

Geomorphic Controls on Hydraulic Responses to Flood Magnitudes: Insights from the Kaveri River, Southern India

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Abstract: *This study conducts a systematic evaluation of at-a-station hydraulic geometry (AHG) within the Kaveri fluvial system, employing Annual Maximum Series (AMS) information to quantify the differential contributions of channel width (w), mean depth (d), and mean velocity (v) (b - f - m respectively) in accommodating discharge variations. Derivation of b/f and m/f ratios, in conjunction with total variance analysis, delineates the relative trajectories of adjustment in channel w , d and v . Furthermore, the HG exponents (b - f - m), calculated across all sampling loci, were projected onto Rhodes' ternary classification scheme, thereby facilitating their partitioning into defined morphological fields.*

Empirical evidence underscores the dominance of vertical deepening and velocity enhancement over lateral expansion, as indicated by the attenuated width-depth ratio (b/f) and elevated velocity-depth ratio (m/f), reinforcing flood conveyance efficiency. The total variance at one site closely approximates the theoretical value (0.33), signifying proportional distribution of discharge across all three hydraulic geometry variables. Conversely, deviations observed at the remaining sites suggest an asymmetric absorption of discharge variations, predominantly by one or two variables, thereby challenging the notion of a self-formative alluvial channel. This disparity implies that the Kaveri river and its tributaries deviate from true alluvial behaviour, lacking independent morphological adjustments.

Sector-specific analyses derived from the b - f - m diagram reveal distinct hydraulic adjustment regimes, with eleven sites classified under sector 2 and two under sector 4. Sector 2 demonstrates heightened hydraulic competence, marked by elevated Froude no. (Fr), increased velocity-area quotient, and intensified gradient-roughness interactions under growing flow conditions. In contrast, sector 4 demonstrates a decline in velocity-area ratio despite maintaining similar trends in other hydraulic parameters. These findings hold significant implications for sediment transport dynamics and flood conveyance efficiency, offering a refined perspective on fluvial system responses to discharge variability.

Keywords: At-a-station HG, Ternary diagram, Kaveri river.

Introduction

The concept of hydraulic geometry (HG) encapsulates the systematic interrelations between fluvial form and discharge variability through time. When examined at a fixed locus, such relationships are expressed as at-a-station hydraulic geometry (AHG), whereas their manifestation along a continuum of interconnected river reaches, where hydraulic parameters exhibit ordered adjustments under comparable discharge regimes, is designated as downstream hydraulic geometry (DHG) by Ferguson (1986). In recent discourse, a couple of classifications of HG have been articulated. Reach-averaged hydraulic geometry (RHG) by Jowett (1998) conceptualises hydraulic relations as mean values integrated across a defined river reach, while the at-many-stations hydraulic geometry (AMHG) of Gleason and Smith (2014) interrogates the systematic variation of hydraulic parameters across multiple observational loci within a fluvial network.

Hydraulic geometry, initially conceptualised by Leopold and Maddock (1953), delineates fundamental geomorphic and hydrologic interdependencies governing fluvial dynamics, remaining indispensable for global water resource assessments (Gleason, 2015; Read, 2006; Stewardson, 2005). In hydraulic geometry, discharge acts as the fundamental independent variable, governing variations in river characteristics while being constrained by defined boundary conditions, which are quantitatively expressed through HG relationships. Downstream hydraulic geometry denotes the ordered transformations in channel width (w), depth (d), and flow velocity (v) that occur as a function of progressively increasing discharge, reflecting the systematic reconfiguration of hydraulic parameters as the river advances along

its longitudinal profile. Likewise, AHG characterises the temporal variations in these parameters at a single cross-section as discharge fluctuates over time (Leopold and Maddock, 1953). Although hydraulic geometry explicitly addresses only three primary parameters, it implicitly incorporates a multitude of ancillary morphologic and dynamic factors that modulate these fundamental constituents. Consequently, the hydraulic geometry equations furnish a concise yet rigorous encapsulation of the complex interdependencies between channel form and hydraulic processes.

Hydraulic geometry equations have traditionally served as analytical instruments for the characterisation and comparative evaluation of stream channels across diverse environmental regimes, with the principal axis of comparison residing in the numerical concordance of the derived exponents. The implicit premise underlying these analyses is that fluvial channels, quantified by the parameters b - f - m vary exclusively in the degree at which they adjust to variations in discharge (Rhodes, 1977). Rhodes (1987) posits that hydraulic geometry equations represent simplified allometric approximations of the profoundly complex interrelationships inherent in fluvial systems. While these geometric relationships provide a framework for scaling river characteristics, they do not comprehensively explain or encapsulate the full complexity of river systems. Comparative analyses of hydraulic geometries across distinct river systems have generated pivotal insights into the functional dynamics of fluvial processes. The exponents b - f - m , normalised to total value of 1.00 at apiece site are conventionally represented within a ternary b - f - m illustration, as outlined by Rhodes (1977), to enable systematic

and rigorous cross-channel comparisons. The b-f-m diagram serves as a diagnostic and comparative tool, underpinning the refinement of hydraulic geometry models by capturing the nuanced interdependencies inherent in river channel responses to changing discharge conditions.

The Kaveri river and its tributaries, comprising alluvial and mixed alluvial-bedrock channel systems, display unique hydraulic behaviour-high magnitude floods do not completely fill the channel, thus confining overbank flooding primarily to the delta region. Despite its alluvial and mixed-alluvial bedrock composition, cohesive banks induce quasi-bedrock responses during high-discharge events. This study interrogates the channel's dynamic response to varying discharges, aiming to delineate variations in hydraulic variables through the application of AHG.

Study area

The Kaveri river, a major fluvial system of peninsular India, traverses a course of roughly 800 km and drains an area measuring 81,155 km² (Fig. 1). Originating at Talakaveri in the Western Ghat at an elevation of 1341 m, the river initiates its flow in Karnataka and follows NW-to-SE gradient. It traverses the morphologically distinct regions of Karnataka, Tamil Nadu, Kerala, and Puducherry, before ultimately discharging into the Bay of Bengal. The significant sub-streams are the Kabini, Shimsha, Hemavati, Bhavani, Arkavathi, Amaravathi and Noyyal. The Kaveri basin is delimited by the Western Ghat along its western margin, the Eastern Ghat along its eastern and southern peripheries, and is segregated from the Krishna and Pennar basins to the north by a series of ridges. The Kaveri basin is partitioned into two primary physiographic

units. The western unit is represented by the Mysore Upland, which exhibits extensive valley systems and gentle-slope fluvial networks. In dissimilarity, the eastern unit comprises the alluvial-deltaic plains of Tamil Nadu, characterised by extensive depositional environments (Kale *et al.*, 2014).

The Kaveri fluvial system is predominantly characterised by Archean-Proterozoic rocks, notably granites, gneisses and charnockites (Sharma and Rajamani, 2001; Valdiya, 2001). In its eastern sector, quaternary deposits prevail, particularly on the alluvial-deltaic plains of Tamil Nadu. Additionally, the basin and its adjacent regions are characterised by a complex structural framework of N-S and E-W trends of faults, shear zones and lineaments (Ramasamy, 2006; Vaidyanadhan, 1971; Valdiya, 2001).

The Kaveri basin is governed through a distinctly monsoonal climatic regime, with mean annual precipitation exhibiting pronounced spatial heterogeneity, surpassing 2,500 mm within the Western Ghat headwaters and attenuating to approximately 700 mm across lower spreads (Kale *et al.*, 2014). Orographic influences exert a controlling effect on precipitation distribution, confining the highest rainfall intensities to the Western Ghat and the Biligirirangan (BR) and Mahadeswaramalai (MM) hill ranges. The Kaveri basin records a mean annual precipitation of approximately 1,172 mm (Pagare *et al.*, 2025 a and b). In the southwest monsoon season, more than 75 % of the basin's annual rainfall and runoff is produced, coinciding with the transport of nearly 85 % of the total annual sediment load (Vaithianathan *et al.*, 1992).

Kale *et al.* (2014) observed that the Kaveri basin exhibits mean annual flow of roughly 21.4 km³ (CWC, 2020), significantly less than

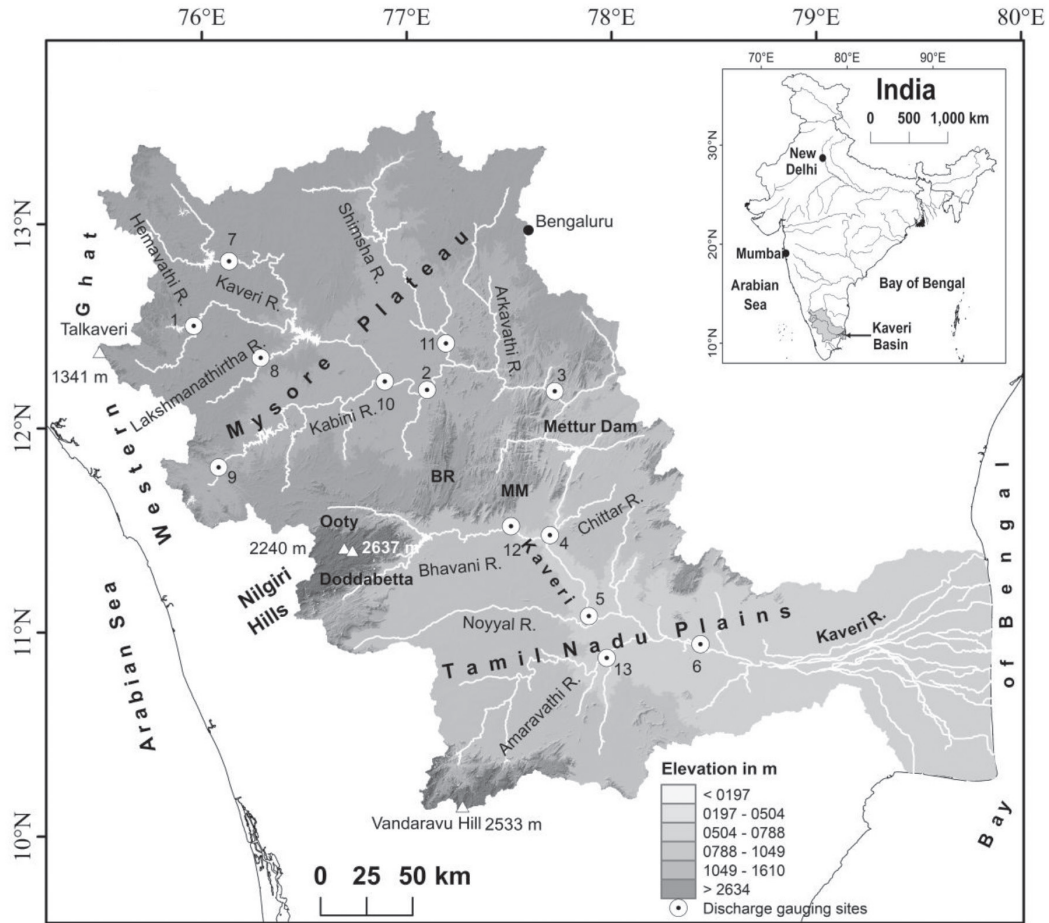


Figure 1. Gauging sites in the Kaveri basin, where: 1=Kudige; 2=Kollegal; 3=Biligundulu; 4=Urachikottai; 5=Kodumudi; 6=Musiri (on Kaveri river.); 7=M.H. Halli (on Hemavathy river.); 8=K.M. Vadi (on Lakshmanathirtha river.); 9=T. Narasipur; 10=Muthankera (on Kabini river.); 11=T.K. Halli (on Shimsha river.); 12=Savandapur (on Bhavani river.); 13=Nallamaranpatty (on Amaravathi river.), BR=Biligirirangan ranges; MM=Mahadeswaramalai ranges.

what is seen in prominent Peninsular river systems viz. Godavari (111 km³), Krishna (78 km³), Mahanadi (67 km³) and Narmada (46 km³). This hydrological limitation yields exceptionally low unit discharge, which in turn corresponds to reduced rates of fluvial erosion (Kale *et al.*, 2014).

Data and methodology

The establishment of at-a-station hydraulic

geometry equations necessitates rigorous empirical determination of channel width (*w*), depth (*d*), and velocity (*v*) under average annual discharge conditions. However, this study leverages hydraulic variable data derived from the annual maximum series (AMS), obtained from six hydrological monitoring stations along the Kaveri river — viz. Kudige, Kollegal, Biligundulu, Urachikottai, Kodumudi, and Musiri as well as from seven other sites on

its tributaries, specifically M.H. Halli, K.M. Vadi, T. Narasipur, Muthankera, T.K. Halli, Savandapur, and Nallamaranpatty (CWC, 2020). In addition to this, cross sectional data for the above-mentioned sites have also been acquired from Central Water Commission (CWC, 2020). Field observations at all the sites have helped in interpretation of results. Empirical datasets obtained through AMS have been applied in the derivation of AHG calculations, thereby quantitatively delineating the functional relationships between hydromechanical parameters and streamflow. Following the seminal approach of Leopold and Maddock (1953), the channel characteristics are expressed as power-law functions of discharge:

$$w = aQ^b \quad \text{Eq. 1}$$

$$d = cQ^f \quad \text{Eq. 2}$$

$$v = kQ^m \quad \text{Eq. 3}$$

where; w is the river width; d is the mean flow depth; v is the average flow velocity; Q is the river discharge; and a - b - c - f - k - m remain numerical constants (Leopold and Maddock, 1953). The three equations presented above serve as fundamental tools for characterising and interrelating stream channel forms. These AMS-derived datasets have been employed within the derivations of AHG equations, wherein discharge functions as the independent variable and hydraulic parameters (width, depth, and velocity) are expressed as dependent variables through simple power-law relationships (Rhodes, 1977, 1978, 1987).

Graphical representation of the hydraulic geometry exponents is achieved by plotting their values on a triangular (ternary) coordinate system. Leopold and Maddock (1953) demonstrated that the HG exponents b - f - m , corresponding to channel width, depth, and velocity, must collectively equal to 1.00.

When plotted within a triangular coordinate framework scaled from 0.00 to 1.00, any valid combination of these exponents can thus be represented as a single point within the triangle. This method provides a concise, graphical summary of the interplay between discharge and channel form.

The conventional b - f - m diagram provides only general information derived from the plotted coordinates. In contrast, subdividing the diagram into five diagnostic fields, defined by constant w/d quotient ($b=f$), competence ($m = f$), Fr ($m = f/2$), v -cross-sectional area quotient ($m = b+f$), and gradient-roughness quotient ($m/f = 2/3$), offers a more refined understanding of the interdependencies among hydraulic variables (Rhodes, 1977). Although Rhodes (1977) initial application of the ternary framework was restricted to AHG exponents, subsequent refinements established the partitioned b - f - m illustration as a versatile instrument for graphical description of HG (Rhodes, 1987). In this study, the exponents b , f , and m derived for stations along the Kaveri trunk stream and its sub-streams were systematically plotted within Rhodes' ternary diagram and classified into the prescribed fields. Furthermore, diagnostic ratios such as b/f and m/f , together with measures of total variance, were computed to assess the relative rates of adjustment in channel width, mean depth, and mean velocity.

Results and discussion

The HG results for six sites on the Kaveri river and seven sites on the tributaries are presented in Table 1 and Fig. 2 to Fig. 14. The results of all stations unequivocally illustrate that the rate of change in average flow velocity (m) and average flow depth (f) to rising flood conditions is more pronounced

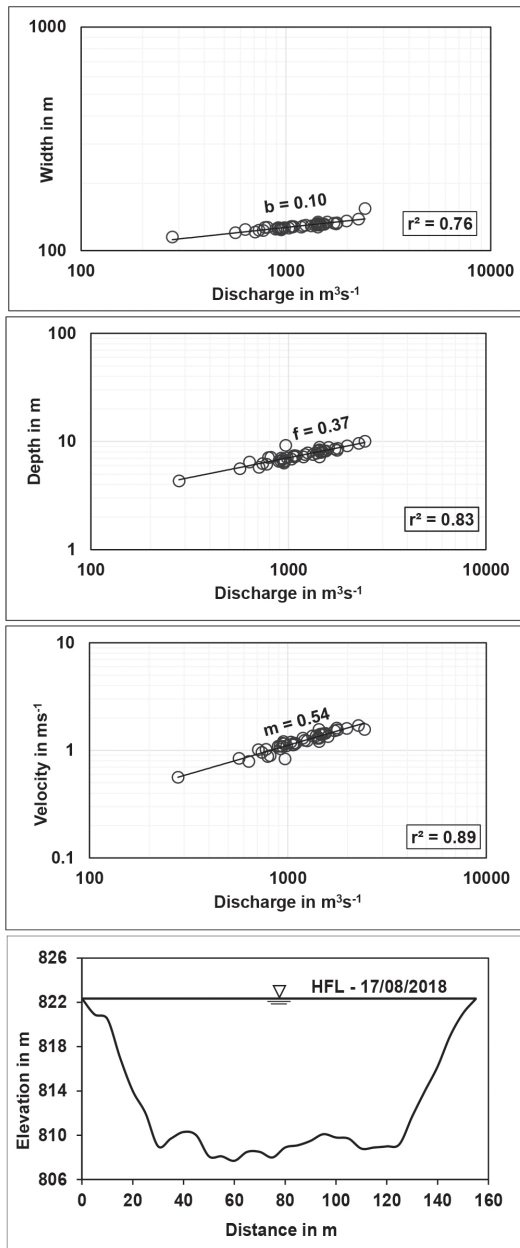


Figure 2. Figure 2: At-a-station hydraulic geometry and a cross-section at Kudige, Kaveri river.

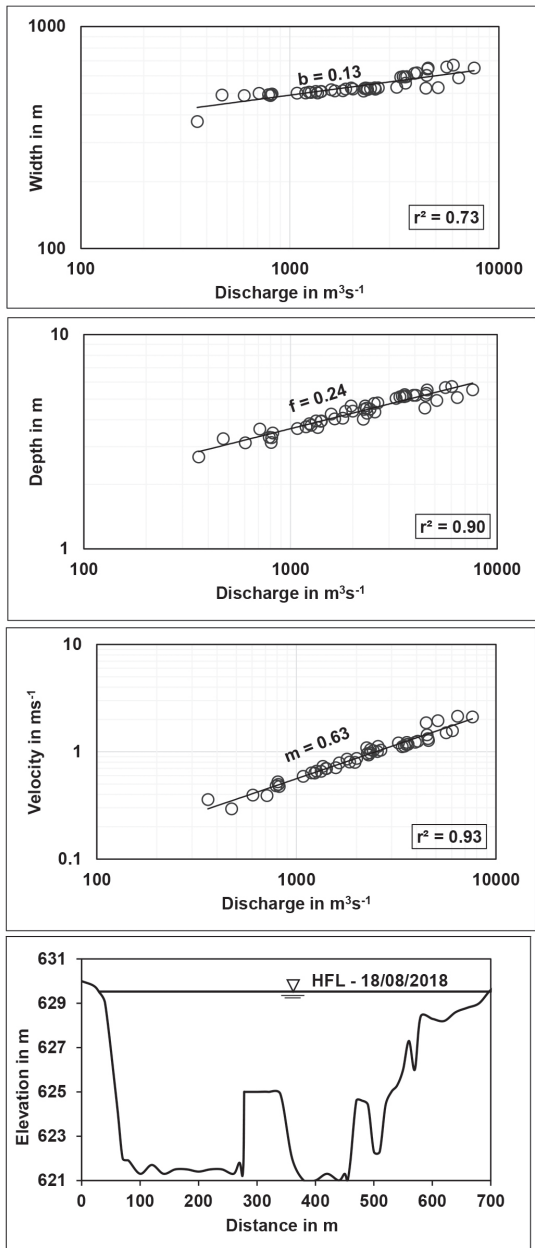


Figure 3. At-a-station hydraulic geometry and a cross-section at Kollegal, Kaveri river.

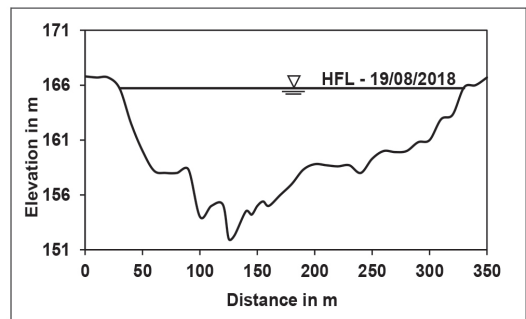
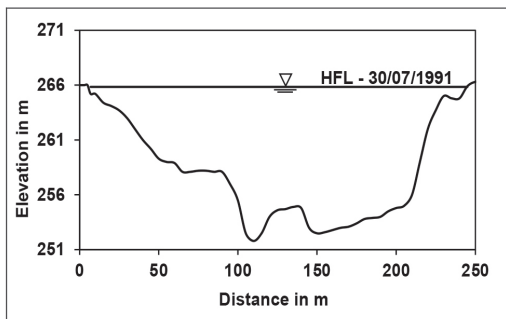
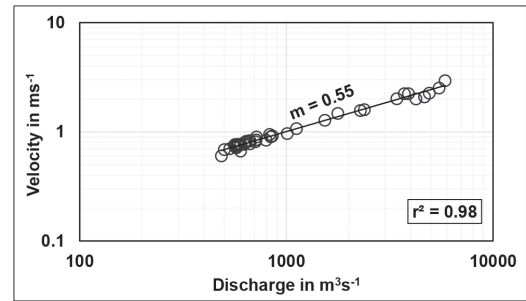
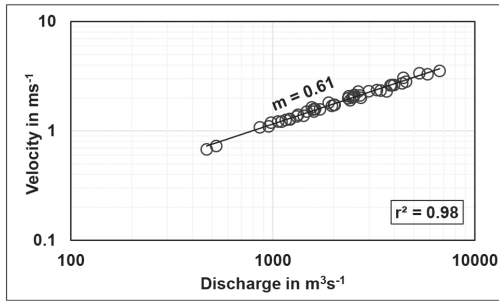
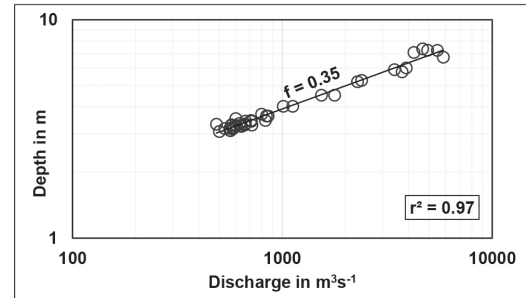
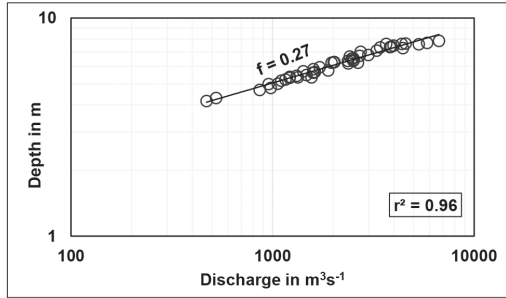
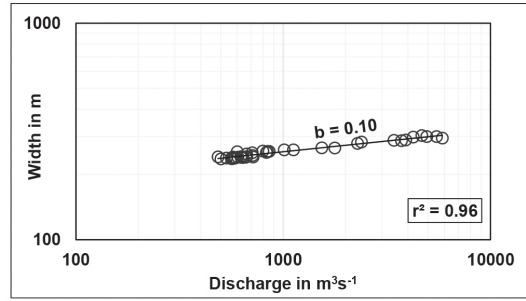
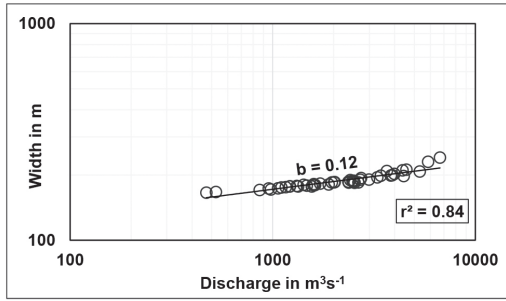


Figure 4. At-a-station hydraulic geometry and a cross-section at Biligundulu, Kaveri river.

Figure 5. At-a-station hydraulic geometry and a cross-section at Urachikottai, Kaveri river.

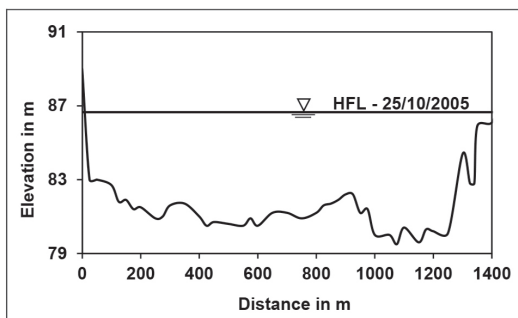
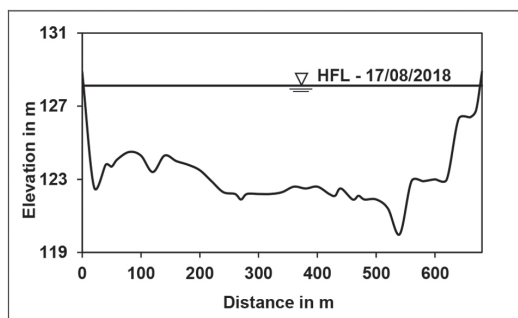
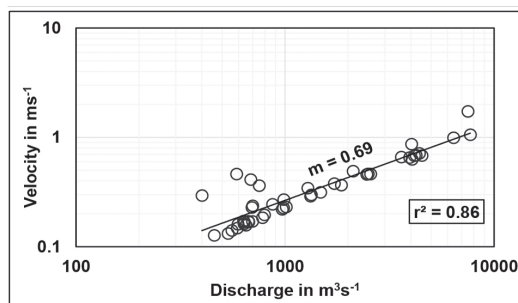
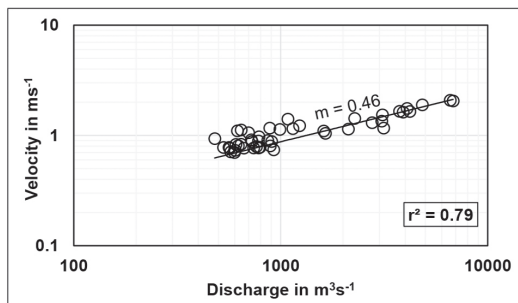
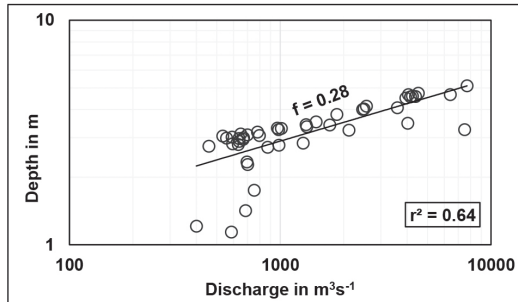
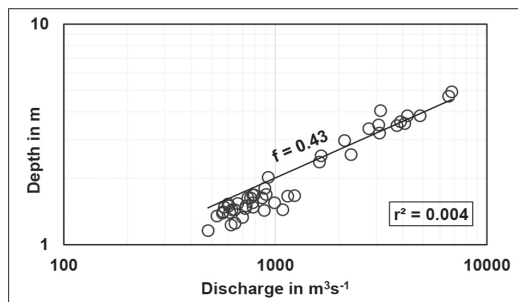
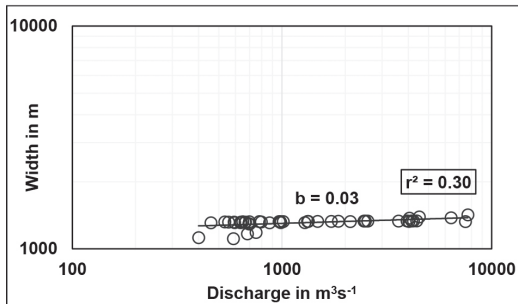
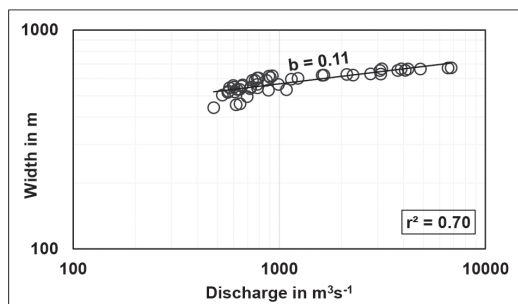


Figure 6. At-a-station hydraulic geometry and a cross-section at Kodumudi, Kaveri river.

Figure 7. At-a-station hydraulic geometry and a cross-section at Musiri, Kaveri river.

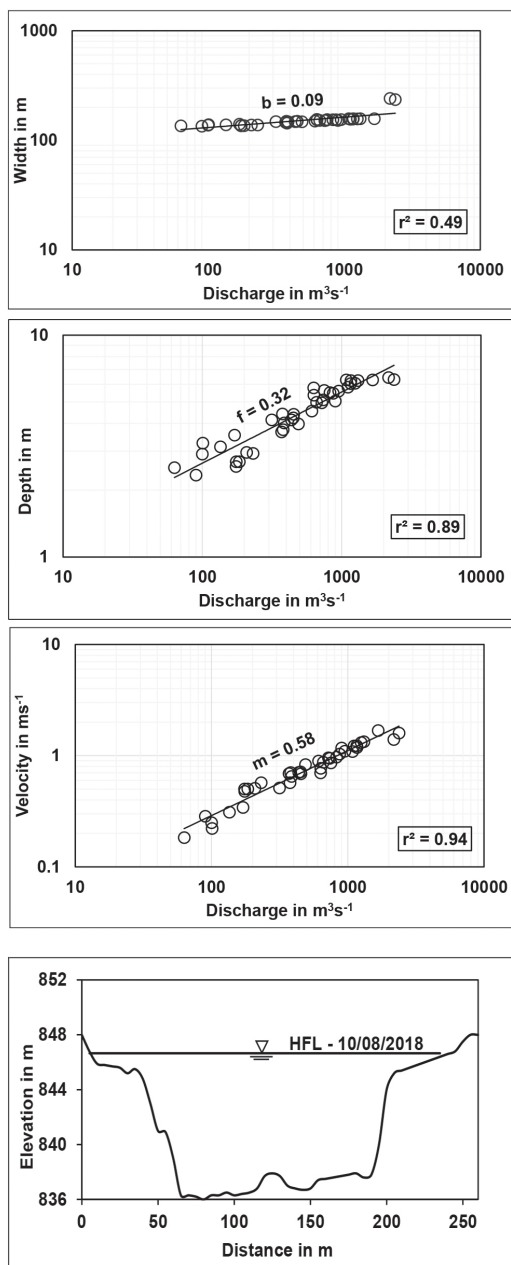


Figure 8. At-a-station hydraulic geometry and a cross-section at Kodumudi, Kaveri river.

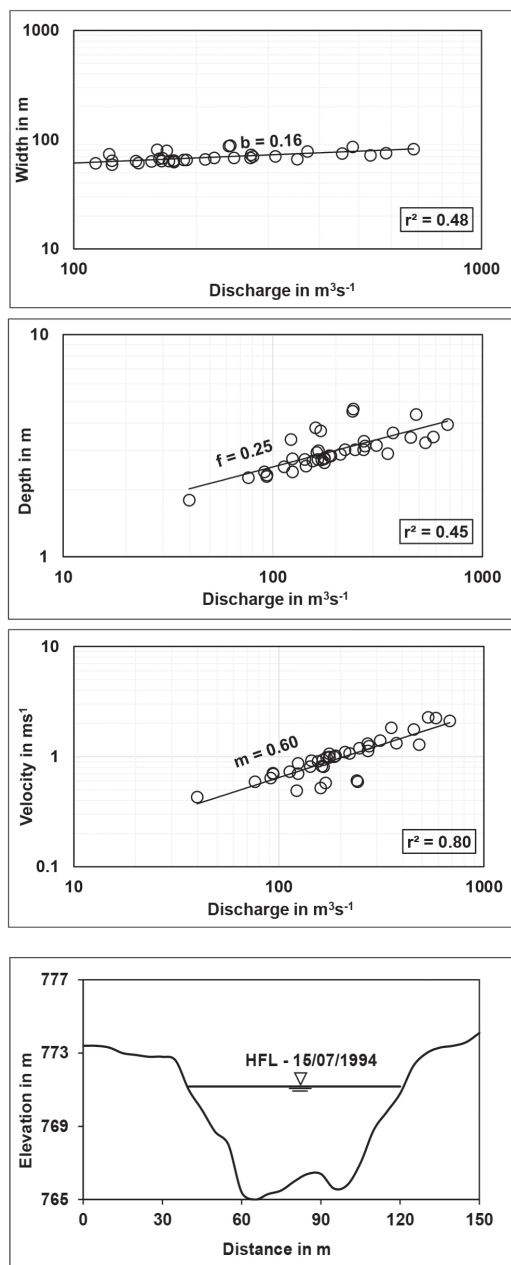


Figure 9. At-a-station hydraulic geometry and a cross-section at Musiri, Kaveri river.

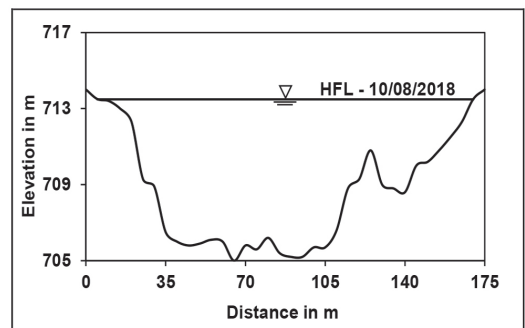
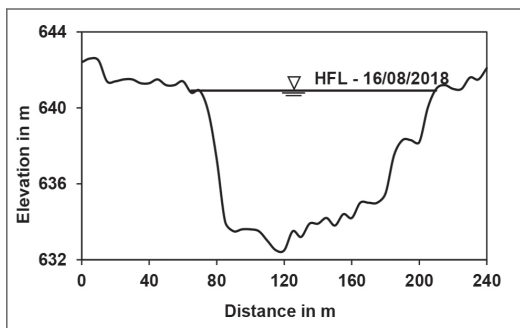
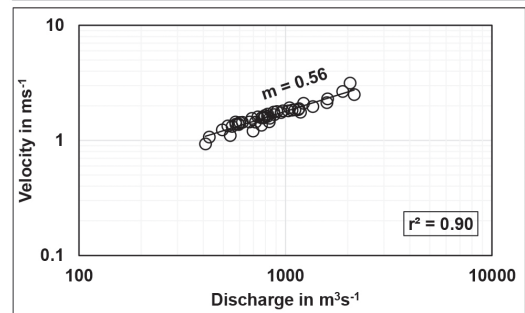
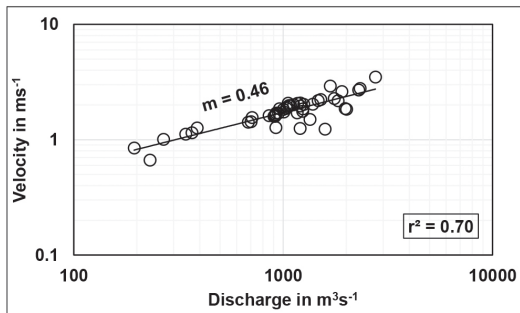
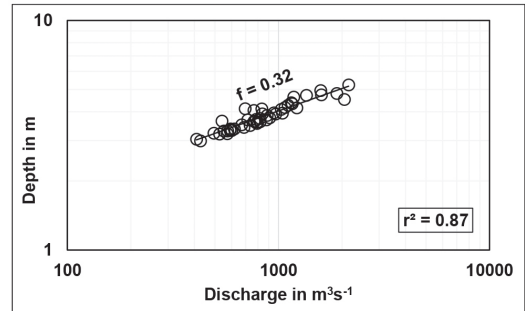
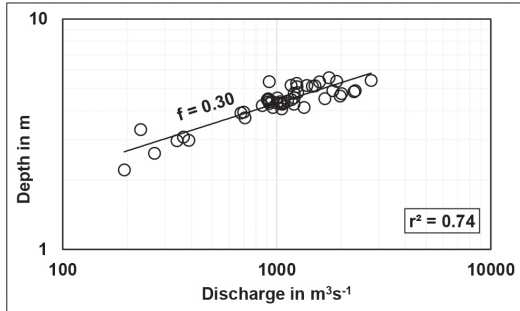
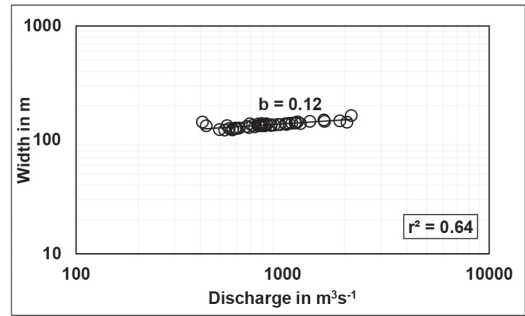
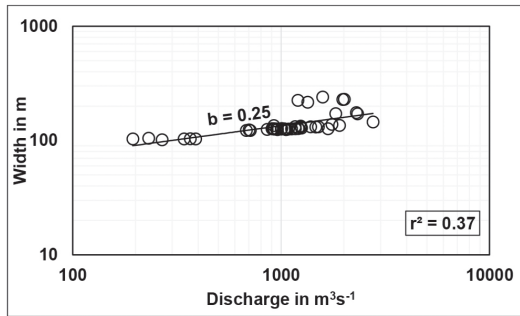


Figure 10. At-a-station hydraulic geometry and a cross-section at Kodumudi, Kaveri river.

Figure 11. At-a-station hydraulic geometry and a cross-section at Musiri, Kaveri river.

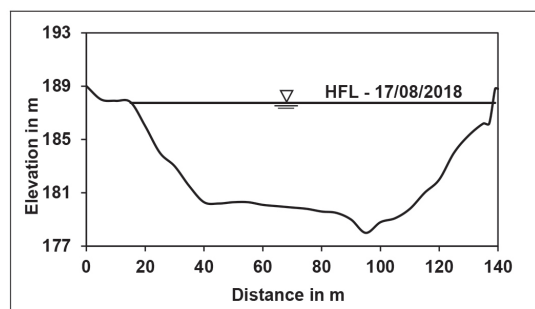
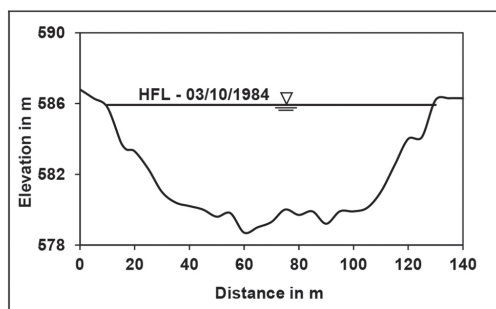
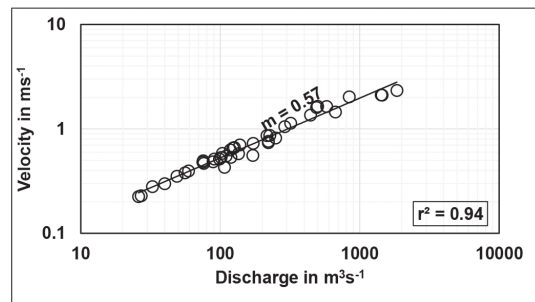
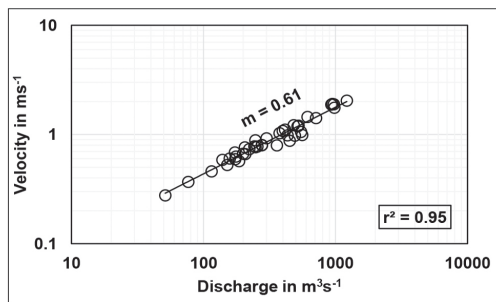
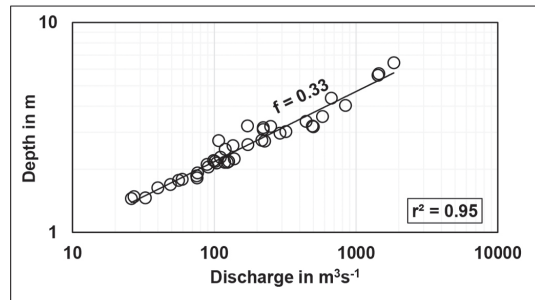
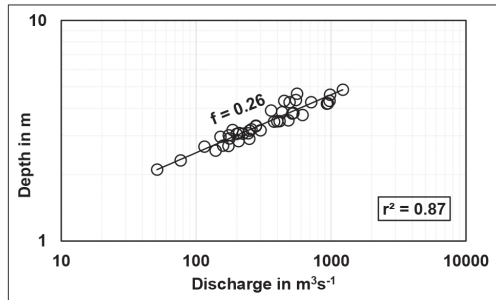
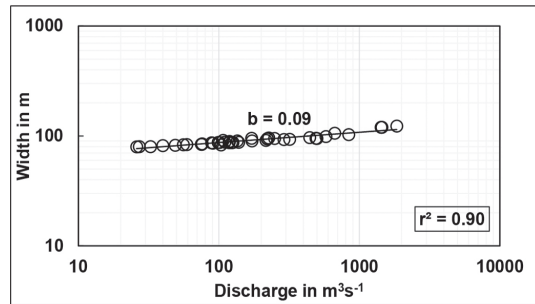
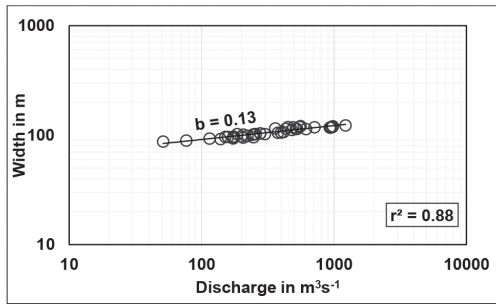


Figure 12. At-a-station hydraulic geometry and a cross-section at Kodumudi, Kaveri river.

Figure 13. At-a-station hydraulic geometry and a cross-section at Musiri, Kaveri river.

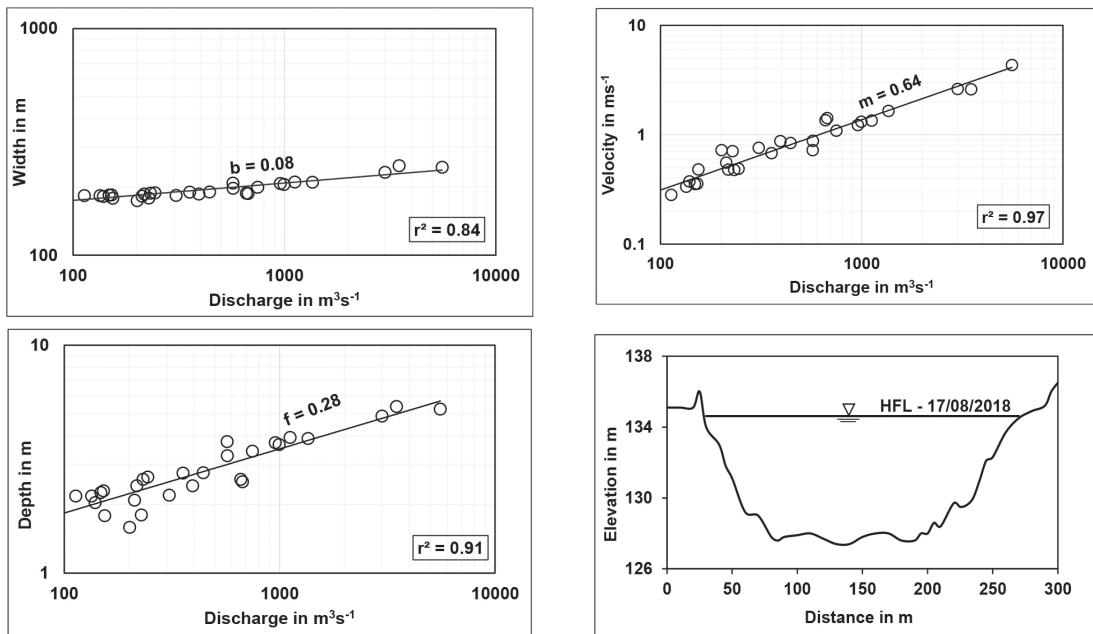


Figure 14. At-a-station hydraulic geometry and a cross-section at Nallamaranpatty, Amaravati river.

than that of channel width (b), indicating that the Kaveri river and its tributaries undergo more pronounced vertical and longitudinal adjustments rather than lateral expansion with increasing discharge. However, a comparative analysis of the hydraulic geometry exponents indicates that the Kaveri river system (Table 1) exhibits a broader range of morphodynamic adjustments compared to the Tapi, Narmada, and Mahi fluvial systems (Table 2). The gauging stations of the main-stream and sub-streams demonstrate a capacity for

lateral expansion in conjunction with vertical deepening and velocity changes, reflecting more diverse adaptive responses to increasing discharge. In contrast, the Narmada, Mahi, Tapi and Par rivers primarily accommodate increased flow through vertical adjustments and velocity enhancements, suggesting a more constrained lateral response and a uniform, depth-dominated scaling behaviour (Kale *et al.*, 1994; Kale and Hire, 2004; Patil *et al.*, 2018; Hire, 2000; Hire and Patil, 2013; Hire and Patil, 2018; Hire and Hire, 2021).

Table 1. Exponent values of at-a-station hydraulic geometry.

River	Sites	Width (b)	Depth (f)	Velocity (m)	b/f ratio	m/f ratio	Total Variance
Kaveri	Kudige	0.10	0.37	0.54	0.27	1.46	0.43
Kaveri	Kollegal	0.13	0.24	0.63	0.52	2.62	0.48
Kaveri	Biligundulu	0.12	0.27	0.61	0.44	2.27	0.46
Kaveri	Urachikottai	0.10	0.35	0.55	0.28	1.56	0.44
Kaveri	Kodumudi	0.11	0.43	0.46	0.27	1.08	0.41
Kaveri	Musiri	0.03	0.28	0.69	0.10	2.50	0.56

Hemavathy	M.H. Halli	0.09	0.32	0.58	0.30	1.82	0.45
Lakshmanathirtha	K.M. Vadi	0.16	0.25	0.60	0.63	2.41	0.44
Kabini	T. Narasipur	0.25	0.30	0.46	0.83	1.55	0.36
Kabini	Muthankera	0.12	0.32	0.56	0.36	1.72	0.43
Shimsha	T.K. Halli	0.13	0.26	0.61	0.48	2.32	0.46
Bhavani	Savandapur	0.09	0.33	0.57	0.28	1.72	0.45
Amaravati	Nallamaranpatty	0.08	0.28	0.64	0.27	2.28	0.50

Table 2. Exponent values of at-a-station hydraulic geometry of the Tapi, Narmada and Mahi rivers

River	Sites	Width (b)	Depth (f)	Velocity (m)	b/f ratio	m/f ratio	Total Variance
Tapi	Gidhade	0.03	0.60	0.36	0.05	0.60	0.49
Tapi	Sarangkheda	0.04	0.59	0.38	0.07	0.64	0.49
Tapi	Ghala	0.05	0.38	0.57	0.13	1.50	0.47
Narmada	Rajghat	0.04	0.46	0.50	0.08	1.08	0.46
Mahi	Padardibadi	0.02	0.45	0.53	0.05	1.18	0.48
Mahi	Khanpur	0.04	0.53	0.43	0.08	0.81	0.47

Source: Kale *et al.*, 1994; Patil *et al.*, 2018; Hire and Hire, 2021

At the Musiri gauging station on the Kaveri (Fig. 7), the channel's anomalously expansive morphology results in an exceptionally attenuated width exponent ($b=0.03$), indicating that lateral adjustments to increased discharge are highly suppressed. Similarly, the channels at the M.H. Halli (Fig. 8), Savandapur (Fig. 13), Nallamaranpatty (Fig. 14) sites are characterised by near-rectangular, box-shaped cross-sectional geometries which exhibit restrained lateral scaling. In these settings, augmented discharge is predominantly accommodated via substantial increases in both mean flow velocity and mean channel depth rather than width, thereby emphasising a vertical and longitudinal adjustment regime. Conversely, the T. Narasipur site on the Kabini river demonstrates a notably higher width exponent, consistent with a semi-circular channel configuration that facilitates more pronounced lateral expansion in response to increasing hydraulic load (Fig. 10).

The width-depth (b/f) ratio quantifies the proportional response of channel width relative to channel depth as discharge increases (Rhodes, 1977). The b/f ratios, varies from 0.10 and 0.86, (Table 1) consistently demonstrate that channel width scales at a slower rate with increasing discharge compared to mean depth. Channel efficiency is strongly influenced by differential scaling, with flood power increasing in proportion to flow depth while diminishing in relation to channel width (Baker and Costa, 1987; Patil *et al.*, 2021).

The (m/f) ratio encapsulates the coupling between flow velocity and channel depth (Table 1). Elevated m/f values imply that the increase in discharge foster a more pronounced acceleration of flow relative to the deepening, which in turn expedites sediment transport rates (Leopold *et al.*, 1964). The highest values of this ratio are observed at Kollegal (2.62) and Musiri (2.50), showing dominance of velocity changes relative to depth. The sites — Kudige, Urachikottai, and Kodumudi (Fig. 1) display comparatively lower (m/f) ratios, indicating that

flow dynamics at these locations favour depth adjustment over velocity scaling.

According to Rhodes (1987), the principles of hydraulic geometry are intrinsically connected to Langbein's minimum variance concept. Consequently, total variance is computed as summation of squares of the individual HG exponents. The total variance column summarises the overall variability of hydraulic adjustments across sites (Table 1).

At the Musiri site, variance reaches its maximum value (0.56), followed by Nallamapanatty (0.50) and Kollegal (0.48), highlighting anomalous hydraulic behaviour likely influenced by broad cross-sectional morphology and modified sediment transport dynamics (Fig. 3, 7, and 14). These results suggest that, at such locations, variations in flows are non-uniformly accommodated across all the three HG attributes. Instead, the adjustments are disproportionately absorbed by one or two parameters (Rhodes, 1987). In contrast, the T. Narasipur (0.36) shows

minimal variance, closer to theoretical minimum total variance, (0.333 by Rhodes, 1987), indicating a more predictable hydraulic scaling regime with uniform flow adjustments (Fig. 10).

The ternary illustration built for the river under review provides a clear visualisation of the relative contributions of channel width (b), depth (f), and velocity (m) to its overall hydraulic response (Fig. 15). Data predominantly clustering toward the velocity axis (m) indicate that the river primarily accommodates increased discharge through enhanced velocity and vertical deepening rather than lateral widening. In addition, sector 2 exhibits a pattern in which greater discharge leads to a lowered width-depth ratio (b/f), accompanied by concurrent upsurge in competence, Fr, v-area quotient, and gradient-roughness quotient. Sector 4 displays a distinctive response in which higher discharge reduces the w/d quotient and elevates competence, Fr, and gradient-

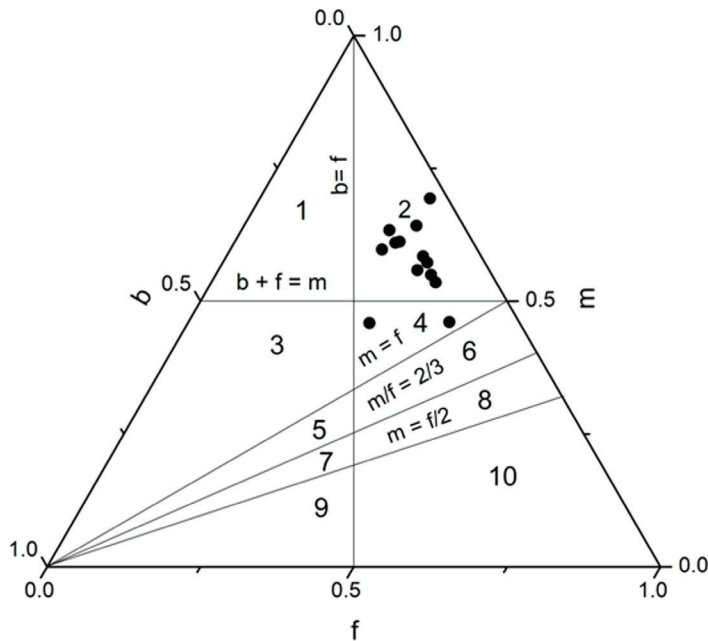


Figure 15. The width-depth-velocity (b-f-m) or ternary diagram of the at-a-station hydraulic geometry.

roughness quotient, though the v -area quotient diminishes instead of rising. These observations underscore the differentiated adjustment mechanisms within the Kaveri river system and have significant implications for sediment transport and flow efficiency.

Conclusion

The hydraulic geometry analysis of the Kaveri river system unequivocally demonstrates that increasing discharge is largely countered by vertical deepening and concomitant velocity enhancement rather than lateral expansion. Variations in the exponents for width, average depth, and average velocity, together with the derived b/f and m/f quotients, highlight a wider range of morphodynamic adjustments than those observed in the Tapi, Narmada, and Mahi river systems. Anomalous behaviour at sites like Musiri, with its exceptionally broad cross-sectional morphology and high total variance, contrasts starkly with the uniform scaling observed at T. Narasipur site. Furthermore, sector-specific analyses reveal divergent adjustment regimes, with sector 2 exhibiting increased competence, Fr , v -area, and gradient-roughness ratios under growing flow, while sector 4 illustrates a decline in velocity-area ratio despite similar trends elsewhere. These findings have critical implications for understanding sediment transport dynamics and flood conveyance efficiency within the Kaveri river system.

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References

- Baker, V.R. and Costa, J.E. (1987) Flood power. In Mayer, L. and Nash, D. (eds.), *Catastrophic Flooding*, Allen and Unwin, London: 1–21.
- CWC: Central Water Commission (2020) *Water yearbook 2018–19. Cauvery and Southern Rivers Circle*. Bengaluru: 287p.
- Ferguson, R. I. (1986) Hydraulics and hydraulic geometry. *Progress in Physical Geography: Earth and Environment*, 10(1): 1–31. <https://doi.org/10.1177/030913338601000101>
- Gleason, C.J. and Smith, L.C. (2014) Towards global mapping of river discharge using satellite images and at-many station hydraulic geometry. *Proceedings of the National Academy of Sciences*, 111: 4788–4791.
- Gleason, C.J. (2015) Hydraulic geometry of natural rivers: A review and future directions. *Progress in Physical Geography*, 39(3): 337–360.
- Hire, P.S. (2000) Geomorphic and Hydrologic Studies of Floods in the Tapi basin. Unpublished PhD thesis, University of Pune, Pune: 192p.
- Hire P.S. and Hire, P.P. (2021) Changes in hydraulic variables with discharge on the Tapi River, India: role of channel geometry. *Transactions of the Institute of Indian Geographers*, 43(1): 21–30.
- Hire, P.S. and Patil, A.D. (2018) Flood Frequency Analysis of the Par River: Western India. *International Journal of Scientific Research in Science and Technology*, 5(1): 164–168.

- Hire, P.S. and Patil, A.D. (2013) Geomorphic Effectiveness of the August 2006 Flood in the Tapi River, India. *Journal of Indian Geomorphology*, 2: 23–28.
- Jowett, I.G. (1998) Hydraulic geometry of New Zealand rivers and its use as a preliminary method of habitat assessment. *Regulated Rivers: Research and Management*, 14: 451–466.
- Kale, V.S., Sengupta, S., Achyuthan, H and Jaiswal, M.K. (2014) Tectonic controls upon Kaveri River Drainage, Cratonic Peninsular India: Inferences from longitudinal profiles, morphotectonic indices, hanging valleys and fluvial records. *Geomorphology*, 227: 153–165.
- Kale, V.S. and Hire, P.S. (2004) Effectiveness of monsoon floods on the Tapi River, India: role of channel geometry and hydrologic regime. *Geomorphology*, 57(3-4): 275–291. [https://doi.org/10.1016/S0169-555X\(03\)00107-7](https://doi.org/10.1016/S0169-555X(03)00107-7).
- Kale, V.S., Ely, L.L., Enzel, Y. and Baker, V.R. (1994) Geomorphic and hydrologic aspects of monsoon floods on the Narmada and Tapi Rivers in central India. *Geomorphology*, 10: 157–168.
- Leopold, L.B. and Maddock, T. (1953) The hydraulic geometry of stream channels and some physiographic implications. *United States Geological Survey Professional Paper*, 252: 1–57.
- Patil, A.D., Bramhankar, G.W. and Hire, P.S. (2018) At-a-station hydraulic geometry of the Mahi River with special implication to annual maximum series. *International Journal of Scientific Research in Science and Technology*, 5(1): 101–105.
- Patil, A., Hire, P., Jaiswal, M., Bramhankar, G. and Goswami, K. (2021) Dyke-controlled chute canyon at Mendha on River Par, western India. *Current Science*, 120: 1507–1513. <https://doi.org/10.18520/cs/v120/i9/1507-1513>.
- Pagare, S.R., Hire, P.S. and Patil, A.D. (2025a) Magnitude and Frequency Analyses of Floods on the Kaveri River of the Southern India by Using Gumbel Extreme Value Type-I Probability Distribution. *Hydrospatial Analysis*, 9(1): 1–9. <https://doi.org/10.21523/gcj3.2025090101>
- Pagare, S.R., Hire, P.S. and Patil, A.D. (2025b) Fluvial and flood regime characteristics of the Kaveri River: Southern India. *Meteorology Hydrology and Water Management*, 13(2): 1–22. <https://doi.org/10.26491/mhwm/210192re>.
- Read, C.H.K. (2006) *Effects of Scale and Spatial Variability on Hydraulic Geometry in the Potomac River basin*. Unpublished PhD thesis, University of Maryland, College Park: 364p.
- Rhodes, D.D. (1977) The b-m-f diagram: Graphical representation and interpretation of at-a-station hydraulic geometry. *American Journal of Science*, 277: 73–96.
- Rhodes, D.D. (1987) The b-m-f diagram for downstream hydraulic geometry. *Geografiska Annaler*, 69(A): 147–161.
- Rhodes, D.D. (1978) Worldwide variations in hydraulic geometry exponents of stream channels: an analysis and some observations—Comments. *Journal of Hydrology*, 33: 133–146.
- Ramasamy, S.M. (2006) Remote sensing and active tectonics of South India. *International Journal of Remote Sensing*, 27: 4397–4431.
- Sharma, A. and Rajamani, V. (2001) Weathering of Charnockites and sediment production in the catchment area of the Cauvery River, southern India. *Sedimentary Geology*, 143: 169–184.
- Stewardson, M. (2005) Hydraulic geometry of stream reaches. *Journal of Hydrology*, 306(1–4): 97–111. <https://doi.org/10.1016/j.jhydrol.2004.09.004>.
- Valdiya, K.S. (2001) Tectonic resurgence of the Mysore plateau and surrounding regions in cratonic Southern India. *Current Science*, 81: 1068–1089.
- Vaithiyanathan, P., Ramanathan, Al, Subramanian, V. (1992) Sediment transport in the Cauvery River basin: sediment characteristics and controlling factors. *Journal of Hydrology*, 139: 197–210.
- Vaidyanadhan, R. (1971) Evolution of the drainage of Cauvery in South India. *Journal Geological Society of India*, 12: 4–23.

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