Chapter-7

PREDICTIVE MODELLING OF CHANNEL PLANFORM

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7.1 Introduction

Channel planform dynamics is a natural processthat occurred due to erosion and accretion of the river banks over a period. The variable, which controls the channel planform dynamics are discharge, sediment supply, runoff events, and vegetation cover. In addition, the channel shifting also depends on local factors like channel types, flow conditions, channel slope, soil types and anthropogenic activity [259]. During the last decade, substantial research has been done to understand the channel planform dynamics.

The published literature reveals that the Geoinformatics based tool and techniques are useful to analyse the channel planform dynamics. However, prediction of the channel planform israrely performed in the published literature. The prediction of channel planform dynamics is a challenging task due to the complex nature of the variables responsible for the planform change [5]. It can be used as a guiding tool for future river management activities. Morphological prediction is possible through the modelling of channel planform dynamics in GIS environment [260].

However, such modelling has some inherent limitations because the output of these models is affected by the degree of uncertainty and complexity of the fluvial environment. As such, any natural or anthropogenic intervention in the channel like flood or river training works can change the river morphology, which may not be reflected in the model. The magnitude and direction of these changing variables are uncertain and unknown. Therefore, more quantitative data of floodplain are required for the modelling of the channel planform dynamics. The channel centerline migration rate is essential data for modelling channel planform dynamics. Thus the prediction of channel centerline migration rate is an essential parameter for the modelling of channel planform dynamics [261].

Geoinformatics based tools and techniques are extensively used to analyse the channel planform dynamics globally and locally [5]. In India, many scholars have used diverse approach to investigate the historical channel planform dynamics in different ways using multi-temporal satellite imageries and GIS techniques [9, 129, 244–249]. Unfortunately, not manystudies have been doneregardingthe prediction and modelling of the channel planform dynamics in India.

Modelling of channel planform dynamics has signification role in the river management activities[6, 240, 250]. Therefore this study will definitely fill the knowledge gaps of the previous studies related to the channel planform dynamics. Here, we focus on the modelling of channel planform dynamics to understand the present and future river planform behaviour using Geoinformatics based tools and techniques. The proposed model is an attempt to predict the channel centerline in the spatial and temporal scale of 40 km and 100 years which are hardly selected in the previous studies of channel planform modelling. The modelling of channel planform dynamics for the Ramganga riverusing RVR meander model has been carried out first time in India.

RVR Meander is a toolbox that can be used to model river meander migration with physically based bank erosion methods over the next 100 years [270]. It was developed as a toolbox for modelling restoration and naturalization processes in rivers [271]. This model is a GIS-based program for analyzing and modelling the channel planform dynamics [272]. Several rivers have been restored due to ecological and environmental problem in different parts of the world. River restoration techniques is a natural technique used for river channelization. Therefore the prediction of channel planform is important for socio-economic development of the areas which are settled along the rivers [271]. These areas are suffering from a loss of agricultural land, damages of infrastructure due to floods, and for the maintenance of biological diversity in rivers.

River channels naturally tend to have sinuous patterns as they carry water downstream through a flood plain. The bends or curves in a river are called meanders. According to equilibrium theory, meanders form as a result of the river balancing a number of physical processes. More specifically, meanders form as soil erosion and deposition create more stable forms of the river through minimizing variability in planimetric geometry and hydraulic parameters of water depth, water velocity, and local channel slope [273]. River meanders are a typical equilibrium form, but they tend to migrate. Migration can involve various types of movement, such as translation, extension, rotation, and lobing and compound growth[85].

However, not all meandering rivers migrate, and sometimes certain reaches are more active than others. Meander bends can also cut off, either due to the development of a chute channel or through progressive narrowing of the meander neck due to channel migration, both of which can ultimately reroute the river, leaving the meander bend abandoned. The forms and processes of meandering rivers have been well-documented in literature[255, 256]. River channels continually evolve and change shape over time, and natural river channel evolution or migration can cause problems for bridge and other structures that are fixed in the flood plain. At times, rivers can migrate in such a way that could weaken or threaten the stability of such a fixed structure in the flood plain. The purpose of employing a river meander model and a two-dimensional hydraulic model was to gain a better understanding of the meandering processes and evolution of the Ramganga river in relation to potential influence on a major bridge structure.

Our findings of channel planform dynamics revel that Ramganga old channel (Gambhiri river) has avulsed by ~8 km into to the present channel (Kunda nala). One another small crevasse channel (Sota nala) has developed from the Ramganga river which presently joins the Ganga river (Fig. 4.7). It is expected that the Ramganga channel may avulse into Sota nadi in the near future [276]. This avulsions in the Ramganga river may make a newly constructed bridge (Bedijor Bridge) useless due to channel migration.Lower Ramganga is one of the highly dynamics river in the Ganga basin (Fig. 7.1). This figure shows the location of the newly constructed bridge *(Bedijor Bridge)* on the Ramganga river. This bridge is located downstream to the highly dynamic Baran meander.

The rural settlements located along the river are highly affected by the meandering rivers. Some of them are highly prone to erosion in the future due to the hazardous nature of the Ramganga river in the downstream. During the monsoon, period flood causes extensive erosion to the villages.So identification of these villagesfor protection is also important for flood hazard management activities.

The objective of this chapter is (i) to investigate the potential future impacts of channel migration on the Ramganga bridge and identification of a suitable site for engineering structure for 100 years (ii) to assess the impact of climate change through the increased flow on the channel planform (iii) to analyse the effect of planform change on the rural settlement along the studied reach for the next 100 years.

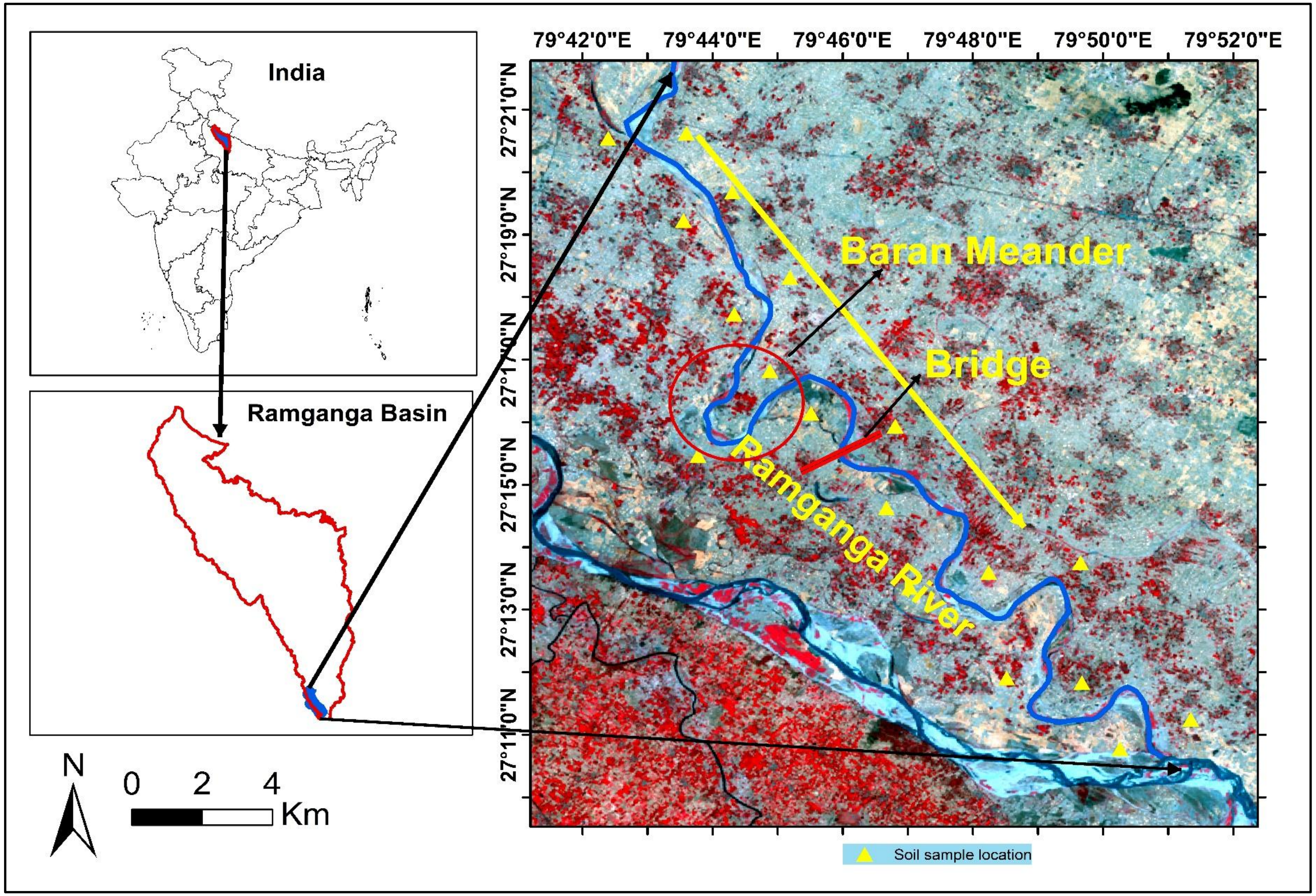

Figure 7.1 *Map showing the highly dynamic Baran meander* and location of soil sample collected along the river.

7.2 Data

The main input parameters are given below which are used in the modelling process

7.2.1 Discharge

The bankfull discharge was determined from the annual peak flow recorded by Central Water Commission (CWC) for the Dabri gauge stations. This is the nearest upstream gauge station and provides continuous daily discharge data for the years (1985–2019) and annual peak discharge data for years (1985–2019).

7.2.2 Soil

The representative 20 undisturbed soil samples were collected for Soil parameters assessment from the study area during 2018. The soil parameter, e.g. soil texture analysis, unit weight, cohesion, and angle of repose were estimated in the Geotechnical Engineering Laboratory of Department of Civil Engineering, Indian Institute of Technology (BHU), Varanasi, India. The soil samples were collected from different locations along the Ramganga river on both banks.These sampling tubes were immediately sealed after retrieval using wax to retain the natural properties of the soil (Fig. 7.10). The soil properties were found the most influential parameter on the model like critical shear stress and erosion-rate coefficients. A single soil layer was used for each bank profile.

7.2.3 Satellite image

The remote sensing of 1990, 2000 and 2010 of Landsat images was used to map the centerline of the channel. The valley line is digitised using the centerlines first and the last node in the Arc GIS software. DEM data are used to get the initial bank geometry on a cross-sectional basis (left and right bank profiles) for the river.

7.3 Model Inputs

7.3.1 Design of bankfull discharge

From the analysis of discharge data from 1985-2019 at the Dabri gauge station, a model discharge data of 2500 m^3/s is accepted for the modelling[7].This value is between the average value and the maximum value of the mean annual streamflow over the period as given in the figure.

7.3.2 Channel dimensions such as width, depth, and slope

A river reaches of 40200-meter long (40000-meter long sinuous section with 100-meter long straight entrance and exit sections) in the downstream area is considered for the modelling. 402 equally spaced nodes describe the initial centerline, yielding a node spacing of 100 m. The initial channel cross-section geometry is trapezoidal with a bottom width of 200 m, bank height of 8 m and the bank slope is 0.007.The bankfull width and channel slope were measured from the Digital Elevation Model (DEM).

7.3.3 Critical shear stress

$$\tau_c^* = 0.1 + 0.1779(SC\%) + 0.0028\,(SC\%)^2 - 2.34 \times 10^{-5}(\mathrm{SC}\%)^3$$

$$\tau_c^* = 0.1 + 0.1779(90) + 0.0028\,(90)^2 - 2.34 \times 10^{-5}(90)^3$$

$$\tau_c^* = 0.1 + 16.011 + 22.68 - 17.0586$$

$$\boldsymbol{\tau_c^* = 21.7324}$$

7.3.4 Erosion-rate coefficient

$$M^* = 2 \times 10^{-7}(\tau_c^*)^{0.5}$$

$$M^* = 2 \times 10^{-7}(21.7324)^{0.5}$$

$M^{*} = 2 \times 10^{-7}\ (4.661802227)$

$\boldsymbol{M^{*} = 9.3 \times 10^{-7}}\mathbf{M/s}$

7.3.5 Soil texture determination in laboratory

The soil sample collected from the field consists of sand, silt, and clay. The fraction of sand, silt, and clay gives an idea of the soil texture. The soil was sieved through 75-micron BIS sieve, and the particle size distribution was studied using hydrometer analysis in accordance with BIS in order to estimate the percentage of silt and clay [277]. The average percentage of silt and clay in the soil samples is found ~ 90% (Fig 7.2).

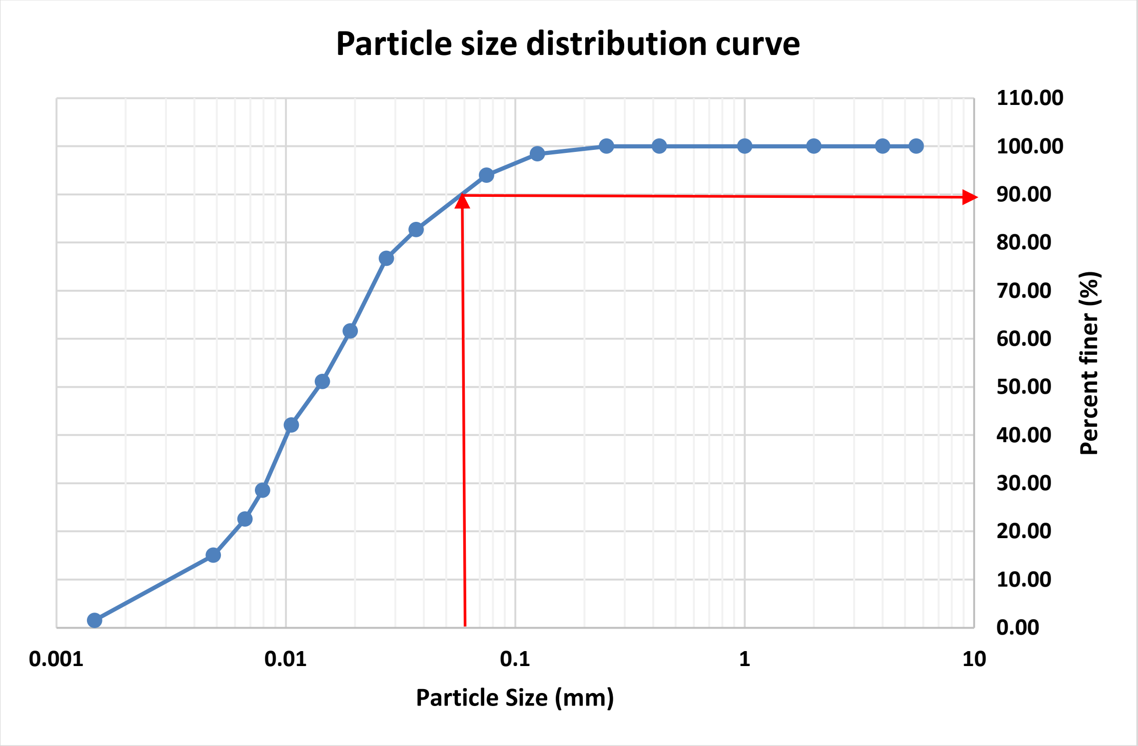

Figure 7.1 Soil texture classification

7.3.6 Unit weight

Unit weight is the weight of a soil per unit volume, it is generally denoted by γ. The unit weight of soil is calculated as per the BIS standard[278]. The unit weight of soil is calculated by given below formula

Unit weight of soil

$$\gamma = \frac{W}{V} \tag{7.1}$$

Calculation

Volume of Core-cutter $V = \frac{\pi D^2 L}{4}$

Weight of Core-Cutter (W1) = 0.3167 Kg

Weight of Core-Cutter + Wet Soil (W2) = 0.6067 kg

Weight of Wet Soil ($W_s = W_2 - W_1$) = 0.29 kg

Volume of Core-cutter (V_c) = 170.1857 cm^3

Core-cutter diameter (D) = 3.8 cm

Core-cutter height (L) = 15 cm.

Unit weight of soil (γ) =0.001704021 kg/cm^3

=17.04 KN/m^3

7.3.7 Shear strength of a soil

Shear strength of a soil may be defined as the maximum internal resistance the soil can with stand against the possible sliding or shearing along the plane. The shear strength of soil on any plane is primarily the function of soil characteristics and the normal stress acting on the plane. The shear strength of soil can be expressed as:

$$\tau = C + \sigma \tan \emptyset \tag{7.2}$$

Where τ = shear strength of soil in a plane; C= unit cohesion; σ = normal stress acting on the plane; $\emptyset$ = angle of internal friction of the soil.

Cohesion (C) is the force that holds together molecules or like particles within a soil. Cohesive soils are clay type soils. The angle of Repose ($\emptyset$) is defined as an angle made by the sloping surface of a soil material with horizontal after it becomes stable. Shear strength parameters of soil samples have been estimated by conducting the unconsolidated undrained triaxial test as per IS 2720 (Part-11)-1993[279]. The values of c and ($\emptyset$) are respectively are 35 KPa and 29°.

7.3.8 Initial section properties

An Excel file “Initial Section Properties Generator.xls” is available for automatically generating the file “InitialSectionProperties.dat”. The first upstream section is specified, then all properties are copied for the next section except Section ID, elevations of the cross-section nodes and groundwater levels, which are calculated once specified Δs (streamwise distance between consecutive centerline nodes), Lv (length measured along the valley centerline), Lc (length measured along the channel), S (valley slope), and depth of the groundwater table at the upstream end (m).The cross-sectional data, which includes the initial bank geometry and soil properties, were equally spaced in the streamwise direction at approximately 100 meters. An idealized bed profile is determined by the model for each cross-section based on channel curvature.

Selected input parameters for the calibrated model are shown in Table 7.1. RVR Meander also contains the ability to specify the number of computational and hydrodynamic parameters, such as methods for bank shear stress and bank failure.

Table 7.1 List of input parameter for RVR Meander Model

Model parameter	**Value**
Hydraulic parameters	
Bankfull flow	2,500 m^3/s
Bankfull width	300 m
Initial channel slope	0.007
Sediment Size	0.003 mm
Upstream bed elevation	133 m
Soil parameters	
Unit weight	17000 N/m^3
Erosion-rate coefficient	9E-07 m/s
Critical shear stress	21Pa
Cohesion	35K Pa
Angle of Repose	29^0

7.4 Methodology

7.4.1 Model Description

RVR Meander is a two-dimensional river meander migration model [6, 257]. This model used to study and investigate future scenarios for the Ramganga river. The current version (2011) of RVR Meander contains the functionalities of a previous version of RVR Meander and a channel evolution model called CONCEPTS[252, 258].The earlier version of RVR Meander focused on the modelling of the planform migration of streams, and CONCEPTS focused on the modelling of sediment transport and bank erosion processes. The most current RVR Meander software was developed as a toolbox for simulating long-term migration of meandering rivers on a reach-scale [282].

The model has a stand-alone version for Windows-based interface and a geographic information system (GIS)-based interface through ArcGIS software. RVR Meander has two methods for computing the river centerline migration: (1) a classic approach (migration coefficient) which is based on the near-bank excess velocity multiplied by a river migration coefficient and (2) a physically based approach are used where the physical processes involved in bank erosion.

The physical bank erosion involves the processes of fluvial erosion and soil mass structure failure. In this study, the physically-based approach is used with the GIS-based interface using ArcGIS 10.0. The physically-based approach is used because it is more advanced and more accurate than the classic approach, especially when modelling for longer periods [7]. The physically-based approach is based on exceedance of critical shear stress instead of relating bank erosion to near-bank excess velocity.

7.4.2 Model calibration

The RVR Meander model for the Ramganga river was calibrated by adjusting the soil parameters in the bank profiles so that a known historic river centerline run through the model matched a known recent river centerline. The first historic river centerline that was used for calibration was from 1990. This year was selected because of the availability of satellite imagery and in order to calibrate to recent migration rates. Daily flow values from the Dabri gauge station were analysed to determine if the 30-year calibration period (1990-2000–2020) was statistically representative of the entire flow record. The values were determined to be similar. Then the historic centerline was derived from bank lines using geoprocessing tools in ArcGIS.

To calibrate the model, the erosion-rate coefficient parameter was adjusted uniformly to get a general agreement with the 1990 river centerline, and then the critical shear stress parameter was adjusted for each cross-section until the 1990 centerline migrated to the 2000 centerline (Fig.7.3). Same presses are followed for the river centerline 2010. Calibration accuracy is decided by visually comparing the historic centerline to the recent (1990) centerline in ArcGIS (Fig.7.4)[283].

Once calibration is done, the model was run for the two scenarios of interest. First is using the model discharge and the second using the 50% increasing the discharge 3800 m^3/s which is approximately equal to the five years recurrent interval discharge (Q_5). Q_5 has a significant impact on Ramganga river morphology.

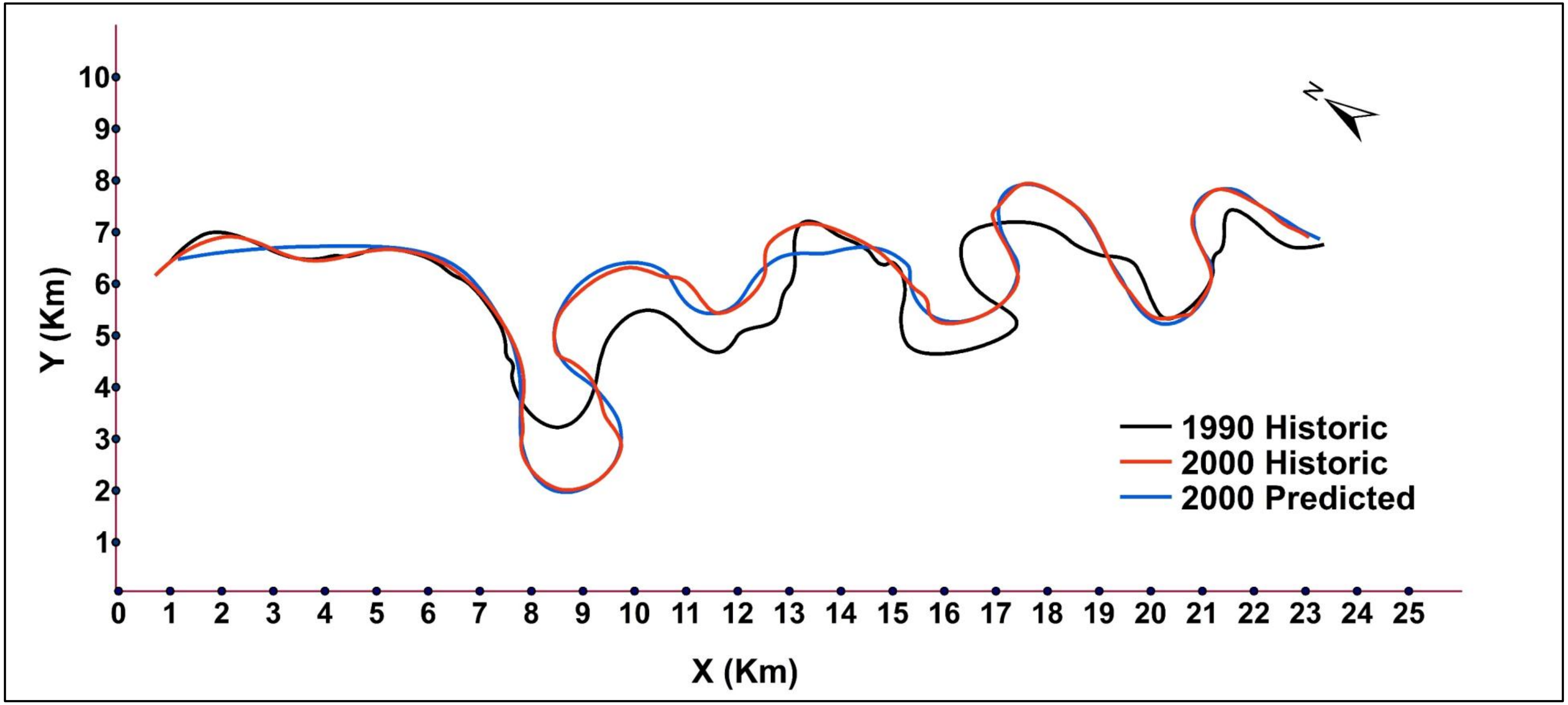

Figure 7.2 Comparison between historic and modelled 2000 channel centerlines of the Ramganga river.

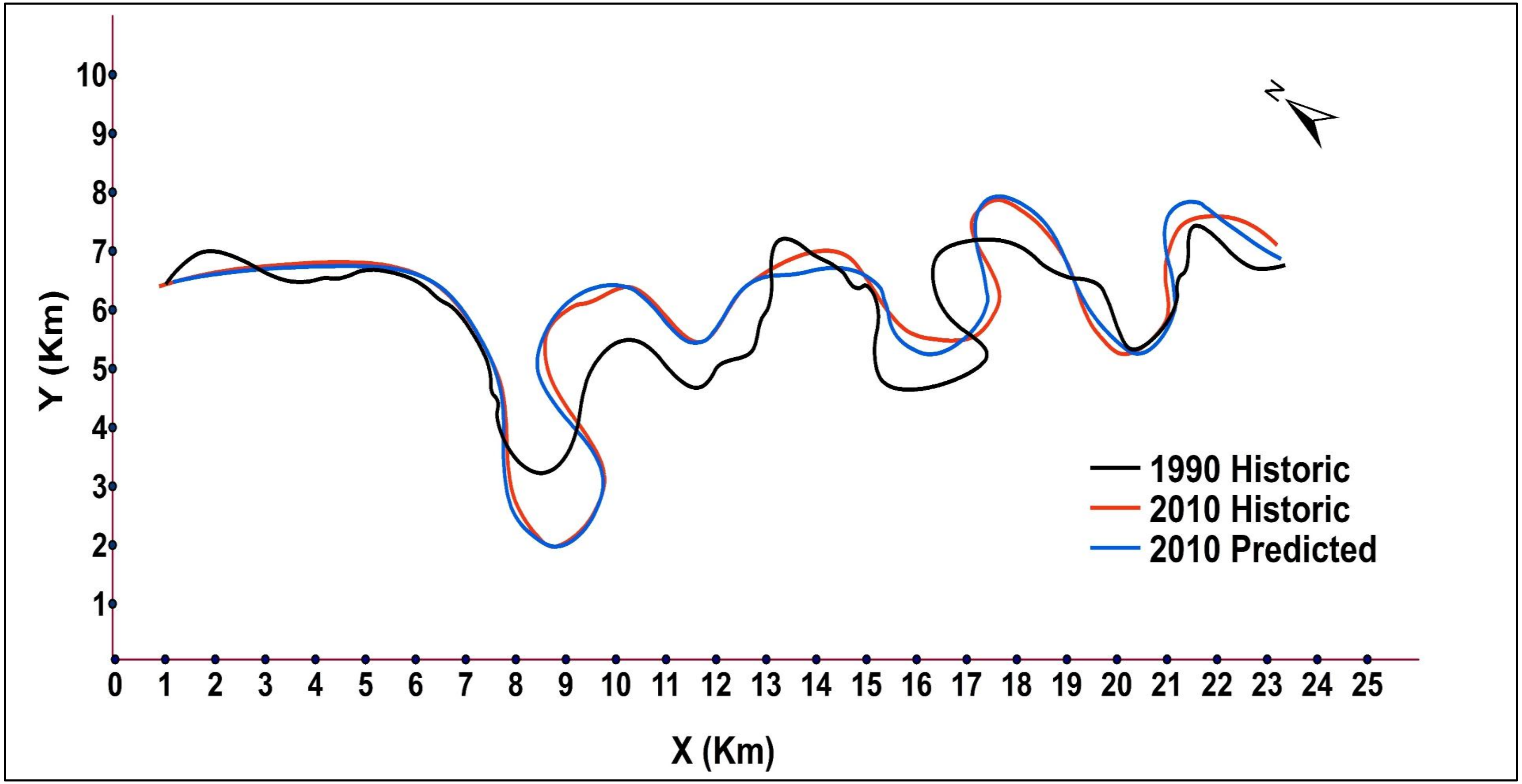

Figure 7.3 Comparison between historic and modelled 2010 channel centerlines of the Ramganga rive

7.5 Results and discussion

The calibrated model was used to run for the two scenarios. The first scenario investigated the natural meandering of the Ramganga river for the next 100 years (2020–2120) and identified a most stable reach for construction of engineering structure. The second scenario predictsthe potential effects of climate change by increasing the model bankfull flow by 50 percent on the meander migration. The third scenario identifies the impact of planform change on the rural settlement along the study reach for the next 100 years. Model outputs include one-dimensional shapefiles of the migrated centerlines at defined increments of 10 years.

7.5.1 Scenario 1: Prediction of planform for 100 years

In the first model scenario, the calibrated model was run for 100 years. The model results show the shifting of the channel centerline in the next 100 years of 2030, 2040, 2050, 2060, 2070, 2080, 2090, 2100, 2110 and 2120. The channel shifting is observed either rightward or leftward movement in the floodplain. The results show that the maximum shifting of the channel may take place near the village Baran ~3 km, whereas the lowest shifting of the channel centerline may take place in the stable reach which may be ~0.4 km.

The modelling results strongly negates the earlier belief that the Ramganga river will avulse to the Sota nala in future. The region behind this Sota nala channel bed is higher than the Kunda nala so during the monsoon it only receives the discharge and in the lean period, it is generally dry over the year.In the near future, the Sota nala may also lost its origin due to meander cutoff, and this cutoff will become an oxbow lake as it observed in the model.

The results also reveal that in the near future the neck cutoffs will take place in Baran meander in next ~30 years near. It occurs through the continued migration and eventual intersection of the upstream and downstream meander limbs. The massive amount of erosion and accretion will take place near the Baran village, and this neck cutoff will reduce the river length ~ 8Km. During the field survey, the two kinds of mechanisms are observed which are involved in the neck cutoff of this meander which are liquefaction with flowage and shear failure of the bank materials [106].

Government of Uttar Pradesh has constructed the Bedijor Bridge on the Ramganga river in 2016. The length of this bridge is ~1.5 km with the construction cost of 66.45 crore rupees. This bridge is established over the highly dynamic reach of the river. The results of the model showed that the Ramganga bridge does not currently appear to be impacted by the migration of the Ramganga river in the next 100 years. The major bank erosion has been occurring just upstream of the Bedijor Bridge near the Baran meander diligent monitoring and re-evaluation are important for the future management of the channel planfrom.

The results show that the channel migrates takes place in some meander section.Just upstream of the Baran meander, a stable reach is found which does not show any historical dynamics in last ~ 100 years (1923-2020) and in next 100 years, no noteworthy movement is observed in the model due to hidden geological structure (lineament) (Fig. 7.5). This reach identifies as a suitable site for the construction of infrastructural development activates.

It has been reported in the previous studies that the confluence of Ramganga and Ganga river is shifted ~ 20 Km due to geomorphic processes like major avulsion, cut-off, and aggradation[204]. The shifting of the confluence points affects the availability of discharge in different reaches and the pattern of sediment dispersal near the confluence point. The major engineering effect of such movements is in terms of scouring or aggradation, which poses serious river management problems. The modelling results show that in the near future the confluence point may shift to the upstream 5km in the Ganga river.

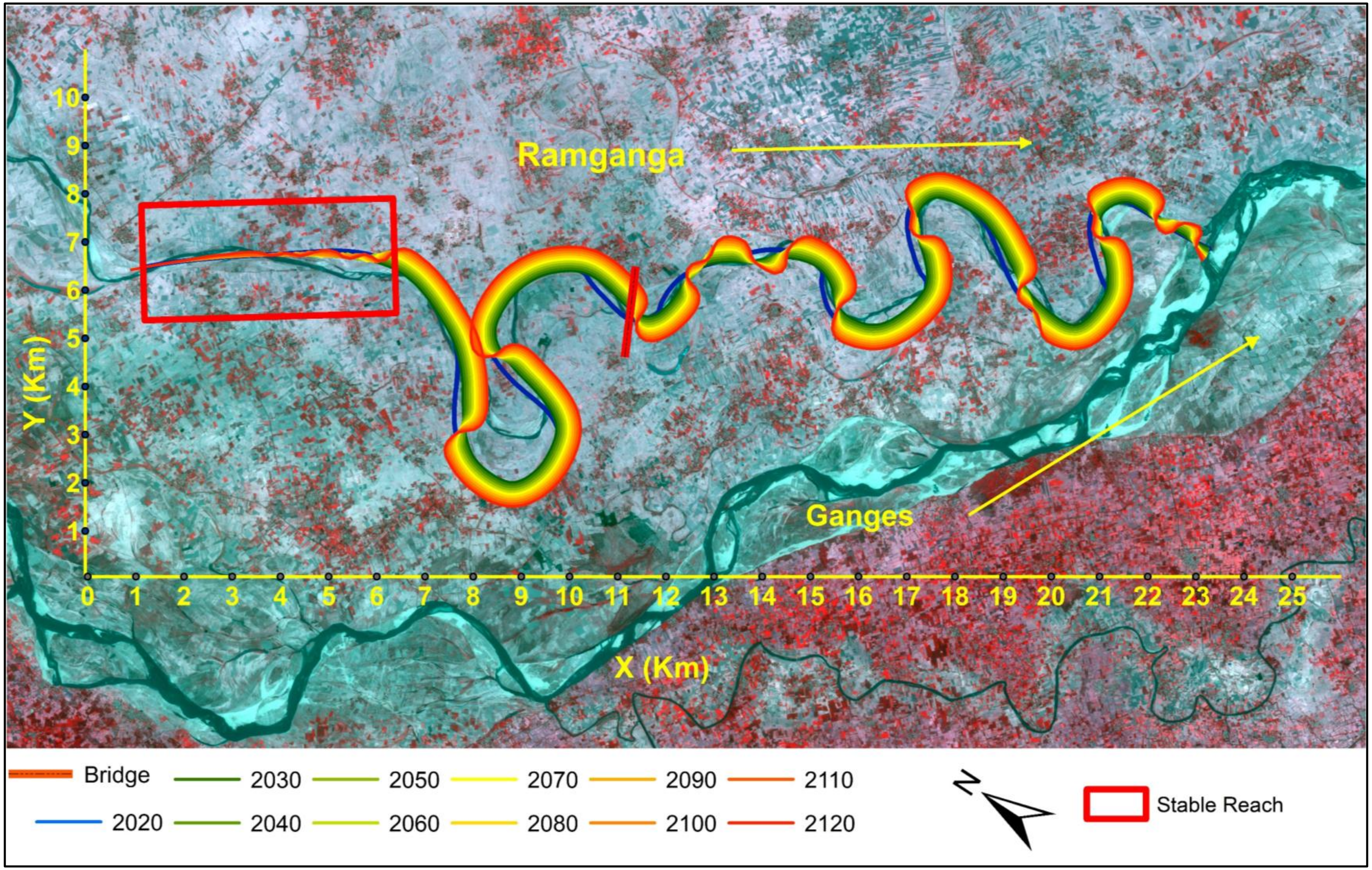

Figure 7.4 RVR Meander output showing migrated centerlines at 10-year increment

7.5.2 Scenario 2: Impact of climate change on the Ramganga river

In the second model scenario, the calibrated model was again run for 100 years with a larger bankfull flow value. This model forecasts the potential effect of increased flood condition,whether due to climate change, land-use change, and reservoir operation change, or something else. In this scenario, the bankfull flow value from the first scenario was increased by 50 percent approximately. The 50 percent increase was selected from the flood frequency analysis it is ~3800 m^3/s, and it is equal to the Q_5 discharge (Table 6.5). The Q_5discharge has the impact on the morphology of the river (Table 6.8). The objective of this scenario is asshowing how meander migration can change due to increased flows in the channel.

The model results show that channel migration is very similar to the first scenario except with slightly increased migration in rightward and leftward movement in the floodplain. The results show that the maximum shifting of the channel may take place near the village Baran ~3.5 km, whereas the lowest shifting of the channel centerline may take place in the stable reach which is ~1 km. In the stable section of the river,the only right side of the river migration is observed, this migration is expected due to the soil properties of this area.

The Baran cutoff may take place in next ~20 years in this flow condition. This neck cutoff will change the morphology in the downstream area (Fig. 7.6). The village Baran and Mastapur are on high risk of erosion due to this neck cutoff, as shown in figure 7.6 and figure 7.1. The Bedijor bridge is not expected to be seriously impacted by the channel migration, but it seems the left side the serious erosion will take place which may be controlled by the flood protection work. Just downstream of the Ramganga bridge, the model predicts that the channel migrates approximately ~ 6 km toward the Ganga side over the next 100 years which may be the potential site for the confluence of Ganga and Ramganga. Overall, the model predicts that the Ramganga Bridge will not be greatly impacted by the migration of the Ramganga river for the next 100 years.

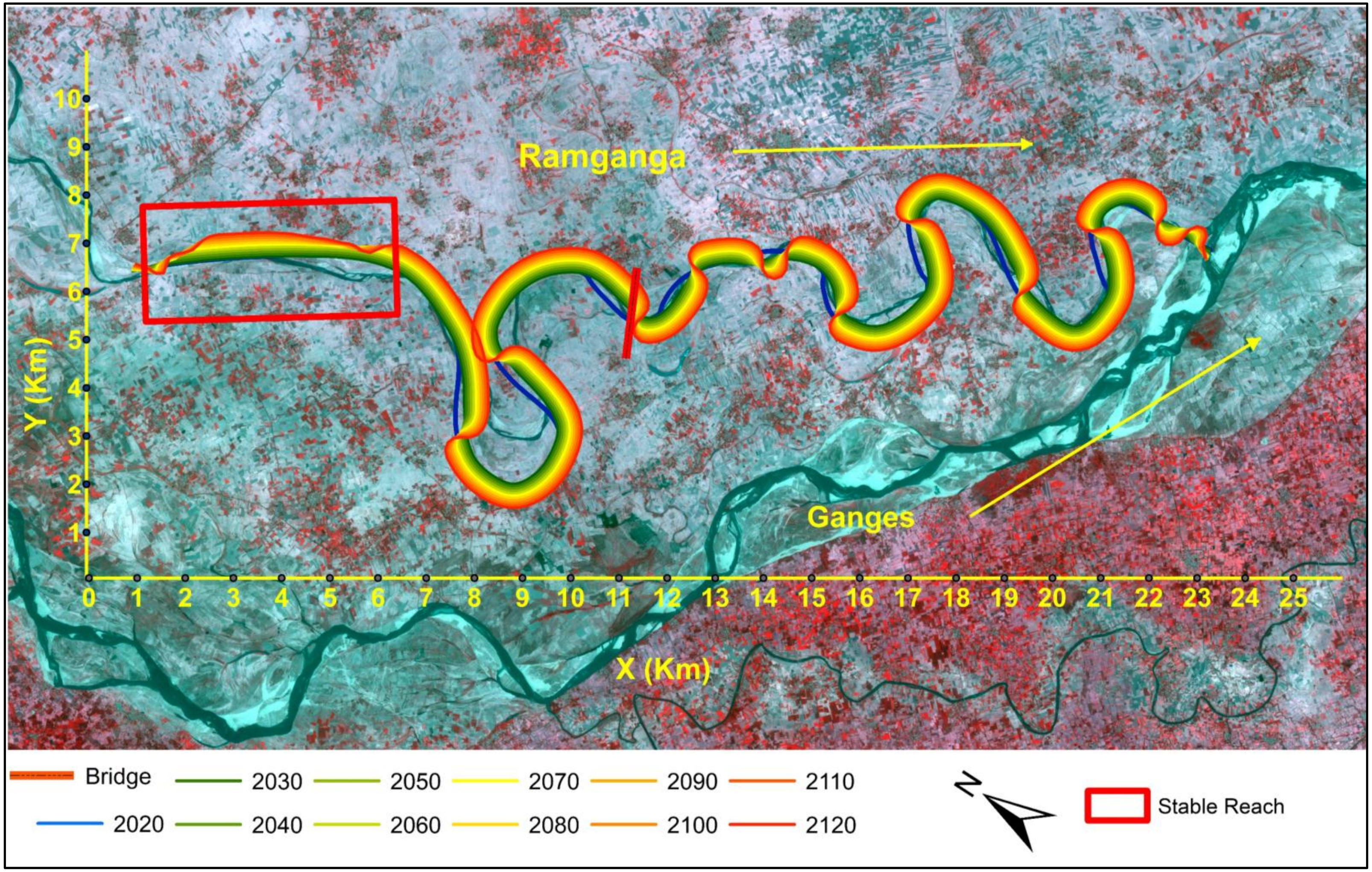

Figure 7.5 RVR Meander output showing migrated centerlines at 10-year increments with increased flow

7.5.3 Impact on rural settlement

It is observed that extensive erosion will take place along the study reach in the next 100 years. Along the Ramganga, many villages are historically eroded, which are now uninhabited, and in coming future, there are many villages which are highly prone to erosion (Table 7.2). It is observed that the population of the eroded villages becomes unemployed and faced economic insecurity due to loss of agricultural land. Destruction of surrounding infrastructure like farmer's houses, agricultural land, and civil infrastructure can directly endanger the lives of the local inhabitant during the river erosion. In the river erosion, the area is decreases towards the eroded side of the bank,and on the other hand,deposition side the cultivated area is increasing. In such a case, the problem of property delineation may lead to a dispute between farmers losing their lands. In some places, the complete erosion of property was observed where the river erodes more than 500 m in less than one year (Figure 7.8 and 7.9). During the field survey, it has been observed thatsome local residents have to reallocate their houses for once or twice respectively in last 20 years in order to cope up with channel migration and some of them has shifted permanently to the urban areas.

Table 7.2 List of the village which is highly prone to erosion in the next 100 years

Sr. no	Location	Village type	Hectare
1	Gangeypur	Uninhabited	50.46
2	Barha Gaon	Inhabited	296.97
3	Chaunpur	Inhabited	361.32
4	Rabiapur	Inhabited	66.46
5	Dharampur	Inhabited	499.93

6	Sarha	Inhabited	680.88
7	Kharagpur	Inhabited	49.04
8	Bari	Inhabited	109.58
9	Bundapur	Inhabited	83.95
10	Dhania Mau	Inhabited	435.88
11	Chanda Mohammadpur Pansa	Uninhabited	375.16
12	Manduwdpur Narautha	Inhabited	301.04
13	Kharuddinpur	Inhabited	137.18
14	Mastapur	Inhabited	207.53
15	Dayalpur	Inhabited	486.93
16	Parchauli	Inhabited	336.47
17	Sitha	Inhabited	128.45
18	Baran	Inhabited	412.17
19	Tikar	Inhabited	197.18
20	Poora Ratan	Inhabited	104.61
21	Behthar	Inhabited	583.29
22	Beerhijor	Inhabited	317.07
23	Murwa Shaha Buddinpur	Inhabited	383.91
24	Arwal Paschim	Inhabited	781.08
25	Behta Lakhi	Inhabited	139.62
26	Arwal Poorab	Inhabited	539.91
27	Nanndana Pansala	Uninhabited	402.62

28	Nanndana Sisala	Inhabited	135.00
29	Murcha	Inhabited	520.68
30	Alampur	Inhabited	125.56
31	Magraura	Inhabited	124.43
32	Nanndana Barar	Uninhabited	95.05
33	Chandrampur Pansala	Uninhabited	398.00
34	Chandrampur Sisala	Inhabited	51.71
35	Siya Kadim	Inhabited	52.25
36	Chandau Bechey	Inhabited	126.51
37	Chhochhpur	Inhabited	277.75
38	Katri Chhochhpur	Inhabited	1665.55
39	Tera Pursoli Pansala	Uninhabited	114.96
40	Katri Gugrapur	Uninhabited	84.38
41	Katri Chandapur	Uninhabited	351.13
42	Kurhar	Inhabited	622.90
43	Dahalitha	Inhabited	1719.39
44	Dhak Pura	Inhabited	327.93
45	Didwan	Inhabited	217.35
46	Surjanapur	Inhabited	62.45
47	Bara Mau Pansala	Inhabited	895.22
48	Bara Mau Sisala	Inhabited	358.98

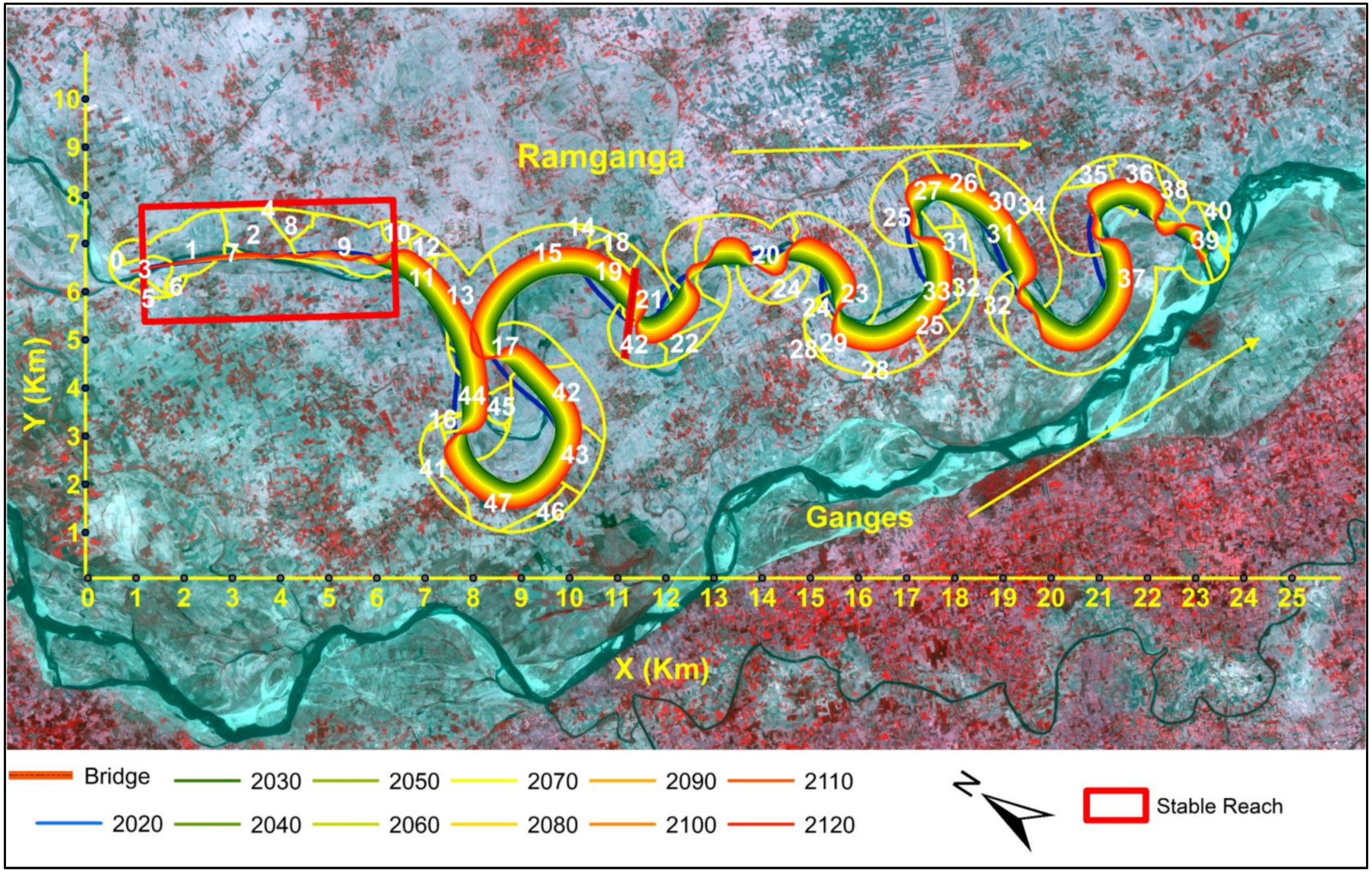

Figure 7.6 Rural settlements which are prone to erosion

Figure 7.7 Endangered houses, trees, and farms due to severe bank erosion of the concave side of bends

Figure 7.8 Severe bank erosion with fracturing and collapse of the bank

7.6 Model Sensitivity Analysis and Limitations

The RVR Meander model was used to make predictions about the channel migration pattern of the Ramganga river, specifically near upstream and downstream of the Ramganga Bridge. The model was calibrated using a historic centerline from the year 1990. The calibrated model was used to understand about the (1) natural meandering over the next 100 years (2020–2120), (2) climate change effects due to increased river flows, and (3) the effect of channel planform dynamics on surrounding settlement.

The model results of these scenarios indicate that the Ramganga bridge will not be threatened by meander migration over the next 100 years. In addition to this model also identified a most stable reach for the establishment of engineering structure like bridge structure.Furthermore, this model mapped the names of potential villages which are highly prone to erosion in the next 100 years. These villages can be protected from the river erosion with suitable river management techniques like constructing embankments. These findings will be helpful for making planning decisions about the Ramganga river in the downstream section. However, the results of the model are an estimate and specific to the RVR Meander model, which is one of several channel migration models.

In order to quantify the uncertainties associated with the RVR Meander model, a rudimentary sensitivity analysis was conducted. In each of the sensitivity analysis, a single parameter was changed at a time, and scenario 1 was considered the baseline for comparison purposes. The two main parameters tested for sensitivity analysis which are the bankfull flow and the soil properties. To test the bankfull flow for sensitivity analysis, Scenario 2 used as the baseline the flow was increased up to50 percent, and those results were presented in “Scenario 2”.To test the sensitivity analysis for soil properties, the first model scenario was rerun with different soil properties. The first rerun decreased the critical shear stress everywhere by 10 percent, and the second rerun increased the erosion-rate coefficient everywhere by 33 percent. Both of these had very similar results, with the change in critical shear stress having a stronger effect, meaning an increase in centerline migration as reported next. As the sensitivity analysis shows, the model is more sensitive to changes in soil properties than it is to changes in flow[270]. Variability in soil properties can be expected, so this analysis helps to quantify the uncertainty in the model results.

There are limitations of the RVR Meander model. First, it is the two-dimensional model which is a simplified version of reality. The variables involved in modelling processes are a constant water discharge, no bed aggradation or degradation data, and a constant channel width which do not simulate the complex process of natural meandering, it requires some other parameter also like river bed topography, vegetation etc. Although a physically-based method for bank erosion is much improved over a migration coefficient method and it still does not completely capture all of the physics involved in bank erosion. Researchers are continuing to improve the numerical modelling of river morphodynamics [284]. Additionally, although this version of the model cannot model the cutoff processes, neck cut-offs can still be predicted by looking at the characteristics of the migrated centerlines. Second, the soil properties were considered to be same throughout the channel for both banks of the river. The flood plain heterogeneity is not considered during the modelling process, but this parameter is related to migrated centerline variability and planform complexity[263, 264].

Finally, this model is based on the calculated parameter for the study area. Any natural or man-made perturbation could alter the results. For example, the frequency and timing of major flood events, streambank modification, or an unexpected local change in soil properties could cause a local perturbation that may then get exacerbated over time. However, given these limitations, this river meander model is still incredibly useful for providing insight into future river morphology and helping to guide planning decisions.

Figure 7.9 Soil sample collection using Shelby tube sampler in the field

Figure 7.10 Soil texture analysis in the lab using Hydrometer test.