Synthesis of Coastal Processes in Southwest Coast of Sri Lanka

W.N.Wilson

Department of Geography

University of Colombo

1. Introduction

Sri Lanka is surrounded by a coastal belt and this makes an impact on socio-economic and political activities of Sri Lanka. This coastal belt is continuously subjected to various changes daily, annually and seasonally and these changes directly contribute to the composition, length, width and shape of the coast. The vegetation and the general environment are also influenced by these changes.

Coastal erosion and deposition of segments are directly a function of the changes that occur in the composition of the coast and its slope.

The main purpose of this study is to find out the impact of the various factors that contribute to changes in the formation of the coast and to demarcate these factors following variables have been taken into consideration.

2. Objectives:

- **i)** To investigate the factors contributing to the daily, seasonal and annual changes of the coast.
- **ii)** To investigate the interrelationship among the factors based for the study.
- **iii)** To identify the grouping tendency of each variables.

3. Research Methodology

In 2007 during the Southwest monsoon period, measurements related to the selected variables have been taken from 50 locations along the South West coast from Colombo to Matara. Various instruments have been used for this purpose and services of 20 trained field assistants have been utilized to collect data. Some measurements have been directly obtained from the field while the others have been obtained by using relevant formula.

Statistical methods such as (i) Principal Component Analysis and (ii) correlation methods have been used to analyze the data.

4. Result and Discussion

The following variables are considered as the existing variables, which are responsible for the present coastal processes of the Southwest coast of Sri Lanka.

1.Beach angle, 2. Beach width, 3. Wave height, 4. Wave period, 5. Wave angle, 6. Uprush, 7. Backwash, 8. Current speed, 9. Breaker type, 10. Wave energy, 11. Grain size, 12. Wave steepness, 13. Long-shore current velocity, 14.Long shore sediment transport rate, 15. Wave angle, 16. Near shore depth.

4.1 Application of the statistical techniques

Most scientists and geographers such as Strahler (1954), Krumbein (1955), Shumm (1959), Melton (1957), Chorly (1966) and Davis (1987), have used various statistical methods to analyze problems and to arrive at decisions and conclusions. During the last few decades, statistical methods have increasingly being used for various studies and research. In this study statistical techniques have been employed whenever their application seemed profitable and helpful in making objectives and meaningful inferences. However, the main statistical methods which have been used for this study is the Multivariate analysis.

4.2 The method Principal Component analysis

Principal component analysis is a technique, which permits identification of mutually uncorrelated linear combinations of the original variables. Thus it provides an effective method for reducing the number of variables in large scale correlation studies.

In the present study, this technique is used to reduce the data through extractions and rotation of the factor loadings matrix. The relationship between rotated factors and original variables is stated in terms of the percentage contribution to the variance of each variable by each rotated factor.

Table I. a - MATRIX TO BE FACTERED

Variable	Beach angle	Beach width	Wave height	Wave Perioiod	Wave angle
Beach angle	1.000				
Beach width	-0.316	1.000			
Wave height	0.491	-0.264	1.000		
Wave period	0.013	0.142	0.078	1.000	
Wave angle	-0.096	-0.055	-0.067	0.063	1.000
Up rush	0.147	0.139	0.198	-0.334	0.172
Backwash	0.072	-0.143	0.290	-0.300	0.113
Current speed	0.068	-0.183	0.049	-0.317	0.071
Breaker type	-0.134	-0.096	0.040	0.059	-0.078
Wave energy	0.531	-0.281	0.912	0.116	-0.160
Grain size	-0.274	0.379	-0.213	0.007	0.025
Wave steep	0.226	-0.254	0.347	-0.572	-0.069
Long shore current velocity	-0.150	0.046	0.154	0.089	0.034
Long shore sediment transport rate	0.180	-0.104	0.551	0.298	0.505
Wave angle	0.123	0.150	0.097	0.790	-0.060
Near Shore Depth	-0.066	0.100	0.258	0.154	0.093

Table I. b - MATRIX TO BE FACTERED

Variable	Uprush	Backwash	Current speed	Breaker type	Wave energy
Uprush	1.000				
Backwash	0.601	1.000			
Current speed	0.287	0.296	1.000		
Breaker type	-0.387	-0.073	-0.095	1.000	
Wave energy	0.094	0.193	-0.076	0.108	1.000
Grain size	-0.030	-0.128	-0.083	0.208	-0.171
Wave steepness	0.333	0.249	0.136	-0.212	0.325
Long shore current velocity	-0.007	-0.054	-0.185	0.078	0.11
Long shore sediment transport rate	0.141	0.082	-0.110	0.072	0.563
Wave angle	-0.375	-0.362	-0.217	0.176	0.181
Near Shore Depth	0.198	0.096	-0.146	0.04	0.285

Table I. c - MATRIX TO BE FACTERED

Variable	Grain size	Wave steepness	Long shore current velocity	Long shore sediment transport rate	Wave angle	Near shore depth
Grain size	1.000					
Wave steep	-0.212	1.000				
Long shore current velocity	-0.274	-0.047	1.000			
Long shore sediment transport rate	-0.064	-0.034	0.148	1.000		
Wave angle	0.183	-0.661	0.099	0.336	1.000	
Near Shore Depth	-0.080	-0.158	0.004	0.333	0.110	1.000

First of all to obtain a general impression of the nature of relationship among the different variables correlations were calculated. The correlation matrix in Table.1.a, b and c shows that some variables are highly correlated with others in the set. For example, wave energy, wave length and long shore current velocity show an exceptionally high correlation. Again back wash long shore sediment transport rate and wave steepness are highly correlated. These high correlations indicate the presence of a high degree of multicollinearity among the variables. Thus the Principal Component analysis is performed to gain an idea of the degree of this interrelatedness.

As a first step an attempt was made to identify few factors from among the 16 variables based on their eigen values. Table.2 shows the highest eigen values of the first five variables. The eigen values of the first five variables each exceeds value 1. As the next step the 16 variables mentioned above are then analyzed according to the component loading. On the results obtained from the latter these 16variables were classified into 5 factors. The relationship between the factor and the original variables are given in Table 3. From this table it can be seen that each factor is more strongly related to some variables than to others. The five factors abstracted on the basis of component loadings show which of these 16 variables are more prominent. The followings are the important variables indicated by the five identified factors.

The sequence of the high values taken by the variables under the first factor are : 1. Wave steepness 2. Wave length, 3. Back wash, 4.Wave energy, 5. Wave length, and 6. Wave period.

The sequence of the high values for the variables in the second factor are 1. Long-shore transport rate, 2. Wave energy, 3.Wave length, 4.Weve period and 5. Wave height respectively. Wave energy and Uprush taken an important place in the third factor, while grain size and long shore current velocity are important as the forth factor. The two latter variables reported negative correlation. Beach width, Wave angle and Breaker type are prominent variables in the fifth factor and Wave angle and Breaker type reported negative correlation under the fifth factor.

Accordingly “Wave” can be identified as a prominent parameter among these variables. Long-shore transport rate, Grain size and Beach width are also important in that order.

Table 2
Eigenvalues

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
3.442	3.062	1.792	1.376	1.221	0.004	0.023	0.744
9	**10**	**11**	**12**	**13**	**14**	**15**	**16**
0.604	0.502	0.421	0.257	0.242	0.130	0.091	0.053

Table 3
Components Loadings

Factors	1	2	3	4	5
Beach angle	0.496	0.366	-0.378	0.207	0.225
Beach width	0.434	-0.114	0.163	-0.175	0.537
Wave height	0.649	0.651	-0.059	-0.205	0.064
Wave period	-0.504	0.661	0.042	0.263	0.142
Wave angle	0.052	0.072	0.596	0.372	-0.552
Up rush	0.592	-0.203	0.589	0.021	0.297
Backwash	0.613	-0.140	0.363	-0.025	-0.038
Current speed	0.355	-0.325	0.044	0.257	-0.189
Breaker type	-0.247	0.232	-0.199	-0.387	-0.528
Wave energy	0.575	0.718	-0.160	-0.238	0.096
Grain size	-0.432	-0.041	0.328	-0.520	-0.001
Wave steep	0.733	-0.274	-0.172	-0.280	0.014
Long shore current velocity	-0.108	0.217	0.228	-0.620	-0.140
Long shore sediment - transport rate	0.250	0.728	0.394	0.109	-0.271
Wave angle	-0526	0.708	-0.046	0.181	0.133
Near Shore Depth	0.098	0.396	0.426	0.031	0.169

Table 4

Variance Explained by Components

Factors	1	2	3	4	5
	3.442	3.062	1.792	1.376	1.221

Percentage of total variance Explained

Factors	1	2	3	4	5
	21.512	19.139	11.202	8.598	7.632

Table 5
Rotated Loadings

Factors	1	2	3	4	5
Beach angle	0.011	0.651	-0.166	-0.459	0.009
Beach width	0.259	-0.324	-0.166	0.402	0.612
Wave height	-0.081	0.939	0.077	0.022	0.026
Wave period	0.866	0.123	0.126	0.006	0.045
Wave angle	-0.032	-0.146	0.885	-0.034	0.011
Up rush	-0.511	0.166	0.239	-0.013	0.695
Backwash	-0.551	0.227	0.296	-0.031	0.294
Current speed	-0.420	-0.098	0.207	-0.327	-0.001
Breaker type	0.118	0.063	0.075	0.401	-0.632
Wave energy	0.015	0.967	-0.014	0.036	-0.035
Grain size	0.108	-0.241	-0.029	0.701	0.060
Wave steep	-0.747	0.343	-0.195	-0.083	-0.008
Long shore current velocity	-0.002	0.170	0.047	0.690	-0.087
Long shore sediment - transport rate	0.238	0.574	0.661	0.096	0.035
Wave angle	0.891	0.173	0.051	0.053	-0.035
Near Shore Depth	0.198	0.300	0.290	0.142	0.379

Variance Explained by Rotated Components

Factors	1	2	3	4	5
	3.038	3.084	1.617	1.651	1.503

Percentage of total variance Explained

Factors	1	2	3	4	5
	18.986	19.272	10.108	10.321	9.395

The results of this test are displayed in table 3. It shows the proportion of the total variance in all data attributable to each factor. The factor values are related to the degree of interrelationship among the variables. When the interrelationship is strong, a few factors can explain a large proportion of the total variance. The results of this original variables are given in table from this it can be seen that each factor is more strongly related to some variables than to others.

The rotated factor loading shows that factor one is strongly associated with wavelength, wave period, and wave steepness. Six variables, which were grouped in the first factor, under the component loadings, were reduced to three variables in the first factor, and wavelength become more prominent under the rotated component loading.

Wave energy, wave height and beach angle were more prominent and strongly associated variables in the second factor. Under the third factor wave angle and long shore transport rate become more prominent. While grain-size and long shore current velocity showed up as more important variables in the fourth factor, up rush, breaker type and beach width become the prominent variables in the fifth factor.

The amount explained by factor one and two here are greater than that explained by factor 3,4 or 5. Also factor one is more important than factor 2 in this respect. As far as total variance is concerned, the first four factors explained only 50% of the total variance, and 68% of the total variance is explained by 5 factors (table 4). Therefore the next step was an attempt to identify the strongest factor.

For the above task, eigen values were calculated for 6 factors. The eigen values of the six factors showed that highest eigen values are restricted to the first 6 variables . The eigen values of the first 6 factors each exceeds 1, while the eigen values of the other factors is less than 1. the relationship between the first 6 factors and the original variables are given in table 3. From this it can be seen that each factor is more strongly related to some variables than to others. This shows that factor one is strongly associated with wavelength, wave period, wave energy and wave height. Wave angle and long shore velocity are dominant variables in factor three. Beach width and Near shore depth are the variables in the forth factor, while breaker type is the dominant variable in fifth factor. Current speed is the dominant variable in factor six.

The results of this test are displayed in tables and show the proportion of the total variance in all the data attributable to each factor. The results of this analysis reveal that factor one and two take more or less similar weight for explaining the variance. While the second factor is less important than factor one, it is more significant than factors 4,5, or 6. rotated component loading method was used. Of these four also, wave energy emerged as the most prominent variable. Under the rotated component loading methods, wave height, wave period and wave steepness were identified as important variable in the second factor. It will be seen here that under this method, wave energy no longer counted as an important variables. Under the third factor, wave angle and long shore velocity emerged as prominent variables according to the rotated component loadings. Long shore transport rate also has some value under the 3rd factor here. Grain-size also emerged as somewhat important in the forth factor. Breaker type and current speed have become important in factor 5, and 6 respectively. As far as the total variance is concerned first three factors explain 50% of the total variance while 80% of total variance is explained by the six factors. (see table 4)

Six factors were analyzed by the Principal Component Analysis and these six factors have explained 80% of the variance. Although this analysis has helped for the identification of certain coastal processes and also to explain some of these processes in term of predominant variables active in the Southwest coast; it does not importantly indicate any grouping tendency among the variables. Therefore it was decided to make another analysis of the variables by applying the Alternating Least Square Method.

4.3 The application of the Alternating Least Squares Method.

This method will give an over view of how the different variables in the study area are related to each other. Because of the kind of data involved, e.g. mainly categorical variables while have nonlinear relations among one another, a computer program of special multivariate analysis was called “PRINCALS” was used. Princal is a Principle Component analysis method based on alternating Least Squares (ALS) together with the program CANNALS which will also be used. These programmes are based on the principles of ALS; which ensure that best solution for categorical data analysis.(Both these computer programmes have been developed by the Department of Data Theory, Leiden University , the Netherlands).

This analysis has been carried out in three phases:

1.Single nominal solution 2. Ordinal solution and 3. Numerical solution. Each phase consist of two steps. 1, Nonlinear transformation in to optimally scaled variables and 2, A linear multivariate analysis applied to those optimally scaled variables.

4.4 The single Nominal Solution

Object scores which were abstracted under the single nominal solution were plotted as shown in figure. 1. These plotting do not show a very clear grouping tendency. Therefore to obtain a clear understanding of certain interrelationships, component loading which were once again plotted as shown in figure 2. This plotting of the component loading represents the angle between variables is closely related to either variables. The size of the arrows obtained through the least squared method corresponds to row sum single fit, and therefore to "explained variance" per item. Projections on the horizontal axis correspond to correlations between object scores on the first dimension and each of the quantified items. Projections on the vertical axis correspond to correlations between quantified item and objects correlated on the seconds.

From the component loadings graph based on single nominal solution, it was observed that Wave period, Wave length, near shore depth, and Breaker type are clustered into one group. Wave steepness shows a high.

Another cluster can be seen consisting of Up rush, Current speed and Backwash. Beach width shows a negative correlation in this cluster, because it is an independent variable. The variables in the second cluster shows a much greater interrelationship with one another than the variables in the first cluster, except in the case of Breaker type. This suggests that Breaker type too does not play a very important role in coastal processes when compared with other variables.

The variables of Long-shore sediment transport rate, beach angle, and wave energy and wave height are grouped under another cluster. Grain size shows a negative correlation in this cluster because it plays a separate role in that cluster when compared with other variables. Grain-size has more to do with inland processes than with marine processes.

The following conclusion can be arrived from the single nominal solution analysis: viz: the different variables relating to coastal process can be grouped into three clusters and independent variables as shown below is responsible for a set.

Cluster	Variables	Independent variable
1	Wave-period Wave-length Breaker-type Wave-steepness	Near-shore depth
2	Uprush Back-wash Current speed	Beach width
3	Long-shore sediment rate Wave energy Wave height Grain-size	Beach- angle

According the results of the single nominal solution show the variables responsible for the coastal process which occur along the south-west coast. The component loading graph show that wave period, Wave length, Wave steepness and Near –shore depth play the most important role. Whereas Back wash, Uprush, Current speed and Beach width play a less prominent role. Wave energy, Wave height, Grain size, and Beach angle play an even lesser role.

The results from the single nominal solution analysis do not actually give a really accurate interpretation of coastal variables and processes. The above analysis is prevent unable to give a satisfactory explanation of the role played by the above mentioned clusters and variables in the coastal processes that are currently operative in the Southwest coastal of Sri Lanka. Therefore the additional step of applying the ordinal solution method to analyze the same data was found to be necessary.

4.5 The Ordinal solution method

Single ordinal solutions involve a joint plotting of variables (arrows based on component loading) and objects. The first dimension correlates with all variables whereas the second dimension contrast with them and also contrast with objects. The unlabeled objects have been plotted in fig 3. This plot does not show any clear grouping tendency. The component loading graph of ordinal solution method (fig 4) shows a fair grouping tendency of coastal variables as follows:

Cluster	Variables	Independent Variable
1	Wave-period Wave-length Breaker-type Wave-steepness	Near-shore depth
2	Uprush Back-wash Current speed	Beach width
3	Long-shore sediment rate Wave energy Wave height Grain-size	Beach- angle

According to this analysis, some of the variables, which grouped under the single nominal, changed their original grouping, so that some variables were excluded from it, for example, the variables which formed a group under the ordinal solution analysis also. One of these variables, namely near shore depth was excluded. Wave steepness was shown relative importance under the single nominal solution showed a greater degree of importance under the ordinal solution.

Wave energy and wave angle, showed a close relationship in the third variable set in the ordinal solution analysis and long shore transport rate and beach angle showed a poor relationship. But Near-shore depth and Back-wash remained equally important under both the 1st and the 2nd variable sets.

4.6 The Nominal Solution

Although a grouping pattern was abstracted from the single, and ordinal nominal solution methods for certain variables, which represented the costal processes, it is necessary to obtain confirmation of these results through another test. A lot of data, which were collected, could not be utilized under the single or ordinal solution. But the application of the numerical solution will help to take some of the unutilized data also into account. This is because the numerical solution analyses not only has linear patters, but also non linear once as well. Therefore the numerical solution method is also applied here to verify the grouping tendencies. Under the numerical solutions, the object scores are plotted and represented in fig 5 and component loading are plotted and represented in fig 6 from the above plotting it is seen that grouping of the relevant variables clearly emerge.

According to the component loadings in fig 6 to prominent groupings can be distinguished. The variables in fig 6 are centered around two axes. Along the vertical axis beach width is represented. Beach width can be considered as the prominent depended variable. A grain size distribution Near shore depth, current speed wave angle, backwash, and wave steepness are closely associated with beach width.

In the horizontal access the variable of Beach angle is represented. Beach angle also can be considered as a major dependent variable in the coast. Wave height, wave energy, long shore transport rate, and long shore current velocity are interrelated and closely related with beach angle. In addition to these, wave period, wave length and Up rush are closely related with each other and also correlated with the variables of Beach-width.

4.7 Conclusion

Above clustering pattern makes it easy to interpret coastal processes in the south-west coast. The two major axes, horizontal and vertical, which represent the Beach-angel and Beach- width respectively indicate two important coastal processes: viz, coastal accretion and coastal abrasion. The vertical axis, which represents beach width, indicates a process of accretion in the coast. This vertical axis, which represents the Beach-width, is well measured. The variables of grain size, Near-shore depth, and current-speed and wave angle are closely related with each other and also associated with Beach-width. This indicates that these variables are mainly responsible for coastal accretion in the south-west coast. The variable of

Wave-steepness lies in the opposite direction from the centre, which means that, when the beach-width is increased, Wave steepness decreases. Among the variables, which are associated with Beach-width, Wave-angle, Current-speed, and Near-shore depth are poorly measured which means that these latter variables play only an insignificant role in the determination of beach width.

The variables of Wave period, Wave period, Wave length and Uprush are associated closely with each other and are located close to the axis of Beach width. This indicates that these variables exert a high degree of influence on the determination of Beach width. In other wards, these four variables can be considered as highly responsible for the process of coastal accretion in the Southwestern coast of Sri Lanka. While Wave period can be regarded as the most important of the variables mentioned above Wave-length and Uprush are the least important of these. Therefore Wave period can be considered as a critical variable for the changing of Beach width in the southwestern coast of Sri Lanka.

The beach-angle, which is represented on the horizontal axis, is responsible for the process of coastal abrasion. Wave energy, Wave-height, Long-shore transport rate and Long-shore current velocity are the variables, which are mostly responsible for changing the Beach-angle. Among these variables Wave-energy and Wave-height are associated with each other very closely and indicate a high correlation with Beach-angle. The close relationship between these two variables is mainly due to the fact that one is the result of the other. In other words, Wave energy is a result of Wave-height. These two variables are highly correlated to Beach angle and therefore it is clear that these two variables are greatly responsible for changing the Beach angle. The long-shore current velocity and Long-shore transport rate are closely related in that are causes the other and therefore each plays an equivalent role in determining the beach angle.

According to the Numerical Solution analysis there is a fairly high grouping tendency. It also helps to identify the important variables responsible for the Southwest coast of Sri Lanka.

Fig - 01

Single Nominal Object Scores Unlabeled

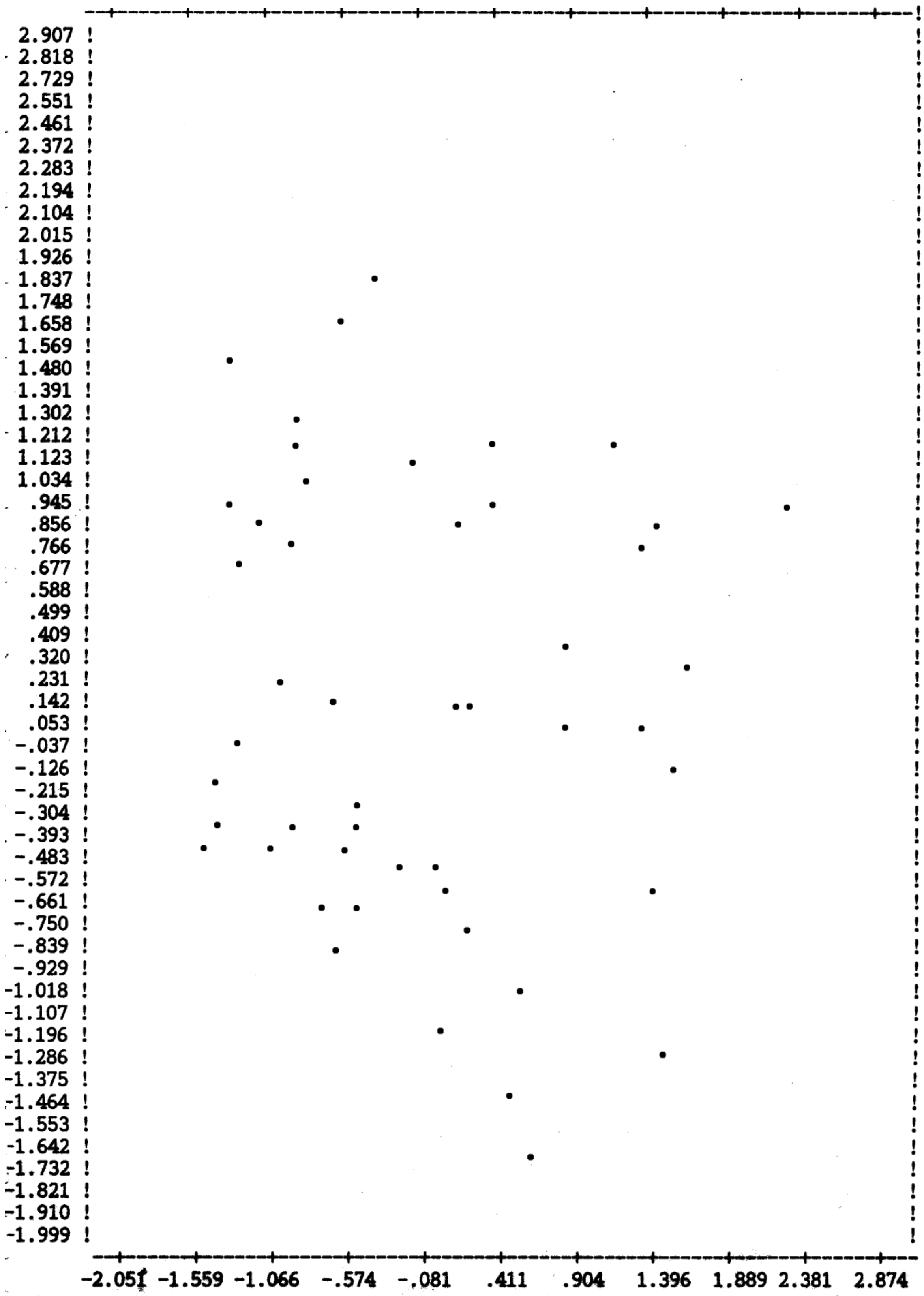
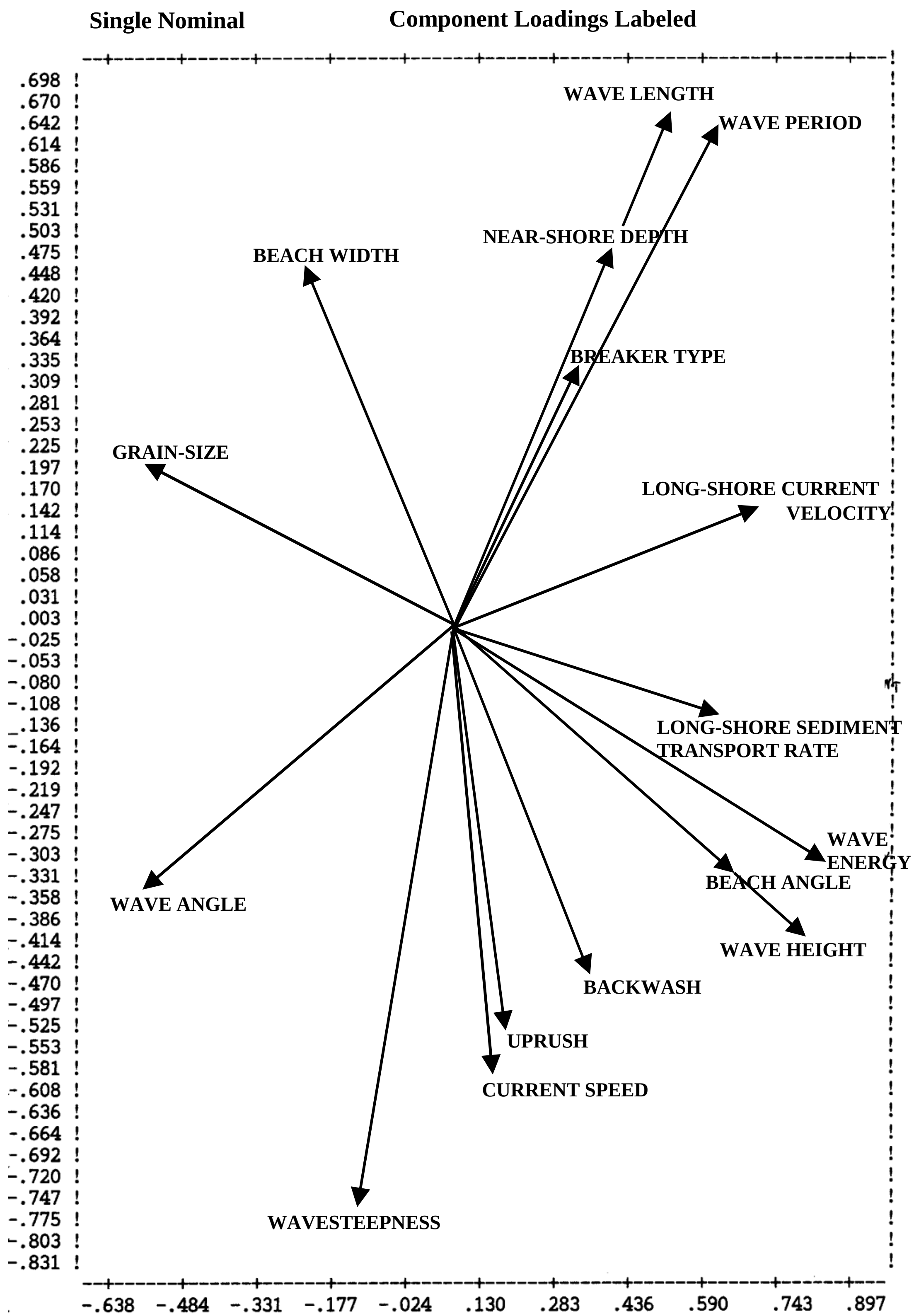


Fig-02



Single Nominal
Component Loadings Labeled
.698
.670
.642
.614
.586
.559
.531
.503
.475
.448
.420
.392
.364
.335
.309
.281
.253
.225
.197
.170
.142
.114
.086
.058
.031
.003
-.025
-.053
-.080
-.108
-.136
-.164
-.192
-.219
-.247
-.275
-.303
-.331
-.358
-.386
-.414
-.442
-.470
-.497
-.525
-.553
-.581
-.608
-.636
-.664
-.692
-.720
-.747
-.775
-.803
-.831
-.638
-.484
-.331
-.177
-.024
.130
.283
.436
.590
.743
.897
WAVE LENGTH
WAVE PERIOD
NEAR-SHORE DEPTH
BEACH WIDTH
BREAKER TYPE
GRAIN-SIZE
LONG-SHORE CURRENT
VELOCITY
LONG-SHORE SEDIMENT
TRANSPORT RATE
WAVE
ENERGY
BEACH ANGLE
WAVE ANGLE
WAVE HEIGHT
BACKWASH
UPRUSH
CURRENT SPEED
WAVESTEEPNESS

Fig-03

Ordinal Solution Object Scores Unlabeled

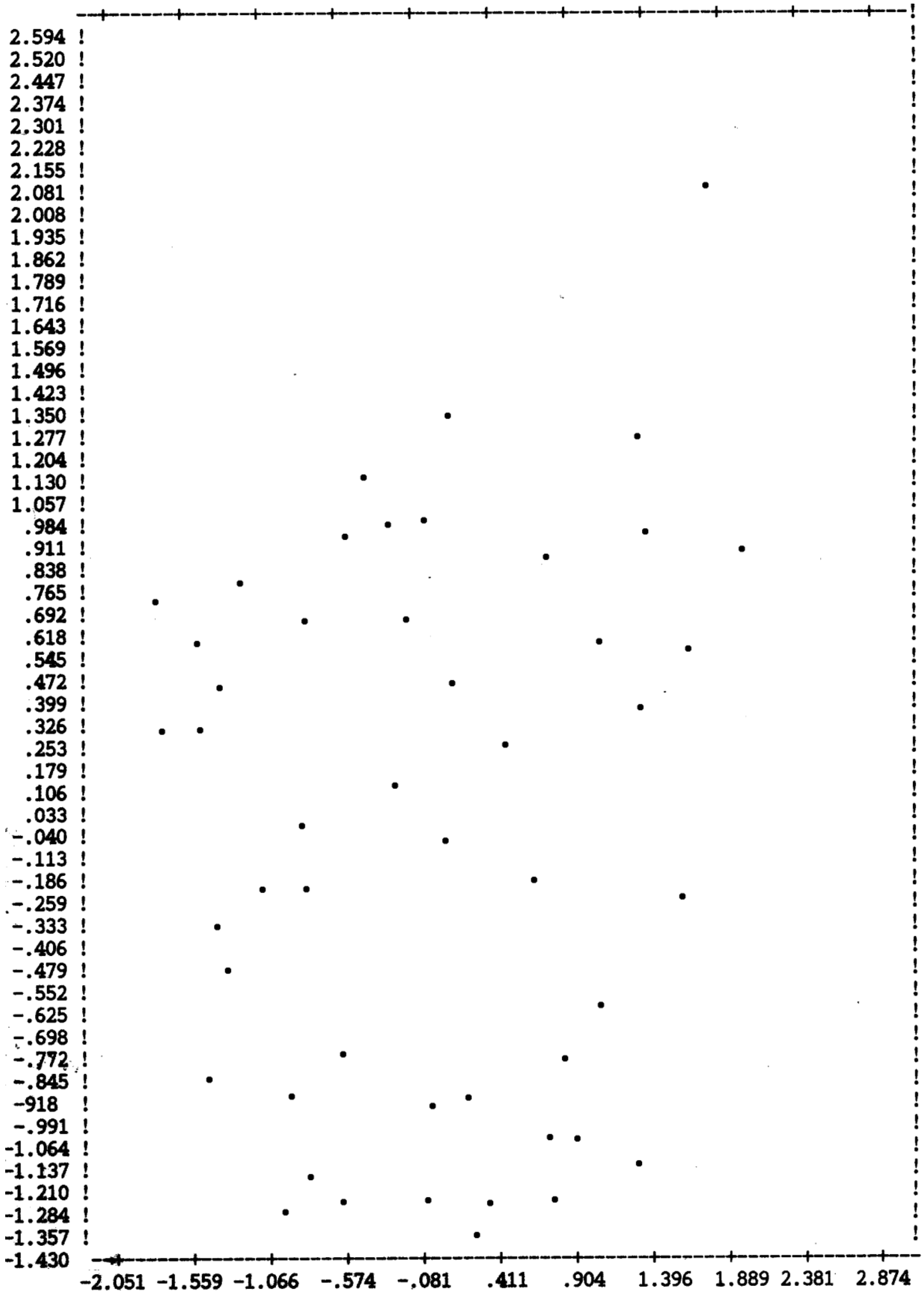


Fig-04

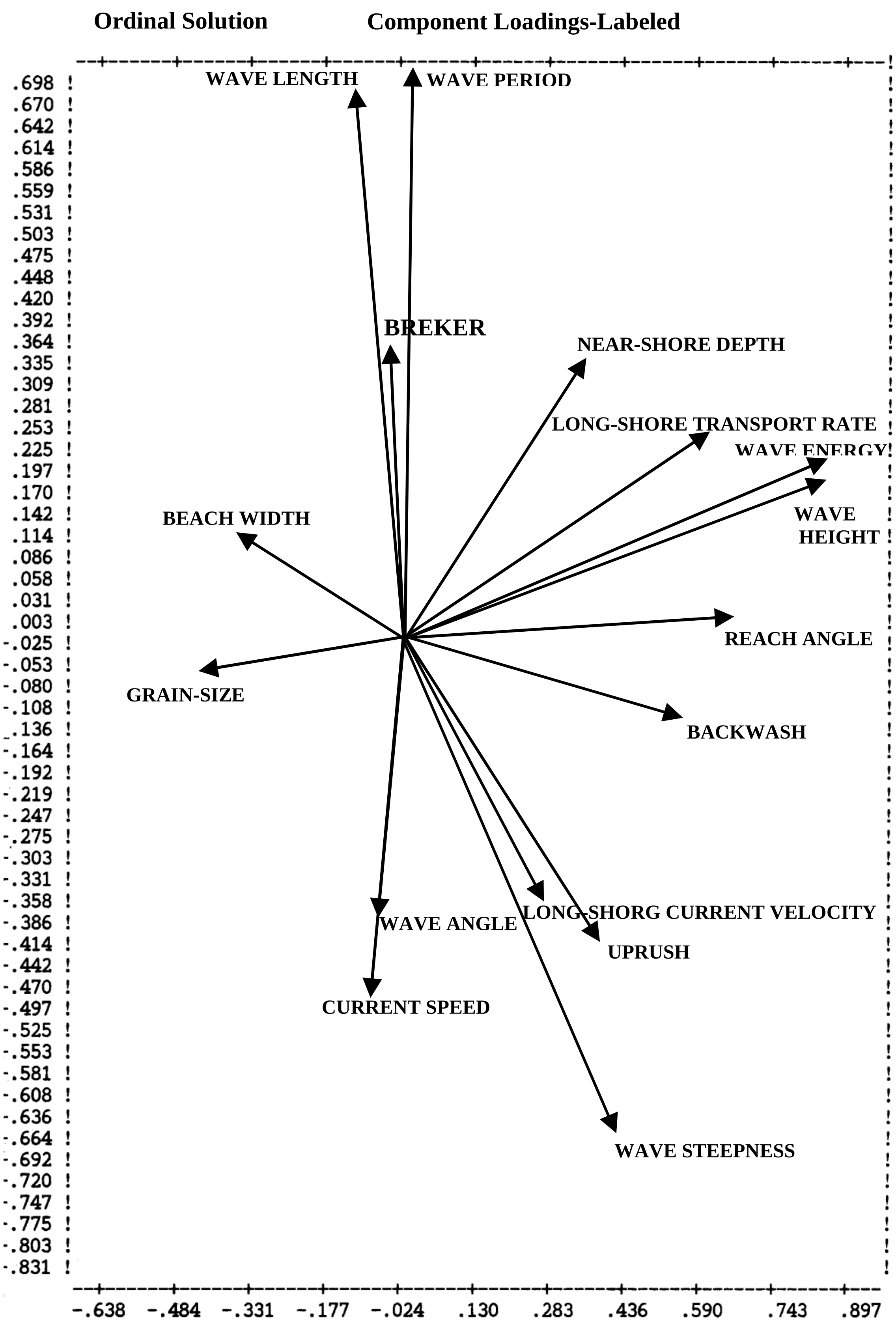

Ordinal Solution
Component Loadings-Labeled
WAVE LENGTH
WAVE PERIOD
BREKER
NEAR-SHORE DEPTH
LONG-SHORE TRANSPORT RATE
WAVE ENERGY
WAVE HEIGHT
BEACH WIDTH
REACH ANGLE
GRAIN-SIZE
BACKWASH
LONG-SHORG CURRENT VELOCITY
WAVE ANGLE
UPRUSH
CURRENT SPEED
WAVE STEEPNESS
.698
.670
.642
.614
.586
.559
.531
.503
.475
.448
.420
.392
.364
.335
.309
.281
.253
.225
.197
.170
.142
.114
.086
.058
.031
.003
-.025
-.053
-.080
-.108
-.136
-.164
-.192
-.219
-.247
-.275
-.303
-.331
-.358
-.386
-.414
-.442
-.470
-.497
-.525
-.553
-.581
-.608
-.636
-.664
-.692
-.720
-.747
-.775
-.803
-.831
-.638
-.484
-.331
-.177
-.024
.130
.283
.436
.590
.743
.897

Fig-05

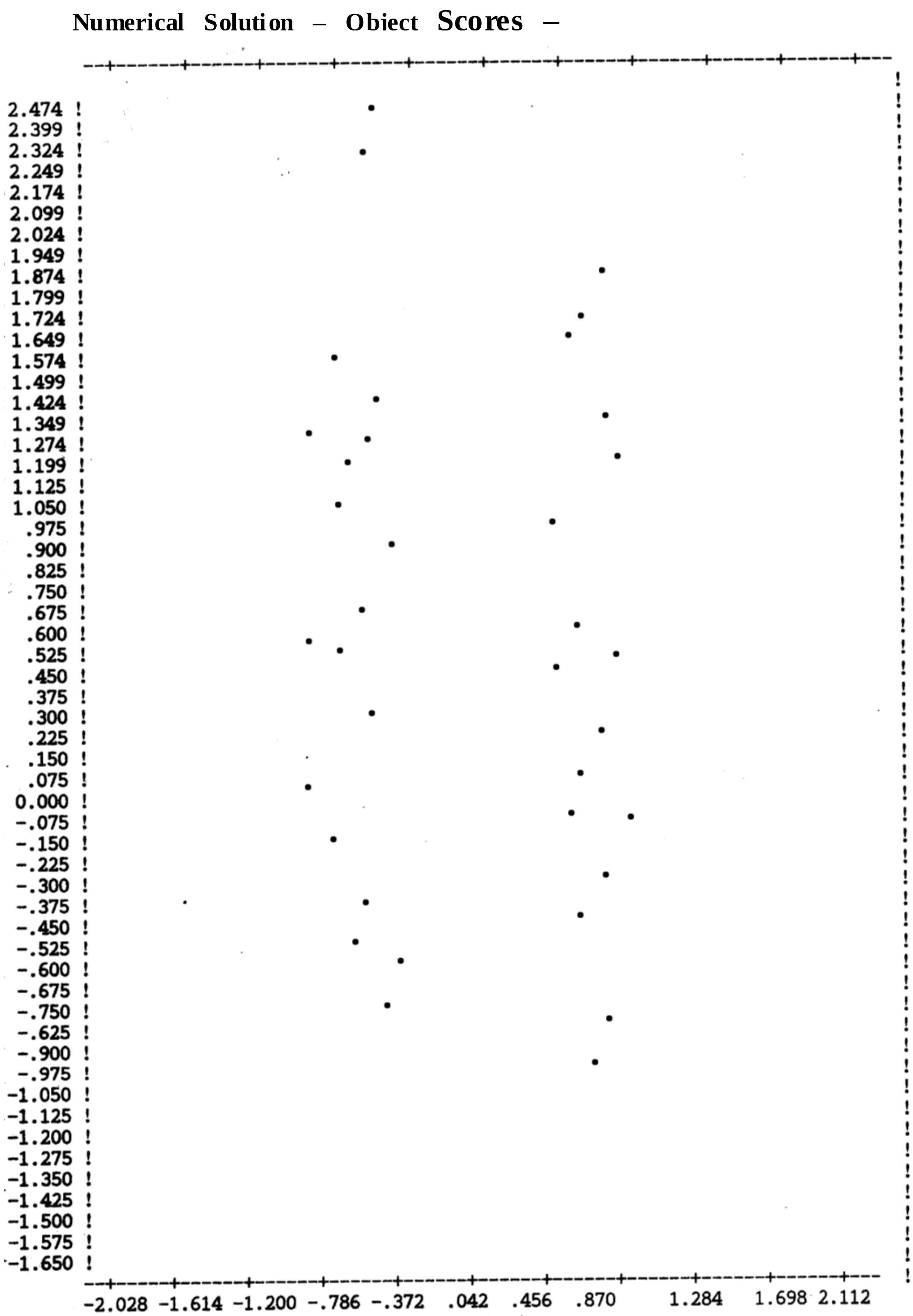
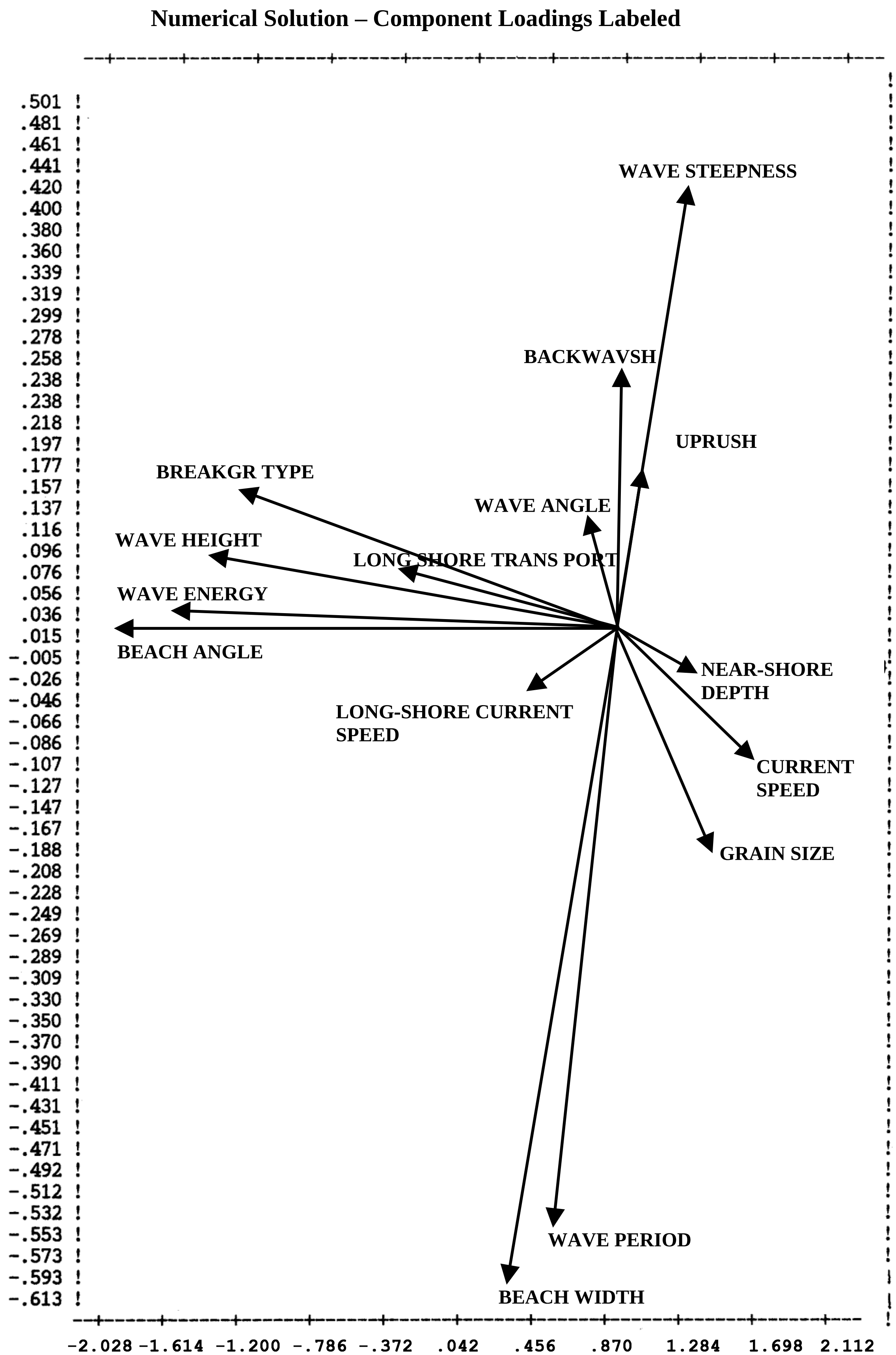

Numerical Solution – Obiect Scores –
2.474
2.399
2.324
2.249
2.174
2.099
2.024
1.949
1.874
1.799
1.724
1.649
1.574
1.499
1.424
1.349
1.274
1.199
1.125
1.050
.975
.900
.825
.750
.675
.600
.525
.450
.375
.300
.225
.150
.075
0.000
-.075
-.150
-.225
-.300
-.375
-.450
-.525
-.600
-.675
-.750
-.625
-.900
-.975
-1.050
-1.125
-1.200
-1.275
-1.350
-1.425
-1.500
-1.575
-1.650
-2.028 -1.614 -1.200 -.786 -.372 .042 .456 .870 1.284 1.698 2.112

Fig-06


Numerical Solution – Component Loadings Labeled
WAVE STEEPNESS
BACKWAVSH
UPRUSH
BREAKGR TYPE
WAVE ANGLE
WAVE HEIGHT
LONG SHORE TRANS PORT
WAVE ENERGY
BEACH ANGLE
NEAR-SHORE DEPTH
LONG-SHORE CURRENT SPEED
CURRENT SPEED
GRAIN SIZE
WAVE PERIOD
BEACH WIDTH
.501
.481
.461
.441
.420
.400
.380
.360
.339
.319
.299
.278
.258
.238
.238
.218
.197
.177
.157
.137
.116
.096
.076
.056
.036
.015
-.005
-.026
-.046
-.066
-.086
-.107
-.127
-.147
-.167
-.188
-.208
-.228
-.249
-.269
-.289
-.309
-.330
-.350
-.370
-.390
-.411
-.431
-.451
-.471
-.492
-.512
-.532
-.553
-.573
-.593
-.613
-2.028 -1.614 -1.200 -.786 -.372 .042 .456 .870 1.284 1.698 2.112

References

Gregory, S. (1963) Statistical Methods and the Geographer, Longmans

Gumble, E. J. (1958) Statistics of Extremes. US. National Bureau of Standards Series 33 Washington DC.

Krumbein, W. C and Graybill, F. A. (1965) An Introduction to Statistical Model in Geography,New York Mc Crow hill Bock Co.

Mather, P. M. (1969) Multiple Discriminate Analysis, Computer Applications in the Natural and Social Sciences, Nottingham University

Miller, R. L. and Kahn, J. S. (1962) Statistical Analysis in Geological Sciences, New York, John Wiley and Sons.

Parks, J. M. (1966) Cluster Analysis Applied to Multivariate Geologic Problmes, J. of Geol, Vol. 74

Spiegel, M. R. (1961) Statistics; Theory and Problems. Schanm's Outline Series

Strahler, A. N. (1954) Statistical Analysis in Geomorphic Research J. of Geol. Vol. 62