WY}, D, E, P_{O-A}, X, F_S	0.868	F_S		6
7	P_{WY}, D, E, P_{O-A}, X, F_S, $S_{L(N-S)}$	0.870	$S_{L(N-S)}$		7
8	P_{WY}, D, E, P_{O-A}, X, F_S, $S_{L(N-S)}$, S_L	0.875	S_L		8
9	P_{WY}, D, E, P_{O-A}, X, F_S, $S_{L(N-S)}$, S_L, G	0.877	G		9
10	P_{WY}, D, E, P_{O-A}, X, F_S, $S_{L(N-S)}$, S_L, G, L	0.881	L		10
11	D, E, P_{O-A}, X, F_S, $S_{L(N-S)}$, S_L, G, L	0.881		P_{WY}	9
12	D, E, P_{O-A}, X, F_S, $S_{L(N-S)}$, S_L, G, L, S_S	0.883	S_S		10
13	D, E, P_{O-A}, X, F_S, $S_{L(N-S)}$, S_L, G, L, S_S, A_S	0.885	A_S		11
14	D, E, P_{O-A}, X, F_S, $S_{L(N-S)}$, S_L, G, L, S_S, A_S, $S_{L(E-W)}$	0.885	$S_{L(E-W)}$		12
15	D, E, P_{O-A}, X, F_S, $S_{L(N-S)}$, S_L, G, L, S_S, A_S, $S_{L(E-W)}$, E_M	0.886	E_M		13
16	D, E, P_{O-A}, X, F_S, $S_{L(N-S)}$, S_L, G, L, S_S, A_S, $S_{L(E-W)}$, E_M, P_{WY}	0.886	P_{WY}		14

Table 6. Summary of regression equations relating climatic physiographic factors to runoff in the Great Salt Lake Division

Eq. no.	Eq. const.	Independent Variables															R
		P_{WY}	P_{O-A}	E	E_M	D	S_S	A_S	$S_{L(N-S)}$	$S_{L(E-W)}$	S_L	L	X	F_S	G	V	
1	- 5.15													22.1464			0.850
2	- 33.14			4.2151										17.2329			0.914
3	-1176.89			5.7152								10.1788		11.6122			0.929
4	-1518.80			4.6540								13.4264		7.0889		-0.5980	0.940
5	-2450.50			4.5558								20.3271	4.1889	3.9961		-1.0758	0.959
6	-2591.11			4.2832		2.0563						21.5203	4.4445	1.9431		-1.1487	0.965
7	-2057.97			3.6616		2.0383						16.8291	4.2535	3.1389	0.0539	-1.2545	0.969
8	-2274.06			4.0407		2.6183					- 9.8812	18.9883	3.7061	1.2959	0.0655	-1.4099	0.972
9	-1585.71		0.3655	1.7723		3.6651					-15.6326	12.6051	4.5909	0.1190	0.0612	-1.5009	0.977
10	-1598.37		0.3667	1.7763		3.6827					-15.7271	12.7161	4.6010		0.0610	-1.5066	0.977
11	- 894.35		0.5905	1.1250	-1.6452	4.3441					-17.7156	6.9338	3.6728		0.0468	-1.7593	0.982
12	-1093.86	-0.3702	0.9356	1.8345	-1.8105	3.3637					-17.1310	8.7230	3.6677		0.0545	-1.7888	0.985
13	-1018.97	-0.3678	1.0111	1.0786	-1.8234	3.5805		0.0066			-18.6741	8.1354	3.5676		0.0507	-1.8719	0.986
14	- 931.48	-0.3843	1.0338	1.1622	-1.8851	3.6152		0.0063	3.2857		-22.5377	7.3921	3.4374		0.0574	-1.8456	0.986
15	- 948.01	-0.3571	1.0107	1.2135	-1.8920	3.6396		0.0079	9.3685	8.2247	-35.3273	7.4982	3.5340		0.0476	-1.8258	0.987
16	- 845.64	-0.4059	1.0372	1.1926	-1.8065	3.2702		0.0088	9.4044	8.2058	-34.1444	6.5905	3.4480	1.5396	0.0511	-1.7496	0.987
17	- 969.07	-0.4303	1.0114	1.4556	-1.7604	3.2847	-2.3977	0.0082	9.0947	7.2683	-32.8566	7.7295	3.3039	1.8547	0.0626	-1.7315	0.987

Table 7. Summary of regression equations relating climatic and physiographic factors to runoff in the Uinta Division.

Eq. no.	Eq. const.	Independent Variables														R
		P_{WY}	P_{O-A}	E	E_M	D	S_S	A_S	$S_{L(N-S)}$	$S_{L(E-W)}$	S_L	L	X	F_S	G	
1	- 8.743		1.0635													0.676
2	- 26.065		0.8310		1.8603											0.782
3	- 22.855		0,6617		1.6549	4.1000										0.806
4	- 20.901		0.5205		1.8377	4.6963	-38.185									0,830
5	- 19.309		0.2022		1.8162	6.3064	-54.100		21.6726							0.862
6	-299.064		0.1971		0.7585	6.9836	-65.728		27.1738				7.1734			0.895
7	-303.300		0.0900		0.9434	6.6369	-78.8767	-0.0071	30.5681				7.3174			0.910
8	-237.401		-0.2260		1.4192	7.0850	-89.1779	-0.0111	46.6023	-17.1467			5.7311			0.922
9	-214.734		-0.1284		1.4617	7.3951	-87.6338	-0.0102	48.3329	-18.8961			5.0101		0.0578	0.931
10	-582.560		-0.2002		1.6022	6.5963	-78.3146	-0.0073	40.7394	-17.8665		2.5703	7.0527		0.0828	0.938
11	-615.570		-0.2498		1.8199	6.5237	-78.1364	-0.0074	42.3057	-17.6467		2.8150	7.1861	-1.6357	0.0787	0.939
12	-621.510		-0.2548		1.8434	6.4583	-78.2988	-0.0075	31.1284	-28.5170	21.7926	2.8615	7.2046	-1.6824	0.0789	0.939
13	-614.400		-0.2515	-0.1387	1.9308	6.4665	-78.4289	-0.0075	31.2540	-28.9888	22.5274	2.7990	7.2066	-1.8413	0.0793	0.939
14	-585.770	0.0359	-0.2720	-0.3228	1.9321	6.4975	-79.4255	-0.0076	31.4088	-29.9147	24.1151	2.5906	7.1025	-1.9209	0.0734	0.939

Table 8. Summary of regression equations relating climatic and physiographic factors to runoff in the Southern Division.

Eq. no.	Eq. const.	Independent Variables														R
		P_{WY}	P_{O-A}	E	E_M	D	S_S	A_S	$S_{L(N-S)}$	$S_{L(E-W)}$	S_L	L	X	F_S	G	
1	- 17.71	0.9918														0.730
2	- 17.61	0.7966				6.6210										0.833
3	- 85.22	0.7228				5.8236							1.8153			0.867
4	- 88.86	0.4907		1.5504		6.4473							1.7082			0.876
5	- 98.58	0.3392		2.4125		5.7982		-0.0070					1.9146			0.882
6	- 92.41	0.2093		3.0889	-0.7131	5.8428		-0.0073					1.8907			0.886
7	- 97.75	0.1871		2.9892	-0.7172	6.1110		-0.0074		- 5.3040			2.0910			0.888
8	- 88.97	0.2077		2.6495	-0.6043	5.0436		-0.0063		- 32.2645	33.1928		1.8662			0.892
9	-215.55	0.2756		2.0300	-0.2363	4.6891		-0.0043		- 52.3086	53.5927	1.0164	2.1879			0.900
10	-213.60	0.1675	0.1347	2.0576	-0.1657	4.8664		-0.0044		- 52.7234	52.9772	1.0087	2.1482			0.900
11	-213.92	0.1900	0.1291	2.0175	-0.1657	4.6885		-0.0049	-54.288	-107.099	161.455	0.9860	2.2268			0.901
12	-200.08	0.1619	0.1372	2.1542	-0.3274	4.7550		-0.0052	-68.945	-121.384	189.970	0.8679	2.2278	0.7191		0.901

Table 9. Summary of regression equations relating climatic and physiographic factors to runoff in the State.

Eq. no.	Eq. const.	Independent Variables														R
		P_{WY}	P_{O-A}	E	E_M	D	S_S	A	$S_{L(N-S)}$	$S_{L(E-W)}$	S_L	L	X	F_S	G	
1	- 11.241	0.7286														0.731
2	- 12.770	0.6457				5.8553										0.809
3	- 18.439	0.5814		0.8291		6.3221										0.824
4	- 23.683	0.1793	0.5119	1.6835		5.4617										0.850
5	- 50.696	0.1242	0.5082	1.7550		5.7277							0.6946			0.858
6	- 62.792	0.0793	0.4876	1.8237		5.4816							0.9629	3.6508		0.868
7	- 62.772	0.0873	0.4385	1.8748		5.2751			4.6228				0.9515	3.2914		0.870
8	- 63.709	0.1061	0.4224	1.7112		5.3814			16.0537		-16.3283		1.0245	3.5626		0.875
9	- 64.1219	0.0292	0.4755	1.8754		5.5215			18.3887		-20.0629		0.9712	3.9739	0.0331	0.877
10	-187.742	0.0066	0.4384	2.3382		5.3973			19.9707		-22.0191	0.9931	1.2289	3.5152	0.0447	0.881
11	-188.352		0.4438	2.3532		5.3979			19.9889		-22.0679	0.9967	1.2320	3.5314	0.0453	0.881
12	-185.726		0.4541	2.2564		5.8812	- 9.2246		20.8500		-23.3081	0.9607	1.2480	4.1156	0.0645	0.883
13	-181.308		0.4385	2.3419		5.6994	- 9.3932	-0.0027	21.1435		-23.4718	0.9212	1.2537	4.1227	0.0625	0.885
14	-185.755		0.4431	2.3324		5.7697	- 9.6819	-0.0023	30.9700	11.6722	-44.3254	0.9501	1.2868	3.9579	0.0597	0.885
15	-165.501		0.4409	2.5845	-0.3468	5.8292	-10.4255	-0.0024	31.5949	12.5369	-45.2524	0.7988	1.2315	4.6116	0.0562	0.886
16	-167.855	-0.0218	0.4579	2.6305	-0.3351	5.8190	-10.4451	-0.0025	31.5100	12.3352	-45.0893	0.8126	1.2434	4.6484	0.0586	0.886

Principal Component Analysis

The particular principal component analysis computer program used in this study was BMDO2M, "Regression on Principal Components," from the program library of Western Data Processing Center. This program computes the principal components of standardized data and regresses the dependent variable on the principal components.

Tables 10, 11, 12 and 13 show the eigenvectors of the orthogonal factors for the watersheds in the Great Salt Lake division, Uinta division, Southern division, and the entire state respectively. These eigenvectors are the linear transformation necessary to define each orthogonal factor. The orthogonal factors for the three divisions and the entire state are shown in Tables 14, 15, 16 and 17 respectively. The coefficients of regression equations using orthogonal factors for standardized independent variables for the Great Salt Lake division are tabulated in Table 18 and those for the Uinta, Southern and entire state are tabulated in Tables 19, 20 and 21 respectively. The output also contains the reduction in residual sum of squares due to using orthogonal factors and correlation coefficients of the stepwise regression equations. These are shown in Tables 22, 23 and 24 for the three divisions and in Table 25 for the entire state.

Table 10. Summary of eigenvectors of the orthogonal factors for the watersheds in the Great Salt Lake Division.

		Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9	Factor 10	Factor 11	Factor 12	Factor 13	Factor 14	Factor 15
1	P_{WY}	-0.3301	-0.0784	-0.0254	-0.2525	-0.3646	-0.0124	-0.0433	-0.1810	-0.1055	-0.0945	-0.0526	-0.1176	-0.3560	-0.0701	-0.6960
2	P_{O-A}	-0.3495	-0.0483	-0.0280	-0.1822	-0.2628	0.0355	-0.0298	-0.2533	-0.2171	0.0209	0.0764	0.1203	-0.2404	-0.4491	0.6153
3	E	-0.2330	0.3213	-0.2543	0.1128	-0.4133	0.1832	0.0534	0.0866	-0.1101	-0.4769	0.1162	0.2529	0.4084	0.2546	0.0255
4	E_M	-0.2724	0.3517	0.0464	-0.0472	0.0357	0.1449	0.2694	0.0879	-0.3668	0.5930	0.2665	-0.3067	0.1398	0.1566	-0.0361
5	D	-0.1815	0.0481	-0.1479	0.7426	0.2259	0.1130	-0.0649	-0.3841	-0.2297	0.0863	-0.2514	0.1509	-0.1149	-0.0480	-0.1196
6	S_S	-0.1636	-0.4203	0.0501	0.3973	0.0085	-0.0623	0.3460	0.4485	-0.0615	-0.2132	0.4409	-0.0972	-0.1678	-0.1695	-0.0380
7	A_S	0.1998	0.0881	-0.5773	0.1092	-0.2693	-0.3548	0.4039	-0.2303	0.3510	0.1981	0.0697	-0.1276	-0.0191	-0.0944	0.0146
8	$S_{L(N-S)}$	-0.2932	0.1029	-0.0664	-0.0417	0.2149	-0.6719	-0.1891	0.1675	-0.1634	-0.0598	-0.1323	-0.0464	0.3971	-0.3417	-0.1061
9	$S_{L(E-W)}$	-0.2341	-0.1550	-0.4200	-0.1492	0.3328	0.4767	-0.2134	-0.0182	0.3391	0.0604	0.2268	-0.0544	0.2470	-0.2937	-0.1309
10	S_L	-0.3159	0.0195	-0.3353	-0.0951	0.2962	-0.2375	-0.2187	0.0535	0.0536	-0.1150	0.1133	-0.0988	-0.4152	0.5714	0.2138
11	L	-0.2138	-0.4274	0.2287	-0.0145	-0.0816	-0.2224	-0.0103	-0.3307	0.1511	0.2854	0.2902	0.4353	0.2902	0.2970	-0.0555
12	X	0.2776	-0.0052	-0.1569	0.2231	-0.3700	-0.0579	-0.6815	0.2214	-0.1300	0.2844	0.2996	0.0032	-0.0667	-0.0416	-0.0304
13	F_S	-0.3043	-0.0291	0.3065	0.2707	-0.2717	0.0229	-0.1834	-0.0741	0.4350	-0.0270	-0.1691	-0.5884	0.1573	0.0803	0.1724
14	G	-0.0880	-0.4985	-0.3093	-0.0687	-0.1906	0.1135	0.0756	0.3312	-0.1915	0.2442	-0.5739	0.0029	0.1347	0.1635	0.0941
15	V	0.2776	-0.3330	-0.1196	-0.0766	0.0631	-0.0120	-0.0411	-0.4258	-0.4531	-0.2760	0.1751	-0.4632	0.2544	0.1073	0.0488

Table 11. Summary of eigenvectors of the orthogonal factors for the watersheds in the Uinta Division.

		Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9	Factor 10	Factor 11	Factor 12	Factor 13	Factor 14
1	P_{WY}	0.3771	0.2097	-0.0928	0.2159	0.3327	0.1059	0.0748	0.2845	0.1769	0.4342	0.0944	0.3808	0.4199	0.0093
2	P_{O-A}	0.3241	-0.1431	-0.3993	0.0062	0.1397	0.2652	0.1584	-0.0054	-0.1132	-0.4063	0.6102	0.0339	-0.2185	-0.0116
3	E	0.3682	0.3187	0.0293	-0.0504	0.1788	0.1532	-0.0426	-0.1685	0.3601	-0.1466	-0.4370	0.1561	-0.5546	-0.0128
4	E_M	0.4064	0.2603	0.0218	-0.1277	-0.0264	-0.2259	-0.0163	0.0066	0.2656	-0.0813	-0.1033	0.7355	0.2655	0.0205
5	D	0.2497	0.0064	-0.3317	0.2821	-0.1501	-0.1773	-0.7597	-0.0363	-0.2849	-0.0867	-0.1413	0.0673	0.0612	-0.0106
6	S_S	0.0591	0.0973	0.3337	0.3420	-0.6013	0.4741	-0.1332	0.2236	0.1849	0.0743	0.2091	-0.0575	-0.1256	-0.0037
7	A_S	-0.0465	0.0831	0.0201	-0.7641	0.0483	0.2149	-0.4406	0.2210	-0.0166	0.2492	0.2149	0.0362	-0.0980	-0.0053
8	$S_{L(N-S)}$	0.3017	-0.3373	0.1810	-0.1550	0.0361	0.4344	0.0675	0.0418	-0.2692	-0.1766	-0.3904	-0.0892	0.3124	-0.4244
9	$S_{L(E-W)}$	0.1574	-0.2819	0.4530	0.0882	0.1841	-0.2928	-0.1995	-0.3253	0.1413	0.1694	0.3515	0.0839	-0.1460	-0.4630
10	S_L	0.2590	-0.3539	0.3662	-0.0177	0.1237	0.0704	-0.0943	-0.1711	-0.0719	-0.0140	-0.0041	0.0258	0.0610	0.7775
11	L	0.1277	-0.4553	-0.2959	0.1128	0.0172	-0.0154	0.1062	0.2298	-0.0133	0.5499	-0.1564	-0.3482	-0.4067	0.0075
12	X	0.2183	0.4117	0.0795	-0.0469	-0.1559	0.0364	0.2310	-0.3851	-0.6277	0.3597	0.0725	-0.0355	-0.1199	0.0012
13	F_S	0.3371	-0.0549	0.1769	-0.1951	-0.3301	-0.5101	0.2150	0.4968	-0.1451	-0.1708	-0.0301	0.2865	-0.1357	-0.0076
14	G	-0.1532	0.2270	0.3342	0.2628	0.5164	0.0182	-0.1192	0.4536	-0.3565	-0.1490	0.0253	-0.2430	-0.2188	-0.0016

Table 12. Summary of eigenvectors of the orthogonal factors for the watersheds in the Southern Division.

		Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9	Factor 10	Factor 11	Factor 12	Factor 13	Factor 14
1	P_{WY}	0.2552	0.4708	-0.0433	-0.1833	-0.1158	-0.0660	-0.0580	-0.1262	-0.0982	-0.1225	-0.3682	-0.1545	-0.6757	-0.0070
2	P_{O-A}	0.2693	0.3999	-0.0647	-0.1116	-0.2875	0.0158	-0.0663	-0.3779	0.3432	0.5035	0.1255	0.2492	0.2709	0.0014
3	E	0.1610	0.4682	0.2635	-0.2161	-0.0087	0.0895	0.2247	0.1878	-0.1357	-0.2883	0.4658	-0.3940	0.2756	-0.0006
4	E_M	-0.1120	-0.0642	0.4925	-0.3184	0.4610	-0.1440	-0.0540	0.1061	0.3328	0.3393	0.2189	0.0039	-0.3424	0.0027
5	D	0.3367	-0.0188	-0.2855	-0.0959	0.3818	0.1687	-0.1700	0.2071	-0.5004	0.5092	-0.0467	-0.1702	0.0977	0.0027
6	S_S	0.2873	0.0624	-0.1664	-0.1465	0.5618	0.2571	0.2126	-0.0677	0.3606	-0.3539	-0.2979	0.2211	0.1991	0.0058
7	A_S	-0.1380	0.0434	0.4727	0.1353	-0.0605	0.6512	0.3207	-0.1609	-0.2704	0.1750	-0.1929	0.1762	-0.0676	0.0061
8	$S_{L(N-S)}$	0.4282	-0.2236	0.0165	-0.0044	-0.0281	-0.0135	0.0149	-0.1161	-0.2375	-0.1945	0.4539	0.4597	-0.2541	0.4201
9	$S_{L(E-W)}$	0.2802	-0.4274	0.0796	-0.0981	-0.2010	0.0941	0.1643	-0.1677	0.2476	0.0937	-0.1645	-0.5761	0.0345	0.4321
10	S_L	0.3758	-0.3526	0.0620	-0.0570	-0.1169	0.0501	0.1090	-0.1501	0.0114	-0.0451	0.1515	-0.0651	-0.1114	-0.7979
11	L	-0.1301	-0.0950	-0.3133	-0.5228	-0.3391	0.1836	0.3436	0.5063	0.1022	0.1079	0.0031	0.2094	-0.1213	0.0051
12	X	0.2947	-0.0007	0.2709	0.1720	-0.2102	0.2946	-0.5715	0.5115	0.2424	-0.1045	-0.1145	0.0785	0.0377	-0.0048
13	F_S	-0.1411	-0.1515	0.1916	-0.6635	-0.0805	-0.0051	-0.4147	-0.2779	-0.2699	-0.1980	-0.1834	0.0893	0.2664	-0.0053
14	G	0.2867	-0.0052	0.3613	0.0305	-0.0761	-0.5620	0.3258	0.2490	-0.1731	0.0877	-0.3910	0.2107	0.2403	0.0007

Table 13. Summary of eigenvectors of the orthogonal factors for the watersheds in the State.

		Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9	Factor 10	Factor 11	Factor 12	Factor 13	Factor 14
1	P_{WY}	-0.2350	-0.4532	0.0388	0.2776	0.1101	0.2781	0.0882	0.2072	0.0987	0.0235	0.0226	0.1076	0.7054	0.0150
2	P_{O-A}	-0.3472	-0.2251	-0.0121	0.2593	0.3029	0.2365	-0.1429	0.2481	0.0510	0.1450	-0.4514	-0.1692	-0.5268	-0.0091
3	E	0.2022	-0.5174	-0.1314	0.0055	-0.0390	-0.0761	0.1420	0.1453	0.0064	0.1972	0.3810	0.5418	-0.3856	-0.0041
4	E_M	0.1572	-0.4421	-0.3528	-0.0938	-0.1283	-0.0391	0.1919	-0.1227	-0.0421	0.0357	0.1290	-0.7346	-0.0249	-0.0143
5	D	-0.2317	-0.0372	-0.2192	0.3387	-0.0620	-0.7568	-0.0566	0.0721	0.3631	-0.2436	-0.0606	0.0198	0.0253	0.0138
6	S_S	-0.2825	-0.0607	0.1668	0.1970	-0.5983	-0.1346	-0.3373	-0.0160	-0.3794	0.4549	0.0705	-0.0580	0.0277	-0.0124
7	A_S	0.2696	-0.1776	-0.0374	-0.4099	-0.0302	-0.0222	-0.7083	0.3768	0.2633	0.0009	-0.0588	-0.0489	0.1185	0.0197
8	$S_{L(N-S)}$	-0.3691	-0.0927	-0.1466	-0.2549	0.2440	-0.1117	-0.1250	0.1147	-0.5452	-0.3398	0.2002	0.0257	-0.0062	0.4648
9	$S_{L(E-W)}$	-0.3431	0.0143	0.0081	-0.4991	-0.0929	-0.0743	0.2872	-0.0874	0.3843	0.4243	-0.1570	0.0527	0.0375	0.4149
10	S_L	-0.4012	-0.0219	-0.0749	-0.4160	0.1219	-0.1179	0.0568	0.0296	-0.0942	0.0206	0.0504	0.0514	0.0418	-0.7810
11	L	-0.2469	0.3819	-0.2396	0.1567	0.0592	0.2635	-0.1004	0.2016	0.3078	0.1388	0.6561	-0.1679	-0.0858	0.0124
12	X	-0.1021	-0.2464	0.4775	0.0212	0.3443	-0.0857	-0.3046	-0.5897	0.1906	0.0122	0.2976	-0.0914	-0.0607	0.0163
13	F_S	-0.1917	-0.1033	-0.4595	-0.0144	-0.3357	0.3713	-0.2400	-0.4863	0.1430	-0.3001	-0.1408	0.2548	-0.0584	-0.0098
14	G	-0.1714	-0.1332	0.5055	-0.1141	-0.4445	0.1465	0.1855	0.2555	0.1882	-0.5163	0.1257	-0.1139	-0.2061	-0.0086

Table 14. Values of each orthogonal factor for the 26 watersheds in the Great Salt Lake Division.

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9	Factor 10	Factor 11	Factor 12	Factor 13	Factor 14	Factor 15
Woodruff Cr.	0.5083	0.3421	-0.3980	0.1202	-0.0872	-0.0714	0.0371	-0.0665	0.0134	-0.0689	0.0381	-0.0247	-0.0928	0.0621	0.0286
Farmington Cr.	-0.1833	-0.3129	-0.0144	-0.2204	-0.2592	-0.1876	-0.0084	-0.0410	-0.1516	0.0034	-0.1034	0.0366	-0.0275	-0.0238	0.0166
Holmes Cr.	-0.5662	-0.3954	-0.3184	0.2909	0.1975	-0.1099	-0.1379	0.1280	0.0007	0.0681	0.0077	0.0668	0.0321	0.0229	0.0197
Parrish Cr.	-0.1613	-0.5148	-0.0837	0.1845	0.0807	0.1859	0.0215	-0.0279	0.0009	0.0979	-0.0149	-0.0519	-0.0136	0.0132	-0.0340
Rick Cr.	0.0813	-0.6684	0.0623	0.0047	-0.1977	0.3038	0.1069	0.0711	0.1763	-0.1167	0.0908	-0.0172	0.0168	-0.0025	0.0241
Centerville Cr.	-0.0506	-0.5796	0.0105	0.0197	-0.0046	-0.0843	0.1145	0.1457	-0.0486	-0.0136	0.0534	-0.0383	-0.0418	-0.0309	-0.0116
City Cr.	-0.0497	-0.0676	0.2786	-0.0842	-0.1158	-0.1746	-0.0197	-0.1541	-0.0130	-0.0762	-0.0185	-0.0471	0.0494	0.0498	-0.0295
Blacksmith Fork	0.6236	0.0630	0.1018	0.0468	-0.1030	0.0145	-0.0950	0.0252	0.0339	0.1261	-0.0033	-0.0135	0.0400	0.0334	0.0131
E. Fk. Little Bear R.	0.4856	-0.0110	0.0456	-0.0767	-0.1105	0.0312	-0.0762	-0.0129	-0.0067	0.0834	0.0571	0.0593	0.0337	0.0214	-0.0028
Hardscrabble Cr.	0.2006	-0.1072	-0.1308	-0.1228	-0.0339	-0.0655	0.0918	-0.1629	0.1270	0.0737	-0.0351	0.0733	0.0094	-0.0278	0.0494
Mill Cr. nr. Bountiful	-0.1325	-0.2156	0.0622	-0.0898	-0.1100	-0.1624	0.0185	-0.0560	-0.0699	-0.0212	-0.0518	-0.0316	0.0076	0.0155	0.0056
Stone Cr.	-0.0674	-0.5019	-0.0345	0.0719	0.0358	-0.1674	0.0663	0.1097	-0.0632	-0.0374	-0.0597	0.0027	-0.0002	0.0114	-0.0175
South Fk. Ogden R.	0.7149	0.2560	0.1442	0.0062	0.2123	0.1388	-0.0914	0.2150	-0.0669	-0.1845	-0.0813	0.0902	0.0093	0.0055	0.0036
Lost Cr.	0.3350	0.0552	0.0967	0.0880	0.0363	0.0910	-0.1786	-0.0616	0.0445	-0.0337	-0.0045	-0.0590	0.0060	-0.0160	0.0169
Big Cr.	0.6579	0.3416	-0.4254	0.1594	0.2052	-0.2410	-0.0876	0.0598	0.0530	-0.0158	0.0268	-0.0748	0.0301	-0.0383	-0.0204
Birch Cr.	1.0301	0.3275	-0.1126	0.1730	-0.3286	0.0341	0.3172	-0.0166	-0.0434	0.0277	-0.0086	0.0303	0.0222	-0.0276	-0.0303
Hobble Cr.	0.0244	0.2557	0.0583	-0.2741	0.4173	0.2225	0.2395	0.0918	-0.0466	0.1149	-0.0949	-0.0711	-0.0025	0.0125	0.0233
American Fork	-0.7105	0.3255	-0.1139	-0.2549	0.0318	0.1138	-0.0007	0.0070	-0.0873	-0.0433	0.0416	-0.0337	0.0274	-0.0012	0.0032
Fork Cr.	-0.3100	0.3540	0.6719	0.2741	0.1654	-0.2537	0.1671	0.0528	-0.0005	0.0349	0.1171	0.0240	-0.0197	-0.0007	0.0143
Dry Cr.	-0.9804	0.2496	-0.0379	0.6208	0.0292	0.1859	0.0154	-0.1995	-0.0827	-0.0460	-0.0530	0.0121	0.0081	-0.0176	0.0053
Big Cottonwood Cr.	-0.6493	0.2720	-0.2421	-0.2769	-0.0733	0.1709	0.0457	0.0119	-0.0563	0.0250	0.0967	0.0807	-0.0104	0.0155	-0.0405
Parleys Cr.	0.2126	-0.0652	0.1975	-0.1347	0.1176	0.0824	-0.0269	-0.1622	0.1165	-0.0577	-0.0527	0.0067	-0.0193	-0.0068	-0.0201
Mill Cr. nr. SLC	-0.3629	0.0923	-0.1172	-0.3041	0.0793	-0.0994	-0.0315	-0.0689	-0.0845	-0.0656	0.1014	-0.0326	0.0298	-0.0252	0.0264
Emigration Cr.	0.1871	-0.1477	0.0548	-0.1610	0.4224	-0.0501	-0.1221	-0.1382	0.1027	0.0261	0.0188	0.0546	-0.0412	-0.0152	-0.0337
Little Cottonwood Cr.	-1.0916	0.5125	0.0024	-0.0754	-0.3028	-0.1056	-0.0314	0.1790	0.2658	0.0093	-0.0892	-0.0124	-0.0106	-0.0049	-0.0126
Logan River	0.2544	0.1401	0.2424	0.0147	-0.3042	0.1670	-0.3341	0.0711	-0.1136	0.0903	0.0216	-0.0295	-0.0422	-0.0245	0.0029

Table 15. Values of each orthogonal factor for the 34 watersheds in the Uinta Division.

Stations	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9	Factor 10	Factor 11	Factor 12	Factor 13	Factor 14
Little Brush Cr.	-0.5210	0.3082	0.0357	-0.0855	0.1316	0.0059	-0.0278	-0.0174	-0.1866	-0.0035	-0.0295	0.0116	0.0422	0.0007
Bruch Cr.	-0.3378	0.1021	0.3859	-0.0167	0.1853	0.1160	-0.1269	-0.2386	-0.0295	0.1181	0.1314	0.0081	-0.0125	
Ashley Cr.	-0.2629	0.2112	0.0965	-0.1844	-0.0766	-0.1503	-0.0345	0.0863	0.0157	-0.0706	-0.0307	-0.0456	0.0480	0.0019
Ashley Cr. below Trout Cr.	-0.4629	0.4281	-0.1531	-0.0952	0.1297	0.0644	0.1053	-0.0765	-0.0014	0.0732	-0.0797	0.0767	0.0031	0.0045
South Fork Ashley Cr.	-0.1043	0.3584	-0.1135	-0.1059	0.1410	0.1192	0.1248	-0.0562	0.0229	-0.0291	-0.0489	-0.0288	0.0373	0.0001
East Fork Dry Fork	-0.3184	0.2720	0.0757	0.3013	0.0966	-0.1216	0.0881	-0.1500	0.0263	-0.0581	-0.0300	-0.0238	-0.0439	-0.0016
East Fk. Dry Fk. at mouth	-0.2301	0.1498	0.2202	0.2639	-0.0746	-0.1756	0.1171	-0.0376	-0.0411	-0.1017	-0.0214	0.0070	-0.0163	0.0006
North Fork Dry Fork	-0.1490	0.3294	0.1992	0.0358	-0.1810	0.0846	-0.1936	0.1604	-0.0028	0.0068	-0.0049	-0.1127	-0.0247	0.0011
Dry Fork	-0.0494	0.2500	-0.0588	-0.1933	-0.0244	-0.0294	0.0517	-0.0431	0.0856	0.0061	-0.0077	0.0128	0.0141	0.0027
Whiterocks River	0.2297	0.1340	0.0548	-0.1684	0.0401	-0.1191	0.0213	0.1377	-0.0622	-0.0802	0.0616	0.0875	-0.0262	-0.0011
Whiterocks River above P.C.	0.1696	0.2238	0.0054	-0.1078	0.1109	0.0167	-0.0413	0.0030	0.0278	0.0161	0.0005	0.0514	-0.0050	-0.0009
Carter Cr.	-0.0772	0.3021	0.0019	-0.0412	-0.1079	0.0486	0.1577	-0.0359	-0.0047	-0.0427	0.0469	-0.0393	-0.0543	0.0008
Farm Cr.	-0.2429	-0.1976	0.4923	-0.0915	-0.1015	-0.0100	-0.1347	-0.0730	-0.1496	0.0459	-0.0679	0.0394	-0.0074	-0.0004
Clover Cr.	0.1434	0.3252	0.1144	0.4913	-0.3129	0.0486	-0.0006	0.1038	0.2430	0.1370	-0.0069	0.1073	0.0139	0.0008
Uinta R. above Clover Cr.	0.4919	0.0483	0.0315	-0.2206	0.1113	0.1123	-0.0138	-0.0468	0.0485	-0.0191	-0.0444	-0.0365	0.0646	-0.0000
Uinta R. below Gilbert Cr.	0.4581	0.3046	-0.2042	0.0172	0.1390	0.2014	-0.0791	-0.0491	0.0984	0.0224	-0.0077	-0.0453	-0.0072	0.0015
Yellowstone Cr. bel. S. Cr.	0.4834	0.0500	0.0753	-0.1513	0.1400	-0.1130	-0.1272	0.0166	0.0328	0.0281	0.0163	-0.0382	-0.0368	0.0026
Yellowstone Cr.	0.4436	0.0101	0.0121	-0.2867	-0.0882	-0.2657	0.0013	0.0525	0.0800	0.0218	-0.0343	0.0261	0.0076	0.0025
Lake Fork	0.5142	-0.0105	-0.0581	-0.1608	0.0452	0.0531	-0.0794	0.0079	0.0563	0.0314	0.0008	-0.0187	0.0068	-0.0018
Rock Cr. nr. Mt. Home	0.4182	-0.1740	0.0901	-0.1906	0.0999	-0.1763	-0.0114	0.1109	-0.0568	0.0256	0.0175	0.0319	-0.0435	-0.0010
Rock Cr. nr. Hanna	0.4318	-0.1330	0.0286	0.2066	0.1455	-0.0654	0.1448	-0.0852	0.0271	-0.0476	-0.0745	-0.0271	-0.0370	0.0013
Duchesne River	0.3042	-0.1105	-0.1701	0.2221	0.1006	-0.0791	0.1885	-0.1117	0.0124	0.0297	0.0752	-0.0446	0.0096	0.0036
Provo River	0.2273	0.0609	-0.7142	0.4655	-0.0808	-0.1333	-0.3897	-0.0442	-0.1819	-0.0060	-0.0258	0.0058	-0.0162	-0.0030
Weber River	0.3445	-0.3865	0.0296	0.0972	0.0546	-0.1593	0.1604	-0.0393	-0.2055	0.0839	0.0632	0.0208	0.0478	0.0018
Wolf Cr.	-0.1380	-0.3366	-0.2422	-0.0943	-0.1561	0.2413	0.0144	0.0226	-0.1274	-0.0050	-0.0378	0.0376	-0.0338	0.0255
West.Fork Duchesne River	-0.2712	-0.1568	-0.3774	-0.1456	-0.0992	0.0125	0.1863	0.1412	-0.0519	0.0391	-0.0691	0.0034	-0.0122	-0.0248
West Fork Duchesne River below Dry H.	-0.2029	-0.1872	-0.3993	-0.0290	-0.0679	0.1518	0.0352	0.0467	-0.0297	0.0651	-0.0189	-0.0292	-0.0403	-0.0056
Water Hollow	-0.1359	-0.6409	-0.3628	-0.2732	-0.4514	0.0059	0.0089	-0.2587	0.1317	-0.0520	0.0519	0.0040	0.0093	-0.0022
White River	-0.5139	-0.4438	-0.1080	-0.0527	0.3089	0.1023	-0.0418	0.2060	0.0527	0.0435	0.0778	-0.0175	-0.0052	0.0026
North Fork White River	-0.4447	-0.3613	-0.2137	0.3261	0.2443	-0.0500	0.0957	0.1558	0.1136	-0.0500	0.0485	-0.0074	0.0352	0.0045
Minnie Maud Cr.	-0.5585	-0.6396	0.3221	0.0022	0.1129	-0.1686	-0.2356	-0.0530	0.1870	-0.0225	-0.0757	-0.0016	-0.0024	-0.0002
Carter Creek at mouth	-0.2598	0.2846	0.2438	-0.0273	-0.4089	-0.1035	0.0671	0.0859	-0.0526	0.0406	0.0926	-0.0721	0.0247	0.0037
Brown Duck Cr.	0.1077	0.1701	0.0234	0.0169	-0.0113	0.2298	-0.1287	0.0225	0.0011	-0.2151	0.0941	0.0877	0.0094	-0.0067
Hades Cr.	0.5132	-0.5442	0.6370	0.2759	-0.0949	0.3055	0.0976	0.0565	-0.0794	-0.0311	-0.0622	-0.0194	0.0188	-0.0054

Table 16. Values of each orthogonal factor for the 24 watersheds in the Southern Division.

Stations	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9	Factor 10	Factor 11	Factor 12	Factor 13	Factor 14
Summit Cr.	0.9094	-0.4211	0.1254	-0.1616	0.0436	0.0974	0.1698	0.0834	0.0681	-0.0586	-0.0587	-0.1117	-0.0061	0.0018
Price River	0.0207	0.3664	0.0806	0.4312	-0.4577	0.0370	-0.0667	0.0503	0.1255	-0.0129	-0.0504	0.0207	-0.0255	-0.0061
Gooseberry Cr.	0.3355	0.3234	-0.1420	0.0062	-0.4334	-0.1873	-0.3625	-0.0162	0.0078	-0.0302	0.0075	-0.0673	0.0120	0.0080
Pleasant Cr.	0.7122	0.2099	-0.1379	-0.1574	0.1606	0.1310	-0.1391	0.0004	0.0321	0.0475	-0.1340	0.0304	-0.0058	-0.0024
Huntington Cr.	0.2581	-0.0296	0.3269	0.1618	-0.2537	0.1530	0.0415	0.0209	-0.0366	0.0951	0.1284	0.0292	-0.0097	-0.0002
Cottonwood Cr.	-0.0282	-0.0159	0.3643	-0.0833	-0.0984	0.1677	-0.1297	-0.0469	0.0109	-0.0072	0.0289	-0.0402	0.0225	-0.0025
Ferron Cr.	-0.1266	-0.0777	0.3126	0.0502	-0.0737	0.1093	-0.0378	0.0511	-0.0274	-0.0314	0.0163	0.0202	0.1257	-0.0011
Muddy Cr.	-0.1094	0.2701	0.2659	0.0197	-0.0547	0.0234	-0.0436	0.0422	-0.0628	-0.0589	-0.0626	0.1368	-0.0493	0.0044
Twin Cr.	0.8590	-0.2677	-0.1726	-0.0484	0.1955	0.1633	-0.1293	0.0388	-0.2090	0.0418	0.0876	0.0628	-0.0102	-0.0015
Ivie Cr.	-0.2631	-0.3770	0.0940	0.3142	0.1995	0.0929	0.1168	0.1946	0.1294	0.0954	-0.0353	-0.0801	-0.0269	0.0024
Chalk Cr. nr. Fillmore	0.2618	-0.3271	-0.2710	0.1263	-0.0902	0.0639	0.1156	0.1146	0.1495	-0.0353	0.0193	0.0893	0.0100	0.0011
Indian Cr.	0.5027	0.2305	0.1900	0.3636	0.3097	-0.3066	0.2897	-0.2887	0.0590	0.0560	0.0347	0.0407	0.0200	0.0026
Center Cr.	-0.1962	-0.3641	0.0624	-0.4357	-0.0442	-0.1007	0.1599	-0.0127	-0.0349	-0.1194	-0.1006	0.0751	0.0069	0.0001
Beaver River	-0.0488	0.1567	0.1112	-0.5165	0.0889	-0.1664	-0.0579	0.0460	0.1069	0.0431	0.1075	0.0229	-0.0506	-0.0011
Sevier River	-0.7412	0.1191	-0.0362	-0.0907	0.0303	-0.0497	0.0829	0.2034	-0.1469	0.1892	-0.0390	0.0104	0.0224	0.0026
Castle Cr.	0.0942	-0.3023	0.2730	0.1474	0.0391	-0.3897	-0.1290	-0.0642	-0.2008	0.0243	-0.0830	-0.0808	-0.0214	-0.0035
Mill Cr. nr. Moab	-0.6149	-0.3255	0.2566	0.0504	0.4721	-0.1708	-0.3573	0.0093	0.1478	-0.0731	0.0458	0.0194	0.0058	-0.0006
North Cr.	-0.4865	-0.1220	-0.0845	0.0213	0.0209	0.3256	0.0183	-0.1507	-0.0671	-0.0591	0.0636	-0.0586	-0.0690	0.0008
Pine Cr.	-0.5022	-0.1325	-0.1576	0.0207	0.0254	0.4006	-0.0538	-0.2913	0.0057	0.0412	-0.0764	0.0007	0.0179	0.0016
Coal Cr.	-0.0976	-0.0189	-0.1376	-0.3758	-0.2248	-0.0826	0.1910	-0.0368	0.0047	-0.0404	0.0833	-0.0616	0.0293	-0.0009
East Fork Boulder Cr.	-0.2443	0.8664	0.3303	-0.0905	0.0665	0.0278	0.2550	0.0416	-0.0419	-0.0731	-0.0113	-0.0418	-0.0139	-0.0012
East Fork Deer Cr.	0.0554	0.7178	-0.6470	0.0683	0.4458	0.0512	-0.0647	0.0801	-0.0073	-0.0470	0.0140	-0.0414	0.0271	-0.0011
Henrieville Cr.	-0.3235	-0.3423	-0.5128	0.4093	-0.1236	-0.1853	0.1146	0.0561	-0.1157	-0.1264	0.0379	0.0125	-0.0083	-0.0008
North Fork Virgin R.	-0.2266	-0.1367	-0.4939	-0.2308	-0.2434	-0.2050	0.0163	-0.1253	0.1031	0.1392	-0.0234	0.0126	-0.0029	-0.0025

Table 17. Values of each orthogonal factor for the 84 watersheds in the State.

Stations	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9	Factor 10	Factor 11	Factor 12	Factor 13	Factor 14
(Great Salt Lake Division)														
Woodruff Cr.	-0.0189	0.1153	0.1061	-0.0458	0.1621	-0.1032	-0.0738	0.0026	0.0824	-0.0074	0.0229	0.0199	0.0138	-0.0884
Farmington Cr.	-0.3766	-0.0542	0.1858	0.0760	0.0532	0.1830	-0.0481	0.1129	-0.0416	-0.0903	-0.0040	-0.0220	-0.0014	-0.0013
Holmes Cr.	-0.6707	-0.0277	0.1112	-0.0762	-0.1751	-0.1708	-0.0820	0.0420	-0.0242	-0.0068	0.0382	-0.0082	-0.0371	0.0036
Parrish Cr.	-0.4302	0.0477	0.1773	0.0577	-0.2319	-0.0477	-0.0381	-0.0121	0.1162	0.0449	-0.0252	-0.0304	0.0088	0.0015
Rick Cr.	-0.2961	0.0997	0.2944	0.1096	-0.3100	0.1644	-0.0707	-0.0473	0.0974	0.1817	-0.0463	0.0430	-0.0129	-0.0016
Centerville Cr.	-0.4091	0.0575	0.2600	0.0685	-0.2262	0.0538	-0.1181	0.0326	-0.0970	0.0759	0.0272	-0.0386	0.0144	-0.0009
City Cr.	-0.2351	0.0465	0.0138	0.0967	0.0929	0.1324	-0.0656	-0.0399	-0.0574	-0.0764	0.0034	0.0311	0.0436	-0.0006
Blacksmith Fork	0.0467	0.2055	0.1505	0.0373	0.0822	0.0334	-0.0373	-0.1156	0.0649	-0.0591	0.0306	-0.0143	-0.0072	0.0040
East Fork Little Bear R.	-0.0194	0.1629	0.1763	0.0303	0.1057	0.0629	-0.0073	-0.0555	0.0601	-0.0046	0.0184	-0.0208	-0.0017	0.0057
Hardscrabble Cr.	-0.1639	0.1174	0.1408	-0.0283	0.0966	0.0594	-0.0328	0.0424	0.0877	-0.0189	-0.0344	-0.0106	-0.0117	0.0067
Mill Cr. nr. Bountiful	-0.3352	0.0049	0.1072	0.0587	0.0191	0.1078	-0.0655	0.0341	-0.0504	-0.0640	0.0048	-0.0072	0.0132	-0.0059
Stone Cr.	-0.4121	0.0656	0.2270	0.0442	-0.1700	0.0007	-0.1074	0.0483	-0.0942	-0.0183	0.0507	-0.0098	0.0106	-0.0001
South Fork Ogden River	0.0878	0.2994	0.1749	0.0142	0.1220	-0.0815	0.0500	-0.1122	-0.0314	-0.0026	0.0567	0.0293	-0.0149	0.0039
Lost Cr.	-0.1160	0.1683	0.0676	0.0362	0.0842	-0.0106	-0.0199	-0.1230	0.0773	-0.0211	-0.0205	0.0361	0.0019	0.0070
Big Cr.	-0.0350	0.2177	0.1050	-0.1761	0.1821	-0.2037	-0.0808	-0.0417	-0.0195	-0.0527	0.0832	0.0160	0.0266	0.0160
Birch Cr.	0.3091	0.2018	0.2101	0.1346	0.0681	-0.0370	-0.1172	-0.0281	0.0883	-0.0107	0.0519	-0.0312	0.0002	0.0075
Hobble Cr.	-0.1255	0.1264	0.0472	-0.0998	0.0858	-0.0071	0.1448	-0.0195	0.0130	0.0180	-0.0222	-0.1281	-0.0047	0.0013
American Fork	-0.4542	-0.1610	-0.0810	-0.0751	0.1603	0.0795	0.0957	0.0416	-0.0045	0.0274	-0.0436	-0.0422	-0.0028	0.0026
Fort Cr.	-0.2417	0.0687	-0.2005	0.1937	0.0254	-0.0651	-0.1658	-0.1532	-0.2569	-0.0047	0.0303	-0.0560	0.0061	-0.0031
Dry Cr.	-0.6138	-0.1889	-0.2399	0.1767	-0.0948	-0.2509	-0.0803	-0.0373	0.1222	-0.0250	-0.0759	0.0208	-0.0458	0.0031
Big Cottonwood Cr.	-0.4204	-0.1743	-0.0055	-0.0716	0.1445	0.0843	0.1059	0.0864	0.0569	0.0791	-0.0388	-0.0570	0.0107	-0.0116
Parleys Cr.	-0.1352	0.1774	0.0756	0.0329	0.1035	0.0717	0.0264	-0.0637	0.0722	-0.0004	-0.0489	0.0323	0.0404	0.0047
Miller nr. SLC	-0.3967	-0.0497	0.0110	-0.0914	0.1863	0.0853	0.0330	0.0587	-0.0641	0.0286	-0.0229	-0.0334	0.0060	0.0065
Emigration Cr.	-0.2352	0.2298	0.0958	-0.0894	0.1447	-0.0429	0.0483	-0.0334	0.0207	0.0191	-0.0214	-0.0049	0.0530	0.0078
Little Cottonwood Cr.	-0.5525	-0.2742	-0.2064	-0.0515	0.1088	0.1867	-0.0379	-0.0157	-0.0581	-0.0832	-0.0273	0.0482	0.0168	0.0015
Logan River	-0.0979	0.0520	0.0931	0.1411	0.1246	0.1233	0.0041	-0.1404	0.0798	-0.0508	-0.0164	-0.0061	-0.0125	0.0031
(Uinta Division)														
Little Brush Cr.	0.3270	-0.0574	0.2588	-0.0315	-0.0403	-0.0217	-0.0180	0.0460	0.0021	-0.1029	-0.0256	0.0027	-0.0026	0.0014
Brush Cr.	0.1906	-0.0831	0.2689	-0.2136	-0.0292	-0.0627	0.0504	0.0701	0.0191	0.0786	-0.0207	0.0091	0.0242	0.0083
Ashley Cr.	0.3015	-0.1201	0.0605	-0.0638	-0.0877	-0.0004	-0.0532	-0.0590	0.0016	-0.0588	-0.0303	-0.0246	-0.0065	-0.0011
Ashley Cr. bel. Trout Cr.	0.4025	-0.1015	0.2251	0.0634	0.0284	0.0220	-0.0085	0.0545	-0.0259	-0.0191	0.0056	0.0356	0.0253	0.0009
South Fork Ashley Cr.	0.3033	-0.2149	0.1246	0.0402	0.0406	0.0274	0.0080	0.0452	-0.0581	-0.0162	0.0208	-0.0199	-0.0033	0.0007
East Fork Dry Fork	0.2158	-0.0715	0.2148	0.0673	-0.0601	-0.0225	0.2212	-0.0652	-0.0156	0.0087	0.0043	0.0119	-0.0423	-0.0015
E. Fk. Dry Fk. at mouth	0.1448	-0.0557	0.1423	0.0245	-0.1081	0.0049	0.1700	-0.1454	-0.0366	-0.0248	-0.0186	0.0291	-0.0438	-0.0051
North Fork Dry Fork	0.2351	-0.1781	0.1208	-0.0194	-0.1615	-0.0666	-0.0603	0.0045	-0.0042	-0.0470	0.0246	-0.0435	0.0001	-0.0014
Dry Fork	0.2914	-0.1917	0.0205	-0.0095	0.0134	0.0130	-0.0489	-0.0235	-0.0112	0.0294	-0.0105	-0.0047	0.0119	0.0003
Whiterocks River	0.1275	-0.2629	-0.0366	-0.0479	-0.0481	0.0595	-0.0617	-0.0468	0.0524	-0.0585	-0.0382	0.0248	-0.0070	-0.0009
Whiterocks R. above P. C.	0.1789	-0.2724	0.0237	-0.0252	-0.0012	-0.0013	-0.0229	0.0251	0.0318	0.0001	0.0080	0.0145	0.0265	0.0023
Carter Cr.	0.2559	-0.1664	0.0817	0.0346	-0.0238	0.0363	-0.0077	-0.0540	-0.0565	0.0195	-0.0070	-0.0171	-0.0452	-0.0029
Farm Cr.	0.1006	0.0045	0.1087	-0.2508	-0.0754	-0.0726	-0.0378	-0.0557	-0.0183	-0.0077	-0.0048	0.0690	-0.0034	0.0008
Clover Cr.	0.0933	-0.2144	0.0470	0.1975	-0.1227	-0.0229	0.1271	-0.1085	-0.0411	0.1004	0.0426	0.0508	0.1049	-0.0016
Uinta R. above Clover Cr.	0.0974	-0.3431	-0.0988	-0.0879	0.0690	-0.0115	-0.0448	0.0271	-0.0251	0.0256	0.0409	-0.0220	0.0207	0.0019

Uinta R. below Gilbert Cr.	0.1438	-0.3823	-0.0193	0.0907	0.0630	-0.0536	0.0092	0.0933	0.0070	0.0451	0.0617	-0.0389	0.0216	0.0015
Yellowstone Cr. bel. S. cr.	0.0680	-0.3320	-0.1041	-0.1031	-0.0143	-0.0173	-0.0151	-0.0007	0.0961	0.0101	0.0297	-0.0224	0.0138	0.0014
Yellowstone Cr.	0.1286	-0.2797	-0.2180	-0.0777	-0.0047	0.0279	-0.0784	-0.1174	0.0654	0.0213	-0.0001	0.0045	0.0289	0.0007
Lake Fork	0.0720	-0.3172	-0.1325	-0.0434	0.0550	-0.0244	-0.0649	0.0217	0.0292	0.0413	0.0348	-0.0189	0.0239	0.0036
Rock Cr. nr. Mt. Home	0.0148	-0.2393	-0.1287	-0.1245	-0.0060	0.0521	-0.0491	-0.0454	0.0878	-0.0236	0.0092	0.0182	0.0056	0.0022
Rock Cr. nr. Hanna	-0.0375	-0.2151	-0.0539	0.0222	0.0447	0.0193	0.1812	-0.0710	-0.0197	0.0348	0.0620	0.0190	-0.0345	-0.0026
Duchesne River	0.0114	-0.1622	-0.0323	0.0973	0.0897	0.0314	0.1593	-0.0615	0.0003	0.0734	0.0210	-0.0332	-0.0089	-0.0008
Provo River	0.0568	-0.1234	-0.0526	0.3804	0.0710	-0.2685	0.0753	0.0250	0.1450	-0.0419	-0.0028	-0.0439	-0.0041	0.0047
Weber River	-0.1010	-0.0944	-0.0784	-0.0367	0.0730	0.0459	0.0787	-0.1028	0.0262	0.0101	0.0029	0.0061	0.0123	0.0010
Wolf Cr.	0.1338	0.0323	0.0106	0.0322	0.1221	-0.0391	-0.1498	0.0437	-0.0759	0.0112	0.0008	0.0367	-0.0470	-0.0119
West Fork Duchesne River	0.2510	0.0258	0.0045	0.1021	0.0896	0.0706	-0.1171	-0.0072	-0.0425	0.0237	0.0074	0.0074	-0.0227	0.0142
W. Fk. Duchesne River below Dry H.	0.2042	0.0106	0.0349	0.1122	0.1145	-0.0156	-0.0954	0.0633	-0.0295	-0.0293	0.0203	-0.0101	-0.0258	0.0059
Water Hollow	0.1873	0.1471	-0.2053	-0.0180	0.2229	-0.1104	-0.1691	-0.0985	-0.0832	0.2096	-0.0801	0.0021	-0.0696	0.0032
White River	0.1574	0.0791	0.1869	-0.0854	0.0486	0.0637	-0.0397	0.1619	0.0282	-0.0219	-0.0068	-0.0070	0.0013	0.0040
North Fork White River	0.0981	0.0875	0.1747	0.1028	0.0344	0.0622	0.1622	0.0454	-0.0045	-0.0106	-0.0102	-0.0051	-0.0109	-0.0010
Minnie Maud Cr.	0.1084	0.1733	0.1097	-0.2622	-0.0266	-0.0847	0.0734	-0.0020	0.0279	0.0624	-0.0175	0.0566	-0.0150	0.0035
Carter Cr. at mouth	0.2620	-0.0775	0.0721	-0.0228	-0.1507	0.0168	-0.0628	-0.1581	-0.0415	-0.0015	-0.0383	-0.0428	0.0054	-0.0036
Brown Duck Creek	0.1335	-0.2443	0.0752	0.0139	-0.0128	-0.0661	-0.0407	0.0491	-0.0431	-0.0091	-0.0562	0.0223	-0.0364	-0.0008
Hades Creek	-0.2727	-0.1481	-0.0212	-0.1905	-0.0338	0.0167	0.1006	-0.0752	-0.1620	0.0388	0.0874	0.0648	-0.0151	-0.0028
(Southern Division)														
Summit Cr.	-0.2503	0.0372	-0.0895	-0.1821	-0.0736	-0.1676	0.0698	0.0413	0.0539	0.0059	0.0747	0.0132	-0.0032	0.0043
Price River	0.1420	0.0699	0.0707	-0.0019	0.1079	0.0918	-0.0082	0.0990	-0.0094	0.0423	-0.0250	0.0205	-0.0075	0.0022
Gooseberry Cr.	-0.0665	0.0393	-0.0582	0.1129	0.0750	0.0660	0.0975	-0.0245	0.0020	-0.0371	-0.0389	0.0944	-0.0233	0.0069
Pleasant Cr.	-0.1592	-0.0174	-0.1108	0.1014	-0.0260	-0.1440	0.0036	0.0476	0.0311	-0.0206	-0.0157	0.0286	0.0147	0.0027
Huntington Cr.	0.0357	0.0284	-0.0649	-0.1473	0.0369	-0.0274	-0.0506	0.0930	0.0258	-0.0176	0.0088	-0.0002	-0.0409	0.0040
Cottonwood Cr.	0.0905	0.0242	-0.1621	-0.1053	-0.0448	0.0511	-0.0669	-0.0223	0.0406	-0.0093	-0.0196	0.0152	-0.0174	0.0004
Ferron Cr.	0.1362	0.0874	-0.1192	-0.1046	-0.0644	0.0342	-0.0578	-0.0014	0.0256	-0.0289	0.0016	0.0076	-0.0410	-0.0002
Muddy Cr.	0.1532	0.0272	-0.0981	0.0049	-0.0474	0.0899	-0.0653	0.0592	-0.0071	-0.0577	0.0114	0.0038	0.0100	0.0028
Twin Cr.	-0.2257	0.0546	-0.1524	-0.0164	-0.0094	-0.2939	0.0097	0.0276	-0.0035	-0.0940	0.0139	0.0415	0.0109	0.0045
Ivie Cr.	0.1851	0.2226	-0.0716	-0.1182	-0.0627	-0.1049	0.0319	0.0373	0.0150	0.0444	0.0180	-0.1019	0.0236	0.0009
Chalk Cr. nr. Fillmore	-0.0663	0.2412	-0.0749	-0.0557	0.0110	-0.0694	0.0591	0.0596	-0.0251	0.0417	0.0666	-0.0276	-0.0140	0.0021
Indian Cr.	0.0485	-0.0458	0.0351	-0.0586	-0.0715	-0.1209	0.1280	0.2097	-0.1513	-0.0410	-0.1530	-0.0172	-0.0184	-0.0043
Center Cr.	-0.0021	0.2099	-0.2727	-0.0947	-0.1781	0.1472	0.0251	-0.0051	0.0377	-0.0434	0.0801	-0.0036	-0.0011	-0.0030
Beaver River	0.0134	0.0518	-0.2717	0.0778	-0.1029	0.1108	0.0679	-0.0026	0.0111	-0.0270	0.0618	-0.0267	-0.0468	-0.0044
Sevier River	0.2695	0.2343	-0.2304	0.0991	-0.1073	0.0815	-0.0099	0.0836	0.0845	-0.0377	0.0506	-0.0468	-0.0077	-0.0004
Castle Cr.	0.0434	0.0765	-0.0795	-0.1150	-0.1169	-0.0440	0.1247	-0.0320	-0.0216	-0.1542	-0.0910	0.0053	0.0286	-0.0031
Mill Cr. nr. Moab	0.2702	0.1588	-0.1945	-0.0355	-0.1486	0.0176	0.0530	-0.1858	-0.1014	-0.0577	-0.0761	-0.0903	0.0159	-0.0079
North Cr.	0.1977	0.2124	-0.2559	-0.0566	-0.0379	0.0280	-0.0798	0.0357	-0.0002	0.0603	-0.0277	0.0251	0.0587	0.0017
Pine Cr.	0.1768	0.2286	-0.2616	-0.0388	-0.0478	0.0372	-0.1246	0.0196	0.0262	0.0733	-0.1055	0.0098	0.0519	0.0015
Coal Cr.	-0.0107	0.1861	-0.2557	-0.0005	-0.0755	0.1336	0.0748	0.0743	0.0365	0.0276	0.0716	0.0448	-0.0405	-0.0019
East Fork Boulder Cr.	0.2797	-0.0741	-0.1096	0.1067	-0.0847	0.1386	-0.0464	0.2055	0.0079	0.0208	0.0305	0.0436	-0.0102	-0.0017
East Fork Deer Cr.	0.1135	0.1060	-0.1308	0.3718	-0.0096	-0.1561	0.0732	0.1293	-0.0751	0.0434	-0.0207	0.0611	0.0361	-0.0008
Henrieville Cr.	0.1224	0.3874	-0.0807	-0.0021	-0.0046	-0.0326	0.1338	0.0683	-0.0897	-0.0099	0.0103	0.0235	0.0431	-0.0006
North Fork Virgin R.	-0.0346	0.3077	-0.2428	0.0883	-0.0340	0.1172	0.1272	0.0419	0.0213	0.0280	-0.0138	-0.0103	-0.0175	-0.0034

Table 18. Eigenvalues, cumulative proportion of total variance, and coefficients of regression equations for the analysis of Great Salt Lake Division.

Eigenvalues

6.9073	2.7798	1.2493	1.1085	0.9981	0.6247	0.4392	0.3081
0.2288	0.1405	0.1005	0.0598	0.0256	0.0161	0.0136	

Cumulative proportion of total variance

0.46	0.65	0.73	0.80	0.87	0.91	0.94	0.96
0.98	0.99	0.99	1.00	1.00	1.00	1.00	

Coefficients of regression equations using orthogonal factors for standardized independent variables

Intercept	11.2896147
Coeff. of factor	
1	-10.2974011
2	1.7805960
3	0.9707227
4	8.1026753
5	-12.2108486
6	0.9754322
7	- 4.5785820
8	2.4763687
9	8.3478537
10	9.0991750
11	- 6.2375371
12	23.9732006
13	2.4812390
14	-24.9401248
15	23.7361906

Table 19. Egienvalues, cumulative proportion of total variance, and coefficients of regression equations for the analysis of Uinta Division.

Eigenvalues

4.0654	3.0708	2.2714	1.3791	0.9748	0.6313	0.5479	0.3749
0.3312	0.1446	0.1043	0.0734	0.0295	0.0016		

Cumulative proportion of total variance

0.29	0.51	0.67	0.77	0.84	0.89	0.92	0.95
0.97	0.99	0.99	1.00	1.00	1.00		

Coefficients of regression equations using orthogonal factors for standardized independent variables

Intercept	10.6141164
Coeff. of factor	
1	11.3946134
2	0.6443955
3	- 6.5398867
4	0.5471651
5	6.7261587
6	- 2.4584332
7	- 0.5257256
8	- 1.2042626
9	-16.1577375
10	1.2859127
11	-16.7057650
12	-15.7376238
13	9.9445006
14	8.2388368

Table 20. Eigenvalues, cumulative proportion of total variance, and coefficients of regression equations for the analysis of Southern Division.

Eigenvalues

4.3656	2.7176	1.8616	1.3870	1.2540	0.8349	0.6360	0.3364
0.2406	0.1431	0.1073	0.0841	0.0316	0.0002		

Cumulative proportion of total variance

0.31	0.51	0.64	0.74	0.83	0.89	0.93	0.96
0.97	0.98	0.99	1.00	1.00	1.00		

Coefficients of regression equations using orthogonal factors for standardized independent variables

Intercept	7.1929160
Coeff. of factor	
1	9.0950645
2	7.1816297
3	- 1.7783582
4	- 3.3103988
5	0.5661619
6	2.7362303
7	- 5.4512215
8	8.7245253
9	- 6.2346119
10	- 0.8841201
11	6.6727305
12	6.0857539
13	0.4831579
14	-75.3204069

Table 21. Eigenvalues, cumulative proportion of total variance, and coefficients of regression equations for the analysis of State.

Eigenvalues

4.7428	2.5024	1.8628	1.0758	0.9170	0.7935	0.6240	0.5112
0.3638	0.2557	0.1597	0.1156	0.0661	0.0095		

Cumulative proportion of total variance

0.34	0.52	0.65	0.73	0.79	0.85	0.89	0.93
0.96	0.97	0.99	0.99	1.00	1.00		

Coefficients of regression equations using orthogonal factors for standardized independent variables

Intercept	9.8457116
Coeff. of factor	
1	-11.9483027
2	-20.9651089
3	- 5.5595341
4	14.8529350
5	8.0916208
6	- 5.3157883
7	- 5.1644294
8	2.6158484
9	8.5779911
10	-11.0135244
11	9.0799360
12	14.6991757
13	-28.2978663
14	44.4225082

Table 22. Reduction in residual sum of squares due to using orthogonal factors and multiple correlation coefficients of the stepwise equations.

Residual sum sq.	28.3118286
Total sum sq.	1087.7168427

Orthogonal factors	Reduction in sum of squares	Accumulative reduction in sum of squares	Correlation coefficients
1	732.4214401	732.4214401	0.821
5	148.8196507	881.2410908	0.900
4	72.7763968	954.0174876	0.937
12	34.3862939	988.4037815	0.953
9	15.9436042	1004.3473857	0.961
10	11.6338952	1015.9812809	0.966
14	9.9867220	1025.9680029	0.971
7	9.2077668	1035.1757697	0.976
2	8.8135710	1043.9893407	0.980
15	7.6879613	1051.6773020	0.983
11	3.9088088	1055.5861108	0.985
8	1.8896822	1057.4757930	0.986
3	1.1772424	1058.6530354	0.987
6	0.5943731	1059.2474085	0.987
13	0.1576801	1059.4050886	0.987

Table 23. Reduction in residual sum of squares due to using orthogonal factors and multiple correlation coefficients of the stepwise equations.

Residual sum sq.	109.3289337
Total sum sq.	921.6161575

Othogonal factors	Reduction in sum of squares	Accumulative reduction in sum of squares	Correlation coefficients
1	527.8405991	527.8405991	0.757
3	97.1475506	624.9881497	0.823
9	86.4666100	711.4547597	0.879
5	44.0995560	755.5543157	0.905
11	29.0976365	784.6519522	0.923
12	18.1782041	802.8301563	0.933
6	3.8153185	806.6454748	0.936
13	2.9130340	809.5585088	0.937
2	1.2751397	810.8336485	0.938
18	0.5436573	811.3773058	0.938
4	0.4129002	811.7902060	0.939
10	0.2391188	812.0293248	0.939
17	0.1514230	812.1807478	0.939
14	0.1065151	812.2872629	0.939

Table 24. Reduction in residual sum of squares due to using orthogonal factors and multiple correlation coefficients of the stepwise equations.

Residual sum sq.	318.1004333
Total sum sq.	730.0650253

Othogonal factors	Reduction in sum of squares	Accumulative reduction in sum of squares	Correlation coefficients
1	361.1234055	361.1234055	0.703
2	140.1629982	501.2864037	0.829
8	25.6033280	526.8897317	0.850
7	18.8978236	545.7875553	0.865
4	15.2001107	560.9876660	0.877
9	9.3538616	570.3415276	0.884
6	6.2509627	576.5924903	0.889
3	5.8873065	582.4797968	0.893
11	4.7786182	587.2584150	0.897
12	3.1155727	590.3739877	0.899
14	1.0694409	591.4434286	0.900
5	0.4019567	591.8453853	0.900
10	0.1118718	591.9572571	0.900
13	0.0073675	591.9646246	0.900

Table 25. Reduction in residual sum of squares due to using orthogonal factors and multiple correlation coefficients of the stepwise equations.

Residual sum sq. 640.4382935
Total sum sq. 2982.5747375

Othogonal factors	Reduction in sum of squares	Accumulative reduction in sum of squares	Correlation coefficients
2	1099.8857269	1099.8857269	0.607
1	677.0912552	1776.9769821	0.772
4	237.3390694	2014.3160515	0.822
5	60.0377188	2074.3537703	0.834
3	57.5773973	2131.9311676	0.845
13	52.8929381	2184.8241057	0.856
10	31.0157948	2215.8399005	0.862
9	26.7701790	2242.6100795	0.867
12	24.9762173	2267.5862968	0.872
6	22.4226334	2290.0089302	0.876
14	18.8158882	2308.8248184	0.880
7	16.6431761	2325.4679945	0.883
11	13.1705462	2338.6385407	0.885
8	3.4980882	2342.1366289	0.886

DISCUSSION

A summary comparing the results from both types of regression analysis is given in Tables 26 and 27. Table 26 compares the percent of the variation in water yield that each orthogonal factor explains with the percent of information from the original physiographic data matrix that it contains. The orthogonal factors are ranked in descending order with respect to the amount of variance in measured water yield that each would account for. For example, orthogonal factor 1 in the Great Salt Lake Division accounts for, or reduces the variance in measured water yield by 67 percent and contains 46 percent of the information in the physiographic data matrix. It may be noted from Table 26 that the rank of the orthogonal factors with respect to water yield is not well correlated with their rank with respect to the physiographic data. In other words, the fact that a particular orthogonal factor ranks high in explaining variation in the data matrix does not guarantee that it will rank high in explaining variation in some other parameter for which a predictive relationship is sought.

This fact needs particular emphasis because a common procedure in using principal component analysis is to only calculate the orthogonal factors whose eigenvalues are greater than unity and assume that all the significant information is contained therein. The acceptance of this procedure would have resulted in the inclusion of only the first four or five orthogonal factors as the principal components for subsequent regression with water yield. Table 26

Table 26. Comparison of reduction in variance of water yield by each orthogonal factor and physiographic information each factor contains.

	Great Salt Lake Division			Uinta Division			Southern Division			State		
Rank according to runoff correlation	Orthogonal factor	Reduction in variance of water yield (%)	Physiographic information contained (%)	Orthogonal factor	Reduction in variance of water yield (%)	Physiographic information contained (%)	Orthogonal factor	Reduction in variance of water yield (%)	Physiographic information contained (%)	Orthogonal factor	Reduction in variance of water yield (%)	Physiographic information contained (%)
1	1	67	46	1	57	29	1	55	31	2	37	18
2	5	14	7	3	11	16	2	12	20	1	23	34
3	4	7	7	9	9	2	8	4	3	4	8	8
4	12	3	1	5	5	7	7	3	4	5	2	6
5	9	1	2	11	3	0	4	2	1	3	2	13
6	10	1	1	12	2	1	9	1	1	13	2	1
7	14	1	0	6 }		5	6	1	6	10	1	1
8	7	1	3	13 }		0	3	1	13	9	1	3
9	2	1	19	2 }		22	11	1	1	12 }		0
10	15		0	8 }	1	3	12 }		1	6 }		6
11	11 }		0	4 }		10	14 }		0	14 }		0
12	8 }		2	10 }		2	5 }	1	9	7 }	1	4
13	3 }	1	8	7 }		3	10 }		1	11 }		2
14	6 }		4	14 }		0	13 }		0	8 }		4
15	13 }		0									
Total		97	100		88	100		81	100		77	100

Table 27. Comparison of correlation coefficients derived from multiple regression (MR) and principal component regression (PC) for equal number of terms in the equations.

No. of	Great Salt Lake Division		Uinta Division		Southern Division		State	
terms	(MR)	(PC)	(MR)	(PC)	(MR)	(PC)	(MR)	(PC)
1	.850	.821	.676	.757	.730	.703	.731	.607
2	.914	.900	.782	.823	.833	.829	.809	.772
3	.929	.937	.806	.879	.867	.850	.824	.822
4	.940	.953	.830	.905	.876	.865	.850	.834
5	.959	.961	.862	.923	.882	.877	.858	.845
6	.965	.966	.895	.933	.886	.884	.868	.856
7	.969	.971	.910	.936	.888	.889	.870	.862
8	.977	.976	.922	.937	.892	.893	.875	.867
9	.982	.980	.931	.938	.900	.897	.881	.872
10	.985	.983	.938	.938	.900	.899	.833	.876
11	.986	.985	.939	.939	.900	.900	.885	.880
12	.986	.986	.939	.939	.901	.901	.885	.883
13	.987	.987	.939	.939	.901	.901	.886	.885
14	.987	.987	.939	.939	.901	.901	.886	.886
15	.987	.987						

shows that this could have greatly restricted the predictive power of any equations developed using the first four factors only. For example, if only orthogonal factors 1, 2, 3 and 4 had been used for the Great Salt Lake division in obtaining a regression equation for water yield a correlation coefficient of 0.86 would have resulted, whereas using factors 1, 5, 4 and 12 gave a correlation coefficient of 0.95. Similar observations may be made for factors in each of the other divisions. This indicates that when principle component analysis is to be used with regression that enough factors should be derived to account for all of the variance in the data matrix of "independent" variables. Otherwise the information thrown out may be that which is most or quite highly correlated with the dependent variable for which a relationship is sought.

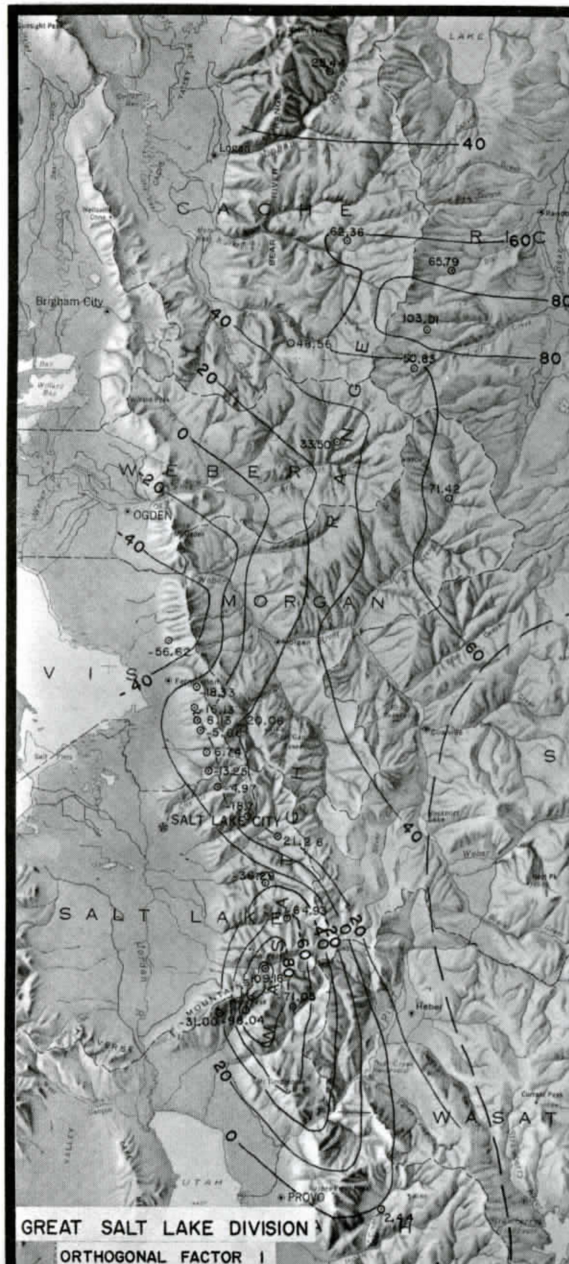
Table 27 gives a comparison of the multiple correlation coefficients of the various equations developed using both ordinary multiple regression and principal component regression. The comparison indicates that principal component regression did not yield better predictive equations that ordinary regression when all variables are included in the predictive equation. In fact, when a single parameter is highly correlated with the water yield, the correlation coefficient of the most highly correlated orthogonal factor may be less than that of a single highly correlated physiographic parameter. This case is shown in Table 27 for the equations developed using data for each division except the Uinta Division. In fact, each of the equations developed using all 84 watersheds in the State derived from ordinary multiple regression had equal or higher correlations than the corresponding equations derived from principal component analysis. The ordinary multiple regression equations developed from Southern division data had equal or higher correlations until 7 terms had been used and those in the Salt Lake division until 2 terms had been used in the principal component analysis. All principal component equations for the Uinta division had higher correlation coefficients than their corresponding ordinary multiple regression equations. This seems to indicate that as the homogeneity of the "independent" variable or information matrix is reduced the more difficult or less likely it is that any single variable will be entirely contained in any one orthogonal factor. In other words the information a single parameter contains will be more widely distributed throughout the whole set of orthogonal factors. Consequently, no single orthogonal factor may be as highly correlated with the dependent variable as the original single untransformed parameter.

A common objective in the application of principal component regression analysis is to reduce the number of variates in the model, thereby effecting an economy in representation and, as a corollary, to develop a rank list for the importance of the several variates. One disadvantage of the principal component analysis is the difficulty in assessing the real physiographic significance of the new factors represented by the relative magnitudes of each element in the eigenvectors of the eigenvector matrix. In the analysis of the Great Salt Lake division, a 0.953 multiple correlation coefficient is obtained when only four orthogonal factors were included in the regression analysis. By considering just those variables of each factor that have large coefficients in the eigenvector it appears that the first factor is a general "precipitation" factor, the fifth is "elevation-latitude," the fourth is "drainage density," and the twelveth appears to be a "slope factor-vegetative" factor, however, the values of the other elements of the respective eigenvectors are not insignificant so these interpretations are still quite arbitrary. An examination of the eigenvector elements for the entire study reveals a similar difficulty so an interpretation of the physiographic significance of each orthogonal factor is not attempted here.

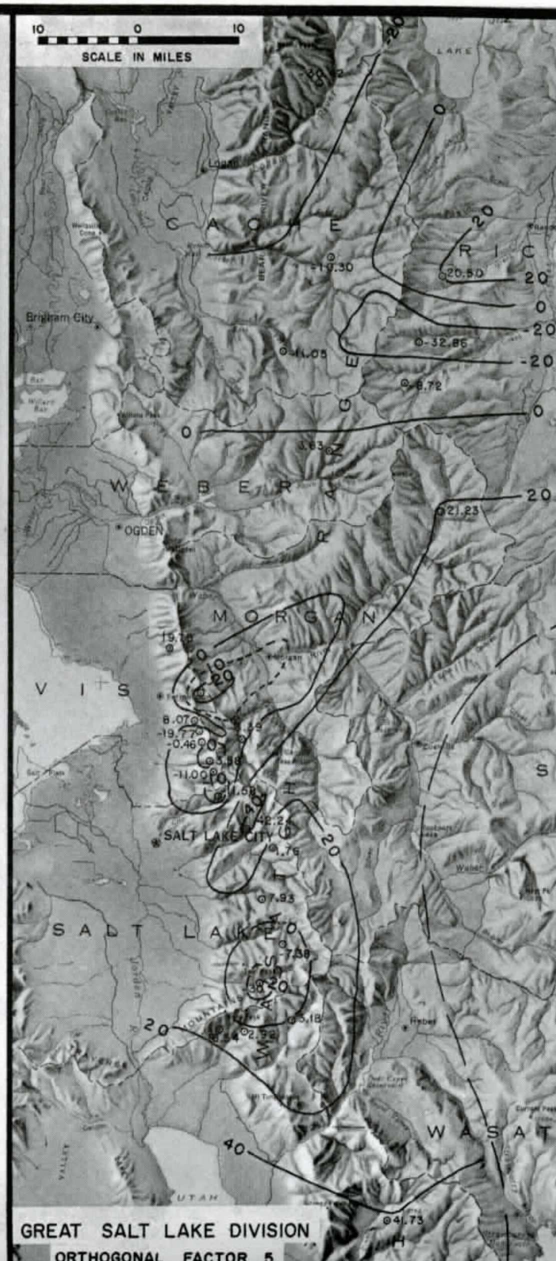
The application of the principal component regression equations is more complicated and more tedious than the ordinary ones because the evaluation of each orthogonal factor requires evaluation or measurement of every physiographic parameter used in the analysis. Thus, even if the equation involving only orthogonal factor one for the Great Salt Lake division was deemed suitable, the evaluation of the value of factor one would necessitate the measurement of all 15 of the physiographic parameters used in the ordinary regression analysis, dividing each element of raw data by its standard deviation and then multiplying that result by its respective element in the factor one eignevector. However, in this report, a simple procedure is proposed to simplify the evaluation of each factor. This procedure is to draw an isogram of each orthogonal factor and then determine the factor value from it much as one determines precipitation from an isohyetal map or elevation from a topographic map. Orthogonal factors 1, 5 and 4 for the Great Salt Lake division have been plotted in Figure 1 to illustrate the procedure. The regression of water yield on these three factors will give a multiple correlation coefficient of 0.937.

The feasibility of using the iso-maps shown in Figure 1 was tested by comparing values of runoff obtained from them with that obtained by using equations given in Special Report 18, Utah Agricultural Experiment Station, for some watersheds in the Great Salt Lake division. The choice of the watersheds used for comparison was primarily a matter of expediency because runoff values for them had been previously computed by Mr. Frank Haws in connection with some other work he was doing. They were thought to be quite suitable for comparison purposes because none of them were used in the development of the regression equations and thus would give some idea concerning the extrapolative power of the two methods. The results are summarized in Table 28 and reveal that the average error from the principal component analysis equations is considerably less than the corresponding error from the multiple regression equations for these watersheds.

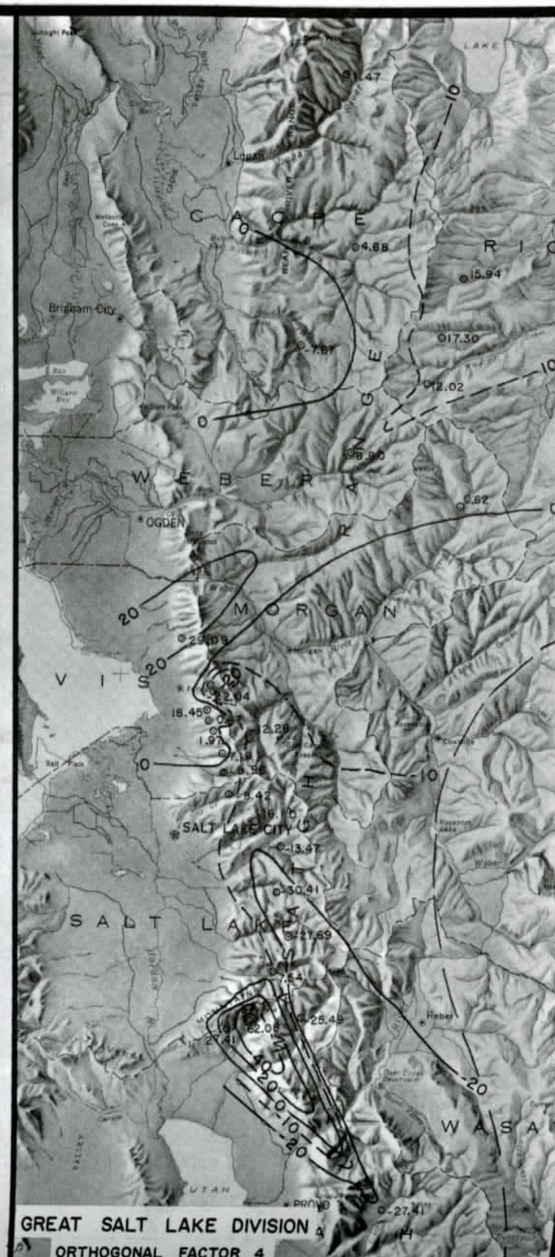
It must be emphasized that these results are not conclusive because the iso-maps in Figure 1 are merely first approximations and to be generally used would require a considerable amount of refinement by calculating factor values for watersheds in areas that will provide definition where uncertainties now exist. However, the results do indicate that the principal component equations may be superior for extrapolative purposes.



GREAT SALT LAKE DIVISION
ORTHOGONAL FACTOR 1



GREAT SALT LAKE DIVISION
ORTHOGONAL FACTOR 5



GREAT SALT LAKE DIVISION
ORTHOGONAL FACTOR 4

Figure 1. Iso-gram of orthogonal factors 1, 4, and 5 for the Great Salt Lake Division.

Table 28. Comparison of water yield obtained by Principal Component Analysis using the iso-grams (Figure 1) with multiple regression equations given in Special Report 18, Utah Agricultural Experiment Station.

Stations	Measured water yield 1931-60	Equations given in Special Report 18		Equation contains first orthogonal factor		Equation contains first two orthogonal factors		Equation contains first three orthogonal factors	
		Computed water yield	Difference	Computed water yield	Difference	Computed water yield	Difference	Computed water yield	Difference
Three-mile Canyon	7.0	8.0 (21)	- 1.0	9.23	- 2.23	7.77	- 0.77	6.36	0.64
Synderville Canyon	22.4	8.0 (21)	14.4	9.54	12.86	7.88	14.52	6.45	15.95
Willow Draw	6.2	14.2 (21)	- 8.0	10.30	- 4.10	9.03	- 2.83	7.57	- 1.37
Red Pine	3.7	19.5 (22)	-15.8	12.53	- 8.83	11.33	- 7.63	9.77	- 6.07
White Pine	11.5	19.1 (21)	- 7.6	12.01	- 0.51	10.79	0.71	9.23	2.27
Lower Thaynes Canyon	9.1	16.1 (21)	- 7.0	9.14	- 0.04	7.02	2.08	5.60	3.50
Average error			8.967		4.762		4.757		4.967

CONCLUSIONS AND RECOMMENDATIONS

The principal conclusion that may be drawn from this study is that considerable caution should be exercised in blindly accepting as superior a new and more sophisticated procedure of analyzing data. In this study two methods of analysis were compared, both of which utilized all of the information available from the data. The main difference between them was the information used in successive steps of analysis. The principal component analysis used data at each successive step that was a part of all the physiographic data, whereas the ordinary multiple regression analysis used all the data from each physiographic parameter added at that step.

Some of the principal advantages claimed for the method of principal component analysis were not borne out by the results of this study, in fact the only real advantage that it showed was in its possible extrapolative superiority. Even though this result was not too conclusive, it is reasonable because each orthogonal factor is a combination of all the physiographic data and therefore its value is not totally affected by a large error in any one criterion observation. If this result is verified by further work, it will be an important advantage of the method.

One advantage which is claimed for the method did not materialize, namely that a reduction in predictor variables (physiographic parameters) is realized. In this study, it was shown that all factors should be calculated and included in the principal component regression analysis. If standard rule of thumb procedures had been accepted concerning the significance of the information contained in the principal component matrix serious limitations would have resulted. For example, analysis of the Great Salt Lake division showed that among the six factors which are most highly correlated with water yield, only factors 1 and 4 had eigenvalues greater than unity. Although the six factors account for only 64 percent of the variation in the physiographic data matrix, they account for nearly 94 percent of the variation in water yield. This points out that factors accounting for a large percentage of variance in the data sample space are not necessarily the same factors that are highly correlated with a dependent variable for which a predictive relationship is sought.

It is often reported that determining the principal components aids in the physical interpretation of the data. However, this was not the experience of this study; in fact, interpreting the physical significance of the orthogonal factors proved so difficult that the attempt was finally abandoned. A possible method of overcoming this problem is by use of what is known as a verimax rotation of the factor weight matrix. The factor weight matrix is simply the eigenvector matrix standardized by multiplying each eigenvector by the square root of its respective eigenvalue.

Figure 2 illustrates a visual interpretation of the factor loading that result from a 2-cluster system of variables projected onto the first and second principal component axes. It can be seen from the figure that the first component has high positive loadings on all variables; the second has high positive and negative loadings with comparatively few intermediate values. Variable loadings similar to those in Figure 2 are the rule rather than the exception when making principal component analysis of correlation matrices.

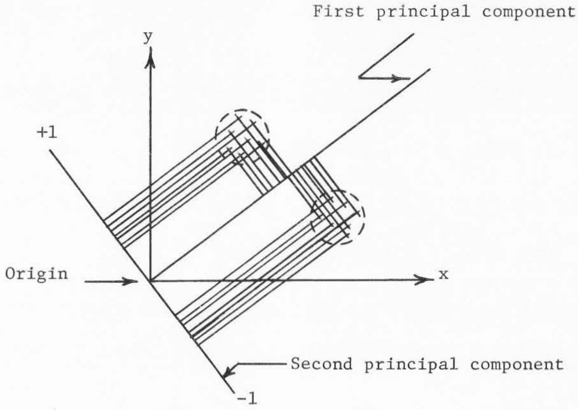


Figure 2. Factor loading on the first and second principal component for a two-cluster system of variables (Wallis, 21).

The verimax rotation would simplify the columns (standardized eigenvectors) of the factor weight matrix while maintaining an orthogonal structure. The effect of such a rotation can be visualized for two clusters of variables and two dimensions by referring to Figure 2 and imagining the factor loadings that would result from rotating the planes of the first and second principal components to the X and Y positions. Such a rotation tends to produce correspondence between the factors and the variables, resulting in fewer problems in accessing the physical significance of the various orthogonal factors.

The recommendations for further study in this area are summarized as follows:

1. Extend the analysis to include a verimax rotation of the factor weight matrix and assess the value of this analysis in obtaining physical interpretation of the various orthogonal factors.

2. Further refine the isograms of the orthogonal factors by using the results of verimax rotation if they prove helpful.

3. Further test the extrapolative power of both the principal component regression equations and the ordinary multiple regression equations to conclusively determine their relative merits.

4. Finally derive an improved water yield or runoff map for the State of Utah that utilizes all of the improvements obtained by the foregoing analyses.

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APPENDIXES

Appendix A

Table 29. Values assigned to the geological formations. (Assigned by James H. Milligan in consultation with J. Stewart Williams)

Symbol	Descriptions	Values
Qay	Relatively younger alluvial deposits, chiefly along active streams.	0.05
Qao	Relatively older alluvial deposits, on terraces above active streams.	0.10
Qas	Alluvial surfaces, mostly sloping and well drained with soil profile suitable for crops.	0.05
Qa	Undifferentiated alluvium.	0.20
Qco	Miscellaneous covering deposits, including wind blown material, thin soil and alluvium.	0.10
Qag	Colluvium and alluvium, mostly stony.	0.10
Qgs	Gravel surface, mainly terrace and pediments undergoing erosion, may not be associated with active streams.	0.40
Qgm	Glaciated ground morains undifferentiated, includes bare rock as well as moraines of all types.	0.50
Qgo	Glacial outwash; fine and coarse materials laid down by streams beyond glacial margins.	0.20
Qls	Landslides and other surficial masses displaced by gravity.	0.50
Qds,Qdo, Qdg	Dunes, Qds, Siliceous; Qdo, Oolitic; Qdg, Gypsiferous	0.20
Qlc	Lake bed sediments, mostly dry clay or dust, poorly drained and with enough salt to prohibit agriculture.	0.50
Qltg	Constructional lake shore features, gravelly.	0.10
Qlts	Constructional lake shore features, sandy.	0.15
Qm	Marshland, mostly freshwater.	0.30
Qb	Quaternary basalt.	0.30
Qlcs	Lake bed sediments, mostly clay with very flat surface.	0.40
Qlsa	Lake bed with permanant salt crust.	0.50
Qlo,Qlcb, Qbi	Underwater sediments of Great Salt Lake; Qb, Oolitic bottom; Qlcb, Clay or mud; Qbi, Algal bioherms.	0.50
Tw	Wasatch formation or group, Variegated continental sediments, ranging from limestone to conglomerate.	0.60
Tvil	Joe Lott Tuff.	0.70
Tvmb	Mt. Belknap Rhyolite.	0.75
Tvdh	Dry Hollow Latite.	0.60
Tvrp	Roger Park Breccia.	0.60
Tvbc	Bullion Canyon Volcanics, Oligocene.	0.70
TQa	Axtell Formation, Conglomerate of pebbles to boulders.	0.50
Tsr	Sevier river formation, partly consolidated coarse conglomerate with volcanic debris	0.65
Tfc	Foll creek Conglomerate, pebble, cobble and boulder.	0.45

Table 29. Continued

Symbol	Descriptions	Values
Tgg	Gray Gulch formation, complex aggregation of pyroclastic rocks with colored sandstone, limestone and shale.	0.70
Tbk	Bald Knoll formation, light gray siltstone.	0.65
Tch	Crazy Hollow formation, sandstone and siltstone.	0.50
Tvg	Goldens Ranch formation, chiefly volcanic conglomerate with minor limestone.	0.65
Tgu	Green River formation, limestone with minor sandstone and conglomerate.	0.70
Tc	Colton formation, fluvial beds with channel sandstone lenses.	0.60
Tf	Flagstaff limestone, fossiliferous limestone.	0.65
TKnh	North Horn formation, variegated continental beds.	0.60
Tsl,Tu	Salt Lake formation, continental sandstone, shale, marlstone, silt, and pyroclastic rocks.	0.70
Tfo	Fowkes formation, tuffaceous and limy beds.	0.65
TK	Knight Conglomerate, chiefly massive conglomerates, minor sand and silt.	0.60
T? bp	Late Tertiary basaltic and basaltic andesitic pyroclatics.	0.50
T? rp	Late Tertiary rhyolite-dacite-quartz latite pyroclastics.	0.60
Tib	Tertiary basic intrusive rocks.	0.70
TKt	Tuscher formation, conglomeratic fluvial sandstone.	0.50
TQu	Tertiary and Quaternary deposits and surfaces.	0.60
Tl	Tertiary limestone, exact age uncertain.	0.75
Tcg	Tertiary conglomerate, exact age uncertain.	0.60
Tb	Tertiary brecia, exact age uncertain.	0.75
Tvu	Tertiary volcanic rocks, undifferentiated.	0.70
T? bf	Late Tertiary basalt and basaltic andesite flows.	0.55
T? af	Late Tertiary andesite-trachyte-Latite flows.	0.65
T? ap	Late Tertiary andesite-trachyte-latite pyroclastics.	0.50
T? rf	Late Tertiary rhyolite-dacite-Quartz latite flows.	0.70
T? ri	Late Tertiary rhyolite-dacite-quartz latite ignimbrites.	0.75
T? bf	Early Tertiary basalt and basaltic andesite flows.	0.55
T? af	Early Tertiary andesite-trachyte-latite flows.	0.65
T? ap	Early Tertiary andesite-trachyte-latite pyroclastics.	0.55
T? ai	Early Tertiary andesite-trachyte-latite ignimbrites.	0.75
T? rf	Early Tertiary rhyolite-dacite-quartz flows.	0.70
T? ri	Early Tertiary rhyolite-dacite-quartz latite ignimbrites.	0.70
Tig	Tertiary granitoid rocks.	0.80
Tip	Tertiary porphyritic intrusive rocks.	0.85
Tvp	Pine valley latite.	0.85
Tvpr	Page Ranch formation.	0.85
Tvr	Rencher formation, mostly rhyolitic ignimbrites.	0.80

Table 29. Continued

Symbol	Descriptions	Values
Tvq	Quichapa formation, mostly rhyolitic ignimbrites.	0.80
Tvi	Ison formation, mostly andesitic-latitic ignimbrites.	0.75
Tvnr	Needles Range formation, mostly latitic ignimbrites.	0.75
Tvbh	Brian Head formation, mostly latitic ignimbrites.	0.75
Tmc	Muddy Creek formation, clay, silt and sand, some evaporites.	0.75
Tcl	Claron formation, limestone, some coarse clastics.	0.70
Tgp_3	Upper unit of parachute creek, Member of Green R. formation.	0.80
Tgp_2	Middle unit.	0.85
Tgp_1	Lower unit.	0.85
Tgs	Older, high level, gravel-colored surfaces of uncertain age.	0.65
Tbp	Browns Park formation, extremely varied formation of gray to buff sandstone, tuffaceous material and conglomerate irrigularity.	0.65
Tdr	Duchesne R. formation, fluvial sandstone and mudstone.	0.55
Tbri	Bridge formation, fluvial and lake beds.	0.70
Tge	Evacuation Cr. member of Green R. formation.	0.75
Tggd	Garden Gulch and Douglas Cr. member of Green river formation.	0.75
Tfu	Fort Union formation, non-marine sandstone and siltstone.	0.55
Tu	Uinta formation, fluvial and lake deposits.	0.70
Ku	Cretaceous undivided.	0.75
KKa	Kaiparowits formation, sandstone and sandy shale.	0.60
Kws	Wahweap and Straight cliffed sandstone undivided.	0.60
Kwa	Wahweap sandstone, minor shale.	0.55
Kst	Straight cliffs sandstone, chiefly massive sandstone.	0.55
Ktr	Tropic shale, marine shale and sandstone with coal.	0.75
Kis	Iron Springs formation, coarse sandstone, grit, and conglomerate.	0.70
Kdt	Dakota and Tropic formations undivided.	0.65
Kd	Dakota sandstone, thin beds of conglomerate, sandstone, shale and coal.	0.55
Ki	Indianola formation, conglomerate, sandstone, and siltstone.	0.70
Ksx	Sixmile formation, sandstone, conglomerate.	0.70
Kfu	Funk valley formation, sandstone, shale, conglomeratic.	0.70
Kav	Allen valley formation, marine shale.	0.80
Kspt	Sanpete formation, sandstone and conglomerate, minor shale.	0.70
Kpr	Price R. formation, sandstone, mudstone, mainly conglomerate.	0.75
Kc	Castlegate sandstone, cliff forming deltaic sandstone.	0.60

Table 29. Continued

Symbol	Descriptions	Values
Kbh	Black Hawk Group, sandstone, shale and coal.	0.65
KTc	Unnamed coglomerate, varied lithology.	0.70
Kec	Echo Canyon conglomerate, sandstone, shale and coglomerate.	0.65
Kw	Wanship formation, marine sandstone and shale.	0.70
Kf	Frontier formation, sandstone, shale and coal.	0.70
Ka	Aspen shale, marine shale.	0.85
KK	Kelvin formation, continental deposits, predominantly red with many conglomerate.	0.70
Ksp	Star Point sandstone, interbedded sandstone and shale, deltaic and marine.	0.70
Kmv	Mesa Verde Group undivided, mixed sandstone, shale.	0.75
Kms	Mancos Shale undivided, non-resistant, marine shale.	0.85
Kmm	Masuk shale member of Mancos shale, marine shale.	0.80
Ke	Emery sandstone, member of Mancos shale, marine.	0.75
Kmbg	Blue Gate shale, member of Mancos shale, calcareous marine shale.	0.80
Kmt	Tununk shale M. of Mancos, marine siltstone, claystone.	0.85
Kfe	Ferron sandstone, M. of Mancos, marine and non-marine sandstone.	0.75
Kcm	Cedar Mt. shale, nodular shale with fluvial sandstone.	0.80
Kdcm	Dakota sandstone and Cedar Mt. shale undivided.	0.75
Kbc	Burro Canyon formation, continental mudstone, sandstone.	0.70
Kdbc	Dakota sandstone and burro Canyon, formation undivided.	0.65
Kcc	Current Cr. formation, fluvial sandstone, siltstone.	0.65
Ker	Kricson formation, cliff-forming sandstone, minor shale.	0.60
Krs	Rock Spring sandstone, sandstone, marine shale and coal.	0.70
Kb	Blair formation, sandy shale and sandstone.	0.70
Kh	Hilliard shale, marine shale.	0.80
Kmf	Mowry shale and Frontier sandstone undivided.	0.75
Kbr	Bear R. formation, carbonaceous shale and sandstone.	0.75
Kgc	Garley Canyon sandstone, M. of Mancos shale, marine and non-marine sandstone.	0.70
Jna	Navajo sandstone, cross-bedded, eolian sandstone.	0.40
Ju	Jurassic undivided, mostly San Rafael group equivalent.	0.45
Jm	Morrison formation, varied continental sediments.	0.65
Jw	Winsor formation, continental sandstone and siltstone.	0.60
Jb	Bluff sandstone, continental sandstone, salt wash in fluvial.	0.45
Jsu	Summerville formation, non-marine sandstone and sandy shale.	0.55
Je	Entrada sandstone, non-marine siltstone and smooth-weathering sandstone.	0.45

Table 29. Continued

Symbol	Descriptions	Values
Jca	Carmel formation, marine gypsum, shale and sandstone.	0.70
JTR k	Kayenta formation, fluvial and eolian sandstone.	0.45
JTR gc	Glen Canyon group, undifferentiated, includes Navajo, Kayenta, and Wingate sandstones and shales.	0.60
Ja	Arapien formation, variegated siltstone, sandstone and limestone, rock salt and gypsum.	0.80
Jtg	Twist Gulch formation, sandstone and siltstone.	0.85
Jat	Twelvemile Canyon formation, shale, sandstone, limestone, rock salt, gypsum.	0.80
Jp	Press sandstone, siltstone and sandstone.	0.70
Jtc	Twin Cr. limestone, limestone.	0.65
Jn	Nugget sandstone, cross-bedded, eolian sandstone.	0.45
Jmbb	Brushy basin. M. of Morrison formation, mostly shale.	0.80
Jmw	Westwater Canyon, M. of Morrison formation, fluvial sandstone and mudstone.	0.70
Jmrc	Recapture Cr. M. of Morrison formation, fluvial sandstone and mudstone.	0.70
Jmsw	Salt Wash sandstone, M. of Morrison formation, fluvial sandstone and mudstone.	0.65
Jcu	Curtis formation, chiefly glauconitic sandstone.	0.65
Jem	Moab sandstone, tongue of Entrada sandstone.	0.60
Jst	Stump sandstone, brown-weathering, glauconitic sandstone and shale.	0.65
TR c	Chinle formation, variegated non-marine sediments.	0.80
TR s	Shinarump formation, conglomeratic sandstone.	0.60
TR m	Moenkopi formation, siltstone and sandstone.	0.80
TR t	Thaynes formation, calcareous marine shale, siltstone and limestone.	0.75
TR u	Triassic undivided, includes Chinle, Shinarump and Moenkopi.	0.80
TR mo	Moenave formation, sandstone, siltstone and shale.	0.65
TR a	Ankareh formation, sandstone, siltstone and shale.	0.75
TR w	Woodside shale, siltstone and shale.	0.75
TR wi	Wingate sandstone, massive, cross-bedded, cliff-forming sandstone.	0.45
TR cm	Moss Back M. of Chinle formation, conglomeratic fluvial deposits.	0.65
TR cc	Church Rock M. of Chinle formation, chiefly sandy siltstone.	0.70
TR co	Owl Rock M. of Chinle formation, siltstone and limy siltstone.	0.70
TR pf	Petrified Forest M. of Chinle formation, bentonitic mudstone, claystone, and siltstone.	0.85
TR mb	Monitor Butte M. of Chinle formation, interbedded mudstone, claystone, sandstone, bentonitic.	0.80
TR ms	Sinbad limestone M. of the Moenkopi formation, thin bedded, marine limestone.	0.75

Table 29. Continued

Symbol	Descriptions	Values
Ᵽg	Gerser formation, limestone with minor sandstone, siltstone, chert.	0.70
Ᵽpl	Plympton formation, mostly dolomite and chert with phosphatic beds.	0.80
Ᵽka,Ᵽki	Kaibab limestone, cherty limestone, dolomite and evaporites.	0.70
Ᵽa	Arcturus formation, shaly limestone, dolomite, silty sandstone and gypsum.	0.80
Ᵽrs	Riepe Spring formation, limestone, wolf-campian.	0.75
Ᵽt	Toroweap formation, cherty limestone, dolomite and siltstone.	0.80
Ᵽco	Coconino sandstone, cross-bedded, non-marine sandstone.	0.65
Ᵽh	Hermit formation, sandstone and shale.	0.70
Ᵽpk	Pakoon limestone, mostly dolomitic limestone.	0.75
Ᵽpo	Oquirrh formation, quartzite, limestone, dolomite, sandstone and shale.	0.80
Ᵽpc	Park City formation, chert, phospharite, limestone and shale phosphate rock.	0.80
Ᵽdc	Diamond Cr. sandstone, cross-bedded, sandstone.	0.65
Ᵽk	Kirkman limestone, thin-bedded, brecciated limestone.	0.80
Ᵽun	Permian Rocks undivided.	0.80
Ᵽcr	Rex Chert Member, chert or cherty mudstone.	0.70
Ᵽcmp	Meade Peak Member, shale, mudstone and siltstone, phosphate rocks.	0.65
Ᵽcgr	Grandeur M. dolomite, silty dolomite and cherty.	0.80
Ᵽp	Pequop formation, limestone, fine-grained sandstone, and siltstone.	0.70
Ᵽpu	Permian and Pennsylvanian formations undivided.	0.80
ᵽT_2ho	Hoskinnini, sandy mudstone and siltstone.	0.75
Ᵽcu	Cutler formation undivided.	0.70
Ᵽwr	White Rim sandstone M. of Cutler formation, cross-bedded, non-marine sandstone.	0.55
Ᵽcd	Dechelly sandstone, M. of Cutler formation, cross-bedded, non-marine sandstone.	0.60
Ᵽor	Organ Rock tongue, thin-bedded sandstone and shale with minor limestone lenses.	0.70
Ᵽcm	Cedar Mesa sandstone, M. of Cutler formation, cross-bedded, non-marine sandstone with calcareous shale.	0.60
Ᵽpr	Rico formation, equivalent in part to Elephant Canyon formation.	0.65
Ᵽha	Halgaito formation, thin-bedded mudstone and siltstone.	0.75
Ᵽpho	Honaker Trail formation, limestone and sandy siltstone with chert.	0.80
Pal	Paleozoic rocks, age uncertain.	0.85

Table 29. Continued

Symbol	Descriptions	Values
Pe	Ely formation, limestone, locally very cherty.	0.75
Pt	Talisman Quartzite, fine grained sandstone and quartzite.	0.75
Pc	Callville limestone, thin-bedded, cliff-forming limestone with silty limestone near base.	0.75
Pw	Weber Quartzite, mainly quartzite, some cherty limestone.	0.80
Pm	Morgan formation, cherty limestone and relatively soft sandstone and siltstone.	0.70
Prv	Round Valley limestone, limestone.	0.70
PMmc	Manning Canyon Shale, block shale with minor park limestone, quartzite and grit.	0.80
PMcd	Chainman and Diamond Peak formation, undivided, chert and quartzite conglomerate, siltstone, shale and silty quartzite.	0.85
Pwe	Wells formation, interbedded limestone and calcareous sandstone.	0.75
Pwmu	Morgan and Weber formation undivided.	0.75
Pmu	Pennsylvanian and Mississippian undivided.	0.80
Mc	Chainman shale, shale with lenses of sandstone.	0.80
Mj	Joana limestone, massive fossiliferous limestone.	0.75
Mr	Redwall limestone, limestone with chert.	0.70
Mu,Mb	Brazer limestone, thick-bedded fossiliferous limestone.	0.70
Ml,Mlp	Lodgepole limestone, thin to medium bedded cherty, fossiliferous limestone.	0.65
Mdo	Doughnut formation, limestone and shale.	0.75
Mgb	Great Blue limestone, pure and cherty limestone.	0.70
Mh	Humbug formation, quartzitic sandstone with minor limestone and dolomite.	0.80
Md	Deseret limestone, limestone or dolomite with chert.	0.75
Mm,Mg	Madison or Gardison limestone, massive fossiliferous limestone and dolomite, minor chert.	0.70
Mun	Undifferentiated Mississippian rocks.	0.80
MDf	Fitchville formation, mostly dolomite, some limy siltstone and quartizite.	0.80
Mom	Ochre Mt. Limestone, thick-bedded, massive, cherty limestone.	0.70
Mw	Woodman formation, calcareous sandstone and sandy limestone.	0.65
Dp	Pilot shale, carbonaceous very soft shale.	0.85
Dg	Guilmette formation, chiefly cliff-forming limestone with much dolomite, sandstone and argillaceous carbonates.	0.80
Dsi	Simonson dolomite, fine to coarse grained dolomite.	0.80

Table 29. Continued

Symbol	Descriptions	Values
Ds	Sevy dolomite, dense, distinctly bedded unfossiliferous dolomite.	0.80
Dj	Jefferson dolomite, dolomite with shale and sandstone.	0.80
Dwc	Water Canyon dolomite, dense splintery dolomite.	0.75
Du	Devonian formations undivided.	0.80
Dv,Dst	Victoria Quartzite and Stansbusy formation, coarse conglomerate, sandstone, quartzite and silty limestone.	0.85
Dpp	Pinyon Peak formation, limy siltstone and dolomitic limestone.	0.75
Djt	Jefferson formation and three formation undivided, dolomite, limestone, siltstone.	0.75
Sl	Laketown dolomite, middle and upper Silurian.	0.80
Os	Silurian and Ordovician undivided, mostly laketown and Fish Haven dolomites.	0.80
Ofh	Fish Haven dolomite, distinctly bedded dolomite.	0.80
Oe,Oes	Eureka and/or Swan Peak Quartzite, vitreous quartzite and hard sandstone.	0.85
Op	Pogonip formation, limestone, silty limestone, olive shale and intraformational conglomerate.	0.85
Opu	Upper Pogonip, Wahwah, Juab, Kanosh and Lehman formations, fossiliferous silty and sandy limestones and shale.	0.75
Opl	Lower Pogonip, House and Fillmore formations, chiefly impure limestone with abundant intraformational conglomerate.	0.75
Ou	Ordovician formations undifferentiated, chiefly Swan Peak and Fish Haven.	0.80
Osp	Swan Peak Quartzite, unfossiliferous quartzite.	0.85
Ogc	Garden City limestone, silty, cherty limestone with abundant intraformational conglomerate.	0.65
Ꞓun	Cambrian undivided, chiefly limestone, some shale, dolomite.	0.80
Ꞓuu	Upper Cambrian undivided, chiefly limestone and dolomite.	0.80
Ꞓmu	Middle Cambrian undivided, chiefly limestone, some shale.	0.80
Ꞓnp	Notch Peak formation, cliff-forming limestone.	0.75
Ꞓdu	Dunderberg shale, shale and thin bedded limestone.	0.85
Ꞓor	Orr formation, thin to medium bedded limestone.	0.65
Ꞓwk	Weeks formation, mostly laminated limestone and dolomite.	0.70
Ꞓmj	Marjun formation, limestone and shaly limestone.	0.75

Table 29. Continued

Symbol	Descriptions	Values
-Cw	Wheeler shale, fossiliferous limy shale, equivalent massive limestone in Wahwah range is included.	0.80
-Csw	Swasey and Whirlwind formation, massive limestone, limy shale and shale.	0.80
-Cd	Dome limestone, gray-weathering massive limestone.	0.80
-Chc	Howell and Chisholm formation, limestone, shaly limestone, and shale.	0.80
-Cta	Tatow formation, interbedded limestone, shale, and quartzite.	0.85
-Cp	Pioche formation, interbedded phyllitic shale and quartzite.	0.85
-Cpm	Prospect Mt. quartzite, quartzite, some phyllite.	0.90
-Co	Ophir shale, olive-green, micaceous shale and limestone.	0.85
-Ct	Tintic quartzite, pure quartzite and sandstone, some conglomerate.	0.75
-Csc	St. Chalres formation, limestone and dolomite.	0.75
-Cn	Nounan formation, limestone and dolomite.	0.70
-Cb	Bloomington formation, interbedded limestone and argillceous shale.	0.80
-Cbl	Blacksmith formation, chiefly thick-bedded dolomite, some limestone.	0.80
-Cu	Ute formation, chiefly silty limestone and shale.	0.80
-Cl	Langston formation, interbedded shale, limestone, dolomite.	0.80
-Cbr	Brigham quartzite, quartzite, sandstone.	0.90
-Cbs	Bushy quartzite, coarse to find sandstone and shale.	0.70
-Cld	Lodore formation, quartzitic sandstone and shale.	0.75
P-Ci	Precambrian intrusive rocks, chiefly granitic.	0.95
P-Csr	Undifferentiated metasedimentary rocks, chiefly quartzite and argillite.	0.95
P-Ccr	Undifferentiated crystalline rocks, schist, gneiss, and grainitoid rocks.	0.95
P-Cdc	Dove Cr. formation, quartzite, schist, limestone.	0.95
P-Ch	Harrison formation, quartzite, schist and dolomite.	0.95
P-Cm	Mutual formation, chiefly quartzite.	0.95
P-Cmf	Mineral Fk. formation, chiefly metamorphosed sediments including boulder clay.	1.00
P-Cbc	Big cottonwood formation, chiefly quartzite and argillite.	0.95
P-Cf	Farmington Canyon complex, schist, gneiss, pegmatites.	1.00
P-Cs	Sheeprock Series, argillite and metaconglomerate.	0.90
P-Crp	Red Pine shale, thin-bedded micaceous shale.	0.85
P-Clu	Lower undifferentiated part of Uinta group, chiefly quartzite.	0.95
P-Crc	Red Cr. formation, metaquartzite, schist and minor basic intrusions.	0.95

Appendix B

Table 30. Percent of area covered by geological formations for the Great Salt Lake Division.

Woodruff Creek

Jtc	8.60	TR t	0.76	€u	0.19	Dwc	0.62
Jn	2.70	TR t	0.60	€un	1.24	Ml	0.24
Qay	4.00	Cbr	9.28	Ogc	1.55	Djt	1.38
IPpc	1.78	Cl	1.01	Os	2.22	Tk	63.83

Farmington Creek

P€f	9200	Tk	8.00

Holmes Creek

P€f	100.0

Parrish Creek

QLtg	1.50	P€f	98.50

Ricks Creek

Qltg	2.50	P€f	97.50

Centerville Creek

Qltg	2.50	P€f	97.50

City Creek

Tk	40.42	Pw	7.86	€mu	1.75	Tsi	1.40
Kec	1.05	Mun	26.20	€o	1.31	TR ap	3.67
IPpc	2.18	Du	3.50	€t	2.45	Ktc	0.87
Qltg	2.97	Tqu	4.37				

Blacksmith Fork

€b	6.80	Mlp	1.17	Qao	2.92
€n	6.06	Mb	0.99	Tk	39.46
€sc	3.45	€bl	3.47	€un	0.36
Ou	13.14	€u	3.29	Ogc	2.16
Os	3.74	€l	3.30		
Du	2.27	€br	8.43		

E. Fk. Little Bear River

Tk	41.50	€l	7.00	€b	3.20	Ou	5.78
Tqu	1.50	€u	7.00	€n	3.74	Os	2.52
€br	12.13	€bl	3.20	€sc	5.41	Qay	0.36
Du	1.50	Osp	1.50	Ofh	1.50	Dwc	1.73
Ogc	0.43						

Table 30. Continued

Hardscrabble Creek

PꞒf	34.50	Ꞓmu	0.94	Mun	7.84				
Tk	38.94	Du	1.46						
Ꞓt	13.40	Pm	0.94						
Ꞓo	1.67	Pw	0.31						

Mill Creek nr. Bountiful

Tk	12.90	Ꞓt	23.10	Du	4.79	Ꞓmu	3.90		
Pef	40.77	Mun	8.87	Ꞓo	5.67				

Stone Creek

Qltg	0.31	Tk	2.20	PꞒf	97.49				

Lost Creek

Jtc	11.29	TR a	0.37	Tk	85.12				
Jn	2.41	TR t	0.81						

South Fork Ogden River

Ꞓbr	3.63	Djt	4.24	Ogc	2.45	Ꞓbl	0.28		
Ꞓl	0.89	Dwc	1.88	Tk	71.90	Ꞓo	0.47		
Ꞓun	3.40	Os	4.07	Ml	3.98	Mb	2.81		

Big Creek

Du	10.30	Ebr	3.30	Tk	78.70				
Qao	7.10	Qay	0.60						

Birch Creek

Ꞓbr	11.55	Jn	1.60	Tk	68.52				
Jtc	17.80	₽pc	0.53						

Hobble Creek

₽po	35.78	Kpr	23.25	₽pc	2.88	Tf	7.53		
Qgm	6.65	Qao	0.35	₽dc	2.56	Tgu	5.17		
Qay	2.96	Tu	10.08	₽K	2.79				

American Fork

Qgm	23.92	₽po	3.14	Mun	7.10	Et	6.54		
Tig	27.03	Mgb	15.98	Pemf	0.72	Eun	5.15		
PMmc	4.24	Mh	3.52	Pem	1.33	Qag	1.33		

Fort Creek

Qltg	32.58	Qay	4.32	Tig	15.78				
₽po	12.48	Qas	17.8	Tf	17.04				

Table 30. Continued

Dry Creek

Tig	66.13	Tf	1.14	Tqu	13.03
Qgm	11.56	Qag	6.19	Qltg	1.95

Big Cottonwood Creek

P€bc	21.53	€un	4.42	TR w	2.61	Qltg	0.15		
Mun	8.96	TR t	4.05	Qgm	28.36	Mh	5.06		
TR a	1.54	Tig	4.82	Mdo	1.96	TR s	0.34		
Pemf	3.47	Pw	5.02	€mu	0.74	IPcm	2.61		
IPpc	3.35	Jn	1.54	TR c	0.43	Prr	0.43		

Parleys Creek

Tk	13.42	KK	7.46	IPpc	0.54	TR s	2.75
Kec	8.95	Tqu	5.51	Qgm	1.34	TR a	3.49
Kw	5.37	Jp	1.05	TR w	0.48	TR c	4.42
Kf	7.16	Jtc	21.50	TR t	8.21	Jn	7.17
Qgm	1.18						

Mill Creek

Pw	18.55	Qgm	26.10	TR a	6.94	TR s	1.51
Mdo	1.47	IPpc	12.35	TR t	13.80		
Mh	3.00	PrV	3.34	Jn	2.20		
Mun	2.67	TR w	6.67	TR c	1.40		

Eimgration Creek

TK	11.66	IPpc	1.39	TR s	2.78	Qltg	2.00
Kec	8.88	TR w	0.83	TR c	4.11		
KK	9.44	TR t	5.00	Jn	5.33		
Jp	7.21	TR a	2.78	Jtc	38.59		

Little Cottonwood Creek

Pebc	14.60	Mh	0.54	€un	8.30
Tig	36.50	Qgm	40.06		

Logan River

Mb	4.89	IPpo	0.31	Os	10.30	€sc	6.15		
Mlp	4.41	Qgm	14.38	Osp	4.54	€b	13.55		
Du	6.92	Ogc	9.31	Tk	16.61	€n	3.92		
Qao	0.85	€l	0.19	€u	0.64	€bl	2.66		
€br	0.37								

Table 31. Percent of area covered by geological formations for the Uinta Division.

Little Brush Creek

Pem	76.53	Mun	2.23
Tbp	19.01	Єld	2.23

Brush Creek

Tbp	34.46	Mun	3.68
Pem	60.65	Єld	1.21

Ashley Creek

TbP	30.43	PMmc	0.52	Pw	5.04
Pem	34.57	Pm	4.90	Qgm	21.84
Mun	2.07	₱pc	0.63		

Ashley Creek below Trout Cr.

Pem	48.60	Qgm	38.10	Tbp	13.30

South Fork Ashley Creek

Qgm	50.85	Pem	49.15

East Fork Dry Fork

Pem	60.33	PMmc	0.81	Mun	2.14
Tbp	34.84	Pm	1.88		

East Fork Dry Fork at Mouth

Pem	41.62	Pm	15.01	PMmc	9.06
Pw	1.31	Tbp	22.71	Mun	10.29

North Fork Dry Fork

Pem	65.60	Pm	2.10	Mun	11.82
Qgm	15.75	PMmc	2.63	Tbp	2.10

Dry Fork above Sinks

Tbp	18.08	Pw	1.05	Mun	0.60
₱pc	1.05	Pem	14.91	Qgm	64.31

Whiterocks River

Pem	47.43	Qgm	45.13
Tbp	5.24	Pm	0.26
Mun	1.94		

Whiterocks River above P.C.

Qgm	53.53	Pem	44.45	Tbp	2.02

Table 31. Continued

Carter Creek nr. Manila							
Qgm	59.85	Pem	40.15				
Farm Creek							
Mun	35.60	Pm	10.18	Tdr	11.00		
Pem	18.62	Tbp	24.60				
Clover Creek							
Pem	3.240	Qgm	67.60				
Uinta River above Clover Creek							
Tk	12.09	Jn	1.28	Qay	13.26	Perp	3.56
Kw	7.34	TR c	0.76	TR w	2.50	Pem	3.07
KK	3.66	TR a	1.22	IPpc	3.95	Qgm	5.24
Tib	0.08	TR t	1.78	Pw	8.85	Dpp	0.14
Kf	6.06	Jp	0.58	Pm	4.90	Et	0.65
Ka	0.75	Qls	1.92	PMmc	1.64	Ju	0.75
Jm	0.61	Qao	2.44	Mu	3.00	Jtc	2.45
Tiap	2.44	Ml	3.03				
Uinta River below Gilbert Creek							
Tk	54.31	Tib	0.38	KK	8.20	Ka	1.87
Kw	13.60	Tiap	0.56	Kf	21.08		
Yellowstone Creek below Swift Creek							
Qgm	56.82	Pem	35.41	Tdr	0.49		
Pelu	5.36	Perp	1.29	Qay	0.63		
Yellowstone Creek							
Tiap	69.14	Ka	0.31	Pw	1.59	Tk	0.73
Qay	13.17	KK	2.17	Tig	0.34	Jtc	0.59
Qgs	0.13	Jm	0.10	Kf	5.33	TR c	0.10
IPpo	0.34	Ju	0.08	Jn	1.84	TR s	0.07
TR w	0.33	Jp	0.11	TR u	0.35	TR a	0.24
TR t	0.95	Qao	1.39	IPpc	0.60		
Lake Fork							
TQu	0.22	Jn	14.78	Pw	3.12	TR t	13.17
KK	0.41	Jtc	7.18	IPpc	3.56	Qay	10.30
Jp	0.81	TR a	9.21	Tiap	3.34	TR w	3.56
TR s	1.99	Qgm	14.32	Tk	7.09	Tig	2.33
TR c	2.12	Mun	0.87	Qao	1.62		

Table 31. Continued

Rock Creek nr. Mountain Home

PrV	0.37	Tig	11.55	Pem	1.96	TR c	1.00
IPpc	2.70	Qay	2.54	Ꞓt	0.85	TR s	0.97
Mun	4.12	Qas	2.35	Ꞓmu	0.43	TR a	1.82
Pw	5.45	Qltg	1.90	Tqu	0.28	TR t	3.74
Qgm	27.90	Pef	0.37	Jtc	4.33	TR w	1.30
Ꞓun	5.45	PꞒbc	11.63	Jn	2.75	Pemf	1.25
Mdo	0.87	Mh	2.12				

Rock Creen nr. Hanna

Tig	12.39	Emu	0.51	Ꞓun	1.59	Qgm	24.24
Tqu	0.33	Pemf	1.19	Qay	3.06	Jtc	5.23
IPpc	3.20	Qas	2.83	Jn	3.32	Pw	4.79
Qltg	2.30	TR c	1.21	Mun	2.78	Pef	0.45
TR s	1.17	Mdo	1.04	Pebc	14.18	TR a	2.19
Mh	2.55	IPcm	2.36	TR t	4.50	Ꞓt	1.02
TR w	1.57						

Duchesne River

Pelu	20.69	Qgm	78.70	Pem	0.61

Provo River

Pem	14.68	Perp	3.49	Qgm	78.20
Pelu	3.63				

Weber River

Pelu	2.93	Ml	2.52	Pw	6.02	TR c	0.64
IPcm	9.81	Mu	2.80	IPpc	4.20	TR t	0.49
Qgm	28.23	Pm	2.30	TR w	1.68	Dpp	0.09
Perp	2.83	Jtc	0.47	TR a	0.82	Ꞓt	0.51
Qay	9.72	Ju	0.26	Ka	0.39	Tk	14.32
Jn	0.22	KK	0.74	Ktc	0.54	Qls	0.52
Jm	0.26	Pwmu	0.84	Kw	4.86	PMmc	0.69
TR u	0.30						

Wolf Creek

Tiap	19.05	TR w	7.13	Qgm	19.05	Pw	3.96
TR t	17.47	IPpc	11.11	Qay	22.23		

West Fork Duchesne River

Tiap	15.68	TR a	2.82	Jtc	9.08	Jm	3.96
Qgm	0.95	TR s	1.28	Qay	6.91	Tgs	25.08
TR w	2.04	TR c	2.82	Jp	6.78		
TR t	7.16	Jn	12.80	Jst	2.64		

Table 31. Continued

West Fork Duchasne River below Dry H.

Tiap	25.64	TRa	0.25	Qay	9.69	Jp	5.39
Qgm	1.29	TRs	0.50	Jtc	8.80	Jst	1.69
Jn	11.85	TRc	0.86	Tgs	31.64	Jm	2.08
Kmf	0.32						

Water Hollow

IPpo	3.93	Qas	88.68	Qltg	0.35
Qay	7.04				

White River

Tu	11.01	Tgpl	68.02	Tc	1.69
Tgp_2	7.27	Tggd	11.29	Qay	0.72

North Fork White River

Tu	13.80	Tgpl	63.28	Tc	3.64
Tgp2	5.82	Tggd	11.63	Qay	1.82

Minnie Maud Creek

IPpo	28.32	Ki	5.56	Tknh	23.72
Kpr	32.63	Tiap	9.77		

Carter Creek at Mouth

Qgm	57.45	Pem	42.55

Brown Duck Creek

Mh	7.70	Ꞓun	11.70	Mdo	0.79
Qgm	25.40	Pw	11.37	IPpc	3.94
Pebc	1.48	Tig	28.12	Mun	9.86

Hadas Creek

Perp	15.62	Qgm	33.20	Ml	1.37
Pem	41.03	Qls	8.78		

Table 32. Percent of area covered by geological formations for the Southern Utah Division.

Summit Creek

TRpo	59.99	T_1ap	4.80	Tc	8.46	Tf	5.14
Eun	4.34	Mg	1.49	Md	1.94	Mh	3.43
Mgb	2.86	PMmc	6.86	Qgm	0.69		

Price River

Kbh	26.12	Kc	11.70	Kpr	2.73	Tf	15.98
Tknh	43.47						

Gooseberry Creek

Tknh	63.23	Tf	17.58	Kbr	8.43	Kc	8.97
Kbh	1.79						

Pleasant Creek

Tknh	48.94	Kpr	29.26	Kc	13.57	Kbh	6.78
Qay	1.45						

Huntington Creek

Tknh	13.20	Tf	0.62	Kpr	22.62	Kc	11.56
Kbh	36.20	Ksp	11.13	Qgs	1.45	Kmin	2.60
Qay	0.62						

Cottonwood Creek

Qls	4.65	Tf	18.18	Qay	7.29	Kpr	9.32
Kc	4.73	Kbh	3.16	Ksp	0.90	Qgs	0.37
Ke	0.22	Kmm	0.80	Tknh	49.23		

Ferron Creek

Tf	27.83	Tknh	46.25	Kpr	6.70	Qgs	0.87
Qay	0.30	Kms	0.57	Kmm	2.39	Kc	9.26
Kbh	13.40						

Muddy Creek

Tf	14.07	Tknh	44.62	Kpr	24.60	Ke	1.03
Ksp	2.63	Kmm	2.75	Kc	5.15	Qay	0.57
Kbh	4.58						

Twin Creek

Tknh	64.71	Kpr	19.25	Kc	8.02	Kbh	8.02

Ivie Creek

Kms	0.99	Qay	1.32	Qgs	5.46	Qls	19.36
Kc	4.86	Kbh	24.50	Kpr	16.71	Tknh	5.96
Tw	12.24	Tf	0.66	Qao	4.30	Tvu	3.64

Table 32. Continued

Chalk Creek							
Tknh	40.54	Tf	1.93	Qgm	0.09	Qls	0.29
Kpr	1.44	Ꞓuu	2.02	Ꞓun	11.02	Ꞓo	1.53
Ꞓt	21.64	Jna	6.49	TR s	0.49	TR m	1.07
Tsr	1.21	Qag	10.24				
Indian Creek							
Tip	28.25	Qgs	5.65	Jm	12.43	Kms	53.67
Center Creek							
Tvu	48.78	Kka	3.49	Tw	34.57	Kwa	0.56
Ku	11.71	Qag	0.89				
Beaver Creek							
Tvrp	12.17	Tvbc	20.99	Tsr	19.41	Qls	12.35
T_2bf	0.34	Qa	3.70	Tvil	11.47	Tvmb	0.17
Tvdh	19.40						
Sevier Creek							
Qay	1.78	T_2af	0.56	Tvm	5.70	Kwa	3.69
Kka	2.80	Qag	0.37	Tsr	0.65	Tqu	2.43
Tw	39.94	Qb	18.82	Tvbh	23.26		
Castle Creek							
TR wi	0.94	TR u	3.77	Qgs	2.04	Kdbc	10.38
Kms	3.14	TR k	1.57	Je	2.67	Jna	3.14
Jnsw	3.14	Jmbb	15.73	Tip	53.48		
Mill Creek nr. Moab							
JTR k	6.86	TR wi	0.94	Je	9.86	Jsu	6.63
Qco	3.42	Jmsw	7.50	Kdbc	6.00	Kms	3.00
Jmbb	9.42	Qgm	4.48	Kbc	0.65	Tip	1.91
Qgs	3.22	TR u	0.85	Jma	35.26		
North Creek							
Kst	38.49	Kwa	3.71	Qa	46.59	Kka	0.68
Qay	1.08	T_2bf	9.45				
Pine Creek							
Qa	56.94	T_2bf	30.74	Jca	4.72	Kst	6.48
Kwa	0.65	Jm	0.28	Jb	0.19		
Coal Creek							
Qb	4.50	Tw	12.43	Tvu	4.20	Jca	1.60
Ju	1.80	Jw	4.20	Kwa	32.12	Ku	9.43
Kdt	11.84	Kka	17.88				

Table 32. Continued

East Fork Boulder Creek

Qgs	3.13	Qls	9.58
Qgn	7.15	Tvu	80.14

East Fork Deer Creek

Qls	50.67	Qgs	49.33

Henrieville Creek

Tw	2.10	Kwa	87.75	Ju	0.60	Kdt	7.45
Qay	2.10						

North Fork Virgin River

T mo	0.40	Qay	0.18	J℞k	1.38	Jna	13.22
Ju	4.95	Jw	1.72	Kdt	10.54	Kst	4.96
Qb	6.38	Kka	1.61	Tw	1.61	Qa	1.52
Qls	0.22	Kwa	40.15				

Appendix C

Table 33. Percent of total area covered by type of vegetation for the Great Salt Lake Division

Watershed	Coniferous trees	Broadleaf trees	Brush lands	Sagebrush	Saltbrush	Herbaceous[a]	Pinon-juniper
Woodruff Cr.	30	17		53			
Farmington Cr.			100				
Holmes Cr.			30	50		20	
Parrish Cr.			60	40			
Ricks Cr.			50	50			
Centerville Cr.			29	71			
City Cr.			92	8			
Blacksmith Fk.	28	27	7	38			
East Fk. Little Bear R.		30	37	33			
Hardscrabble Cr.		58	42				
Mill Cr. nr. Bountiful			100				
Stone Cr.		7	47	46			
South Fk. Ogden R.		24	54	22			
Lost Cr.	3	29	27	35	6		
Big Cr.	17	18		65			
Brich Cr.		20		80			
Hobble Cr.	23	70				7	
American Fk.	18	23	34			25	
Fort Cr.			50	10		40	
Dry Cr.			65			35	
Big Cottonwood Cr.	46	11	7	14		22	
Parleys Cr.		43	56	1			
Mill Cr. nr. SLC	61	25	14				
Emigration Cr.			87	13			
Little Cottonwood Cr.	17			10		73	
Logan R.	51	13	11	18		1	6

[a]Also includes desert type, foothill types, mountain types, and barren inaccessible.