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Monitoring Geomorphic changes due to Flooding in an Arunavati River Basin by Total Station

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Abstract: The research study was conducted along the river line of the Arunavati, which are frequently affected by the floods and due to that erosion is happening. Total station survey (TSS) useful for detecting the land cover change & estimation of sediment capacity, therefore suggesting the necessary steps for precautions needed for future flooding pattern. Research focus on the problem of an unnecessary widening of bank full width by TSS. This problem is serious and should be inspected regularly. Otherwise, there is a chance of river widening which can lead greater damage to surrounding features which is located near the site of river line. Observations taken by TSS include flood and existing river line, Geomorphic changes in Bank full width, channel migration, longitudinal profiles and cross section. In the first section, the left side of river span increases 35 to 40% of its actual span. Due to curvature the outer span of the river is scouring rapidly, the same time the silt is continuously deposited on the inner span, So that expands the span in inner river line, due to this increase the actual span of the river observed in section two. River flow in section 3 is straight flow, so not silting, scouring and widening observed.
***Keywords**: Flood Problem, Geomorphic changes, River Line Survey, Total Station*

I. INTRODUCTION

The research study focuses on assessing the impact of changes in river longitudinal and cross-section during a previous year extreme flood event on water surface elevation and subsequently the depth and extent of flood inundation.

A. River Survey Approaches for Flood Assessments

Rivers surveys are typically conducted for evaluating geomorphic changes and sediment transport analysis of river bed channel. It includes activities of geomorphic, hydrologic, and biologic evaluations of the river reach. It generates the basic data and information necessary for the subsequent flood assessment and planning. From a research point of view, accurately precise river surveys are conducted for the design and construction of appropriate river training structures and bank protection works. In addition to ground-based surveys, total station and an aerial survey have been traditionally used to define the topographic details, geomorphic changes, and estimation of flood analysis of river bed channel. Periodical observation is at the same spot by total station survey activities required for assessment of river flooding conditions. These include ground control surveys, stream cross-sections, profile surveys, bathymetry, and hydrometric measurements.

II. LITERATURE SURVEY

Topographic surveying is commonly used in geomorphic studies to measure channel slope, channel bed roughness, and other spatial characteristics of geomorphic features; however, multiple survey techniques exist. Investigators often use the most convenient survey technique available and report their methods in insufficient detail, resulting in an inability to assess the appropriateness of the survey procedure for achieving the project objectives. We are unaware of any rigorous comparison of different methods of surveying and calculating channel slope, despite numerous high-profile studies reporting channel bed slopes that provide important evidence for their conclusions without explicitly detailing how slope was calculated. Calculating sediment budgets, estimating transport rates, and understanding changes in sediment storage are also fundamental aspects to quantify geomorphological changes due to flood events and changes in flow regime. [1]

Methods for surveying and analysing channel bed topography commonly lack a rigorous characterization of their appropriateness for project objectives. We compare four survey methods: a hand level, two different methods of surveying with a laser rangefinder, and a real-time kinematic GNSS to explore their accuracy in determining channel bed slope and roughness for a study reach in a small, dry, steep channel. Additionally, we evaluate the variability among four operators for each survey technique. Two methods of calculating reach slope were computed: a regression on the channel profile and a calculation using only survey endpoints. Due to reach-scale concavity, calculating slope using a regression produced significantly different values than those obtained by using only survey endpoints, suggesting that caution must be taken in choosing the most appropriate method of calculating the slope for a given project objective. [2]

The traditional techniques of terrain survey (e.g. total station devices, differential Global Positioning System; in the evaluation of morphological changes across large areas have so far demonstrated to be expensive, time-consuming and difficult to apply in zones with limited accessibility. Some innovative methods are good alternatives for producing high-resolution Digital Terrain Models of fluvial systems. [3]

Geomorphic variations at the reach scale are a direct consequence of sediment erosion and deposition processes, which are in turn influenced by the size and volume of sediment supply, transport capacity of the flow, and local topographic constraints. The actual ability to quantify the interaction of these processes is limited by the difficulty of collecting high spatial resolution data in river environments. Traditional approaches, based on the application of hydraulic formulas at cross-sections, fail when aimed at describing non-uniform natural conditions. Three-dimensional and high-resolution representations of river bed morphology are used in many applications such as hydraulic and cellular modelling, evaluation of climate change impacts on river systems, flood hazard management, assessment of erosion and deposition areas along the river corridor. Calculating sediment budgets, estimating transport rates, and understanding changes in sediment storage are also fundamental aspects to quantify geomorphological changes due to flood events and changes in flow regime. [5, 6, 7]

River channels can be represented by a simplified geometry that is implicitly assumed to remain unchanged during flood events and under long-term erosion and deposition. However, bed load may become highly mobile during floods, forces on the bed, banks, and floodplain are sufficient to mobilize the boundary sediments resulting in significant changes in channel morphology (cross-section and long-profile) and even channel. [4]

Channel geometry and floodplain topography are the principal variables that affect the flood wave propagation and are therefore critical to the prediction of flood dynamics. A small degree of uncertainty in bed elevation may have a relatively large effect on model predictions. [10]

This study was conducted along the river of the Ganga, which is frequently affected by the floods and due to that erosion is happening. Many socio-economic and demographic factors were changed for such natural hazards in those areas as well as it has affected to the whole district. It was observed that growth of urban settlements was rapid since 1987 to 1997 and surprisingly it was decreasing from 1997 to 2013. [8]

III.METHODOLOGY

A. Ground Control Surveys

A survey of the stream channel is a critical component of the monitoring activities and provides a reference for othermeasurements and photographs. Replicate channel surveys with a common datum and coordinate system will enable detection of geomorphic change that might occur as a result of flood scour, bed-material aggradation, or lateral channel migration.

The total station survey monitoring is dependent on the size of the river project, geomorphic and ecological variability within the reach, the project cost, and other site-specific considerations. At a minimum, monitoring data are collected over a stream reach of at least several channel widths in length. Periodical monitoring reaches may be established if the river project is large. These measurements will be replicated in subsequent years to evaluate channel change in the reach. The interval between replicate measurements will be determined partly by the hydrologic history and geomorphic response of the reach.

The scope of the channel survey varies but could include the river bed, low-lying gravel and cobble bars, islands, side channels, banks, levees, and nearby terraces that would contain up to about the 5- or 10-year flood. One purpose of the channel survey is to capture the topographic variability of the streambed and nearby surfaces that the water may flow over. Vertically, the survey should include the deepest portion of the channel to the top of the flood-confining terrace, bank, or levee. Where the channel cannot be waded safely, estimates of streambed elevation can be made from direct observation but should be clearly labelled as estimates.

Establishing horizontal and vertical control of river bed channel is used for determination of water level difference and bank full-width span in flooding and normal river flow condition. Permanent benchmarks are typically established near river banks with the use second order or first order triangulation work. These main triangulation points were referred to the mean sea level (MSL). These points are considered the TP station for total station survey. In horizontal control, the position and location of points are very necessary to give the information about water body.

B. River Cross-Section Surveys

Monitoring cross sections are most beneficial if located along the reach channel in areas most sensitive to alteration by stream flow; such as areas that might scour or aggrade as bed material is transported, or in meander bends where lateral erosion could occur. Cross sections should be oriented perpendicular to the bank full flow and should be spaced upstream and downstream along the channel at an average of about 3 to 6 times the mean bank full channel width. Cross sections can be spaced wider apart where the channel is uniform cross-section shape has little curvature, grade, roughness and should be spaced more closely where the channel is irregular, variability in width or slope, roughness, present islands or bends, near bridge abutments, and piers. Survey shots along the cross-section should be in a straight line and should number about 30-40 locations between the banks.

The total-station survey must produce location (Northing and Easting) and elevation data that can be used to quantify longitudinal and cross-sectional characteristics of the reach. For the development of master plans, river cross sections at typical sites are typically done every 100 m to 500 m intervals along the stretches of river depending on the bank full span of the river from topographic maps. However, for implementation of typical river structure projects, finer scale surveys are conducted with the horizontal scale of 1:500 to 1:2,000 depending on the size of the river. Vertical scales have scales of 1:100 to 1:500 depending on the topographic condition. Measurement interval between cross-section survey ranges from 100 m to 1,000 m. The width of the survey area are typically extended at least 20m beyond both banks but may be further widened provided the location is still a flood-prone area. The interval of measurement along the river-cross section ranges 50m to 100m on wide rivers. For the research presented here, total station survey is employed to define Arunavati river cross-section data in both upper and lower banks and on both sides of the river.

C. River Profile Surveys

River profiles describe the longitudinal configuration of the river necessary to determine the slope/grade and configuration. Profile along the upper bank, the lower bank on both sides of the river is typically generated to fully describe the channel geometry. For fixing the central alignment and edges of the river the 10 to 20m interval distances are marked by total station survey, it gives the necessary data of river bed profile and span when it's widening at the time of flooding. For controlling the geomorphic changes, the old and new river line points are marked parallel to river flow direction by total station survey. These data also can be used to generate topographic maps of the reach, the streambed, gravel bars, banks, and low terraces. Miscellaneous features, such as levees, diversion structures, habitat-enhancement boulders, and bank-protection structures also can be surveyed.

The longitudinal section does not need endpoint monuments because their location will change from year to year in future resurveys and because shots along them are referenced to the channel survey northing and easting coordinates. The spacing between longitudinal section shots can be wider than for the cross section shots.

D. Survey point numbers and descriptive codes

Each survey shot should have a unique point number. Descriptive codes should be created for all benchmarks, reference points, photo monuments, cross-section endpoints, or other permanent monuments. Other descriptive codes might include: a cross-section identifier, the edge of the water, high-water marks, top of the bank, estimated sediment size, the toe of bank or slope, change in vegetation and bridge abutments or piers, etc. Point numbers and descriptive codes will help subsequent investigators reproduce and interpret the surveys Monuments.

IV. RESULT AND DISCUSSION

A. Study Area

The Arunavati is a north bank tributary of river Tapi and seven Sub-basins of Arunavati river rises in the rugged hills of Satpuda ranges at height 650 m from sea level near Jhirpan village in Madhya Pradesh. It flows south-west direction and covers area 738 sq.kms which lies between 21°18'N to 21°37'N latitude and 74°49'E to 75°13'E longitude. It travels about 69.5 km. It begins at Sendhava Tahasil in Madhya Pradesh and meets the river Tapi at village Vanaval in Shirpur Tahasil of Maharashtra. Geologically the Arunavati river basin has the strong foundation of horizontally bedded basaltic lava flows, commonly referred as Deccan trap, exhibits the differential rate of weathering and erosion. The seasonal rainfall and alternate wetting-drying of the land promote soil erosion, soil creep, landslides and gully erosion. Such various types of geomorphic processes are operating in the study area. The study is purely based on extensive field observations and total station results of different parts of the river basin.

In addition to observations of the study area in form of Satellite image in figure no.1, the field work included identification of various landforms, processes, origin, structure deposition, weathering, soil and sedimentary profiles, drainage network, the channel forms, gradient types of flow channel, cross-section parameters, erosional and depositional features.

Fig. 1 Satellite image of Study Area

The table no. 1 shows that local northing, easting coordinates and elevation of surveyed points with reference to known points (TBM). (TP: Station point, N: New (existing) line of river, O: Old line of river, D: Dam line, C: Centre line of river, B: Bridge embankment line)

The figure no. 3 shows that topographic details of stream bed such as old river line, existing new river line, centre line of river which shows deepest point position of river, widened portion of river, catchment area of river as well as Bridge structure, and dam structure.

Table 1 Northing Easting Coordinates and Reduced level of Point along River line

PN	N	E	RL	PC	PN	N	E	RL	PC	PN	N	E	RL	PC	PN	N	E	RL	PC
1	5000	5000	100.00	TP	41	5069	5245	99.65	N	81	5047	5556	98.90	N	121	4348	5861	98.22	C
2	5002	5000	99.83	N	42	5045	5246	99.15	O	82	5014	5548	99.16	C	122	4340	5887	98.20	O
3	5096	4913	100.80	D	43	5017	5248	99.37	C	83	5006	5573	99.23	C	123	4336	5900	98.55	N
4	4897	4917	100.71	D	44	4952	5237	102.51	O	84	5030	5594	98.77	O	124	4280	5875	97.82	C
5	4912	4940	100.60	O	45	4943	5274	102.79	O	85	5046	5593	99.05	N	125	4275	5849	98.87	N
6	5011	4946	99.28	C	46	5019	5280	99.80	C	86	5029	5622	98.69	N	126	4129	5880	97.52	TP
7	5036	4942	99.68	O	47	5045	5279	99.12	O	87	5022	5619	98.54	O	127	4127	5879	97.51	TP
8	5075	4939	100.75	N	48	5081	5277	99.68	N	88	4995	5600	99.09	C	128	4177	5898	98.05	N
9	5064	4972	101.66	N	49	5044	5399	99.75	TP	89	4962	5649	98.55	C	129	4135	5891	96.73	O
10	5034	4978	99.49	O	50	5044	5408	99.67	TP	90	4986	5670	98.44	O	130	4138	5881	97.70	C
11	5014	4982	98.93	C	51	5033	5348	99.73	B	91	4976	5694	99.61	N	131	4142	5873	97.75	O
12	4929	4981	100.04	O	52	5033	5341	99.21	B	92	4963	5690	98.47	O	132	4077	5876	97.38	N
13	4932	5014	100.40	O	53	5033	5337	99.72	B	93	4944	5673	98.77	C	133	4068	5868	96.94	O
14	5015	5016	98.94	C	54	5033	5328	99.30	B	94	4920	5697	98.68	C	134	4064	5850	97.42	C
15	5033	5016	99.96	O	55	5095	5409	100.76	N	95	4936	5720	98.48	O	135	4068	5827	98.38	O
16	5045	5017	101.53	N	56	5082	5442	100.45	N	96	4889	5762	100.04	TP	136	4064	5828	98.19	O
17	5050	5050	102.42	N	57	5075	5478	100.16	N	97	4889	5764	100.10	TP	137	4033	5846	97.12	O
18	5029	5044	99.74	O	58	5062	5421	98.96	O	98	4876	5755	97.02	O	138	4019	5795	97.89	C
19	5013	5043	99.00	C	59	5030	5412	99.89	C	99	4852	5741	99.05	C	139	3998	5812	97.22	O
20	4934	5044	100.69	O	60	4996	5400	100.00	O	100	4802	5767	98.80	C	140	4036	5775	98.48	C
21	4940	5079	100.67	O	61	4969	5390	101.33	N	101	4814	5794	97.83	O	141	3981	5763	97.86	C
22	5010	5075	99.20	C	62	4954	5425	103.08	N	102	4819	5803	97.55	N	142	3960	5769	96.86	O
23	5029	5077	99.90	O	63	4953	5450	103.31	N	103	4720	5844	98.53	O	143	3938	5749	98.62	O
24	5053	5079	102.18	N	64	4948	5477	103.28	N	104	4715	5798	98.98	C	144	3938	5749	98.64	TP
25	5061	5108	101.88	N	65	4956	5501	102.38	N	105	4691	5770	99.81	O	145	3937	5747	98.58	TP

26	5029	5109	99.70	O	66	4938	5547	102.72	N	106	4691	5742	101.10	N	146	3945	5756	98.20	N
27	5012	5111	99.41	C	67	4923	5581	102.33	N	107	4631	5769	99.52	N	147	3955	5745	97.58	C
28	4945	5116	101.19	O	68	4908	5610	100.01	O	108	4605	5806	99.46	O	148	3967	5732	97.70	O
29	4942	5136	101.57	O	69	4934	5579	100.43	O	109	4609	5824	98.87	C	149	3937	5708	97.49	O
30	5013	5143	99.29	C	70	4948	5547	100.19	O	110	4613	5869	98.52	O	150	3924	5709	98.98	N
31	5027	5143	99.70	O	71	4959	5514	100.49	O	111	4583	5878	98.48	O	151	3943	5662	97.56	C
32	5075	5134	102.16	N	72	4964	5484	99.79	O	112	4583	5833	98.88	C	152	3945	5647	96.97	C
33	5086	5156	103.06	N	73	4985	5437	99.55	O	113	4574	5800	99.22	O					
34	5027	5179	99.18	O	74	5016	5433	100.03	C	114	4538	5809	99.26	O					
35	5015	5180	98.83	C	75	5066	5454	98.41	O	115	4542	5844	99.10	C					
36	4946	5182	101.88	O	76	5060	5488	98.34	O	116	4544	5890	98.65	O					
37	4946	5218	102.71	O	77	5006	5459	100.03	C	117	4462	5903	98.07	O					
38	5015	5213	99.13	C	78	5012	5501	99.71	C	118	4450	5876	98.54	C					
39	5035	5213	99.05	O	79	5019	5523	99.47	C	119	4449	5838	98.60	O					
40	5061	5211	100.04	N	80	5053	5522	98.51	O	120	4356	5846	98.24	O					

The total station data (northing, easting, and RL) import from instrument total station to PC by a cord through datalink software. This transferred data obtained in form of excel sheet, which gives the point numbers, northing, easting, RLs and point code. After that, this excel file (.exl) is converting into contour map, so it is required quick grid software which gives the contour map of that area with different contour intervals shown in figure no 2. Also, this excels file import to the third stage of datalink software, which gives the AutoCAD (.DXF) file of the area. Then plotting the actual River Longitudinal plan with Surveyed point's location shown in figure no. 3, which indicates that actual river span at each location, cross section, river bed ht. with respect to outer river line and old river line marked by existing big boulders. We estimate how the river span increases due to flooding and location and position of scouring and silting shown in figure no. 3 by yellow colors. The longitudinal plan divided into three sections depends on the river bank full width and its curvature. The first section of chainage 100m to 700m shown in figure no 4 indicates that the left side of river line increases 35 to 40% of its actual span. The second section start from chainage 700m and end to 1243m shown in figure no 5, it is curvature section of the river. Due to curvature or bend, the outer span of the river is scouring rapidly, the same time the silt is continuously deposited on the inner span. So that expands the span of inner river line, due to this increase the actual span of the river. After that river flow is the straight line from chainage 1243 to 1943m, due to straight flow no silting, scouring and bank full widening observed in figure no. 6. River cross-section with Surveyed point's location is also shown in figure no. 7.

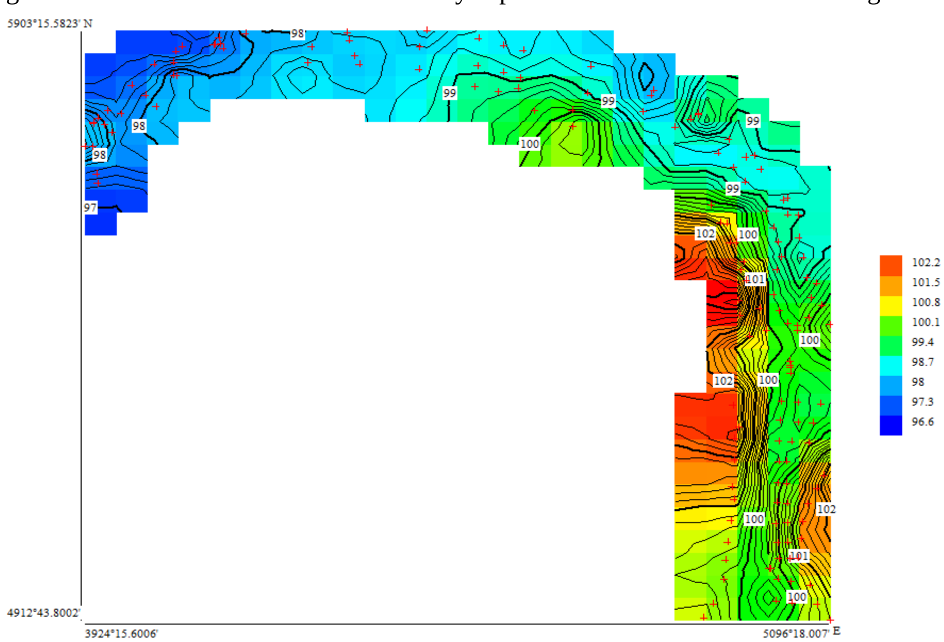

Fig. 2: Contour Grid of Arunavati River bed

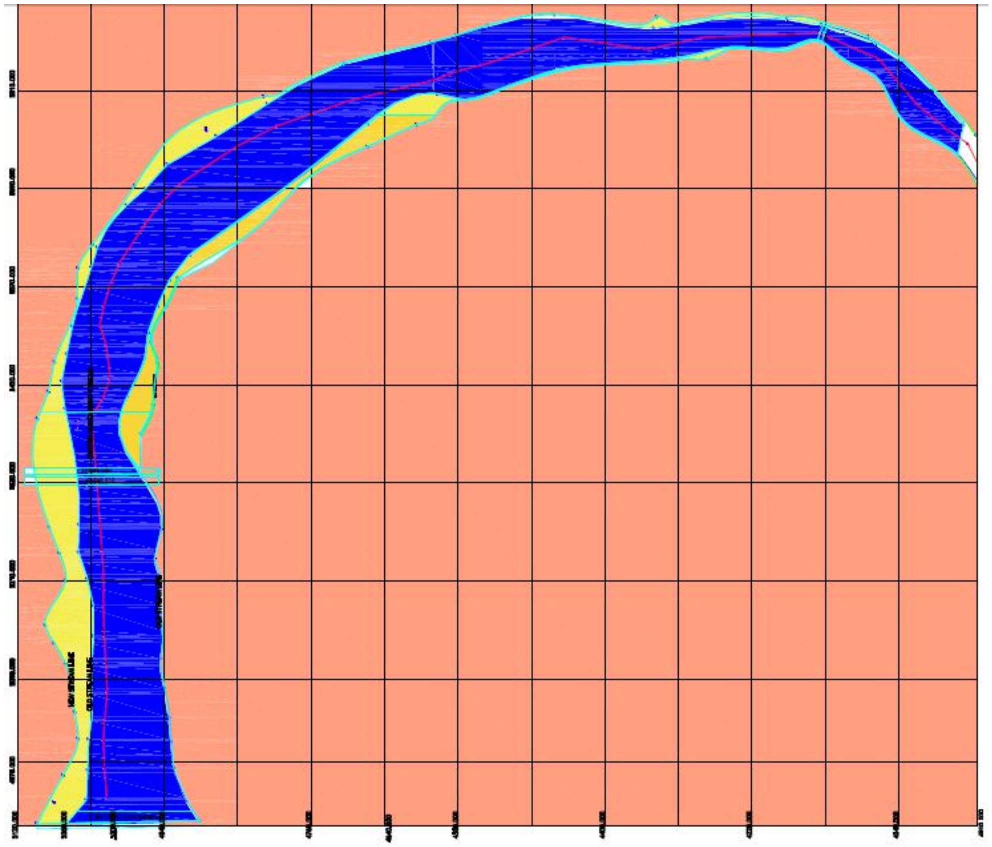

Fig. 3 River longitudinal plan with Surveyed point's location

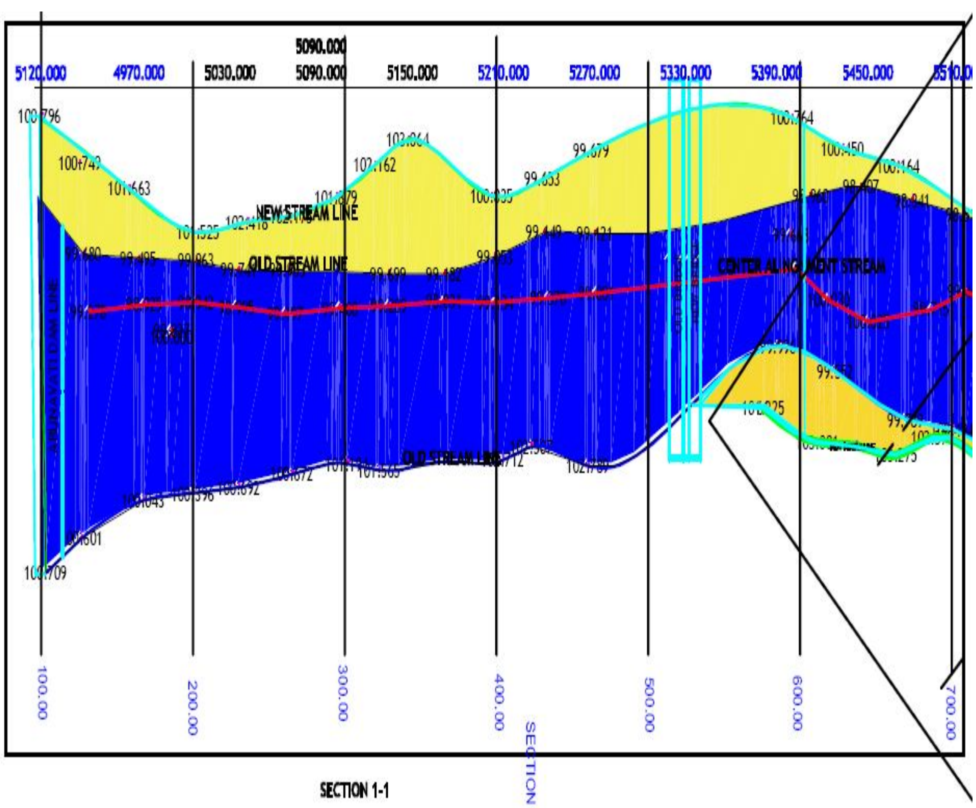

Fig. 4 River Section 1-1 with surveyed point's location

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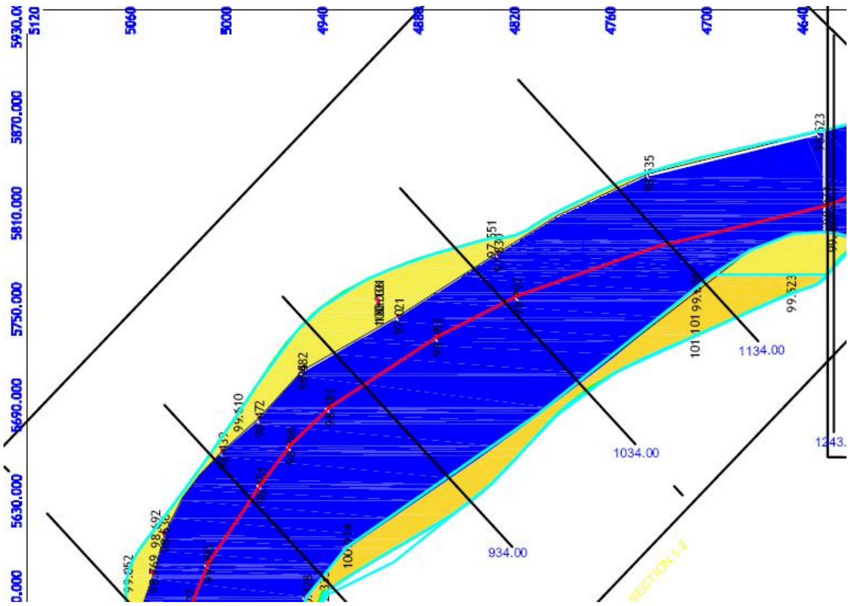

Fig. 5 River Section 2-2 with surveyed point's location

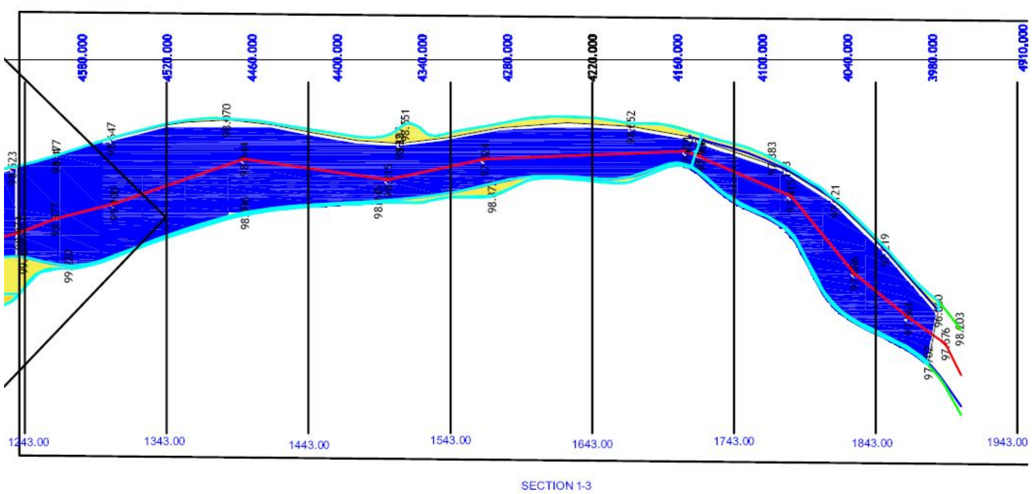

Fig. 6 River Section 3-3 with surveyed point's location

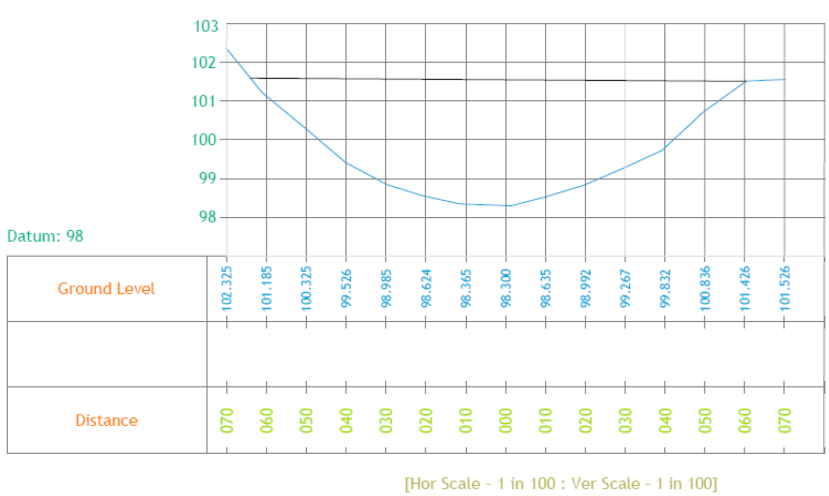

Fig. 7 River Cross Section with surveyed point's location

V. CONCLUSIONS

A. After studying all visual and data observation, it is concluded that,

1) It indicates that first section of chainage 100m to 700m of the left side of river line increases 35 to 40% of its actual span.
2) The second section start from chainage 700m and end to 1243m, it is curvature section of the river. Due to curvature or bend, the outer span of the river is scouring rapidly, the same time the silt is continuously deposited on the inner span. So that expands the span of inner river line, due to this increase the actual span of the river.
3) River flow in section 3 is the straight line from chainage 1243 to 1943m, due to straight flow no silting, scouring and bank full widening observed.
4) The river is extremely widened at left and right edge of the bank due to flooding occurs in past 10 years. This also indicates that the new bridge abutment position is displaced 20m from old bridge abutment position. If not paid due attention, due to continuous action of flooding, the river will be more widened and it is problem to surrounding features located near river line.
5) The data of surveyed points in Cartesian coordinate can be used to quantify sediment deposit measurement, the area of a widening of the river, storage volume of river and flood level difference.
6) The research work demonstrates the ability of the challenges of flooding pattern is studied by total station, so monitoring assessment of river is essential for preventing the widening problem.
7) Coordinates data was very useful for locating position of structure such as bridge and dam, because it depend upon the previous record taken by total station measurement.

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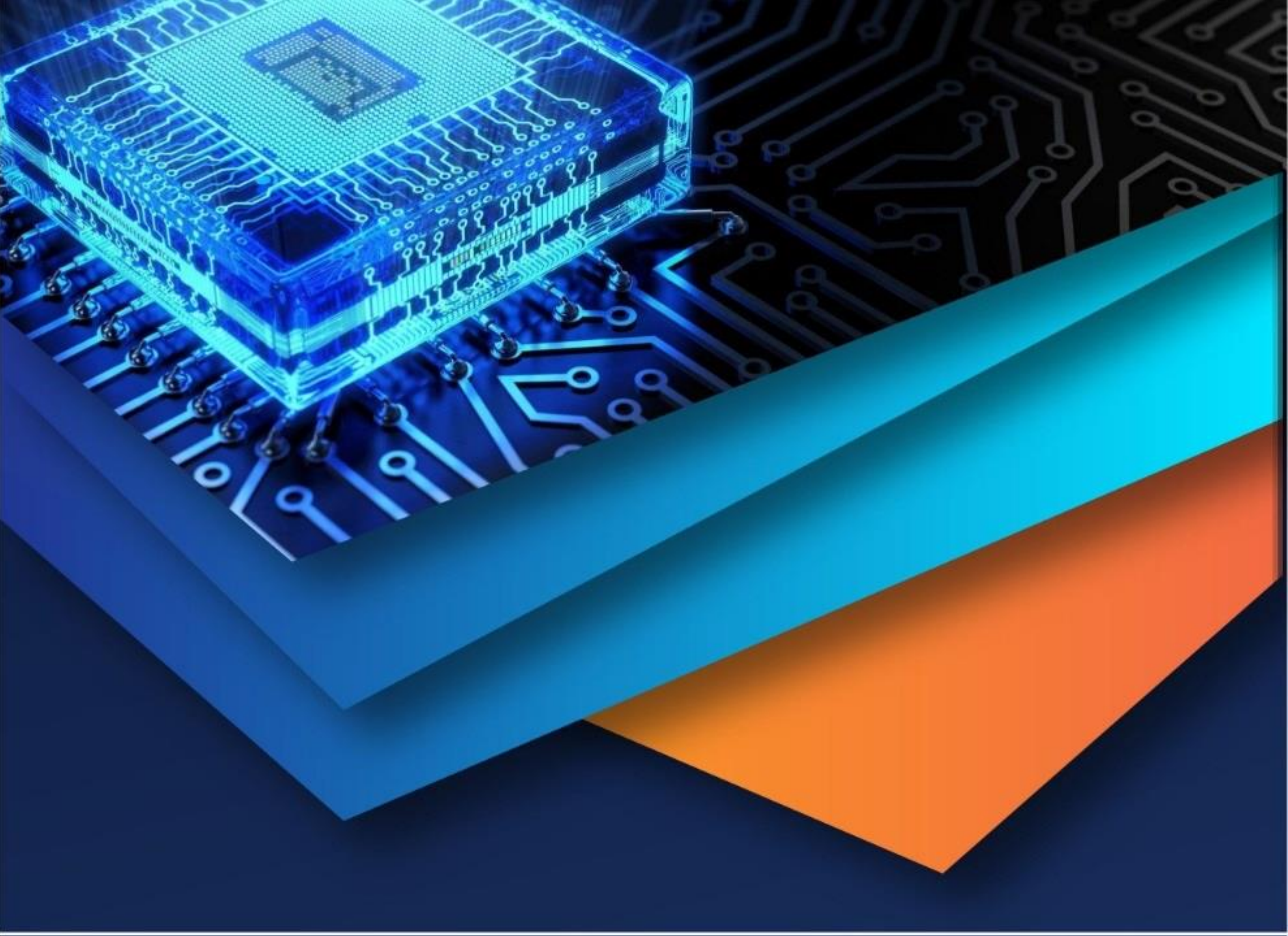

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