Krishna River Downstream Temporal Channel Variations

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Abstract

All rivers undergo changes in channel geometry downstream systematically. A river adjusts its channel geometry (width,depth,cross-sectional area)within the limitations imposed by discharge, channel lithology. As not much studies on channel geometry on large monsoon-fed rivers. Therefore, in this study an attempt will be made to understand the fluvial geomorphological characteristics and variation for 2 decades of major Indian Peninsular River namely Krishna, in terms of channel geometry, discharge. Present study focusses on channel geometry changes downstream for a large Peninsular River . The Krishna River is the third largest river in India.Cross-sectional data for a downstream gauging sites during 1990-2010is downloaded from India Water Resources Information System (India-WRIS) WebGIS. portal. Channel Geometry parameters in terms of Channel Cross-Section Area,Width,Depth,Wetted Perimeter,Hydraulic Radius,Form Ratio are derived from the data involving 9 sites on main river. The Graphs indicate as the maximum discharge increases with corresponding increase in Cross-Sectional Area,Width,Depth,Wetted Perimeter,Form Ratio,Velocity,Hydraiulic Radius is observed with corresponding decrease in Mean Velocity downstream.Channel forms upstream to downstream becomes less steep.APower-log regression equation carried out to evaluate the level of confidence between the parameters.

MANUSCRIPT

1. **Title Page**

Krishna River Downstream Temporal Channel Variations

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2. Key Points-

- Discharge increases downstream
- Hydraulic Parameters increases downstream
- Temporal changes in the channel geometry of Krishna river

3. Abstract:All rivers undergo changes in channel geometry downstream systematically. A river adjusts its channel geometry (width,depth,cross-sectional area)within the limitations imposed by discharge, channel lithology. As not much studies on channel geometry on large monsoon-fed rivers. Therefore, in this study an attempt will be made to understand the fluvial geomorphological characteristics and variation for 2 decades of major Indian Peninsular River namely Krishna, in terms of channel geometry, discharge. Present study focusses on channel geometry changes downstream for a large Peninsular River . The Krishna River is the third largest river in India.Cross-sectional data for a downstream gauging sites during 1990-2010is downloaded from India Water Resources Information System (India-WRIS) portal. Channel Geometry parameters in terms of Channel Cross-Section Area,Width,Depth,Wetted Perimeter,Hydraulic Radius,Form Ratio are derived from the data involving 9 sites on main river. The Graphs indicate as the maximum discharge increases with corresponding increase in Cross-Sectional Area,Width,Depth,Wetted Perimeter,Form Ratio,Velocity,Hydraiulic Radius is observed with corresponding decrease in Mean Velocity downstream.Channel forms upstream to downstream becomes less steep.APower-log regression equation carried out to evaluate the level of confidence between the parameters.

PLAIN LANGUAGE SUMMARY:River dimensions (area,width,depth)primarily along with other criteria displays changes as they move from source towards sea.In this paper such changes is studied thoroughly for Krishna river for 2 decades(1990-2010) after analyzing data as obtained from Central Water Commission and ISRO launch Water Resources Information System (WRIS), a comprehensive solution for accessing data on water in India.

4. KEYWORDS: Krishna river,Downstream, Channel Geometry, Discharge, Peninsular River,Power-log relationship

5**.Text**

1.INTRODUCTION

Modification of Channel Geometry takes place in the following –

1)Cross-Sectional form i.e. the size (Channel Width w,Mean

Depth d,Cross-Sectional Area Ac,Wetted Perimeter WP and Hydraulic Radius R and the shape of the channel in terms of Width to Depth Ratio or Form-Ratio) downstream. Change in these properties is fundamental to hydrologic geometry, which refers to the rate of change of hydraulic variables (width, depth and velocity) as discharge increases (Leopold and Maddock, 1953). The basin area increases downstream, discharge in most rivers also increases with the distance (Leopold et al., 1964).

Downstream trends in channel geometry are important from the standpoint of the understanding of the river behavior (Pitlick and Cress, 2002). Studies on downstream Hydraulic geometry downstream ,receives very little attention which otherwise should have.Channel Geometry of rivers have received wide attention for the last 5 decades years (W.B.Langbein,1964;Richard David Hey,1978;M Paul Mosley 1981;Colin P Stark 2006; Mingfu Guan et al 2016).Effects on Channel Geometry due to discharge variation have been studied by (Mingfu Guan et al 2016;O.Turitto et all 2008;Stephen R.Holnbeck Holnbeck 2004;W Robert C Myers 1991;Mehmet Isak Yuse eta all 2012;Ellen Wohl .A.Wilcox 2005;Yanjum Wang et all 2020; Guangming Hu et all 2016; W.R Osterkamp et all 1982;Changes in Channel Geometry due to sediment size researches undertaken by(Demetrio Antonio Zema et all 2018; W.R Osterkamp et all 1982;L.B Leopold 1992; Ellen Wohl 2004)Channel Geometry and channel lithology was studied by(Naser Naimi-Ghassabian 2014).Recent studies on Channel Geometry downstream on World rivers like Colorado river (John Pitlick,Robert Cress 2002)exhibit that channel properties,bank-full width, depth, slope change systematically downstream,the Blue river (Scot A Lecce 2013) studied that lack of a downstream trend in the width:depth ratio along the Blue River.Niger River(Olutoyin A Fashae et al 2020)depicts The channels of four basins out of six becomes progressively narrowed and deepened downstream while that of the remaining two becomes progressively wider and shallower downstream.Uper Ogun River Basin(Adeyemi Olusola et al 2020) focuses on variation in downstream hydraulic geometry and increase in downstream discharge. Studies on Channel Geometry on the Indian rivers like River Kolong(Minakshi Bora et al 2017)studied highest rate of increase of velocity with discharge, Burhi Dihing river(Jogendra N Sarma et al 2017)have shown width decreases but depth and velocity increase towards downstream. William L. Graf (2006),Downstream hydrologic and geomorphic effects of large dams on American rivers Geomorphology (2006) concluded Very large dams on American rivers have large, statistically significant effects on downstream hydrology and geomorphology.

Thus,it is observed that channel geometry systematically changes downstream both on a Global and Indian scale.

1.1 INTRODUCTION TO STUDY AREA

The Krishna River is the second largest river in the Peninsular India and stretches over an area of 2,58,948 km2.It rises in the Western Ghat at an elevation of about 1337 m a.s.l. adajacent to the north of Mahabaleshwar,near Jor village,around 64 km from the Arabian Sea and flows for about 1400km before debouching into the Bay of Bengal.

The river drains through the states of Karnataka(1,13,271 km2),Andhra Pradesh (76,252 km2) and Maharashtra (69,425 km2).Geographically Krishna Basin is between 73˚17’ to 81˚9’east longitudes and 13˚10’ to 19˚22’north latitudes, representing almost 8% of surface area of India.It is bounded by Balaghat range in the north ,by the eastern Ghat in the south and east and by the Western Ghats in the west.The Mullayanagiri Peak (1930 m a.s.l),in Karnataka it is the highest point within the Krishna Basin. The principal tributaries joining the Krishna River are Tungabadhra,Malaprabha,Ghataprabha(Right)and Bhima,Musi,Munneru(Left). Krishna ranks as fifth largest river basin in India with a catchment area of ~2.6 × 105 km2. The river traverses a length of ~1400 km across the states of Maharashtra, Karnataka and Andhra Pradesh, before draining into the Bay of Bengal. The Geology of the basin is dominated by basalts, crystalline rocks,deccan trap,peninsular gneiss,quaternary alluvium. With red,black,saline,alkaline,lateritic mixed, minor components. It has about thirteen major tributaries (the Bhima and the Tungabhadra are the two largest) and several small-to-large-scale reservoirs for irrigation and/or hydropower generation schemes (e.g. Nagarjuna Sagar and Srisailam). The climate of the region is mostly monsoonal-humid to semi arid along the Western Ghats.Rainfall of 400-5000mm.Rainy season comprises July,August .September. Soils in the basin are generally shallow in depth, and they belong to the type Entisols, Alfisols and Vertisols (black soils for cotton and sugarcane). The major cultivations of the basin are rice, sugarcane and oil seeds. Concerns are raised about shrinkage of the basin, frequent emergence of extreme events such as floods and degradation of water quality of the Krishna and its tributaries. Despite no major annual rainfall variation, observation of large-scale decrease in water discharges in both upper and lower reaches of the basin has stressed the need of management and allocation of water resources in the basin. It has 176 Hydrological Stations on Main River and has 251 dams.

Table(I).Here

Fig.1.1. Here

2. METHODOLOGY

The following methods and datasets were entailed in order to meet objectives of the study .

Cross-sectional data were downloaded from India Water Resource Information System (India-WRIS) portal. For two decades (approximately from 1990-2010) at an interval of 5 yrs nearly for 176 profiles was choosen. Although a number of variables have been used to describe the cross

sectional form, to define the channel morphology in terms of shape, size and efficiency

(Petts and Foster, 1985). However, taking into consideration the availability of data, the

morphological parameters used in the present study.

Table (II). Here

Cross-Sections were plotted in MS Excel and data for Width,Depth,Cros-Sectional Area,Wetted Perimeter,Hydraulic Radius,Form Ratio,Mean Velocity were derived for 9 Stations namely Karad,Kurunwad,Arjunwad,Huvenhedgi,Deosugur,Agraharam,Pondugala,Wadenapalli,Vijayawada Downstream on Main Krishna river was analyzed.

The Bankfull stage were considered to determine the channel Cross-Sectional Area (using area of Trapezium),the width,and wetted perimeter using Phythagoras Formula in MS EXCEL.Depth(d) and Hydraulic Radius® parameters were derived accordingly.

1)Depth(d)=Cross-Sectional Area(Ac)/Width

2)Hydraulic Radius®=Cross-Sectional Area(Ac)/Wetted Perimeter(Wp)

3)Form Ratio=Width/Depth

4)Wetted Perimeter(WP)=B+2H   where,B=base,H=height of flow in mts

5)Qmax=A*V in m3/s

6)Mean Velocity(V)=Qmax/Ac

As Discharge data is not available for many sites,the maximum discharge(Qmax)was estimated for each cross-section by using the following equation,where A is the upstream catchment area

Qmax=392.8 A0.337(r2=0.68)

3. RESULTS AND DISCUSSION: Channel form varies in the Downstream direction as discussed previously.Channel Width,Depth,Hydraulic Radius,Wetted Perimeter,Form Ratio,Qmax,Mean Velocity have been evaluated alongwith channel Cross-Sectional Area. Area generally increase downstream as expected. with certain derivations .

Table (III)Here

3.1 Bankfull Area

The Channel Bankfull Area (Ac) increases downstream as expected.Increase is not uniform but there are deriviations in this pattern at some channel cross-sections.

1) In 1990 upstream area is 6558.35m sq at Huvenhedgi increasing to16353.48 m sq at Vijayawada downstream.

Fig.1.2(i) Here

2) There are noteworthy derivations in Area and width at Pondugala in 1995.Whereas a remarkable increase in Channel Bankfull Area(Ac) and Bankfull Width is observed at Vijayawada in the lower reaches. Channel Area. In 1995 Channel Bankfull Area (Ac)varies between 4653.64 m sq upstream at Karad to 16571.58 m sq downstream at Vijayawada

Fig.1.2(ii)Here

3) In 2000 Channel Bankfull Area (Ac)varies between upstream Karad with 4565.95 m sq and increases downstream to 16399.4 m sq at Vijayawada.

Fig.1.2(iii)Here

4)Similarly in 2005 Channel Bankfull Area (Ac)varies between upstream Karad having 4190.01 m sq,increasing downstream to 12413.78 m sq at Vijayawada.

Fig.1.2(iv)Here

4) In 2010 Channel Bankfull Area (Ac)varies from upstream Karad having 4266.655 m sq increasing to downstream to 6073.6 m sq at Vijayawada.

Fig.1.2(v)Here

3.2 Channel Form

The channel cross-section is characteristically irregular in outline and is locally highly variable in nature. Although a number of morphological variables have been used to describe the channel form, the most frequently used variables are the channel width, depth, the wetted perimeter, the hydraulic radius and the width/depth or form ratio. The Channel form is defined as a function of discharge.Thus an increase in discharge is reflected in increase in channel parameters namely width and depth..Accordingly in the following paper downstream changes of channel form is discussed

3.2.1 Channel Width(W)- maximum channel width refers to the water surface width at maximum discharge (Qmax).Channel Width is mostly used to define the size of the channels, and been described by Leopold et all (1964) as one of the three variables to define the Hydraulic Geometry of different river channels and is expressed as W=aQb.In the Upland region, although the channel width goes on increasing downstream and there is variation in channel size from place to place.Channel width is a function of the prominent discharge and is related to the flow velocity. The channel size is a function of flow (Leopold et al., 1964). This suggests that the channel dimensions of these rivers are adjusted to large flowThe channels are narrow in the source region,and mostly less than 1000/0m wide.Whereas further eastwards,the channel width increases to more than1400m.The channels are wider in Semi-Arid regions.Width increases in a more consistent manner than any other factor(Leopold et al 1964).Width is increasing downstream as expected.

The average channel width is 922.5m, in the Upland region at Huvenhedgi is 760m with at Upstream region to 1480m at Vijayawada in downstream (1990).

The average channel width is 816.4m with 420m at Karad in upstream area and 1482m at Vijayawada in downstream (1995).The average channel width is 686.5, having upstream Karad as 420m and downstream Vijayawada1452m(1995)

The average channel width is 732.75m,420m at upstream Karad and1452m at Vijayawada downstream.(2000)

The average channel width is 746.43,380m, at upstream Karad and 1440m at downstream Vijayawada.(2005)

The average channel width is 757.43m,upstream Karad is 385m and Downstream Vijayawada increases to 1417m(2010)

In the present study too width increases in a consistent manner at every 5 yrs interval.

Some typical channel cross-sections of the Krishna river for a decade (1990-2010)is seen Fig1.2(i-v).

3.2.2 Channel Depth(D)- Channel Depth analysis is an important river channel parameter for estimation of stream energy.In general depth varies between 8-16m in the study area.Depth in the upstream is less than 12m deep.Depth is seen to be consistently increasing in the downstream direction as expected and reaches great heights of >10m.

The average channel depth is 10.95, Upstream Huvenhedgi depth is 8.63m and Downstream Vijayawada depth escalates to 11.05m(1990)

The average channel depth 8-16m in depth.As expected, the maximum depth increases in the downstream direction.(1995)

The average channel depth is 10.28m,Upstream Karad depth is 10.87m increasing to 11.29m at Downstream Vijayawada(2000)The average cannel depth is 9.60m,with Upstream depth at Karad is 11.03m and Downstream depth is 13.734m at Wadenapalli(2005)

The average channel depth is 8.97m.The Upstream channel depth at Karad is 11.08m and Downstream depth increases to 13.73m at Wadenapalli is 11m.Upstream at Karad depth is 11.08m increasing to 11.18m Downstream at Vijayawada. . In the Upstream areas the channels are less than 15m depth.The depth generally ranges between 8-16 m(2010)

3.2.3 Hydraulic Radius-Hydraulic Radius,is a measure of channel efficiency(Petts and Foster,1985),referring to the proportional losses of energy by friction between the flowing water and channel beds and banks, as compared to the losses within the water.Large values of R are often associated with streams with large discharges,conversely low values (and reduced efficiency)are given by small streams(Blackie s Dictionary of Geography).

Hydraulic Radius ranges between 8.62 and 11.04.The mean is 7.08m.Hydraulic Radius ranges from 8.62 to 15.25m(1990),(1995)H.R ranges from 2.14m to 15.46m and the average Hydraulic Radius is 9.16m. In most cases Hydraulic Radius upstream is observed to be low depicting shallow channels.On the contrary Hydraulic Radius is found to be higher in the downstream direction.This reveals that the channels are incised downstream. Hydraulic Radius varies from 8.41m to 15.63m and average hydraulic radius is 9.04m(2000)In 2005 Hydraulic Radius to range from 0.09 to 15.46m.Mean hydraulic radius is 9.25m,2010 revels hydraulic radius ranging from 0.09m and 11.49m with mean value of 7.34m.

Hydraulic Radius from 1990-2010 is seen to be directly associated with discharge except for cross-section at Karad in 2010 where hydraulic radius is very low inspite of moderately high discharge. In most cases the hydraulic variables like channel depth is low in the upstream reaches showing the shallow nature of the channels, for example the R value at Karad(2010) is about 0.09m. As against this in the lower reaches the hydraulic radius is high and most large rivers have R-values around 13.66m at Wadenapalli in 2005. This points to the incised nature of the channels in the downstream direction.

3.2.4 Wetted Perimeter-Wetted Perimeter is the area of the cross-sectional area that is "wet". Wetted Perimeter shows an increasing trend downstream. River channel width and channel wetted perimeter is positively co-related. Channel wetted perimeter is always slightly more than the channel width at all cross-sections .Wetted Perimeter is >300 for every year.The mean wetted perimeter is 925.29m.Width is 922.5m(1990),Table(III)The average wetted perimeter is 819.88m.The width is 4082m and the wetted perimeter is 4099.38m(1995)In 2000,mean wetted perimeter is 748.82m.The width is totaled to be 5862m and wetted perimeter is 5990.53.The mean wetted perimeter of 750.34m. The width is 5225m and wetted perimeter is 5252.38(2005),In (2010)total width is 5302m and wetted perimeter is average wetted perimeter is found o be 623.59.Wetted Perimeter of a river channel is also a function of Discharge.

3.2.5 Form Ratio(width-depth ratio)-The width-depth or form ratio (F) is a measure of channel shape and is related to boundary resistance and sediment transport (Schumm, 1977). The shape of the channel (narrow, shallow) is determined by the nature of material on the bed and banks (Schumm, 1977). Shape refers to the dimensions or form of channel in cross-section.Shape of the channel is controlled by its width and depth.It is therefore measured by the ratio of water surface width to mean depth.This ratio is known as the Form Ratio(Schumm,1977).It is a dimensionless number. The shape of the channel (narrow,shallow)is determined by the nature of material on the bed and banks(Schumm,1977). Rivers increase their width-depth ratio in the downstream direction and Big rivers relatively have large width-depth ratio(Kale,Gupta 2001). In general, the channels of the Upland rivers have a box-shaped appearance (Kal.e, 1990; Deodhar and Kale, 1999). Narrow and deep channels are characterized by low form ratio,and shallow ,wide channels have high form ratio(Leopold et al 1964).

Form Ratio in 1990,is 253.73m.1995 is 400.45m.2000,F.R is 505.21m,2005 is 532.58m,2010 is 737.62.

Form Ratio upstream values are lower than 40m in few cases,indicating the channels are narrow,F-Ratio downstream is greater than greater than 130m.This focuses that the channels show wide and shallow channels. The box-shaped nature of the channel reflects that during low flows the flow width-depth ratio is very high and the geomorphic of the channels is very low. However, with the arrival of high flows the width-depth ratio goes on decreasing and the geomorphic effectiveness of the flows increases. Thus it can be concluded that high flows have an important role to play in the erosion and sediment transportation.This form in channel shapes upstream(box-shaped) to downstream(wide and shallow channels) at 5 yr interval is correlated in figures given below.

3.2.6 Qmax-Maximum discharge or annual peak discharge data was available from Water Resource Information System(WRIS)website.The dimensions of a river channel at all points is dependent on the Discharge(Q).This voluminous amount of water travels through river cross-sections at a point of time.Upstream the area being drained being small,discharge is also small. Contrarily Downstream, the amount of Discharge increases, Qmax is high upstream but decreases remarkably in the middle reaches and then is found to increase downstream,Qmax increases upstream to downstream..Significant high or low discharge values are seen at Pondugala cross-sections.

3.2.7 Mean Velocity-Velocity tends to increase slightly downstream in most rivers,velocity (Leopold et all 1964).Present study too follows the sameVelocity in rivers is not confined to a point but rather to the mean velocity for the river channel on a whole.Velocity increase is directly co-related with increase in depth.Deeper is the maximum velocity (Chow 1959).1990 the Mean velocity is 1.28m/s .Velocity decreases as expected from 1.18m/s at Huvenhedgi to 0.75m/s at Vijayawada .In 1995, the Mean Velocity is 0.40 m/s.Upstream Velocity upstream at Karad decreases from 0.63m/s to is 0.23m/s at Vijayawada downstream. In 2000, the Mean Velocity is 3.31,Velocity decreases from 6.10m/s upstream at Karad to 0.50m/s at Vijayawada.Table 1.4(d)/2005 the Mean Velocity is 2.30 m/s,similar decrease in velocity upstream to downstream is observed from 1.51m/s at Karad to 0.01m/s in Vijayawada.The Mean Velocity in 2010,is 0.91m/s. reverse trend in velocity from upstream velocity 0.2m/s at Karad increases to 1.m/s at Wadenapalli is observed.

3.3 Cross-Sections Shape

The shape of the cross-sections of a river channel at any location is a function of the flow ,the quantity and character of the sediment in movement through the section,character or composition of the material making up the bed and banks of the channel(Leopold et all,1964).

The plots in 1990,show that by and large the channels from upstream Huvenhedgi to downstream Vijayawada.Channel gradually transforms from upstream box-shaped at Huvenhedgi to saucer shaped at Vijayawada.

The plots in 1995 from upstream Karad to downstream Vijyawada are box-shaped.The channels are irregular upstream and flat channel beds are found downstream.

In 2000 from Karad Upstream to Vijayawada Downstream.Upstream banks steep with narrow channels,with downstream progression steepness reduces and channels become wide.

2005,Representative channel cross-sections from Upstream Karad to Downstream Vijayawada.Upstream channels are steep and narrow and steepness gradually lessens and channels become wider.

2010,shows channel cross-sections from Upstream Karad to Vijayawada Downstream.Channel are naow and steep upstream and flattens Downstream.Upstream banks are steeper and gradually steepness reduces downstream.

3.4 Cross-sectional area vis-à-vis channel geometry and hydraulic parameters Relationship

In order to depict the relationships,power law regression analysis was carried out. Power-law regression equation and correlation was derived using drainage area,width,depth,wetted perimeter,hydraulic radius,Qmax,form ratio ,velocity and cross-sectional area available for nine gauging sites and cross-sectional area. The obtained correlation shows strong and positive correlation for drainage area,width and wetted perimeter and weak correlation for depth,hydraulic radius,discharge and mean velocity.

Table (IV).Here

Gradual increase in Drainage Bain(Db) is seen with Cross-Sectional area(Ac) and strong correlations for 2000,2005,2010.The correlations statistically significant at 0.05/95% confidence level.Low correlation in 1990 and neither statistically significant at 95%confidence level is seen.Correlation is strong in 1995 but not statistically significant at 95% confidence level is observed.

- Significant increase in Cross-Sectional Area(AC)and Channel Width(W) and strong and positive correlations is present, indicating width increases consistently downstream in 1995,2000,2005,2010 except 1990.The correlations are statistically significant at 0.05/95% confidence level.

- . Poor correlations is found between Cross-sectional Area(AC)and Channel Depth(D) states that depth is not found to be increasing downstream correspondingly from 1990-2010 and co-relations are not statistically significant at 95%/0.05 Confidence level.

- Poor correlations is found between Cross-sectional Area(AC)and Hydraulic Radius,shows low rate of increase downstream and correlation not statistically significant at 0.05/95% confidence level from 1990-2005.Exception in statistically significant value is found in 2010. This points to the incised nature of the channels in the downstream direction.

- Strong and positive correlations is found between Cross-Sectional Area and Wetted Perimeter (1995-2010),indicating wetted perimeter increases downstream systematically with increase in area.The correlations are statistically significant at 0.05/95% confidence level. 1990 shows low correlation and not significant at 95% confidence level.
- Positive correlations is found between Cross-Sectional Area and Form Ratio indicating Form Ratio increases downstream and channels become wider.The correlations are though not statistically significant at 0.05/95% confidence level in 1990-2000. Moderately Strong and Statically significant correlations are found in 2005-2010 .
- Poor correlations indicate Qmax and crosssectional area does not increase downstream systematically and there are latitudinal differences resulting from local factors.The correlations are statistically significant at 0.05/95% confidence level in 1990-1995.Qmax in year 2000-2010 do not follow the trend of and thus insignificant correlation at 0.05 level is observed in Qmax downstream
- Significantly Low Correlation between Velocity and cross- sectional area in downstream direction and reveals that variability in Qmax downstream seriously affects Mean Velocity.The correlations are not statistically significant at 0.05/95% Confidence level.Velocity has strong correlation wirh cross-sectional area in 1990 though not statistically significant.

From the study of channel morphology major conclusions are derived.

A. As the maximum discharge /Q max increases corresponding increase in Cross-Sectional Area,Width,Depth,Wetted Perimeter,Form Ratio,Velocity,Hydraiulic Radius is observed upstream Karad to downstream Vijayawada.

B. Significant increase in Area and Width is observed at Vijaywada station in 1995.

C. The Channel Depth,Hydraulic Radius increase downstream.

D. The Form -Ratio varies between 88.07-141.04(1990),37.91-132.54(1995),30.98-128.56(2000),34.95-167.04(2005),34.04-330.59(2010),

E. The Channels Forms Upstream generally depicts greater depths in comparison to width,which changes downstream to box-shaped forms depicting greater width in relation to depth,indicating high Form Ratio(Width-Depth)Ratio.Some channels are vertical in forms whereas the others have asymmetrical, symmetrical side banks and saucer shaped banks.

Noticeable variations in Channel Geometry of the downstream channels can be contributed both fluvial forces and lithologic resistance.Most importantly channels adjust their channel Geometry corresponding to the downstream channel discharge.Close observation of the hydrological parameters display that the entire data set presents a very well developed downstream hydraulic geometry but mainly between depth and velocity suggests that there is a weak influence of lithologic resistance over width.

Basin area increases downstream, discharge in most rivers also increases with the distance (Leopold et al., 1964).In the present study too changes in both parameters is applicable.

Global Concern - Understanding the downstream Temporal Channel Geometry/Hydraulic Parameters variations of rivers is of prime importance in planning the long term implications of increase/decrease of channel area,width,depth,hydraulic radius,wetted perimeter and mean velocity..Study on the Temporal Channel Geometry is useful to study the influence of human activity and dams in catchment area if any**.**

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8.TABLES

- **Table (I)**

FEATURES	FACTS
Length	1400km
Catchment Area	254945km
Major Tributaries	Tungabadhra,Malaprabha,Ghataprabha(Right) Bhima,Musi,Munneru(Left)
Geology	Deccan Trap,Peninsular Gneisses,Quartenary Alluvium,Crystalline Rocks
Climate	Monsoonal-humid to semi arid
Rainfall(mm)	400-5000
Soil	Red,Black,Saline,Alkaline,Lateritic,Mixed
Rainy Season	July,August,September
No. of Hydrological Stations on Main River	176
Dams	251

➢ Table (II).

Parameters	Symbol/Unit
WIDTH	W/m
MEAN DEPTH	D/m
WETTED PERIMETER	WP/m
HYDRAULIC RADIUS	R/m
FORM RATIO	W/D/m
CROSS-SECTIONAL AREA	XS/m
MEAN VELOCITY	V/m/s
Qmax	$Q/m^3/s$

➢ Table (III).

STATION	DRAINAGE BASIN AREA(m)	Xs AREA(A_C)m^2	WIDTH(m)	DEPTH(m)	WETTED PERIMETER(m)	HYDRAULIC RADIUS(m)	FORM RATIO(m)	Qmax(m^3/s)	MEAN VELOCITY V(m/s)
1990									
1)KARAD	5462	NA							
2)KURUNWAD	15190	NA							
3)ARJUNWAD	12660	NA							
4)HUVENHEDGI	55150	6558.35	760	8.63	761.24	8.62	88.07	7752	1.18
5)DEOSUGUR	129500	NA							
6)AGRAHARAM	132920	8307.4	960	8.65	961.58	8.64	110.98	10800	1.30
7)PONDUGALA	221220	7569.66	490	15.45	496.37	15.25	31.72	14145	1.87
8)WADENAPALLI	235544	-							
9)VIJAYAWADA	251360	16353.48	1480	11.05	1481.95	11.04	133.94	12239	0.75
1995									
1)KARAD	5462	4653.64	420	11.08	425.74	2.14	37.91	2944	0.63
2)KURUNWAD	15190	NA							
3)ARJUNWAD	12660	NA							
4)HUVENHEDGI	55150	6597.3	760	8.68	762.12	8.66	87.56	3572.223	0.54
5)DEOSUGUR	129500	NA							
6)AGRAHARAM	132920	7905.75	940	8.41037234	941.76	8.39	111.77	4218	0.53

7)PONDUGALA	221220	7513.3125	480	15.65	485.89	15.46	30.67	690.6	0.09
8)WADENAPALLI	235544	NA							
9)VIJAYAWADA	251360	16571.58	1482	11.18	1483.87	11.17	132.54	3764	0.23
2000									
1)KARAD	5462	4565.95	420	10.87	425.2662	10.74	38.63	27870.82	6.10
2)KURUNWAD	15190	3684.7	430	8.57	436.78	8.44	50.18	2593.78	0.70
3)ARJUNWAD	12660	3942.75	430	9.17	436.12	9.04	46.90	1747.292	0.44
4)HUVENHEDGI	55150	6404.68	760	8.43	761.40	8.41	90.18	3765	0.59
5)DEOSUGUR	129500	NA							
6)AGRAHARAM	132920	8090.6	940	8.61	941.87	8.59	109.21	5601	0.69
7)PONDUGALA	221220	7584.69	480	15.80	485.16	15.63	30.75	6423	0.06
8)WADENAPALLI	235544	9057.81	950	9.53	1050.301	8.62	99.64	2956.996	0.33
9)VIJAYAWADA	251360	16399.4	1452	11.29	1453.63	11.28	128.56	8135.13	0.50
2005									
1)KARAD	5462	4190.01	380	11.03	384.45	0.09	34.46	6312 NEW	1.51
2)KURUNWAD	15190	4007.75	395	10.15	403.12	9.94	38.93	10092	2.52
3)ARJUNWAD	12660	NA							
4)HUVENHEDGI	55150	6647.95	770	8.63	771.84	8.61	89.19	10047.24 NEW	1.51
5)DEOSUGUR	129500	NA							
6)AGRAHARAM	132920	8081.55	960	8.42	961.97	8.40	114.01	53545.5	6.63
7)PONDUGALA	221220	7513.3125	480	15.65	485.86	15.46	30.67	17719.061	2.36
8)WADENAPALLI	235544	10980.84	800	13.73	803.97	13.66	58.28	16792.73	1.53

9)VIJAYAWADA	251360	12413.78	1440	8.62	1441.17	8.61	167.04	16650.31	0.01
2010									
1)KARAD	5462	4266.655	385	11.08	389.8175	0.09	34.74	1188.739	0.28 NEW
2)KURUNWAD	15190	4039.975	420	9.62	426.55	9.47	43.66	3846.78	0.95
3)ARJUNWAD	12660	3182.425	340	9.37	346.55	9.18	36.32	2587.448	0.81
4)HUVENHEDGI	55150	6433.35	760	8.46	761.54	8.45	89.78	8097.146	1.25
5)DEOSUGUR	NA	NA							
6)AGRAHARAM('09)	132920	8081.55	960	8.42	961.97	8.40	114.0375	-	-
7)PONDUGALA	221220	NA						-	
8)WADENAPALLI	235544	6020.967	1020	11.53	1023.08	11.49	88.49	6005.742	1.00
9)VIJAYAWADA	251360	6073.6	1417	4.29	1417.59	4.28	330.59	6954.427	1.15 NEW

Table (IV).

YEAR	CORRELATION	SIGNIFICANCE at 0.05/95%
1990	$Y=78.537x^{2.51}$ R2=0.4681	X
1995	$y=595.23x^{1.70}$ $R^2=0.6088$	X
2000	$\log y=308.67\ x^{1.91}$ $R^2=0.742$	✓ ✓
2005	$\log y=374.96x^{1.01}$ $R^2=0.8457$	✓ ✓
2010	$\log y=878.12\log x^{1.46}$ $R^2=0.62$	✓ ✓

(ii)

YEAR	CORRELATION	SIGNIFICANCE 0.05/95%
1990	$y=0.200x^{8.26}$ $R^2=0.65$	X
1995	$y=0.1309x^{9.17}$ $R^2=0.76$	✓ ✓
2000	$y=0.4084x^{6.77}$ $R^2=0.72$	✓ ✓

2005	$y=0.08x^{10.43}$ $R^2=0.74$	✓ ✓
2010	$y=0.0002x^{56.53}$ $R^2=0.75$	✓ ✓

(iii)

YEAR	CORRELATION	SIGNIFICANCE at 0.05/95%
1990	No Correlation	
1995	$y=7.65x^{1.09}$ $R^2=0.004$	X
2000	$y=3.02x^{1.37}$ $R^2 0.1026$	X
2005	$y=10.05x^{1.01}$ $R^2=0.0001$	X
2010	$y=127.96\ x^{0.48}$ $R^2=0.0956$	X

(iv)

YEAR	CORRELATION	SIGNIFICANCE at 0.05/95%
1990	$y=4.7626x^{1.22}$ $R^2=0.02$	X
1995	$y=0.0007\ x^{2.47}$ $R^2=0.41$	X
2000	$y=0.0071\ x^{1.06}$ $R^2=0.03$	X
2005	$y=1E\text{-}08x^{1.84}$ $R^2=0.29$	X
2010	$y=0.0001x^{17.08}$ $R^2=0.05$	✓ ✓

(v.)

YEAR	CORRELATION	SIGNIFICANCE at 0.05/95%
1990	$y=0.2097x^{8.18}$ $R^2=0.66$	X
1995	$y=0.142x^{8.99}$ $R^2=0.77$	✓ ✓
2000	$y=0.29x^{6.56}$ $R^2=0.82$	✓ ✓
2005	$y=0.119.57\ x^{9.57}$ $R^2=0.77$	✓ ✓
2010	$\log y=0.003\ x^{27.97}$ $R^2=0.72$	✓ ✓

(vi).

YEAR	CORRELATION	SIGNIFICANCE at 0.05/95%
1990	$y=0.0402x^{6.82}$ $R^2=0.28$	X
1995	$y=0.0058\ x^{10.81}$ $R^2=0.53$	X
2000	$y=0.01x^{9.71}$ $R^2=0.43$	X
2005	$y=0.011x^{2.78}$ $R^2=0.47$	✓ ✓
2010	$y=2E\text{-}05x^{60.26}$ $R^2=0.52$	✓ ✓

(vii)

YEAR	CORRELATION	SIGNIFICANCE at 0.05/95%
1990	log y=4.6116+6.9log x $R^2=0.901$	✓ ✓
1995	log y=2E+0.01 log x $R^2=0.043$	✓ ✓
2000	log y=200.1+2.32 log x $R^2=0.045$	X
2005	log y=6.59+7.40 log x $R^2=0.32$	X
2010	log y=33.23+3.36 log x $R^2=0.04$	X

(viii)

YEAR	CORRELATION	SIGNIFICANCE at 0.05/95%
1990	$y=918.99+0x^{0.19}$ $R^2=0.62$	X
1995	Log y=66483+0.05 log x $R^2=0.13$	X
2000	log y=759.21+6.65 log x $R^2=0.11$	X
2005	log y=(6E+09)+0.003log x R=0.2703	X
2010	log y=0.007+3.46 log x $R^2=0.04$	X

9.FIGURES

KRISHNA FIGURES PDF.pdf

10.TABLE CAPTIONS

- Table (I). 2020 Salient features of the Krishna River Basin
- Table (II).2020Cross-sectional parameters used is the present study
- Table III. (1990-2010)Channel Geometry and Hydraulic parameters for channel Cross-Sections.
- Table (IV).(1990-2010)(Power-Law relationships for Krishna Bain between CrossSectional Area(Ac) and (i)Drainage Basin(Db),(ii)Channel Width,(iii)Channel Depth,(iv)Hydraulic Radius,(v)Wetted Perimeter,(vi)Form Ratio,(vii)Qmax,(viii)Velocity

11.FIGURE CAPTIONS

- FIG.1.1(A)Map of Krishna river Basin
- FIG 1.1(B)Krishna river basin showing Hydrological Observation Stations
- Fig.1.2(i)DOWNSTREAM CHANNEL CROSS-SECTIONS ON KRISHNA RIVER Huvenhedgi to Vijayawada (1990)
- Fig.1.2(ii)DOWNSTREAM CHANNEL CROSS-SECTIONS ON KRISHNA RIVER from KARAD to Vijayawada (1995)
- Fig.1.2(iii)DOWNSTREAM CHANNEL CROSS-SECTIONS ON KRISHNA RIVER (2000)
- Fig.1.2(iv)DOWNSTREAM CHANNEL CROSS-SECTIONS ON KRISHNA RIVER(2005)
- Fig.1.2(v)DOWNSTREAM CHANNEL CROSS-SECTIONS ON KRISHNA RIVER

FIGURE CAPTIONS

FIG.1.1(A)Map of Krishna river Basin

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Fig.1.2(iii)DOWNSTREAM CHANNEL CROSS-SECTIONS ON KRISHNA RIVER (2000)

Fig.1.2(iv)DOWNSTREAM CHANNEL CROSS-SECTIONS ON KRISHNA RIVER(2005)

Fig.1.2(v)DOWNSTREAM CHANNEL CROSS-SECTIONS ON KRISHNA RIVER