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Fluvial Geomorphic Analysis of Suru-Zanskar Valley, Ladakh Jammu & Kashmir, India

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Abstract:
The drainage system of the study region is dominated by the strike valleys of the Stod and Lungnak rivers, each flowing towards each other along the foot of the Himalayan range to meet on the Padum plain and then flowing northwards across the geological grain to meet the Indus river in its own strike valley. The morpho-metric analysis of the study region reveals that the first order streams have the shortest length and the stream length increases with each successive order. The mean stream length ranges between 1.79 of the first order to 132 kms of the fifth order. The slope of the basin appears to be the valid reason for variation in the mean length of different orders of streams. The drainage density of the basin varies from 0.610 to 0.018. The basin as a whole has the drainage density of 0.42. The drainage frequency in the lower to higher order of the basin ranges from 1.42 to 0.340. The geomorphic indices of the profiles indicate that the relative slope ration (SL/K) values ranges from 0.41 to 2.06 in Stod-Zanskar however in the Lungnak valley value vary from 0.75 to 1.11. The study reveals that the Lungnak valley has much steeper section in comparison to the Stod valley as a consequence of tectonic activities.

1. Introduction

Rivers constitute an important natural resource as they form the basis of irrigation, domestic and industrial water supply, hydropower generation, inland water transport and fishing. The importance of rivers can be gauged from the fact that many religious, cultural and commercial centres were established on the banks of rivers. They are the agents of erosion and transportation, removing water and sediments from high lands and transferring them to lowlands. They are thereby making lowland and plain areas an important resource for generating agricultural and developing economy all around. They also determine the land use and basin physiography. There is a close interaction between the highlands and lowlands through the network channels if there is some sought of change in the high lands. These channels will reflect to lowlands. The human influence is becoming increasingly relevant through river regulation schemes and changing pattern of land use. The fluvial system, the transfer of water and material from mountainous areas to the plain is characterized by tendency towards increasing the concentration and organization. A specially diffused input in the form of precipitation and weathered material is combined by a system of hill slope and network of channels into single output at a mouth of drainage basin available in hierarchy of sizes, the drainage basin is typically well defined topography and hydro-logically entity which is regarded as a fundamental special unit (Chorley,1969) while the links between the slope and channels in the movement of water and material through the drainage basin is recognized at the outset, even through those links tend to become leakier for larger streams with well developed flood plain, drainage network is a basin for demonstrating the effects of environmental control on fluvial systems for it suggest how network evolve and also for predicting the basin output variables such as stream discharge which are related to net. A drainage basin is extensively accepted as an ideal aerial unit in the milieu of geomorphology for the study of stream orders, topographic unit, geology, sedimentation, erosion, climate, vegetation and many more environmental phenomenons. Considering a drainage basin as a unit of study and systematic analysis of landforms contributed by drainage network were pioneered by Horton (1945) for a detailed quantitative expression of drainage basin in the form of stream hierarchy, this was further extended research scientists all over the world for the last five decades. Among the early researchers, (Strahler 1952 and 1964) and his associates published a number of papers establishing the base of quantitative techniques. The present Study of the Suru-Zanskar drainage basin has been accomplished using the above techniques. In the study area, the Lungnak and the Zanskarriver is the higher order or fifth order stream. The Stod is the fourth order streams which join with Lungnak near Padum. For the different orders of the drainage basin, various parameters have been carried out. (Table 1.) The number of parameters used for this study endeavours to be as comprehensive as possible.

2. Study Area

The Suru-Zanskar valley is sandwiched in southern Ladakh between the greater Himalayan range to the southwest and the Zanskar and Ladakh ranges to the northeast. Situated on the northern fringe of the western Himalayan, the study region includes all the areas along the two great branches of the Zanskar River. It lies between 32º 52' 30" N to 33º 52' 30" N latitudes and 76 14' 5" E to 77º 32' 4" E longititudes covering an area of 7000 km². Its largest length is 116 km and its mean length is 90 km and its mean breadth is 89 km. It is confined between the altitudes of 3340 ms to 6478 ms above the mean sea level (Figure1.1).

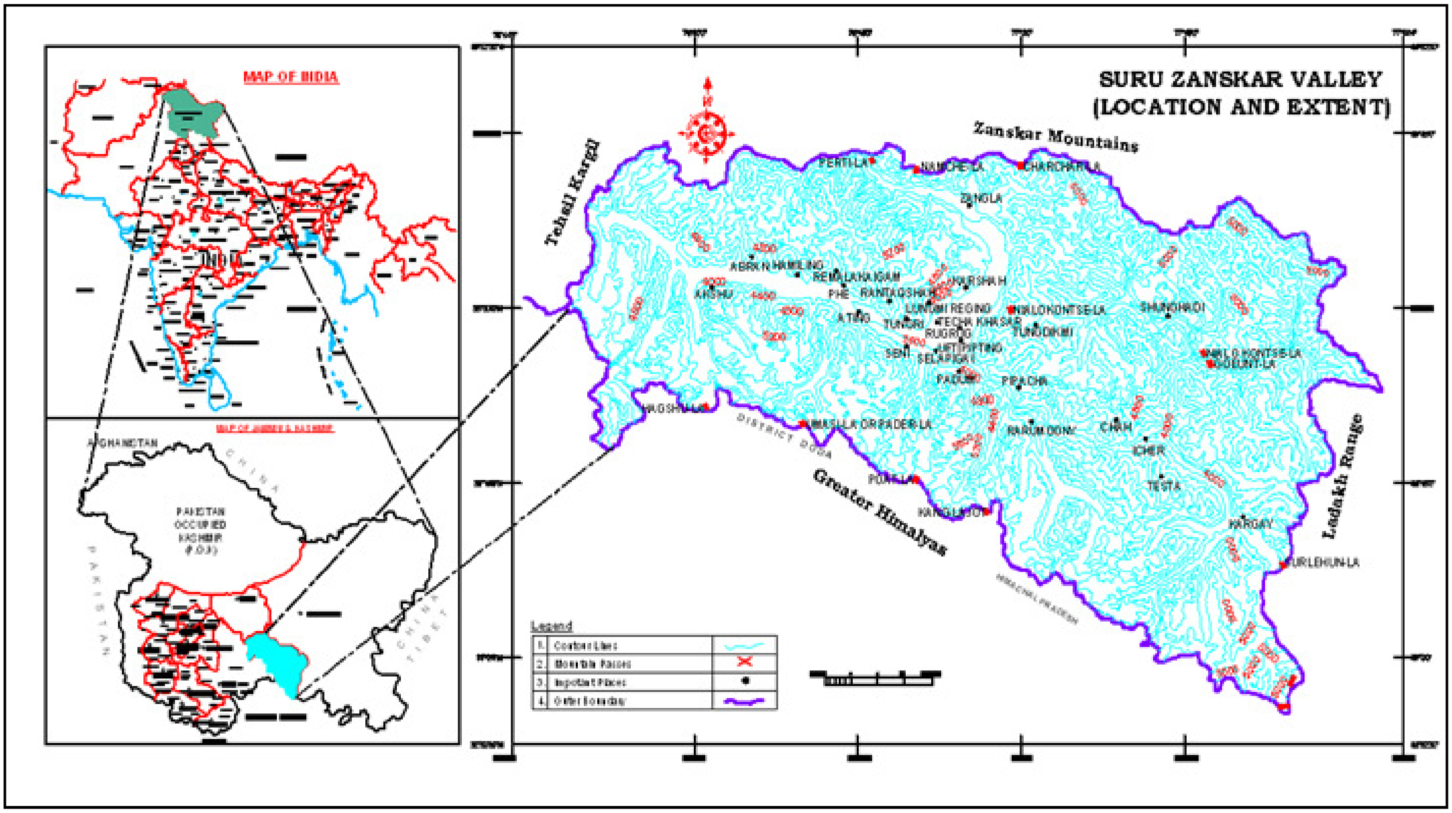

Figure 1: Suru-Zanskar valley Location and Extent Extracted from Survey of India Toposheets

The study region comprises a tri-armed valley system lying between the Great Himalayan Range and the Zanskar Mountain: the three arms radiate star-like towards the west, north and south form a wide central expanse where the regions two principle drainage meet to form the main Zanskar River. It is surrounded by Pensi-la pass and DurungDrung Glacier in northwest, Mulung, Hapatal, Shimiling, Yaranchu glaciers, Umasi-la pass (5342 meters) and Hagshu-la pass (4975 meters) in west and southwest, Yara-la (5697 meters) in the east and Baralacha-la (4650 meters) in the southeast, Perfi-la (4444 meters), Namche-la (4460 meters) and Charchar-la (5830 meters) in the north. In the west Umasila pass along Great Himalaya connects the Zanskar valley with Padder valley of Kishtwar. The pass is through a huge ice field of Haptal glacier. Kang-la (5468 meters) which remains open from June to September connects the study region with the Himachal Pradesh. The interior of northwestern part of Zanskar has a concentration of high lofty mountain ridge along with huge glacier basins that run almost parallel to the course of the river.

3. Methodology

The Research work involves interpretation of the Indian Remote Sensing Satellite (IRS) IC/D imageries covering paths 76.15-77.0 and rows 33.15-33.45 for the months of May and October 2001. In addition, the topographic sheets of survey of India of the year (1962-63) and surveyed in 1964-65on the Scale of 1; 50,000 where used to study the drainage network variables of the study region. Comprehensive field techniques and field measurement involves tomeasure the accuracy of the different variables.

4. Results and Discussion

The drainage network of the Suru-Zanskar valley is dominated by the strike valleys of the Stod and Lungnak rivers, each flowing towards each other along the foot of the Himalayan range to meet on the Padum plain and then flowing northwards across the geological grain to meet the Indus river in its own strike valley The Stod is the fourth order streams which join with Lungnak near Padum (Fig: 1 3). For the different orders of the drainage basin, various parameters have been carried out. (Table .1.) The number of parametersused for this study endeavours to be as comprehensive as possible. The (Fig: 1:2) display the drainage network of Suru-Zanskar valley. In the study area, the Lungnak and the Zanskar river is the higher order or fifth order stream.

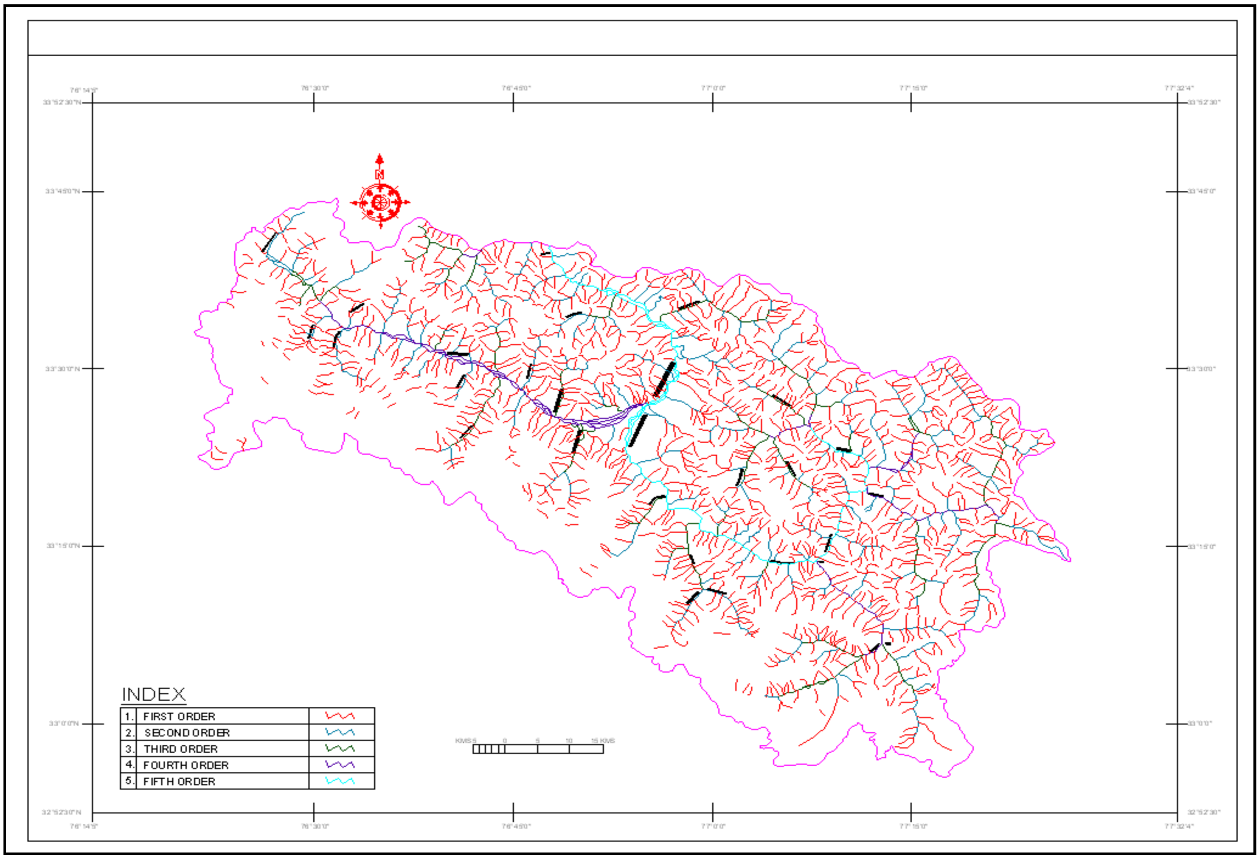

Figure 2: Suru-Zanskar Valley: Drainage Map

4.1. Stream order and Stream Length

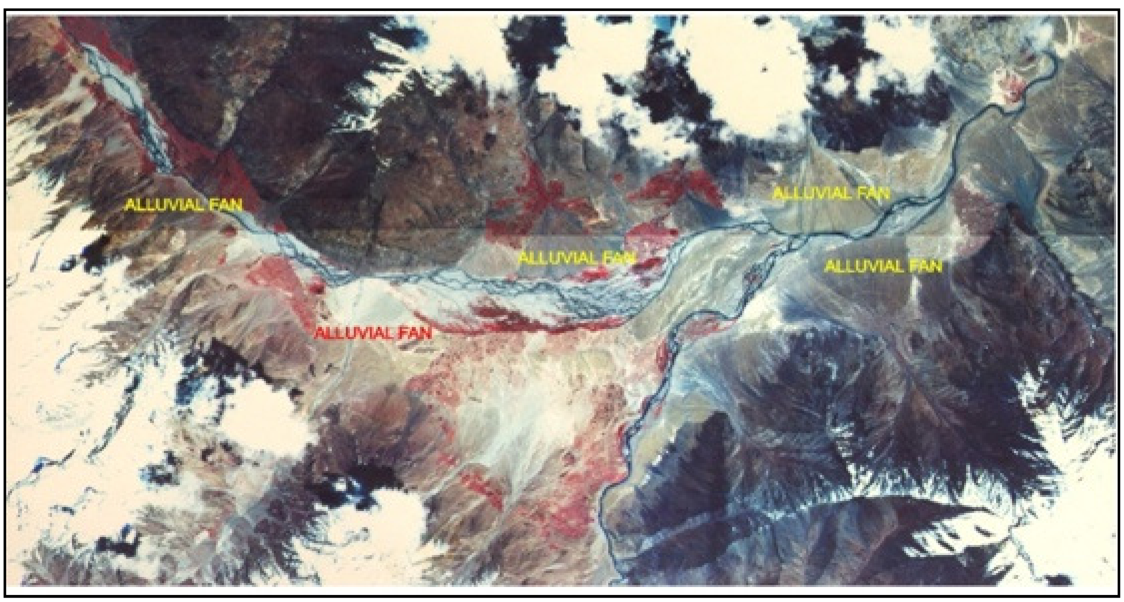

Figure 3: Satellite Data of IRS 1C/ 1D of 2001 Showing the Location of Alluvial Fans in Suru Zansar Vally

Stream order is defined as a measure of the position of a stream in the hierarchy of tributaries. In the Suru-Zanskar valley the drainage basins are designated into different orders from the particular streams and confluence of the streams. The finger tip streams having no tributary are designated as first order stream. The confluence of two first order streams defines the head of a second order stream, the confluence of two second order streams defines the head of a third order streams, similarly the confluence of two third order streams, defines the head of the fourth order streams, and so on. An increase in the streams order only occurs at the point when two streams of the same order join each other. If any lower order stream enters to a higher order, either first or second, third, fourth or higher or second to third, or third to fourth, fourth or higher or third to fourth, or fifth, sixth or higher, etc. There is no change in the ordering system. Table .1reveals that there is a specific relationship between the stream length and stream order. Thus in the Suru-Zanskar basin the first order stream have the shortest length. The stream length increases with each successive order. The mean stream length increases with the each successive order. The mean stream length of the Suru-Zanskar basin ranges between 1.79 of the first order to 132 kms of the fifth order. The slope of the basin appears to be the valid reason for variations in the mean length of different orders of streams.

4.2. Bifurcation Ratio

Bifurcation ratio is a dimensionless property of the drainage basin is supposed to be controlled by drainage density, stream entrance angles, litho-logical characteristics, basin shapes, basin areas etc. The bifurcation ratio between the successive stream orders in the basin ranges from 7.81 to 8.00. The bifurcation ratio of second and third order streams which ranges from 4.34 to 4.37 reveals that the great homogeneity is found in the rocks, but bifurcation of first and fourth order streams indicate that a pounced structural control encourage the development of elongation narrow drainage basin.

4.3. Drainage Density

Drainage density refers total stream length per unit area, obtained by dividing the whole length of the streams by the area of the basin. The analysis of drainage density controls the texture and spacing of stream channels. Drainage density as an important parameter of basin morphometry is one of the factors that control the rate of runoff following a period of precipitation. The greater the density the faster is runoff. Table 1.1 gives the drainage density of Zanskar River. It varies from 0.610 to 0.108 from lower to higher order, whereas the basin as a whole has the drainage density of 0.421. The upper drainage basin and its major tributaries of different orders have high drainage density. The low drainage density found in the lower reaches of the basin.

Stream Order	No. of Streams of each order	Bifurcation Ratio	Total length of Streams of each order	Mean Length	Area of basin Km^2	Basin length Km	Basin width Km	Basin Perimeter	Total Length of streams	Area of Basin Km^2	Drainage frequency	Circulatory Ratio	Elongation Ratio	Drainage density	Drainage Texture
1st order	**1188**	**-**	**2127.5**	**1.79**	**3486.52**	**-**	**-**	**-**	**-**	**-**	**0.340**	**-**	**-**	**0.610**	**0.2074**
2nd order	**152**	**7.81**	**437.5**	**2.87**	**2692.68**	**-**	**-**	**-**	**-**	**-**	**0.056**	**-**	**-**	**0.162**	**0.009**
3rd order	**35**	**4.34**	**235**	**6.71**	**2872.63**	**-**	**-**	**-**	**-**	**-**	**0.012**	**-**	**-**	**0.081**	**0.0009**
4th order	**8**	**4.37**	**105**	**13.12**	**3478.43**	**-**	**-**	**-**	**-**	**-**	**2.29**	**-**	**-**	**0.030**	**0.0687**
5th order	**1**	**8.00**	**132**	**132**	**7,000**	**135 Km**	**60 Km**	**462.5**	**3073**	**7,000**	**1.42**	**15.13**	**0.70**	**0.108**	**0.02556**

Table 1: Drainage Network Variables

4.4. Drainage Frequency

Drainage frequency or stream frequency is another important parameter of basin morphometry. It is the measure of number of streams per unit area. It is controlled by various factors like, climate, underlying rocks, vegetation and slope. In the study region, relatively, stream frequency is higher as the decrease of stream order. It is therefore contributed maximum dissection and erosion in the higher reaches of the basin. The drainage frequency in the lower to higher order of the basin ranges between l.42 to 0.340 (Table 1.1)

4.5. Drainage Texture

It can be expressed by the equation (Smith, 1950)

- T = Dd x Fs
- T = Drainage texture
- Dd = Drainage Density
- Fs = Stream frequency

Based on the values of drainage texture it is classified as:

- For 4.0 and below-coarse
- From 4.0 to 10.0-Intermediate
- Above 10.0 – Fine
- Above 5.0 – Ultra Fine (badland topography)

The drainage texture of the Suru-Zanskar basin from higher order to lower order ranges from 0.02556 to 0.2074, which indicates the texture of the basin area, is coarser in character as the values are less than 4.0.

4.6. Drainage Patterns

Drainage pattern means the 'form' (geometrical forms) of the drainage systems and the spatial arrangement of steams giving rise to a particular design in a particular locality or region. The location, number and flow direction of different steams of a particular region depends on the nature of slope, structural control, Litho-logical characteristics, tectonic factors, climatic conditions, vegetal characteristics etc. Since the environmental conditions of the present study area are different from the other areas of the state hence reflects spatial variations in drainage pattern. Following types of drainage pattern are observed in the Suru-Zanskar valley (Fig 1.4).

4.7. Dendritic Pattern

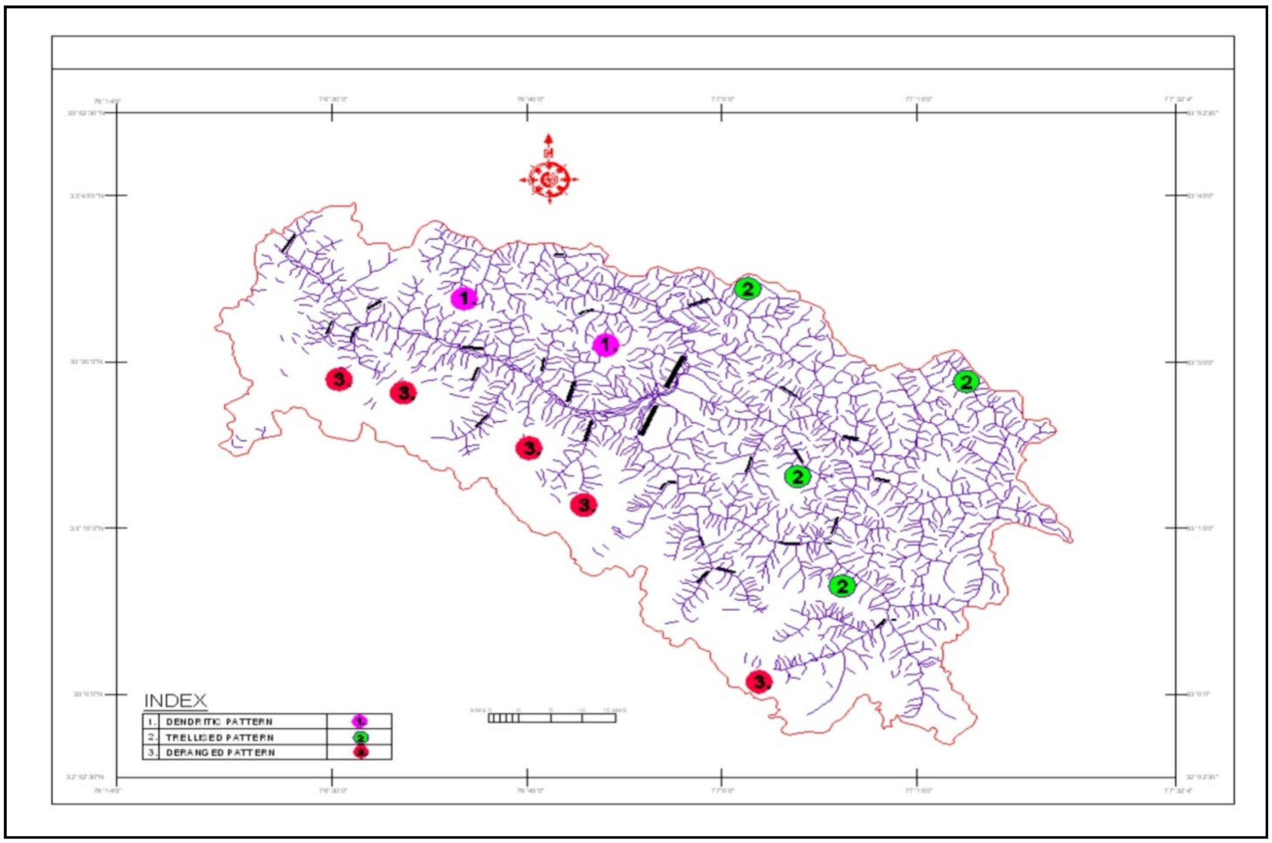

Figure 4: Suru-Zanskar Valley: Drainage Pattern

Dendritic drainage pattern is the most common and widespread pattern to be found on the earth's surface. In the Dendritic drainage pattern the network of tributaries of various orders and magnitudes joining the trunk or masters steam resembles the branches of a tree. In the study area dendritic drainage pattern has developed below the altitude of 4800 meters in the Stod basins. Streams of various orders and magnitudes merged with trunk of Lungnak and Stod at different points and elevations hence developed dendritic drainage pattern in the basin. This type of drainage pattern is also observed in the upper Zanskar valley. Homogenous litho-logy and controlling slope factors are responsible for the development of dendritic drainage pattern in the region.

4.8. Trellised Pattern

Trellised drainage pattern tends to develop where there is strong structural control upon streams because of geology. This type of drainage pattern in the Zanskar valley developed on the folded sedimentary rocks in sunshade, Lungnak and lower Stod valleys, the Spacing between the above mentioned valleys are very close and the pattern is structural in origin.

4.9. Deranged Pattern

Deranged pattern is the distorted pattern of aimlessly directed short streams. This kind of drainage pattern is observed in areas of recently disturbed by events like glacial activity or volcanic deposition, In the study region deranged drainage pattern is found above the altitude of 4500 meters in upper Stod, upper Zanskar, upper sunshade, Testa-Kargeakh and Tema valleys as the streams in the above mentioned areas are involved to adjust the topography of the area by transporting sediments to improve flow and channel pattern.

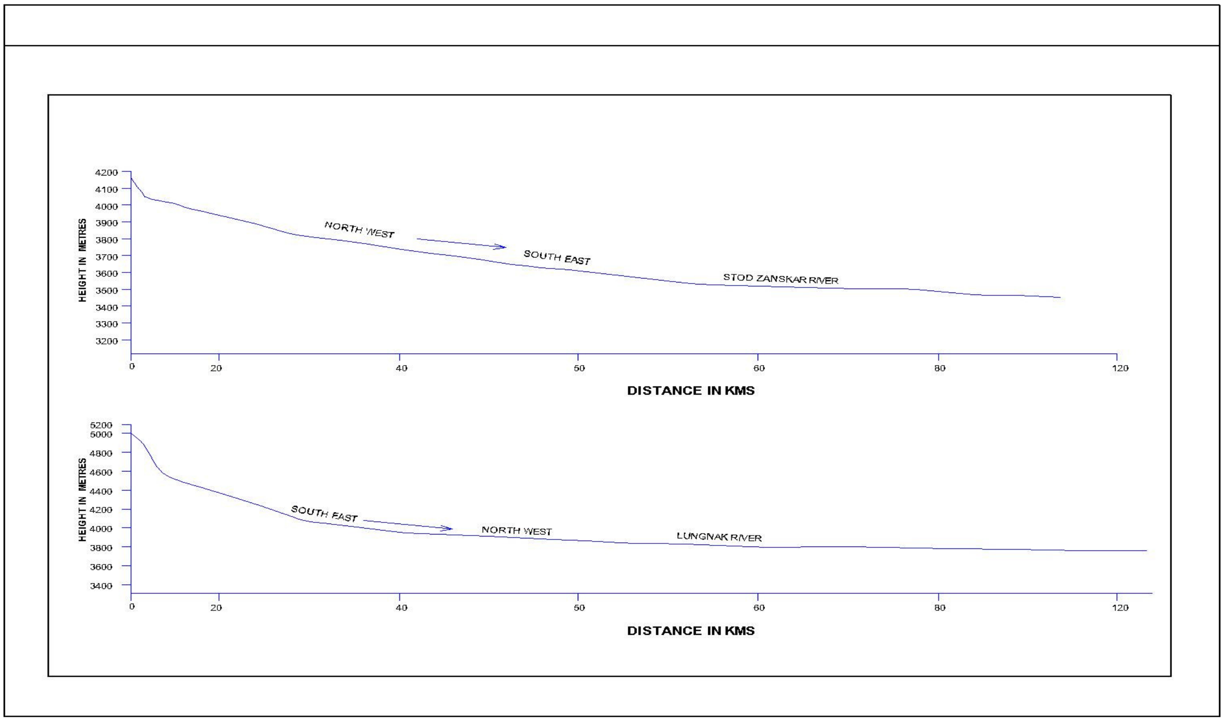

Figure 5: Longitudinal of Profiles STOD Zansker and Lungnak Valleys

4.10. Longitudinal Profile

The longitudinal course or a river from its source to mouth is called longitudinal profile. The longitudinal profile of a river represents channel gradient of the river from its source to the mouth. Longitudinal profiles are an important element of drainage basin geomorphology together with the channel network. These fix the boundary condition for slope processes, one of the important aspects of stream flow is that as the quantity of water in a stream increases, the downstream slope of water surface decreases. As an empirical rule, slope is an average function of discharge; the stream flow has caused change in the form of longitudinal profiles of the Stod-Zanskar and Lungnak rivers (Fig: 1.5). In this change the character and distribution of joints in bedrocks disc large and load have played an important role, since the natural river is an open system with inflow and outflow of energy matter, the variation in profiles of the main valleys particularly the Stod and Lungnak is appreciable.

4.11. Stod-Zanskar Valley

The Stod valley hosts the streams which drain the broadening mountain slopes along the western margin of the basin constitute the drainage network of Stod valley. The Stodriver which carries the melt water of the great DurungDrung glacier below Penzi-la flows down in a broad open valley, whose sweeping lines speak of its origin in the movement of glacier. The four important tributaries which join the Stodriver towards the north at different elevations are PholokolowNalla, ChanuTokpo, KyalaNalla and TungriTokpo. Among them Pholoklow is the largest tributary originating from the Pholoklow glacier, flowing from north to south over a distance of 12.5 Kns joins the main Stod river in the vicinity of DurungDrung glacier. Various melt-water streams (Haskira, Kange, Sumche, Denyai, Mulung, Haptaletc) originate from the glaciers located at higher elevations in the south in upper Stod valley merges with the main stream at different points. HapatalTokpo is the largest glacier melt water stream in the south originating from Haptal glacier carries the melt water of Haptal, Yaranchu, Chogo and other small niche glaciers of the Haptal basin. It is 15.5 Kms long and joins the Stodriver at an elevation of 3560 meters in the vicinity of Sani village. The Stodriver flows from west to east and have developed braided form at several places during the course and the largest braided plain of it is found between the Sani and Karsha. It is 1.5 Kms wide 7.5 Kms long. It is in this section the river has developed large number of point bars particularly gravel bars which extend for nearly 2 to 2.5 km. Stodriver is 72.75 kms long form valley head to the confluence which is at an altitude of 3452 meters above the sea level. The river flows in desperate geological set up and have distinct glacio-fluvial characteristics. After leaving the confluence point, the united waters of Lungnak and Stod forms a Suru-Zanskar river. The river has developed meandering form from Rinam to Zangla It flows 10 to 15 meters deep in this section. It takes turn towards west at Pishu and then flows to north up to Zangla. Form Zangla onwards the river flows in a straight mood up to Pidmu. The river again developed meandering form till it reaches to Hanamur. The river takes a sharp turn towards northeast and flows through a deep gorge for 50 Kms from Kilma to the point where Khurmariver merges with it. The cold swift water of this river flows between the rocky walls too steep to scale. The river leaves Zanskar in the vicinity of Perfi-la pass (4444 ms) and finally merges with the Indus at Nyemo.

4.12. Lungnak Valley

Lungnak valley is a narrow valley in the study region and is very different from the broad valleys of Stod and Zanskar. The Lungnak River is formed by the united waters of Tsarap and Kargiak streams which takes tortuous course through the mountains of Zanskar region. Kargiakriver is an important tributary of Lungnak river originates from Tingdur glacier at an altitude of 4660 meters carries the melt water of small and large streams flows from southeast to northwest. The united waters of Lenak and Gimbal streams join it at an altitude of 4050 meters. In the Tsarap valley on the north east of Lungnak, Zara and Tsarap rivers merge to form Tsarap-Chu river. In the Sha-de valley HumlungNalla, Shingri-chu and Nigri-chu streams join each other at an altitude of 4260 meters. From here the river is known as Niri-chu and flows from northwest to southwest. The river finally turns to south to meet the Tasarp-chu at Sumdo. Niri-Tasarp-chu flows through a deep gorge in the upper Lungnak basin and meets the Kargiakriver at Char at an altitude of 3715 meters. The Lungnak river is also known as Tasarp-Lingti-chuNalla or Dark gorge in the region. The river passes through 32.5 Kms long rocky gorge from Char to Rarumoony. The Reru and Tema are the two main tributaries of the Lungnak on the south side which deflects the present river into a bend to the north. The river after passes through Rerumoony and Pipcha merges with the Stodriver near Padum at an altitude of 3452 meters. It is 48.5 Kms long from Char to Padum.

4.13. Gradient Indices of Profiles

Gradient indices are useful reconnaissance tools in tectonic geomorphology because they may be generally obtained quickly from measurements taken from topographic maps, aerial photographs and field surveys and provide insight concerning adjustments of bedrock and landform to tectonic and climatic perturbation. Indices are an important variable of slope and are expressed as ratio. It determines the power that river has applied to mould the valley and cut the bench marks and rock basins on the bed. The shape and altitude of the valley are related to the litho-logy of bed at different altitude. The longitudinal profiles of the Stod and Lungnak have been analyzed to determine the gradient indices at different section. They have been calculated from the following formula given by Hack (1973).

$$K = \frac{Hi - Hj}{InLj - InLi}$$

Where:

- K = Slope of valley profile termed gradient index,
- Hi = the highest elevation of valley head.
- Hj = the height of the valley in the entrance to the fluvial section.
- Li = the length of the valley section above the given altitude, and
- Lj = the length of the fluvial section of valley.

4.14. The Gradient Index

The Gradient Index of small reach (SL) for different segments between the consecutive contours has been calculated for the aforesaid valleys from Seeber and Gornitz formula (1983).

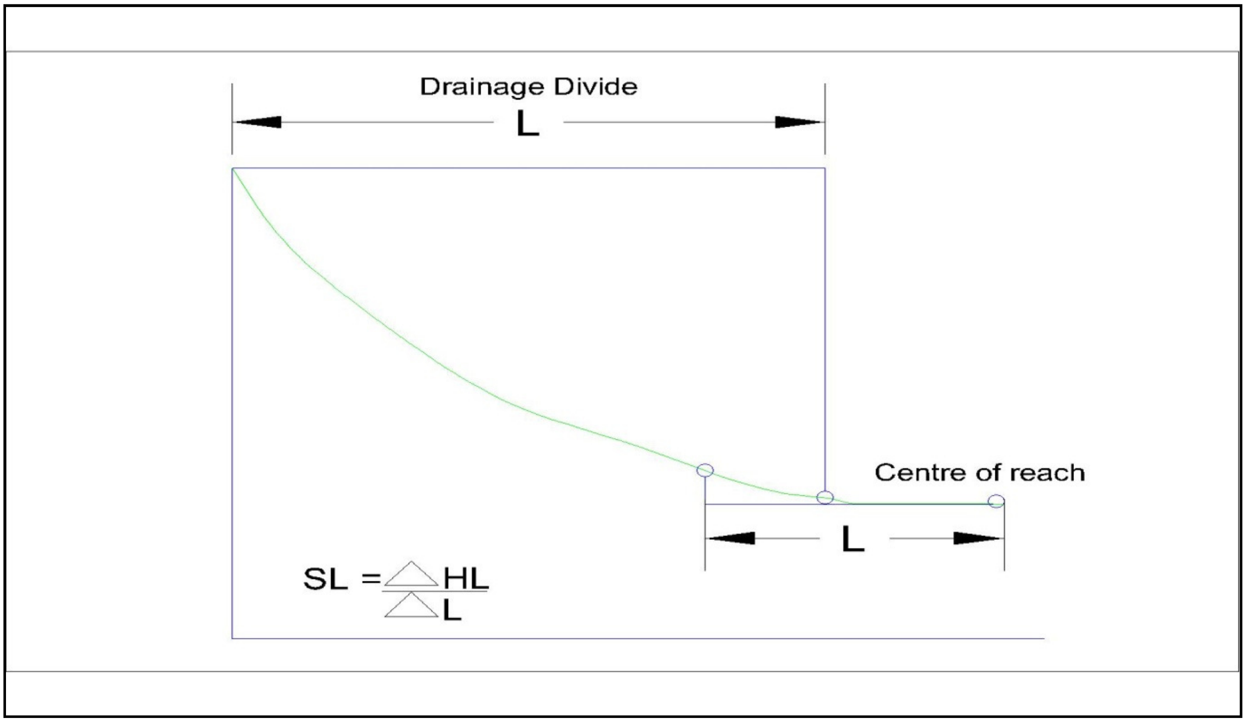

Figure 6: Idealized diagram showing how the stream gradient (SL) index is calculated

SL = gradient index
ΔH = elevation difference between upper and lower parts sections. It is calculated from the contour lines and field measurements.
ΔL = Planimetric length of given valley section.
L = Length of the section of the valley from the valley head to the middle point of section.

Segment	Length of Segment (L)	Relative relief of segment (ΔH)	Plainmetric length of valley section (ΔL)	Gradient index of valley K	Gradient index of segment S1=ΔH x L/ΔL	Relative ratio of slope SL/K
1.	3000	150	6000	179.06	75	0.41
2.	13750	200	14750	179.06	186.4	1.04
3.	34250	200	26750	179.06	256.0	1.42
4.	59750	150	24250	179.06	369.5	2.06
5.	89250	50	35000	179.06	127.5	0.71
6.	110250	20	7500	179.06	294	1.64

Table 2.Gradient index of Stod-Zanskar river.
Source: Calculated from Longitudinal Profile

Segment	Length of Segment (L)	Relative relief of segment (ΔH)	Plainmetric length of valley section (ΔL)	Gradient index of valley K	Gradient index of segment S1=ΔH x L/ΔL	Relative ratio of slope SL/K
1.	1625	600	3250	377	300	0.79
2.	11250	600	16000	377	422	1.11
3.	25625	200	12750	377	402	1.06
4.	47500	200	31000	377	306	0.81
5.	76500	100	27000	377	283	0.75
6.	104500	100	29000	377	360	0.95

Table 3: Gradient index of Lungnak river.
Source: Calculated from Longitudinal Profile

The gradient index of short reach (SL) of different sections of Stod-Zanskar and Lungnak has reduced to relative ratios with respect to slope of the valley (K) by dividing SL by K. A ratio of 1.0 indicate that gradient index of given section is same as that of logarithmic profile of a valley. A small ratio of 1.0 indicates gentle section and large ratio of more than 1.0 indicates steeper section. A sharp increase in value indicates bench cut. In the Stod-Zanskar SL/K value ranges from 0.41 to 2.06 whereas in the Lungnak the values vary from 0.75 to 1.11 (Table: 5.6). Further, the values shows decrease from 1.04 to 0.41, 2.06 to 1.42 and 1.64 to 0.71 at 3800 to

3450 meters in the Stod-Zanskar River. In the Lungnak valley, the values decrease from 1.11 to 0.79, and increases from 0.81 to 1.06, 0.75 to 0.95 at 4000 to 5200, 3600 to 4000 and 3452 to 3600 meters respectively. The above study clearly indicates that the glacio-fluvial agencies and tectonic activities have played a dominant role in shaping the large scale features of river profiles of Lungnak and Stod-Zanskar.

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