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Integrated Morphometric and Morphotectonic Analysis to decipher the Basin Dynamics: A Case Study of the Auranga River, North Koel Tributary, Central India

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Abstract: **The present investigation examines the morphometric and morphotectonic attributes of the Auranga River Basin, an important tributary of the North Koel River in Jharkhand, India, using remote sensing and geographic information systems techniques. The watershed boundary, along with its three sub-basins, was extracted from digital elevation model data, and multiple linear, areal, relief, and tectonic indices were derived to assess drainage patterns, basin forms, hydrological responses, and geomorphic development. The drainage network exhibits a well-developed hierarchical pattern with moderate drainage density, indicating balanced infiltration and runoff conditions. Basin shape indices reveal an elongated geometry associated with delayed peak discharge and longer runoff duration. Relief characteristics indicate considerable topographic variation, moderate ruggedness, and active erosional processes. According to morphotectonic indices, the basin appears to be in a mature geomorphic stage, with localized structural influence on basin asymmetry and drainage alignment. Variations among sub-watersheds indicate differences in slope conditions, erosion susceptibility, and hydrological response. The integrated assessment demonstrates the usefulness of morphometric and morphotectonic techniques in explaining basin dynamics and provides a scientific framework for watershed prioritization, soil conservation, groundwater evaluation, and sustainable water resource management within Auranga River Basin.**

Index Terms: **Basin Morphology, Auranga River Basin, Morphometric Analysis, GIS and Remote Sensing, Watershed Management.**

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I. Introduction

The geomorphological and hydrological dynamics of river basins have become increasingly important of environmental degradation, water scarcity, and sustainable resource management. A basin represents a fundamental hydrological unit where all surface runoff converges to a single outlet, making it an ideal system for studying the interaction between landforms, geology, climate, and hydrological processes (Babar, 2005; Gautam et al., 2025; Gobinath & Sahu, 2026; Raut, n.d.; Winter, 2001). Morphometric analysis, which involves the quantitative assessment of drainage network and basin characteristics, provides a scientific basis for interpreting these interactions and understanding basin evolution (Basavareddy et al., 2025; Melsse et al., 2025; Prakash et al., 2016; P. Singh et al., 2023). One of the most effective ways to characterize a drainage basin is through morphometric analysis — quantitative measurement of geometry and organization of drainage network. First formalized by (Horton, 1945) and later systematized by (A. Strahler, 1957; A. N. Strahler, 1964), morphometric evaluation has become an essential part of modern quantitative geomorphological research (Shekar & Mathew, 2024; A. Strahler, 1957). Geomorphological parameters indicate hydrological processes such as erosion, sediment transport, runoff generation, and infiltration (Chethan & Vishnu, 2018; Cho et al., 2023; Soomro et al., 2026). For example, lower drainage density commonly indicates permeable subsurface materials, adequate vegetation cover, and greater infiltration capacity, while a high drainage density suggests impermeable rock strata, limited vegetation, and increased surface runoff potential (Gan et al., 2023; Ingle et al., 2021). Similarly, bifurcation ratio reflects the degree of structural control on drainage patterns, with higher values often indicating tectonic disturbances or geological complexity. Thus, morphometric analysis not only helps in understanding basin geometry but for supporting hydrological evaluation and environmental assessment (Mahala, 2020; Rai et al., 2018; Acosta et al., 2025). In current academic discussions, the application of remote sensing and Geographic Information Systems has notably advanced morphometric and morphotectonic research by facilitating the accurate and effective extraction of hydrological parameters from digital elevation models (Anusree et al., 2026; Subramaniyan, 2026). Traditional methods of basin analysis were timewasting and error-prone, whereas GIS-based techniques offer high precision, reproducibility, and spatial analysis capabilities. DEM data derived from satellite missions such as SRTM and ASTER have been widely used to delineate drainage networks, calculate slope and relief parameters, and generate thematic maps for basin analysis. These advancements have significantly enhanced the reliability of morphometric analysis and expanded its applications in watershed management and planning. Morphometric study has been widely applied in various regions of the world for watershed prioritization, groundwater assessment, flood analysis, and soil erosion studies (Ghosh n.d., 2025; Kumar et al. 2025). Studies conducted in the Ganges delta region demonstrated that morphometric parameters can effectively represent hydrological behavior and help in identifying flood-prone and erosion-sensitive areas (Joy et al., 2023). Similarly, morphometric-based prioritization techniques have been successfully used to identify erosion-prone sub-watersheds and assist soil and water conservation planning in Indian river basins (Dutal, 2023; Kumar et al., 2022). Morphotectonic assessment is important for determining the impact of tectonic processes on drainage development and the evolutionary pattern of river basins. Morphotectonic indices such as hypsometric integral, asymmetry factor, elongation ratio, and sinuosity index are useful for interpreting basin tilting, structural influence, and different stages of geomorphic evolution (P. Singh et al., 2023; Yadav & Singh, 2022). These parameters provide insights into the interaction between tectonic activity and surface processes, which is essential for interpreting landscape dynamics. Research from different parts of India shows that tectonic processes play a key role in shaping river basin morphology, especially in regions influenced by major fault systems like the Narmada-Son Lineament (Joshi et al., 2013). For instance, morphotectonic analysis of central Indian basins has revealed that the reactivation of basement faults and subsurface lineaments significantly influences drainage development and geomorphic evolution (Malik & Mohanty, 2007). Studies in the Himalayan region show that morphotectonic parameters can effectively identify active tectonic zones and assess seismic vulnerability (Agrawal et al., 2022). Additionally, the sustainable management of natural resources and watershed prioritization both benefit greatly from morphometric analysis (Abdeta et al., 2020). Rising pressure on land and water resources, driven by population growth and climate variability, has made it necessary to identify critical sub-watersheds requiring immediate conservation(R. E. Horton, 1945a; P. Singh et al., 2014). Morphotectonic parameters provide a quantitative framework for ranking sub-watersheds by their vulnerability to erosion, runoff generation, and land degradation (Barman et al., 2021). The Auranga River Basin, a branch of North Koel River in Jharkhand, India, exemplifies a structurally influenced drainage basin in the peninsular region. The basin exhibits diverse geomorphic features, varying relief conditions, and complex drainage patterns, making it suitable for morphometric and morphotectonic analysis. Despite its hydrological significance, detailed quantitative studies of this basin remain limited, underscoring the need for comprehensive analysis using modern geospatial techniques. The present study addresses this gap through a GIS-based integrated assessment of the Auranga River Basin and its three constituent sub-watersheds. The primary objectives of this study are: (i) to examine linear drainage attributes; (ii) to evaluate areal characteristics; (iii) to determine relief parameters; and (iv) to assess morphotectonic indicators.The findings are expected to inform watershed prioritization, soil and water conservation measures, groundwater resource assessment, and the sustainable management of the Auranga River Basin.

II. Study Area

The Auranga River Basin is situated in mid-western part of Chhotanagpur Plateau in Jharkhand, India (Fig. 1). Geographically, the basin extends between 23°35′N to 23°58′N latitude and 84°08′E to 84°47′E longitude, covering a total area of approximately 1549.68 km². The Auranga River originates at Chulha Pani, near the Lohardaga–Latehar border, and flows broadly westward through Richughutu, Latehar, and Palamu before joining the North Koel River at the Kechki Sangam, an important tributary. The river thus forms a significant component of the peninsular drainage system of eastern India.

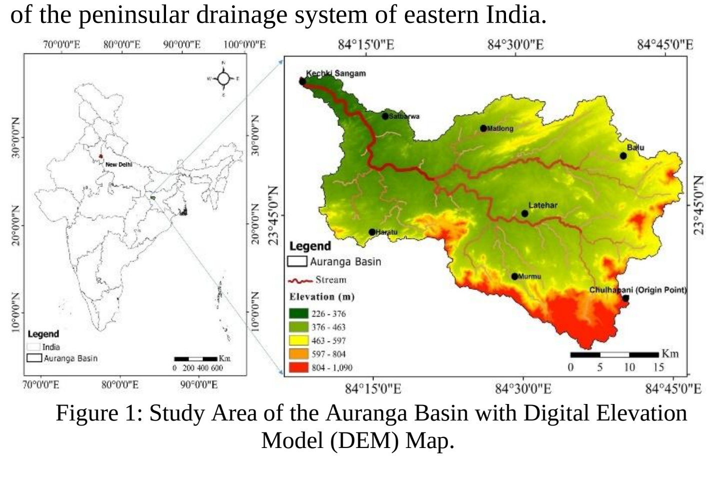

Figure 1: Study Area of the Auranga Basin with Digital Elevation Model (DEM) Map.

The basin terrain exhibits significant relief variation, with elevation ranging from 226 m to 1090 m and a total basin relief of 864 m. The drainage system is well developed and systematically arranged, comprising stream orders from 1st to 6th order, while the main Auranga River extends for about 103.96 km. Administratively, the basin is bordered by Lohardaga district to the south, Chatra district to the northeast, and Palamu (Daltonganj) district to the northwest. Geographically, it is situated between the drainage divides of Amanat River basin toward the northeast and the North Koel River basin toward the southwest. The basin boundary is further delineated by prominent hill ranges — the Satbarwa Range, Murwai Range, and Herhang Range — which exert considerable control over local drainage development and watershed limits. From a regional tectonic perspective, the Auranga Basin is part of the western extension of the stable Indian Peninsular Shield and is separated from the Shillong Plateau by the Malda Gap. Geologically, the basin is dominated by the Chhotanagpur Gneissic Complex, with significant occurrences of Gondwana formations and metamorphic rocks (Acharyya, 2018) (Fig. 3(C)).The geological units substantially influence slope morphology, drainage texture, infiltration dynamics, and groundwater potential throughout the basin (Jha et al., 2022). The main drainage network is composed of the Auranga River and its tributaries, including the Sukri, Bagdagga, Ghaghri, and several smaller streams, which together form an integrated and structurally responsive fluvial system. The close interaction among geological structure, geomorphological units (Fig. 3(D)), and hydrological activities makes the Auranga Basin a particularly suitable and scientifically interesting subject for detailed morphometric analysis.

III. Material and Methodology

The present investigation adopts a geospatial approach, integrating remote sensing data, Survey of India toposheets, and Geographic Information System techniques for the morphometric and morphotectonic analysis of the Auranga River Basin and its sub-watersheds. The primary dataset for terrain evaluation is the ASTER Digital Elevation Model, with a 30 m spatial resolution, acquired from the USGS Earth Explorer portal. SOI toposheets at a scale of 1:50,000 served as base maps for drainage validation and basin delineation. The major toposheets covering the Auranga Basin include F44F6, F44F7, F44F8, F44F10, F44F11, and F44F12, while F44F5, F44F9, F44F13, and F44F14 were used for partial boundary reference. Additional thematic layers, such as geomorphology and geology, were obtained from the Bhuvan portal (NRSC–ISRO) and Google Earth Pro, and field verification was carried out. Watershed and sub-watershed boundaries were delineated from the DEM using hydrological tools in ArcGIS 10.1, including flow direction, flow accumulation, and pour-point techniques (Fig. 2). The drainage network was extracted and ordered using the (A. N. Strahler, 1957) stream-ordering system. All spatial analysis, calculations, and map preparation were carried out in the GIS environment, ensuring accuracy and consistency in evaluating morphometric and morphotectonic characteristics of the Auranga River Basin.

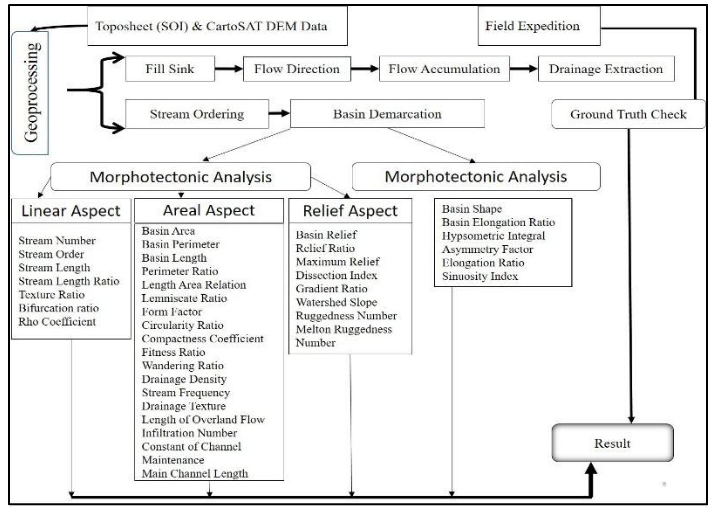

Fig 2: Methodological Flowchart for Morphometric and Morphotectonic Analysis.

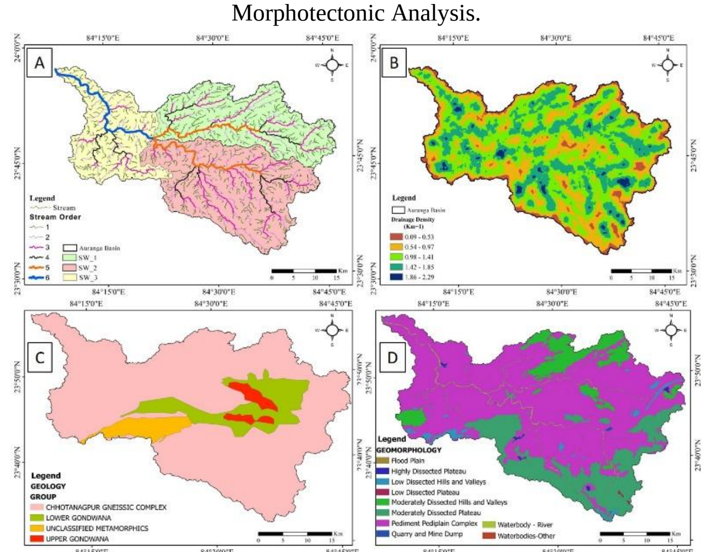

Fig. 3:Thematic maps of the Auranga River Basin, Jharkhand, India showing: (A) stream order and sub-watershed delineation, (B) spatial distribution of drainage density (km⁻¹), (C) geological formations, and (D) geomorphological units of the basin.

IV. Result and Discussion

A. Morphometric Parameters Analysis

The morphometric analysis of the Auranga Basin and its sub-basins (SW_1, SW_2, and SW_3) shows significant differences in linear features, areal shape, and relief characteristics (Table 1), indicating variations in geomorphic development and hydrologic behavior.

1) Linear Aspect

a) Stream Order (U) and Number of Streams (Nu)

Stream order is the hierarchical ranking of streams using the Strahler method (A. N. Strahler, 1964a). The Auranga River Basin exhibits stream orders ranging from 1st to 6th, indicating a well-developed, mature drainage system. Similarly, SW1 and SW2 show up to the 5th order, while SW3 also reaches the 6th order, suggesting comparatively higher drainage development in the main basin and SW3 (Fig. 3(A)). The Auranga Basin has 1277 streams, while SW_1, SW_2, and SW_3 have 410, 540, and 329 streams, respectively. Higher stream numbers indicate greater drainage dissection.

b) Stream Length (Lu) and Mean Stream Length (Lsm)

Stream length refers to the total length of all stream segments within a basin. The Auranga Basin's total stream length is 1802.80 km, significantly higher than those of SW1 (593.13 km), SW2 (770.00 km), and SW3 (439.00 km). This indicates that the main basin has a more extensive drainage network. Mean stream length represents the average length of stream segments per order. The Auranga Basin has an average of 15.31 km, while SW2 has the shortest at 3.46 km, suggesting steeper slopes and quicker runoff compared to other sub-basins.

c) Bifurcation Ratio (Rb) and Mean Bifurcation Ratio (Rbm)

The bifurcation ratio (Rb) compares the number of streams in one order to those in the next higher order, indicating how drainage branches and how structural features influence drainage. The mean bifurcation ratio (Rbm) averages these values across all stream orders, providing an overview of the drainage network. In the Auranga Basin, Rbm is 3.30, whereas the sub-watersheds have Rbm values of 3.40 for SW1, 3.66 for SW2, and 3.53 for SW3.

d) Rho Coefficient (ρ)

The rho coefficient quantifies the relationship between stream length and bifurcation ratio, reflecting the basin's storage capacity and hydrological performance. The Auranga Basin has a higher value of 4.63, indicating it can store more water and exhibits delayed runoff. Conversely, the sub-watersheds have lower values (SW1 = 2.91, SW2 = 0.95, SW3 = 2.71), which suggest they have less storage capacity and respond more quickly hydrologically, especially in SW2.

2) Areal Aspect

a) Basin Length (Lb)

Basin length (Lb) is the basin's longest dimension, measured along the principal drainage line or as the basin's longest diagonal. It is a key parameter governing runoff, travel time, and hydrological response. The Auranga Basin is 68.12 km long, while the sub-watersheds are 42.15 km (SW1), 40.23 km (SW2), and 37.25 km (SW3).

b) Basin Perimeter (P)

The basin perimeter measures the total length of the basin boundary, reflecting the size of the watershed. It helps in evaluating the basin shape and how compact it is. The Auranga Basin has a perimeter of 281.23 km, whereas SW1, SW2, and SW3 have perimeters of 157.24 km, 158.56 km, and 140.85 km, respectively. The larger perimeter of the main basin indicates greater boundary complexity, while lower values in the sub-basins reflect smaller localized drainage divisions.

c) Basin Area (B)

Basin area is the total runoff-contributing area to the drainage system and a key hydrological parameter. It directly influences discharge, sediment yield, and water availability. The Auranga Basin covers 1549.68 km², while sub-watersheds occupy 500.00 km² (SW1), 666.78 km² (SW2), and 376.93 km² (SW3).

d) Relative Perimeter (Pr)

The relative parameter expresses the relationship between basin area and perimeter and is used to evaluate basin compactness and shape characteristics. Higher values correspond to more compact basins, whereas lower values indicate elongated basins. The Auranga Basin records a Pr value of 5.51, while SW1, SW2, and SW3 show Pr values of 3.18, 4.21, and 2.68, respectively. The higher value of the main basin suggests greater compactness, whereas the lower value, especially in SW3, reflects a more elongated basin form.

e) Length-Area Relation (Lar)

The length–area relationship shows how basin length varies with basin area, helping to analyze the scaling characteristics of drainage basins. It reflects how basin size influences longitudinal development. The Auranga Basin shows a Lar value of 114.89, while sub-watersheds exhibit 58.28 (SW1), 69.27 (SW2), and 49.19 (SW3). The higher value in the main basin indicates greater longitudinal extension relative to area, whereas lower values in sub-watersheds reflect smaller-scale basin development.

f) Lemniscate Ratio (k) and Shape Factor (Sf)

The Lemniscate ratio is used to evaluate basin shape and degree of elongation. The shape factor ratio is similar to the Lemniscate ratio and provides information about basin shape and elongation. Higher values indicate elongated basins, while lower values indicate more compact forms. The Auranga Basin has a value of 2.99, whereas the sub-watersheds show values of 3.55 (SW1), 2.43 (SW2), and 3.68 (SW3). Higher values in SW_1 and SW_3 indicate more elongated basin shapes, while the relatively lower value in SW_2 suggests a comparatively less elongated geometry.

g) Form Factor (Ff)

The form factor, the ratio of basin area to the square of basin length, measures basin shape and flood response. Higher values indicate more circular basins with higher peak flows; lower values suggest elongated basins with slower runoff. The Auranga Basin's form factor is 0.33, with sub-watersheds at 0.28 (SW1), 0.41 (SW2), and 0.27 (SW3).

h) Circularity Ratio (Rc)

The circularity ratio measures how similar a basin is to a circle. The Auranga Basin has an Rc of 0.25, with the sub-watersheds showing 0.25 (SW1), 0.33 (SW2), and 0.24 (SW3). Generally, low values indicate an elongated basin shape, while the higher Rc of SW_2 suggests a more circular shape and better runoff efficiency.

i) Compactness Coefficient (Cc)

The compactness coefficient measures a basin's compactness compared to a circular basin. Lower values are more compact; higher values are elongated. The Auranga Basin has a Cc of 2.03, with sub-watersheds showing 2.00 (SW1), 1.74 (SW2), and 2.06 (SW3). These indicate less compact, more elongated basins, with SW_2 being relatively more compact.

j) Fitness Ratio (Rf)

The fitness ratio measures the main channel length relative to the basin perimeter, reflecting the degree of channel development. Higher values suggest better channel adjustment to basin geometry. The Auranga Basin shows an Rf value of 0.37, while the sub-watersheds exhibit 0.37 (SW1), 0.41 (SW2), and 0.40 (SW3). The relatively higher values in SW_2 and SW_3 indicate better channel adaptation and drainage efficiency, whereas the slightly lower value in SW1 indicates moderate adjustment.

k) Wandering Ratio (Rw)

Wandering ratio measures deviation and sinuosity of channels. The Auranga Basin has an Rw of 1.53; the sub-watersheds show Rw values of 1.38 (SW1), 1.63 (SW2), and 1.51 (SW3). These indicate moderate sinuosity, with SW_2 being more meandering.

l) Drainage Density (Dd)

Drainage density, the total stream length per unit basin area, reflects drainage spacing and is influenced by lithology, permeability, slope, and climate (Fig. 3(B)). The Auranga Basin has a drainage density of 1.16, with sub-watersheds showing 1.19 (SW1), 1.16 (SW2), and 1.16 (SW3). These values indicate moderate density, balancing infiltration and runoff. The higher value in SW1 suggests greater runoff potential and lower infiltration.

m) Stream Frequency (Fs)

Stream frequency measures the number of stream segments per unit area, indicating drainage network development and runoff behavior. Higher values suggest increased runoff and reduced infiltration. The Auranga Basin has an Fs of 0.82, while the sub-watersheds show 0.82 (SW1), 0.81 (SW2), and 0.87 (SW3). These values suggest a moderate level of stream frequency, indicating moderate drainage development. The higher Fs in SW3 indicate more runoff and a denser channel network.

n) Drainage Texture (Dt)

Drainage texture indicates the spacing of drainage lines, reflecting terrain dissection and roughness. Higher values mean finer texture; lower, coarser. The Auranga Basin's Dt is 0.95, with SW1 at 0.98, SW2 at 0.94, and SW3 at 1.01. These indicate moderate-to-coarse textures, suggesting moderate dissection and structural control. SW3's higher Dt implies a finer texture.

o) Length of Overland flow (Lg)

Lg indicates the distance water travels over land before reaching a stream, representing the balance between infiltration and runoff. In the Auranga Basin, Lg is 0.43; sub-watersheds vary from 0.42 to 0.43, suggesting moderate overland flow and a balanced mix of runoff and infiltration.

p) Infiltration Number (If)

The infiltration number combines drainage density and stream frequency to evaluate infiltration and runoff potential. Higher values mean lower infiltration and more runoff; lower values indicate better infiltration. The Auranga Basin records an IF value of 0.95, while SW1, SW2, and SW3 show 0.98, 0.94, and 1.01, respectively. The higher value in SW3 suggests greater runoff, whereas SW2 indicates relatively better infiltration.

q) Constant of Channel Maintenance (C)

The channel maintenance constant indicates the area required to sustain a unit length of channel; it is inversely related to drainage density. The Auranga Basin has a C value of 0.86, while sub-watersheds show 0.84 (SW1), 0.87 (SW2), and 0.86 (SW3). These values indicate moderate channel maintenance conditions, suggesting a balanced relationship between drainage development and infiltration capacity across the basin.

r) Main Channel Length (Cl)

Cl is the total length of the principal stream from source to outlet and is a key parameter that controls runoff concentration time and basin hydrology. The Auranga Basin has a main channel length of 103.96 km, while the sub-watersheds have lengths of 58.00 km (SW1), 65.61 km (SW2), and 56.22 km (SW3). The longer channel length in the main basin indicates a longer flow path and a delayed peak discharge, whereas shorter lengths in sub-watersheds suggest a comparatively faster hydrological response.

3) Relief Aspect

a) Basin Relief (R)

R shows the difference in height between the highest and lowest points of a basin. The Auranga Basin has a total relief of 864 m, which indicates strong variation in elevation and a higher chance of erosion. Among the sub-watersheds, SW3 (792 m) and SW2 (772 m) have higher relief values, while SW1 (698 m) has comparatively lower relief. This variation demonstrates differences in topography and erosional processes across the basin.

b) Relief Ratio (Rr)

Rr reflects the overall slope and steepness of the basin. The Auranga Basin shows a value of 0.01, while all sub-watersheds exhibit values around 0.02, indicating generally low-to-moderate slopes. These low values suggest gradual elevation and controlled runoff processes.

c) Maximum Relief (Z) and Absolute Relief (Ra)

Maximum relief represents the highest elevation within the basin derived from DEM data. Absolute relief represents elevation above mean sea level. The Auranga Basin and SW2 both reach 1090 m, indicating similar peak elevations. In comparison, SW3 (1018 m) and SW1 (1016 m) show slightly lower maximum elevations. This indicates that the main basin and SW2 are at higher elevations.

d) Dissection Index (Di)

The dissection index quantifies the degree of terrain dissection and erosion. The Auranga Basin shows a high value of 0.79, indicating a highly dissected landscape. Among sub-watersheds, SW3 (0.78) and SW2 (0.71) also show significant dissection, while SW1 (0.69) indicates relatively lower dissection. Higher values suggest intense erosion and advanced geomorphic development.

e) Gradient Ratio (Rg)

The gradient ratio represents the overall slope gradient and elevation change along the basin length. The Auranga Basin shows a value of 12.68, indicating moderate slope conditions. The values increase from SW1 (16.56) to SW2 (19.19) and SW3 (21.26), suggesting progressively steeper terrain in the sub-watersheds, particularly in SW3. Higher values indicate a steeper slope and greater erosion potential.

f) Watershed Slope (Sw)

The watershed slope represents the basin's average slope. The Auranga Basin has a value of 12.68, indicating moderate slope conditions. Sub-watersheds show higher values (SW1 = 16.56, SW2 = 19.19, SW3 = 21.26), indicating steeper terrain and relatively faster runoff generation than the main basin.

g) Ruggedness Number (Rn)

The Rn number combines relief and drainage density to quantify terrain ruggedness. The Auranga Basin has a value of 1.01, indicating moderately rugged terrain. Sub-watersheds show slightly lower values (0.83–0.92), suggesting comparatively less rugged than the main basin. Higher ruggedness indicates increased erosion susceptibility to erosion.

Table 1: Morphometric Parameters (Linear, Areal and Relief Parameters) and Results of the Auranga Basin and its Sub-Watersheds.

Morphometric Parameters			**Result**			
Parameters	**Formula**	**References**	**Auranga Basin**	**SW_1**	**SW_2**	**SW_3**
Linear Aspect						
Stream order (U)	Hierarchical rank	(A. N. Strahler, 1964)	1-6th	1-5th	1-5th	1-6th
Stream length (Lu)	Length of the stream	(R. E. Horton, 1945)	1802.8	593.13	770	439
Total Stream	Count of all streams	_	1277	410	540	329
Mean stream length (Lsm)	Lsm = Lu/Nu	(A. N. Strahler, 1964)	15.31	9.9	3.46	9.56
Mean bifurcation ratio (Rbm)	Rbm=average of bifurcation ratios of all order	(A. N. Strahler, 1964)	3.3	3.4	3.66	3.53
Rho Coefficient (ρ)	Lur/Rb	(R. E. Horton, 1945)	4.63	2.91	0.95	2.71
Areal Aspect						
Basin length (Lb)	Longest diagonal across the basin	(Schumm, 1956)	68.12	42.15	40.23	37.25
Basin perimeter (P)	Calculated from Auranga basin boundary in GIS	(Schumm 1956)	281.23	157.24	158.56	140.85
Basin area (A)	Calculated from Auranga basin boundary in GIS	(Schumm 1956)	1549.68	500	666.78	376.93
Relative parameter (Pr)	Pr=A/P	(Schumm 1956)	5.51	3.18	4.21	2.68
Length area relation (Lar)	Lar=1.4*A0.6	(Hack, 1957)	114.89	58.28	69.27	49.19
Lemniscate's (k)	Lb2 /A	(*Chorley 1957*, n.d.)	2.99	3.55	2.43	3.68
Form factor (Ff)	Ff=A/L2	(R. E. Horton 1945)	0.33	0.28	0.41	0.27
Shape factor ratio	Sf=Lb2 /A	(R. E. Horton 1945)	2.99	3.55	2.43	3.68
Circulatory ratio	Rc=4pA/P2	(A. N. Strahler 1964)	0.25	0.25	0.33	0.24
Compactness coefficient (Cc)	Cc=0.2841*P/A0.5	(Gravelius, 1914)	2.03	2	1.74	2.06
Fitness ratio (Rf)	Rf=Cl/P (Main channel length/Perimeter)	(Melton, 1957)	0.37	0.37	0.41	0.4
Wandering ratio (Rw)	Rw=Cl/Lb	(Smart & Surkan, 1967)	1.53	1.38	1.63	1.51

Drainage density (Dd)	Dd=Lu/A	(R. E. Horton 1945)	1.16	1.19	1.16	1.16
Drainage texture (Dt)	Dt=Dd*Fs	(R. E. Horton 1945)	0.95	0.98	0.94	1.01
Stream frequency (Fs)	Fs=Nu/A	(R. E. Horton 1945)	0.82	0.82	0.81	0.87
Length of overland flow (Lg)	Lg=1/Dx2	(R. E. Horton 1945)	0.43	0.42	0.43	0.43
Infiltration Number (If)	If=Fs*Dd	(Faniran, 1968)	0.95	0.98	0.94	1.01
Constant of channel maintenance	C=1/Dd	(Schumm 1956)	0.86	0.84	0.87	0.86
Main Channel Length (Cl)	GIS measurement	–	103.96	58	65.61	56.22
Relief Aspect						
Total basin relief (R)	R=H-h (height of the mouth)	(A. N. Strahler 1952)	864	698	772	792
Relief ratio (Rr)	Rr=R/L	(Schumm 1956)	0.01	0.02	0.02	0.02
Maximum relief (Z)	Calculated from DEM data in GIS	–	1090	1016	1090	1018
Absolute relief (Ra)	Calculated from DEM data in GIS	–	1090	1016	1090	1018
Dissection index (Dis)	H/Ra	(Singh & Dubey, 1994)	0.79	0.69	0.71	0.78
Gradient ratio (Rg)	Z-z/Lb	(Sreedevi et al., 2005)	12.68	16.56	19.19	21.26
Watershed Slope (Sw)	Sw=H/Lb	(Sreedevi et al., 2005)	12.68	16.56	19.19	21.26
Ruggedness Number (Rn)	Dd*(H/100)	(Patton & Baker, 1976)	1.01	0.83	0.89	0.92
Melton Ruggedness Number (MRn)	H/A0.5	(Melton, 1957)	0.69	0.99	0.95	1.29

h) Melton Ruggedness Number (MRn)

MRn reflects terrain steepness and flash-flood potential. The Auranga Basin has an MRn of 0.69, indicating moderate relief and moderate flood potential. Among sub-watersheds, SW3 (1.29) has the highest value, indicating steeper terrain and greater susceptibility to flash flooding. SW1 (0.99) and SW2 (0.95) also show moderate-to-high ruggedness.

B. Morphotectonic Parameter Analysis

Morphotectonic analysis reveals how tectonic activity influences basin development by evaluating parameters like basin shape, elongation, hypsometric integral, asymmetry, and sinuosity (Table 2). It offers a framework for understanding landscape evolution driven by tectonic forces.

Table 2: Morphotectonic Parameters and Result of the Auranga Basin and its Sub-watershed.

Morphotectonic Parameter	**Formula**	**References**	**Auranga Basin**	**SW_1**	**SW_2**	**SW_3**
Basin Shape (Bs)	Bs=Lb/Wb	(Cannon, 1976)	2.99	3.55	2.43	3.68
Basin Elongation ratio(Re)	2*(sqrtA/3.14)/Lb	(Schumm, 1956b)	0.65	0.60	0.72	0.59
Hypsometric Integral (HI)	HI=(Hmean-Hmin)/(Hmax-Hmin)	(Pike & Wilson, 1971)	0.49	0.22	0.24	0.18
Asymmetry Factor (Af)	Af= 100(Ar/A)	(Cox, 1994)	42.87	33.80	60.34	53.26
Sinuosity Index (SI)	SI=Cl/Lb	(Leopold & Wolman, 1957)	1.53	1.38	1.63	1.51

1) Basin Shape (Bs)

Bs is the ratio of basin length to width and indicates whether the basin is elongated or circular. The Auranga Basin shows a value of 2.99, indicating a clearly elongated basin, which is generally controlled by geological structures. Among the sub-watersheds, SW3 (3.68) and SW1 (3.55) exhibit even higher elongation, suggesting a stronger structural influence. In contrast, SW2 (2.43) is relatively less elongated, indicating comparatively weaker structural control. Overall, the basin geometry reflects tectonic and lithological control over drainage development.

2) Basin Elongation Ratio (Re)

Re is used to characterize basin shape and hydrological response. Values near 1 indicate circular basins, whereas lower values indicate elongated forms. The Auranga Basin has an elongation ratio of 0.65, indicating an elongated basin with lower peak flow and longer runoff duration. Among the sub-basins, SW2 (0.72) is relatively more circular, while SW1 (0.60) and SW3 (0.59) are more elongated. These variations reflect spatial differences in geomorphic control and runoff behavior.

3) Hypsometric Integral (Hi)

HI represents the stage of landscape evolution by comparing mean elevation to total relief. The Auranga Basin shows an HI value of 0.49, indicating a mature stage of geomorphic development in which both erosion and deposition are active. In contrast, sub-watersheds show lower values **(**SW1 = 0.22, SW2 = 0.24, SW3 = 0.18**)**, indicating a late-mature to old stage, where erosion has significantly reduced relief. This suggests that the main basin is less eroded than its sub-basins.

4) Asymmetry Factor (Af)

The asymmetry factor indicates basin tilting and tectonic influence. A value close to 50 represents no tilting, while deviation indicates tectonic activity. The Auranga Basin shows a value of 42.87, indicating slight tilting and minor tectonic influence**.** However, SW2 (60.34) and SW3 (53.26) show higher deviation, suggesting possible tectonic tilting or structural control in these regions. In contrast, SW1 (33.80) indicates tilting in the opposite direction. Overall, the basin shows localized tectonic influence rather than strong regional tectonics.

5) Sinuosity Index (Si)

The SI measures the degree of river meandering. The Auranga River shows a sinuosity value of 1.53, indicating moderate meandering, which reflects adjustments to slope, sediment load, and structural controls. Among sub-watersheds, SW_2 (1.63) shows higher sinuosity, indicating more channel deviation, while SW_1 (1.38) is relatively straighter. This variation suggests that local slope and structural conditions influence channel pattern.

Conclusion

The present study examined the Auranga River Basin and its three sub-watersheds (SW1, SW2, and SW3) through a quantitative assessment of drainage, areal, relief, and tectonic parameters using GIS and remote sensing. The basin's drainage network extends to the 6th stream order, indicating a well-developed fluvial system shaped over a long period. Stream frequency, drainage density, and infiltration number all fall within moderate ranges, suggesting that the basin neither loses too much water as runoff nor retains it all through infiltration — a reasonably balanced state for water movement through the landscape.

Shape-related parameters, such as form factor, elongation ratio, circularity ratio, and compactness coefficient, consistently indicate that the Auranga Basin is elongated. This shape generally means that flood peaks are lower and that runoff takes longer to reach the outlet. Among the sub-watersheds, SW2 is less elongated, indicating a somewhat quicker hydrological response, while SW1 and SW3 are more elongated and thus slower to drain. The relief analysis shows that the basin has notable elevation variation, with a total relief of 864 m. The ruggedness number and gradient ratio indicate moderately rugged terrain with ongoing erosion. Moving from SW1 to SW3, both the gradient ratio and watershed slope increase, indicating that SW3 has steeper ground and is more prone to erosion than the other sub-watersheds. The dissection index values further confirm that much of the terrain has already been significantly carved by stream processes.

The hypsometric integral of the main basin (0.49) indicates a mature stage of landscape development, where erosion and deposition are both active. The sub-watersheds, with lower HI values (0.18–0.24), are further along in this cycle, indicating that erosion has already reduced much of their original relief. The asymmetry factor values indicate localized tilting in SW2 and SW3, which may reflect some degree of structural or tectonic control, while the sinuosity index values of 1.38–1.63 indicate moderate channel meandering, governed by slope and rock structure rather than by free alluvial conditions.

Taken together, the findings show that the Auranga River Basin is a structurally controlled, moderately dissected drainage system at a mature geomorphic stage. Variation across sub-watersheds in slope, shape, and tectonic response underscores the need to treat each unit separately when planning conservation or water management interventions. The study demonstrates that combining morphometric and morphotectonic parameters in GIS offers a practical, data-efficient approach to understanding such basins. The results can directly guide decisions regarding sub-watershed prioritization, soil erosion management, groundwater recharge areas, and overall water resource planning within the region.

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