Geospatial Technology for Climate-Resilient Road Infrastructure Management and Planning in the Inland Regions of Papua New Guinea

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CLIMATE IMPACT ON INFRASTRUCTURE

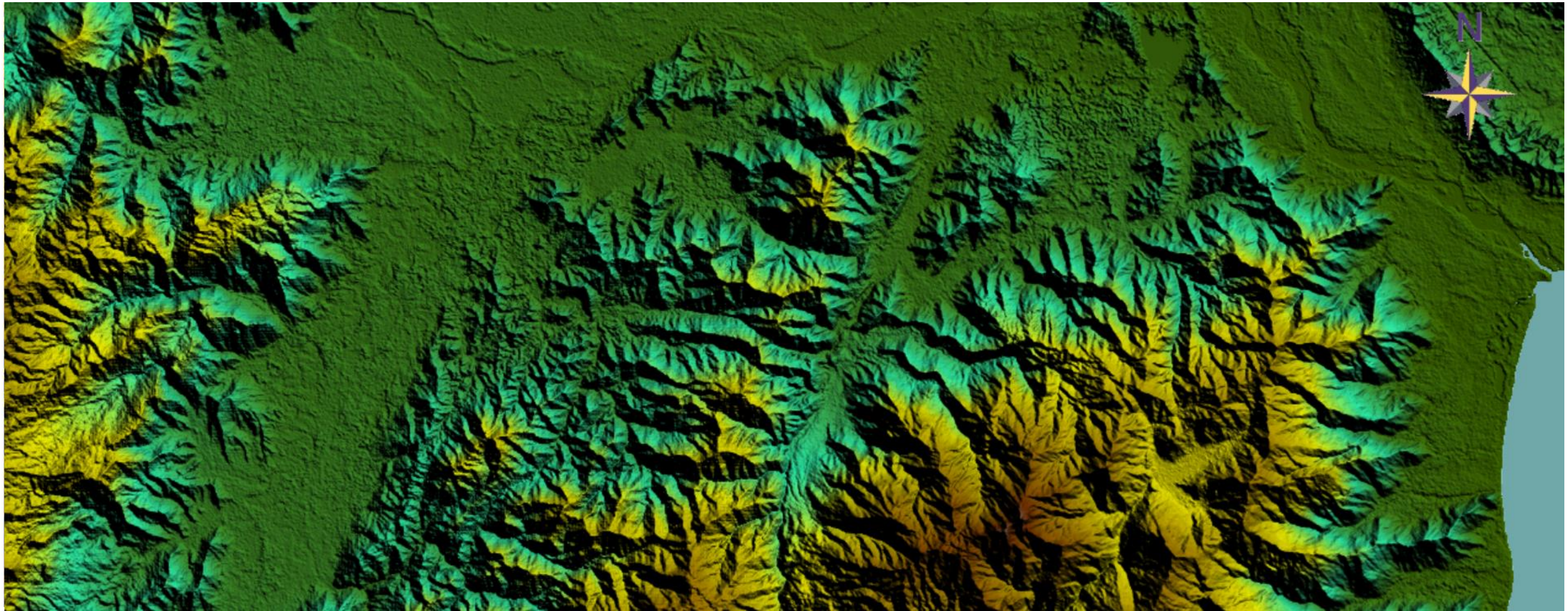
- Papua New Guinea (PNG) is facing increasing challenges due to extreme weather events, which are having catastrophic impacts on both human populations and built infrastructure.

Current construction cannot withstand rainfall weather pattern

Approx. 70 years Bridge has collapsed-2024

UNDERSTADING TOPOGRAPHY AND HYDROLOGICAL SYSTEMS

- PNG landscape/Topography is very complex and highly vulnerable to hazard and disasters
- 80% population are rural and mostly inland.
- Effective Construction and maintenance of road is the major challenges in PNG,



RURAL ROAD INFRUSTRUCTURE

- Connect PNG - Connecting rural population with road infrastructures.

- Connecting roads across terrains is challenging.

- Many roads are initially constructed but fail due to continuous rainfall, resulting in collapses.

- Applying geospatial tools and knowledge in collaboration with engineers can effectively address these issues more efficiently

RESEARCH GOALS AND OBJECTIVES

- ❑ Our main goal is to ensure that the design and operation of road infrastructure, to be more efficient, sustainable, and resilient to climate impact.

- ❑ Proposed and Highlight data and solutions for climate proofing road infrastructure

- ✓ Inventory management of existing road

- ✓ Analyzing Catchment Hydrological structures and systems.

- ✓ Optimal route Computation and selection – Climate Proofing.

ROAD INVENTORY

- ❑ Developing and Keeping up to date inventory database;

- ✓ Identifies repair needs and optimizes resource allocation.
- ✓ Helps in planning future expansions and upgrades.
- ✓ Minimize hazard and transport risk
- ✓ prioritize spending on the most critical repairs
- ✓ selecting the most safest and least cost road network

OPTIMAL AND LEAST COST ROUTE IDENTIFICATION AND SELECTION

- ❑ Before new cut road, consider;

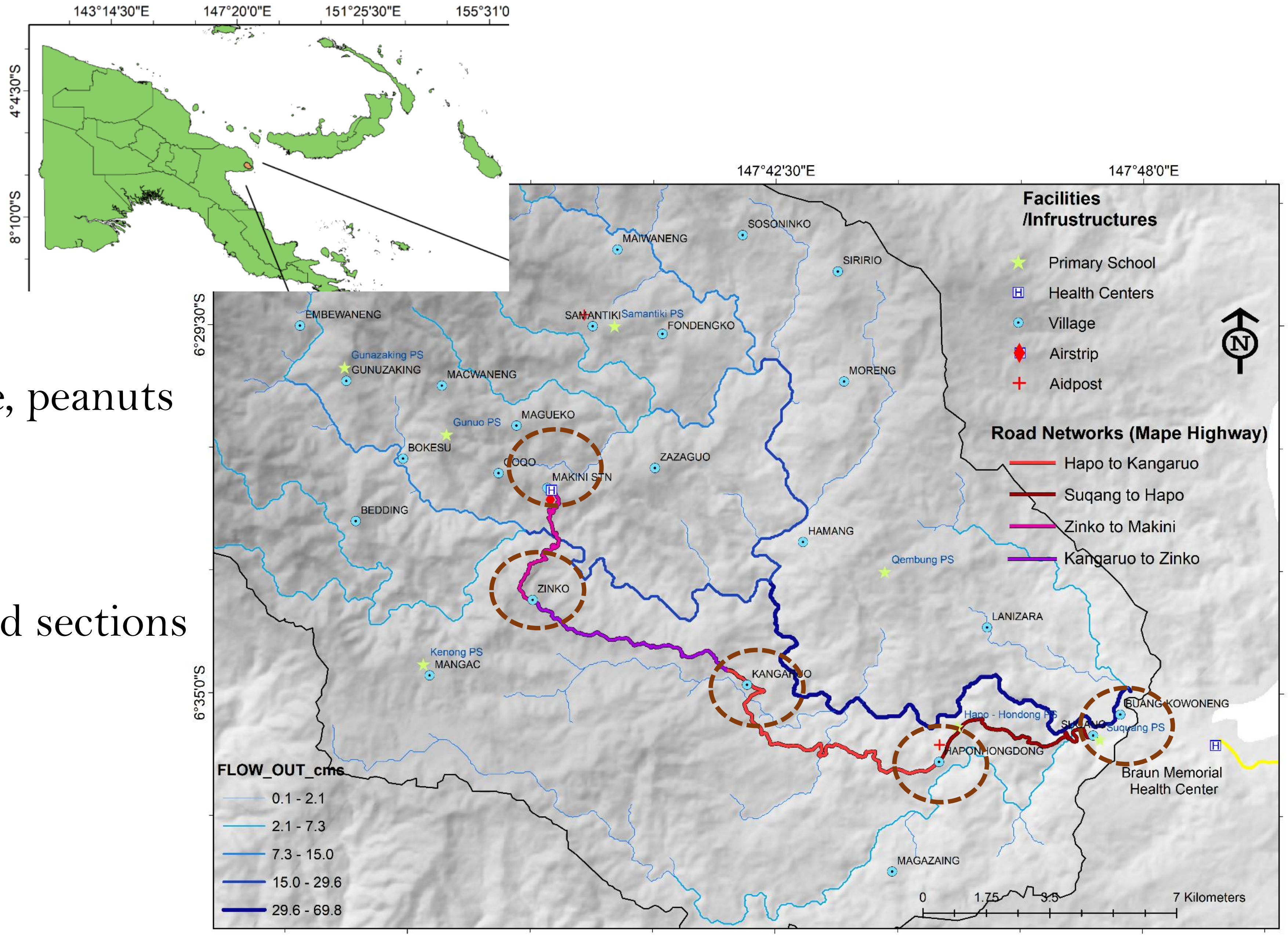
  - Slope Gradient/Topography
  - Creek/river(Hydrology)
  - Land use/land cover type
  - Land issue/restriction
  - Site soil geology
  - Reaching enough population

- ❑ Proper road alignment selection stage is critical.

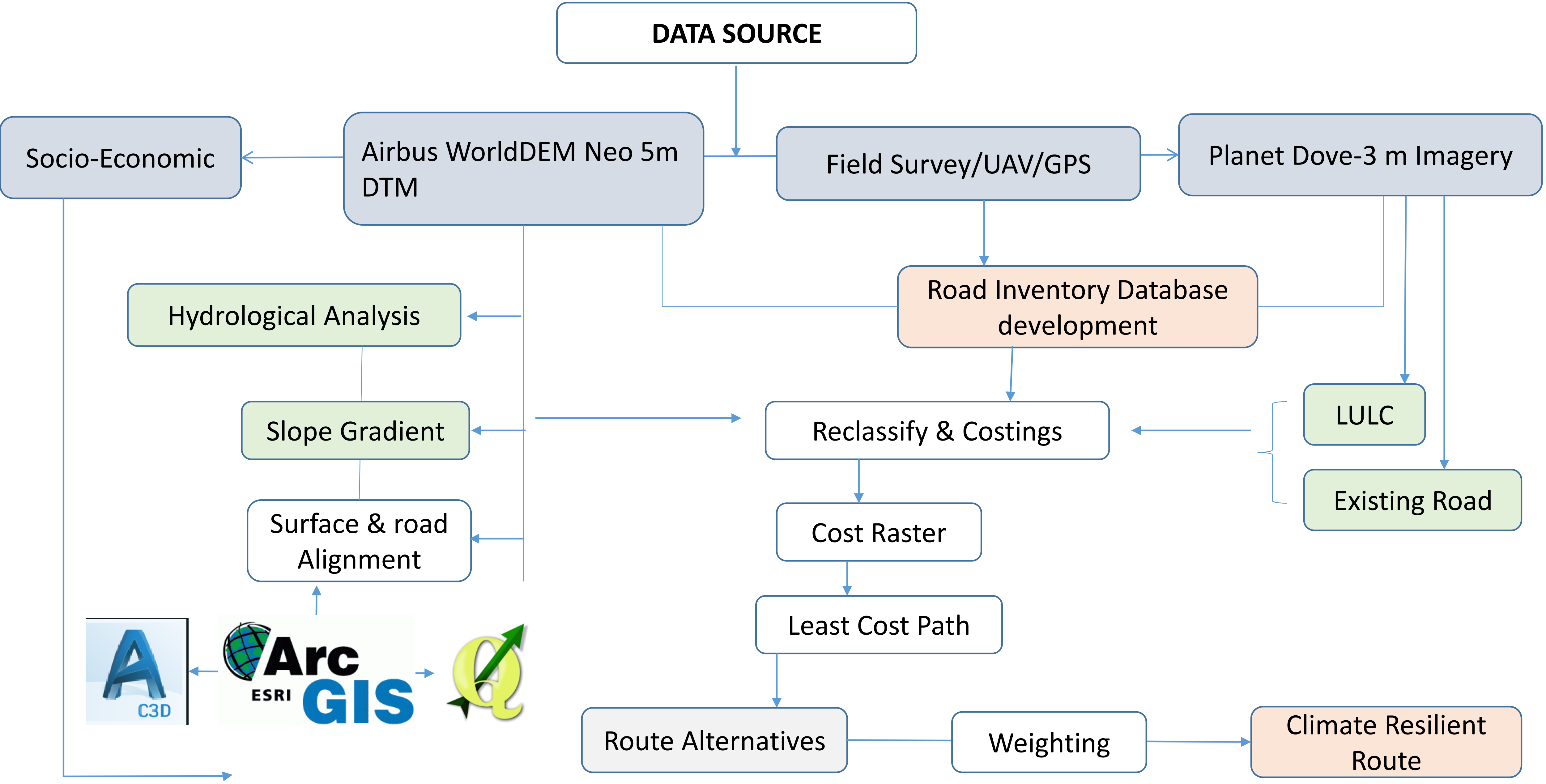
- ❑ Route alternatives are compared to minimize negative impacts and select the most suitable path that can be climate resilient.

CASE STUDY REGION

- ❑Population of 8000 plus
- ❑27 villages/rural places
- ❑Main cash crop activities:
  Coffee, cacao, vanilla, rice, peanuts
- ❑Four (4) road sections
- ❑Study limits to two (2) road sections



CASE STUDY METHODS

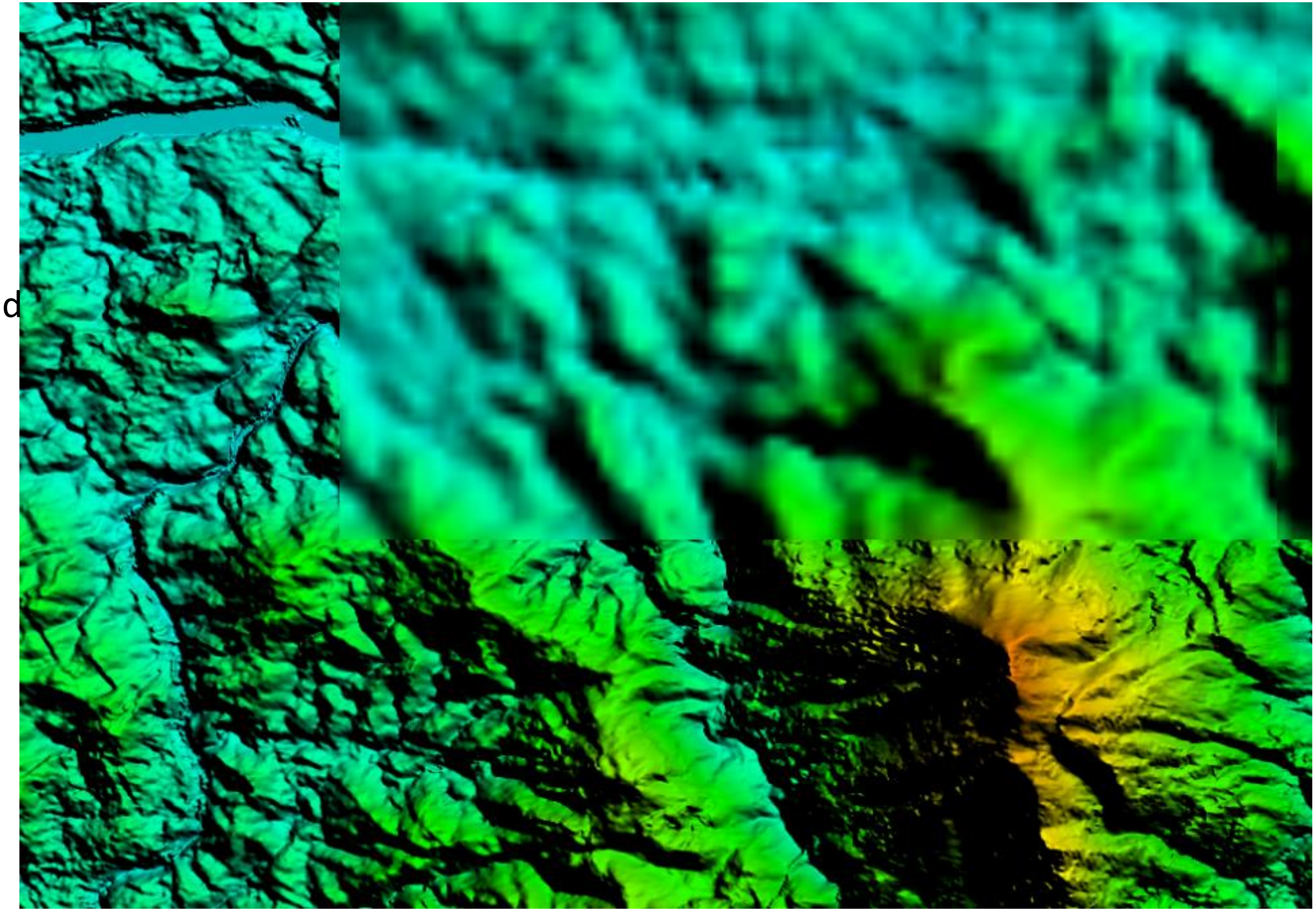


CASE STUDY METHODS – FIELD DATA

Formulating innovative approaches to follow

CASE STUDY METHODS

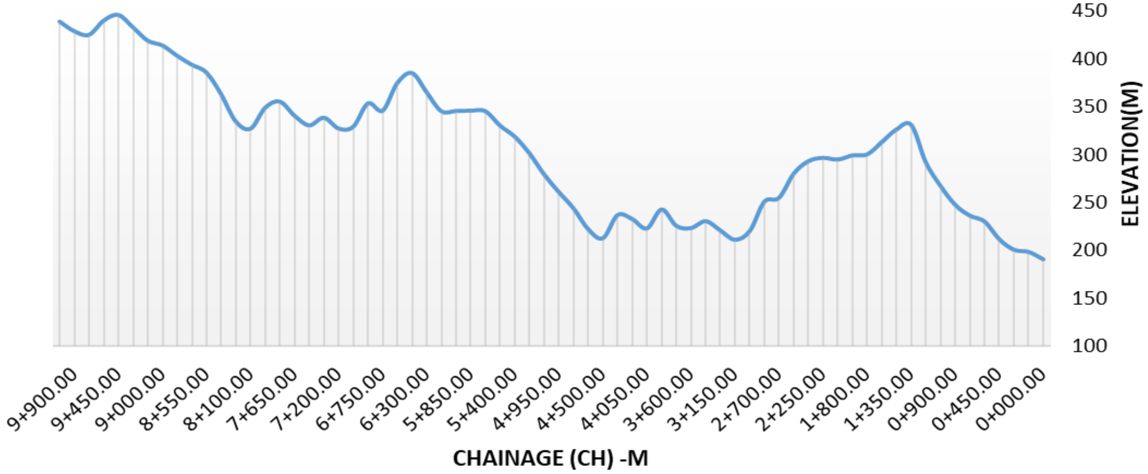
- ❑ Utilizing 5 meter spatial resolution Airbus NEO DEM and Contour
- ❑ Ready Processed and enhanced
- ❑ Comparison of 5 meter DTM and 30 meter SRTM

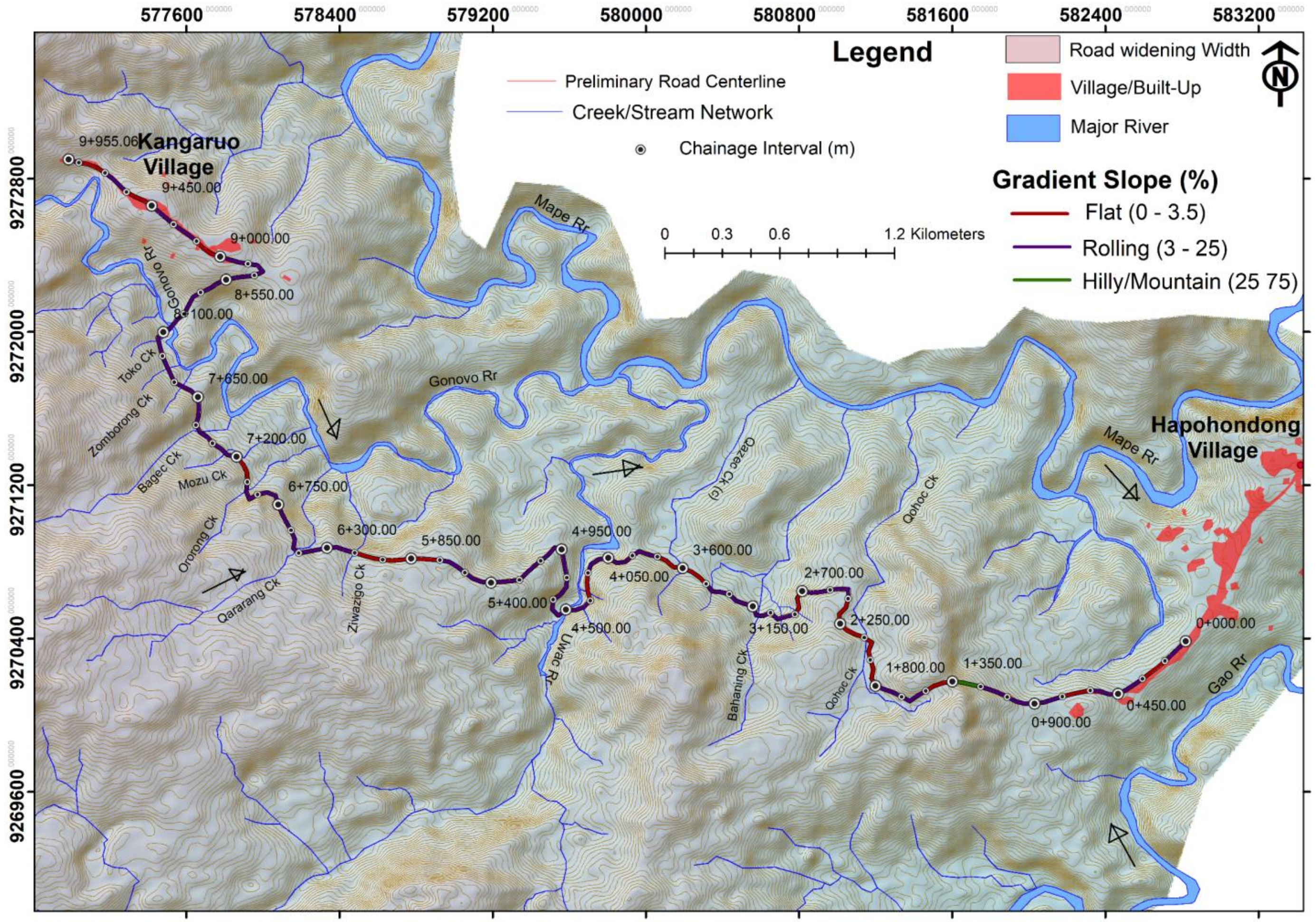


EXSITING ROAD ROUTE

Road Section: Hapo (CH 00+000) – Kangaruo (CH 9+900) Road Inventory

District: Finschhafen



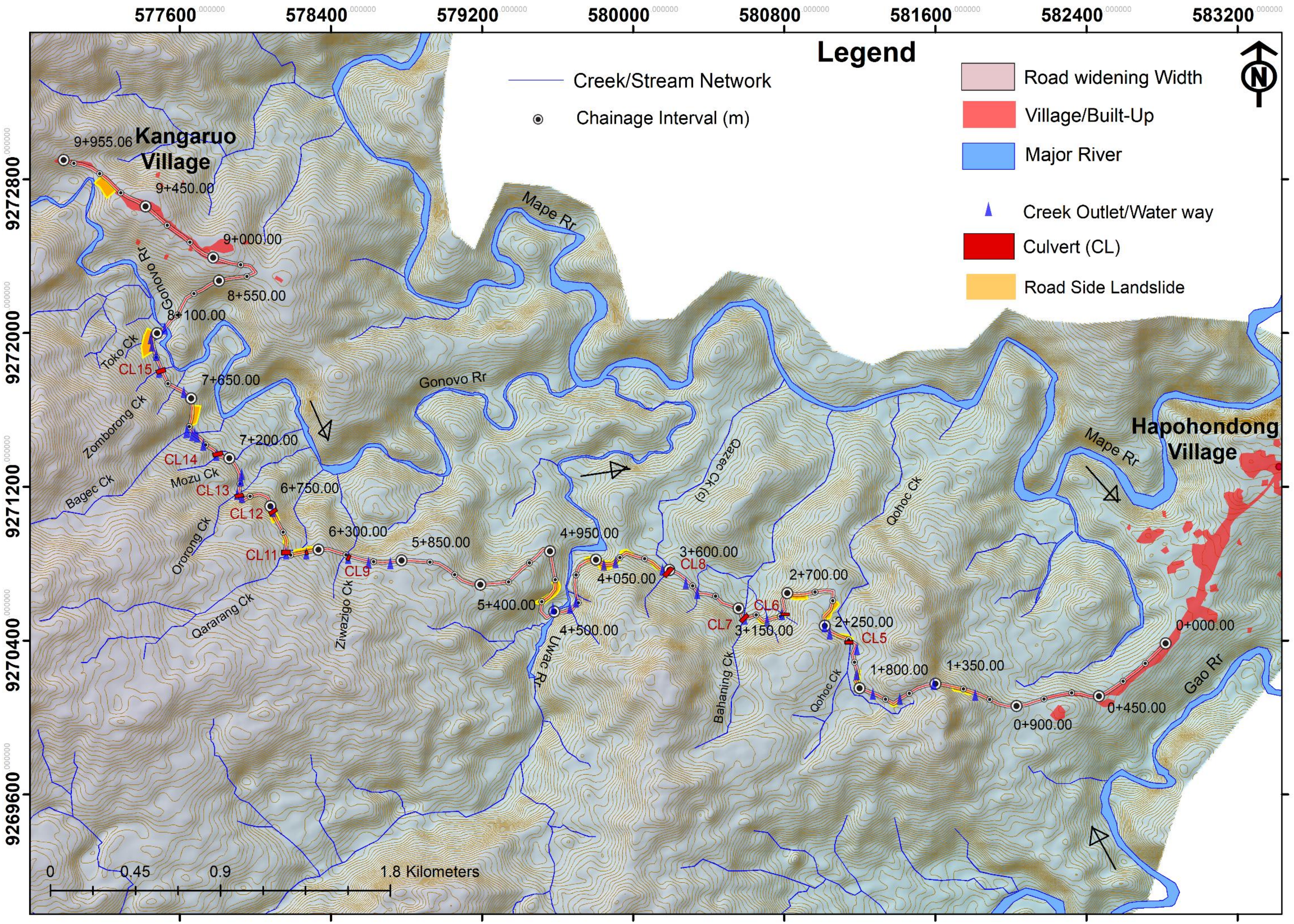


High risk of collapse within shorter period

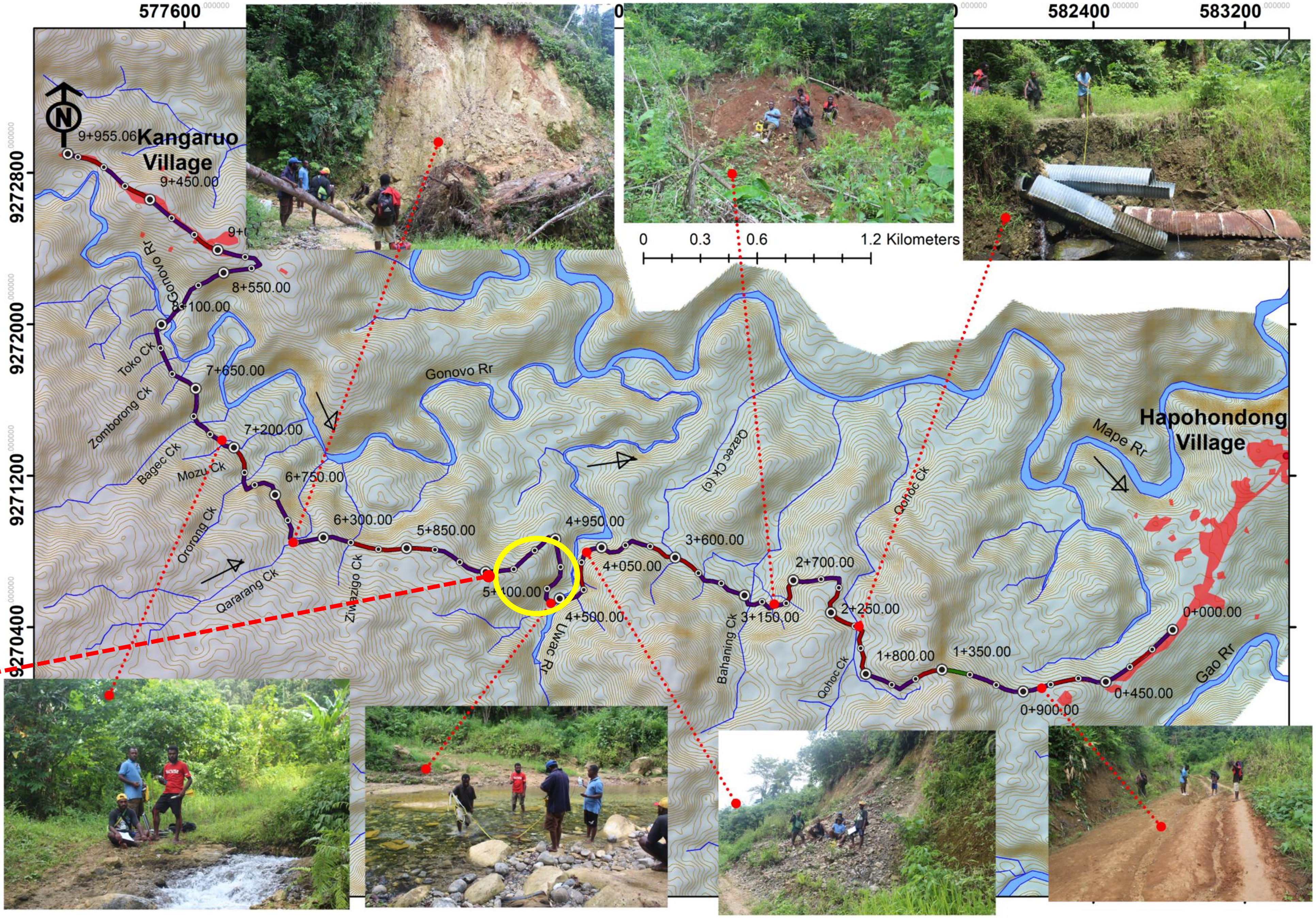
Road Name	Pilot tract	Wide (m)	Total length (m)	Statues/condition	Re-constructed	Chances of deteriorate	Gradient slope	Population Size	Surface type	Site Soil Geology
Mape Highways	1997/1998	Max-10 Minimum – 3	9,900	Deteriorated- (Vehicles either pass or not)	Yes (3 – 4 times	High	Rolling/Flat	27 villages/800 0+	Earth	Calcarite and Clayer red soil

EXISTING ROAD BASELINE DATA

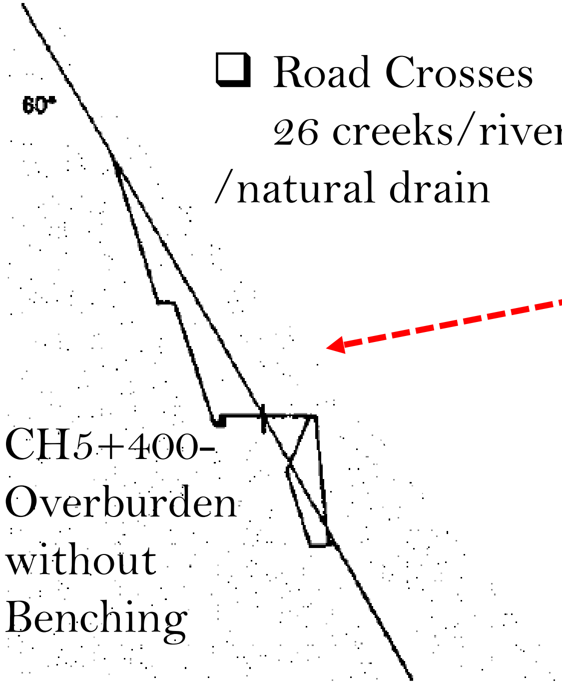
- ✓ Culvert location and Information
- ✓ Road side Landslide
- ✓ Inundation/flood zone
- ✓ River/creek location and Information.
- ✓ Site soli Geology
- ✓ Vulnerable zone of collapse
- ✓ Possible embankment and revetment location



- ❑ Road data collected during field visit.
- ❑ CH 6+300 to CH 8+100 And CH 4+050 to 4+ 500-Unstable road and in high risk of deterioration every after construction.



- ❑ Road Crosses 26 creeks/rivers /natural drain



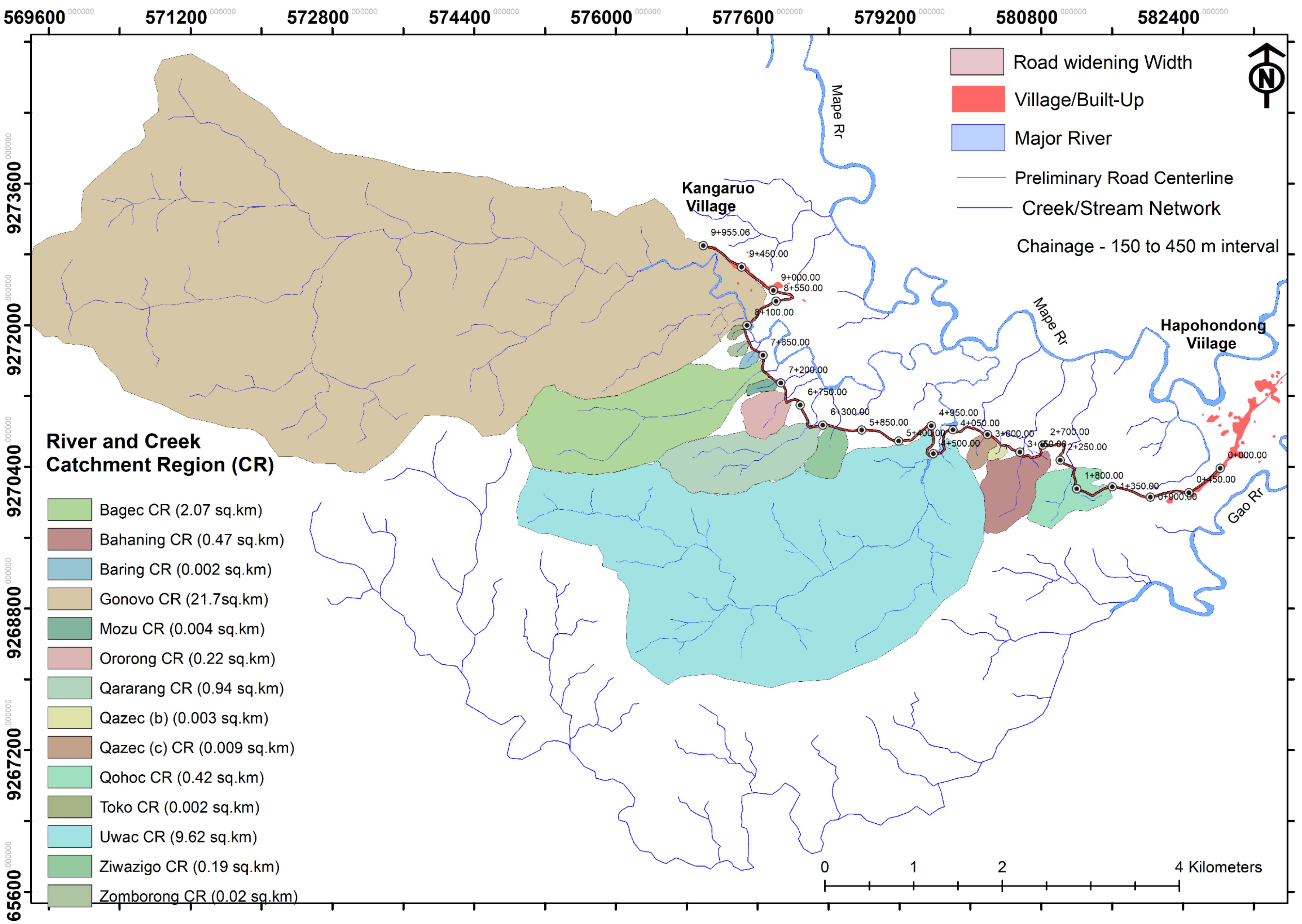
CH5+400- Overburden without Benching

CATCHMENT ALONG EXISTING ROAD

- ❑ Extraction and preparation of hydrological baseline data

- Catchment size and shape
- Rivers and creek
- natural storm water drainage
- Slope/Length
- Discharge (cms)

- ❑ Creating pathways for In-depth Engineering computation



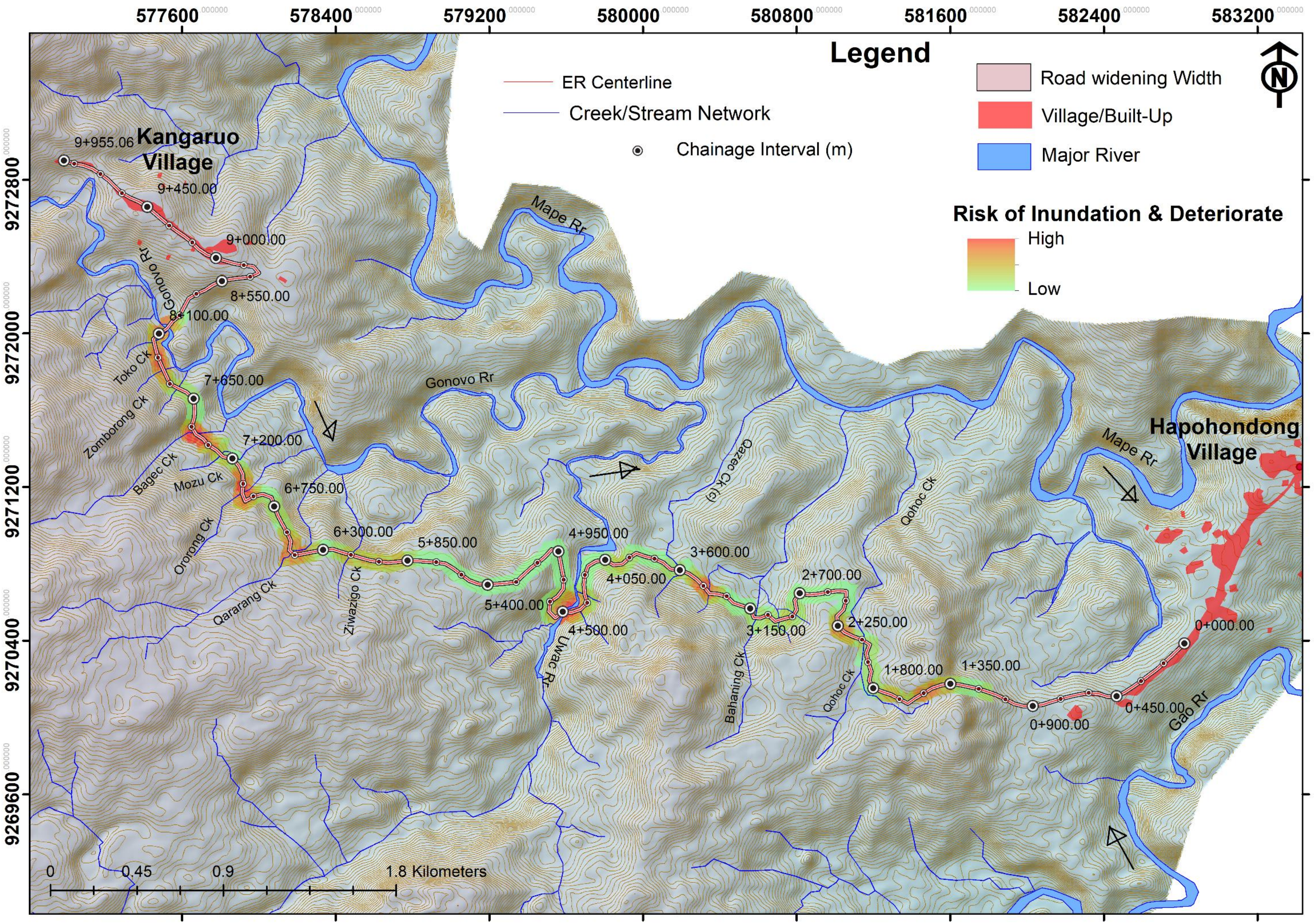
RISK OF INUNDATION/DETERIORATE ALONG EXISTING ROAD

- ❑ Road sections that are at risk of collapes due to surface water.

- ❑ High risk route; CH 6+300 to CH8+100

To protect:

- ✓ Slab culvert with whole structure.
- ✓ Good ambackment with spoilage.
- ✓ Quality drainage



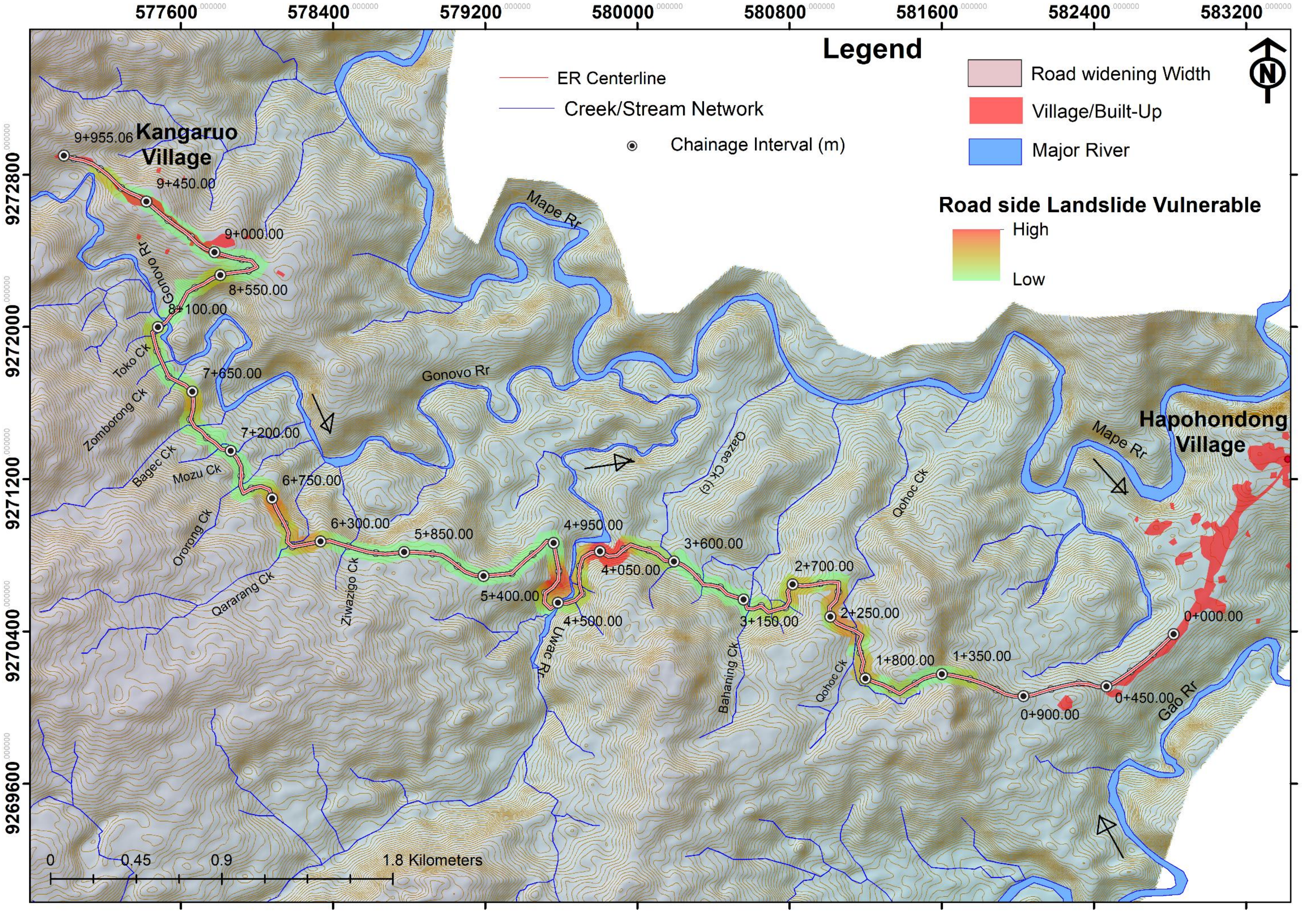
LANDSLIDE VULNERABLE ALONG EXISTING ROAD

Risk of Road side Landslide:

CH4+050 to CH4+350
CH6+300 to CH6+750
2+250

To protect:

✓ Expensive bedding, embankment and revetment required



UPDATING AND KEEPING ROAD INVENTORY

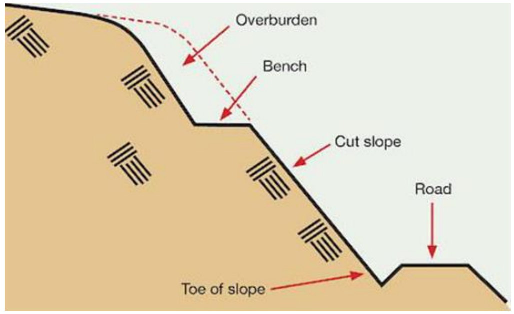
CH/Ref Map	River/Crks	Choice of Bridge/Culvert	Bridge/Culvert Constructed	Catchment area	Wide/Max Flood	Ave. Discharge	Catchment Length	Catchment Slope
4+450 - 4+600	Uwac	Bridge	☒	9.62Sq.km	8.5/40	2.3	4145	10%
8+100 - 8+200	Gonovo	Bridge	☒	21.7Sq.km	30/100	2.5	7700	6%
1+130	Crk1	Culvert/drain	☒	No	1.5/3	No	Steep Falling	Steep Falling
1+405	Crk2	Culvert/drain	☒	No	1.5/3	No	Steep Falling	Steep Falling
1+600	Crk3	Culvert/drain	☒	No	1.5/3	No	Steep Falling	Steep Falling
2+050 -2+100	Qohoc Crk	Culvert	☑	0.42Sq.km	10/16	0.2	664	3%
	Qohoc Crk Culvert Information							
	Culvert Name	*type*	*Length*	*Diameter*	*Structures*	*Condition*	*Recommendation*	
	CL5-Ref. Map	Corrugated Metal Pipe	6	0.8	Wing Wall ☒	Deteriorated	Bridge/Slab Culvert with Whole Structure - 17 meter wide slab, 1.5 – 2m culvert size	
					Head Wall ☒			
					Concrete Apron ☒			
					Scouring ☒			
					Wall Structure ☒			
3+070 – 3+100	Bahaning Crk	Culvert	☑	0.47Sq.km	8/10	No	788	15%
	Bahaning Crk Culvert Information							
	Culvert Name	*type*	*Length*	*Diameter*	*Structures*	*Condition*	*Recommendation*	
	CL7-Ref. Map	Corrugated Metal Pipe	6	0.8	Wing Wall ☒	Deteriorated	Slab Culvert with Whole Structure - 10 meter wide slab, 1.5 – 2m culvert size	
					Head Wall ☒			
					Concrete Apron ☒			
					Scouring ☒			
					Wall Structure ☒			

OPTIMAL ROAD ROUTE ALTERNATIVES

Optimal Route Factors:

✓ Avoiding Steeper Slope

Class	% Slope	Degree Slope	Suitability
Flat	0 - 3	0 - 2	Highly Suitable
Rolling	3 - 25	2 - 14	Suitable
Hilly/Mountainous	25 - 75	14 - 37	Less Suitable
Mountainous/Escarpment	>75	>37	Unsuitable



✓ Cutting road through existing route

✓ Avoid crossing rivers, creek and low lying zones

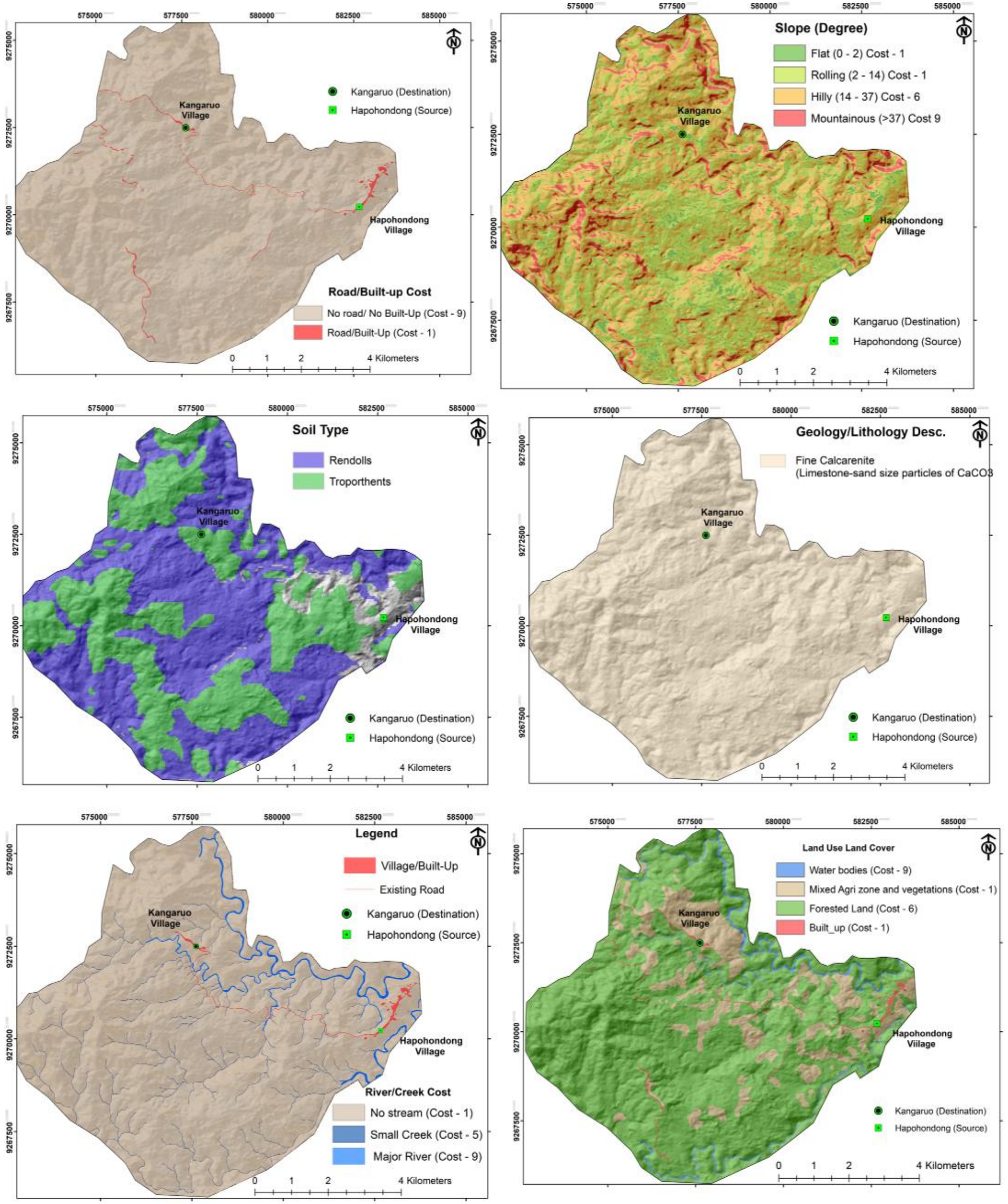
✓ Most dense forest to avoid.

✓ Avoid Restricted land

✓ Minimize areas required for embankment and revetment

✓ Cross section steep cutting to be minimize

✓ Rendolls soil preferred

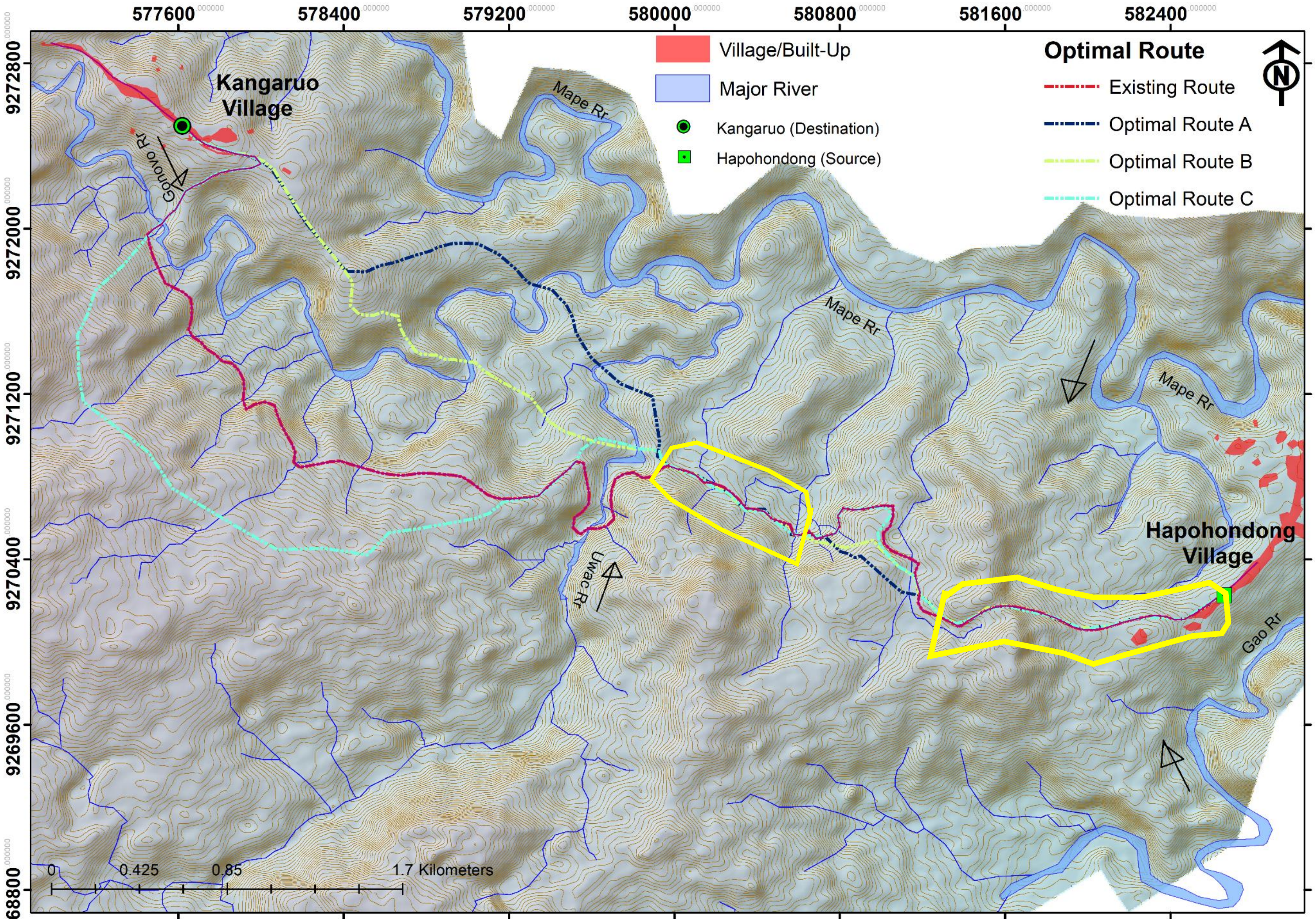


SITE SOIL GEOLOGY

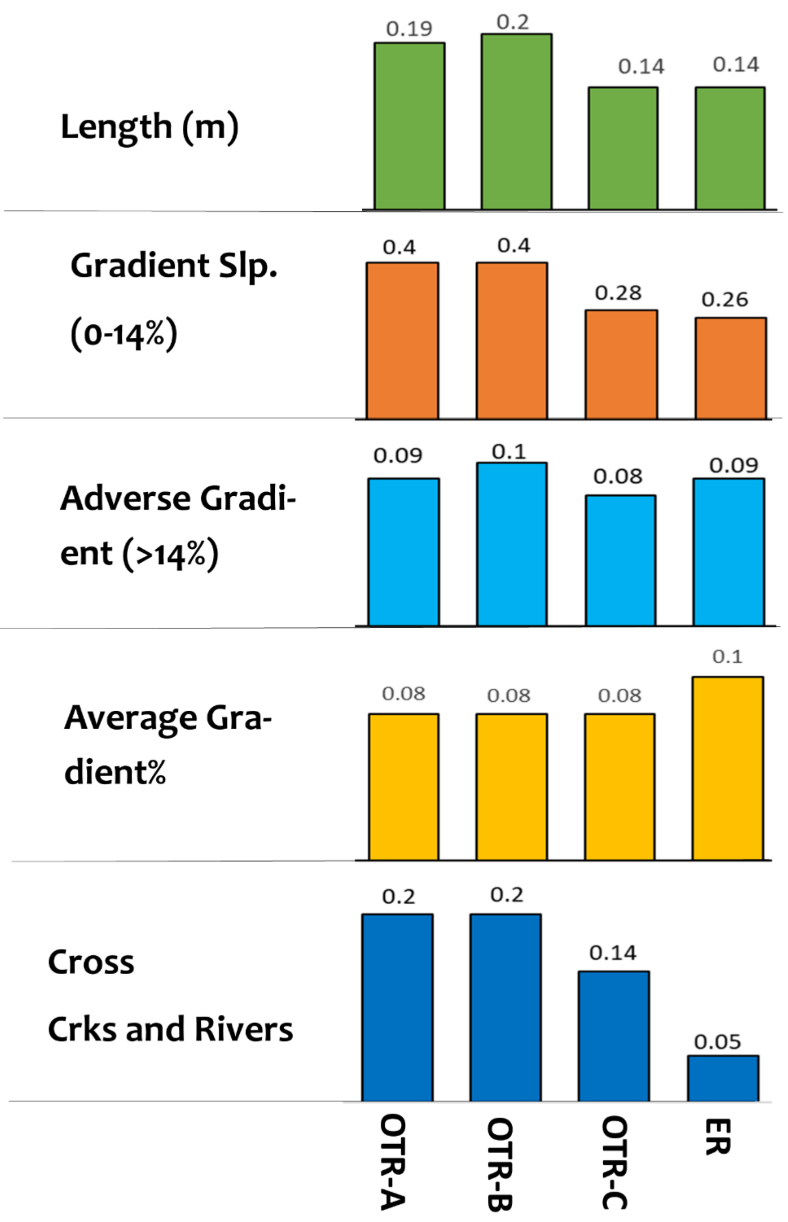
- ❑ **Geology/Lithology Desc.**
- ✓ Geological Formation: Fine Calcarenite (Limestone-sand size particles of $CaCO_3$):
- ✓ Low bearing capacity
- ✓ High susceptible for weathering and erosion
- ❑ **Great Soil Group**
- ✓ Rendolls are lime stone soils
- ✓ Tropothents are high weathered soil – weaker structural properties

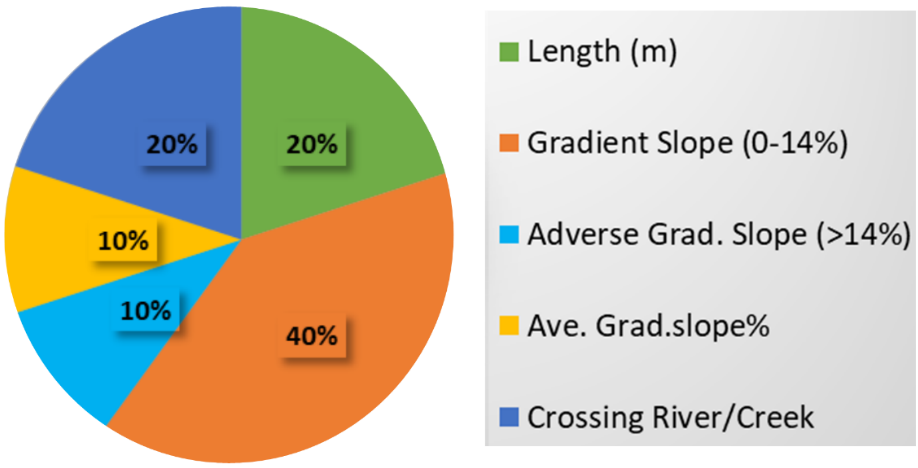
OPTIMAL ROAD ROUTE ALTERNATIVES

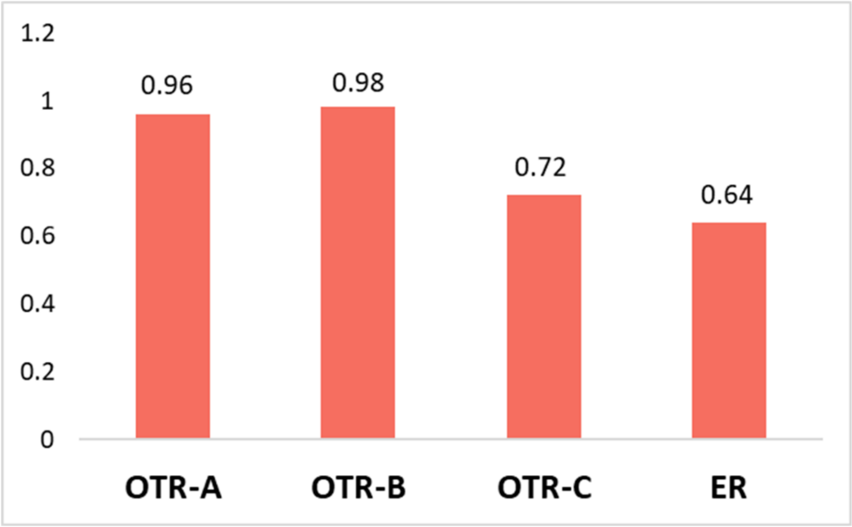
❑ Alternate route Identified.



CRITERIA WEIGHTING

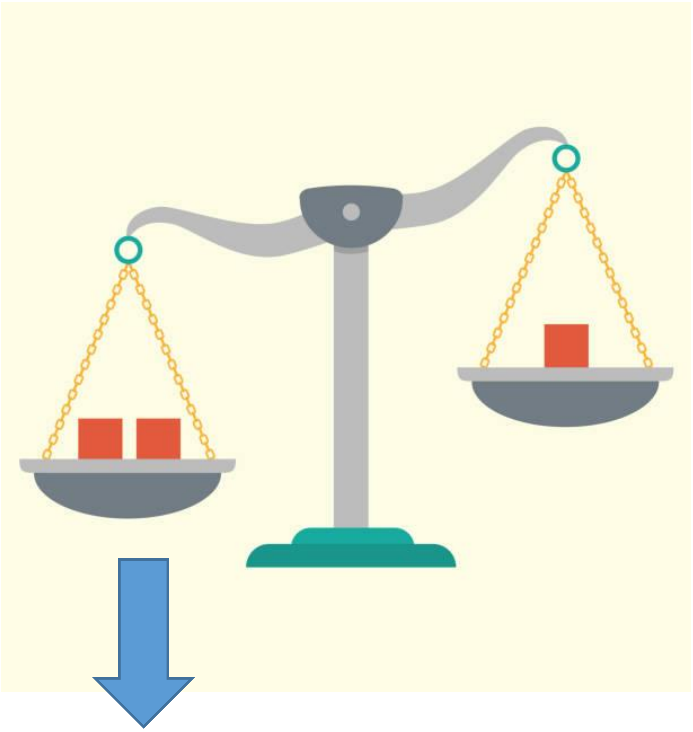






Additional Criteria:

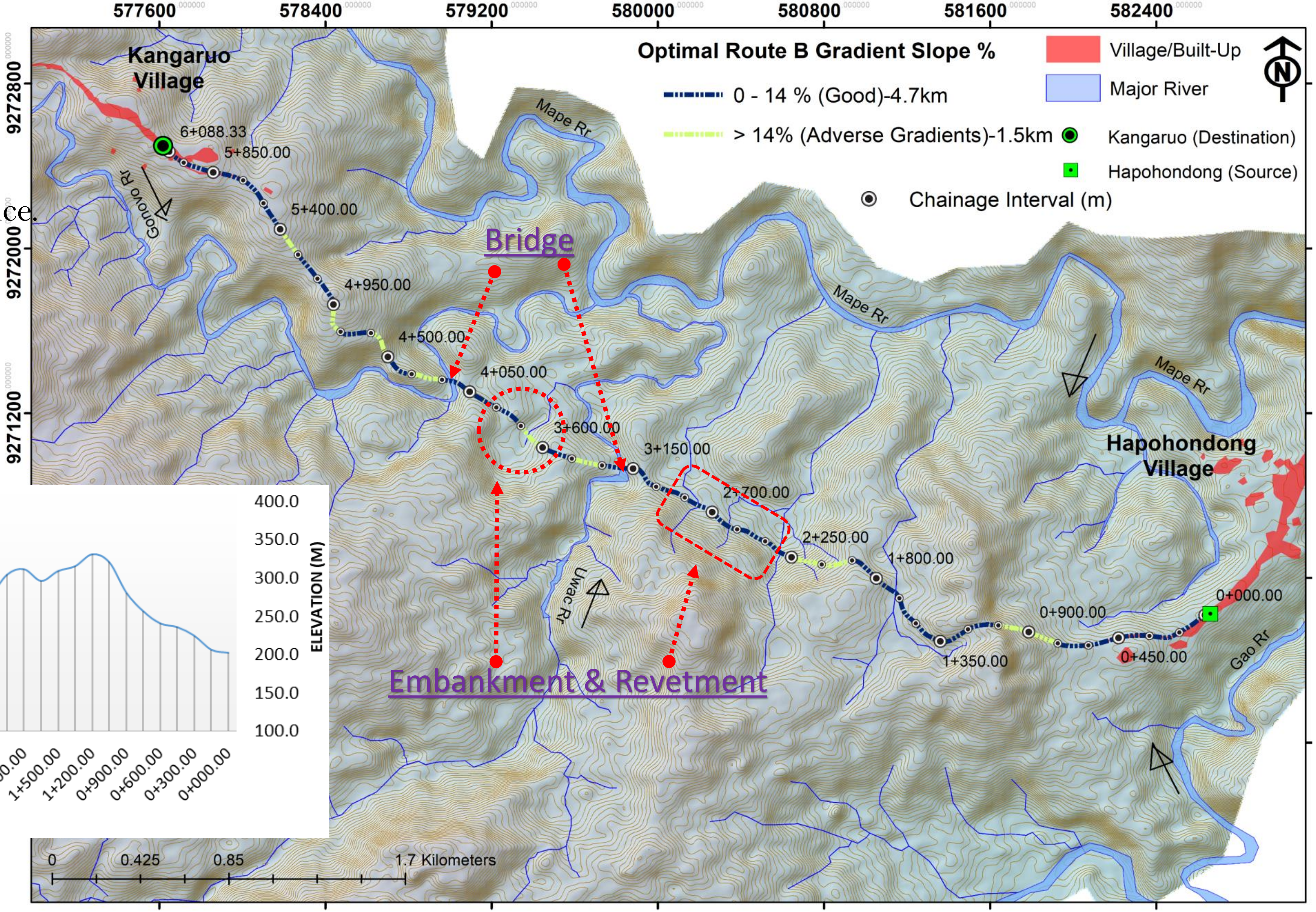
- ✓ Field Observation
- ✓ Communities discussion

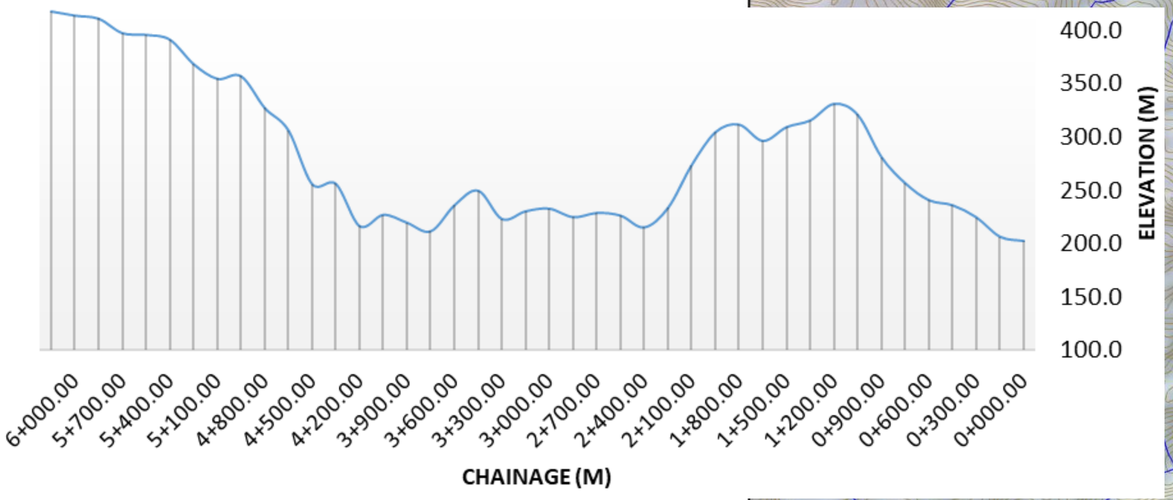


From the weights analysis, the Optimal Route B (OTR-) Weighs the best

OPTIMAL ROUTE B – LEAST COST

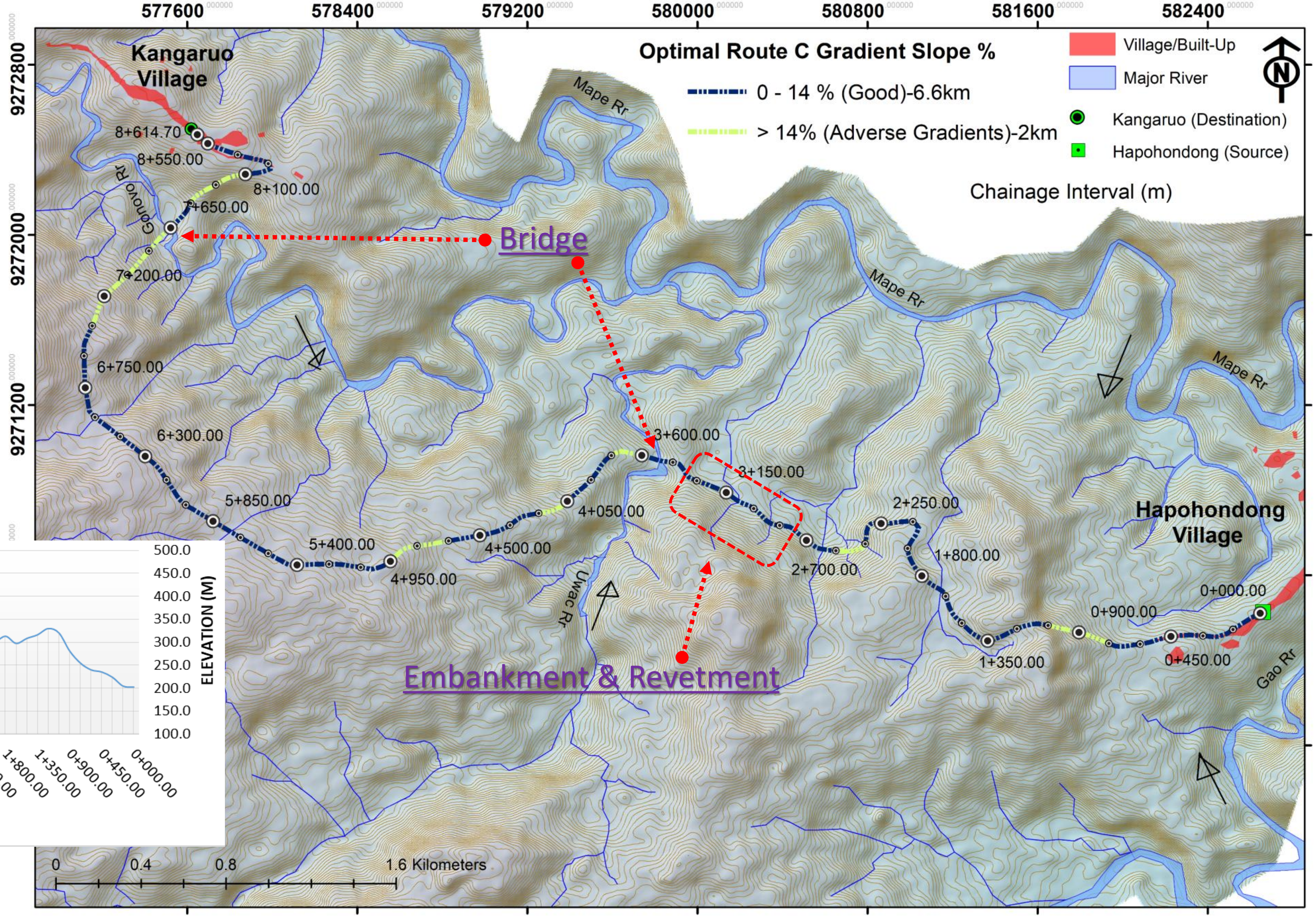
- ❑ Cost Effective route
- ❑ Protected/Restricted areas exist
- ❑ Avoiding areas prone to erosion, flooding, or landslides 40% confidence.

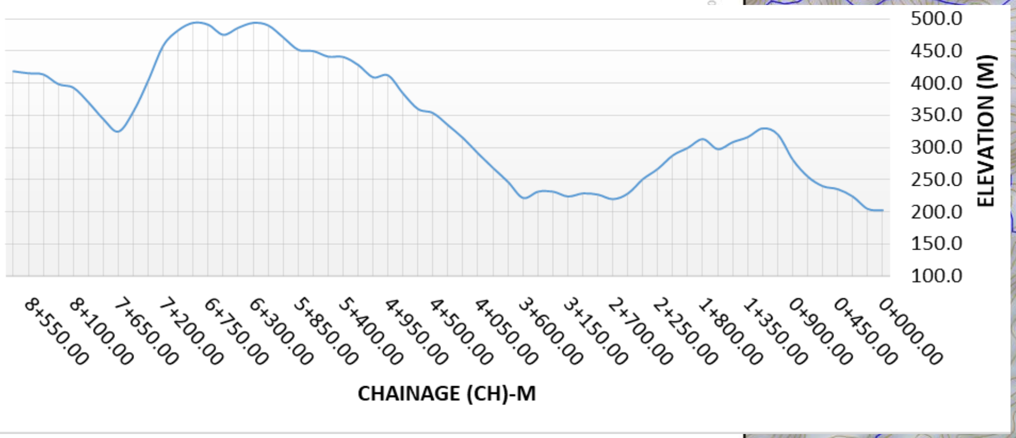




OPTIMAL ROUTE C – CLIMATE RESILIENT

- ❑ Route that is less prone to damage from weather or natural Disasters (60% confidence).
- ❑ Not cost effective
- ❑ No restricted zones





FURTHER REVIEW & ANALYSIS CONTINUES

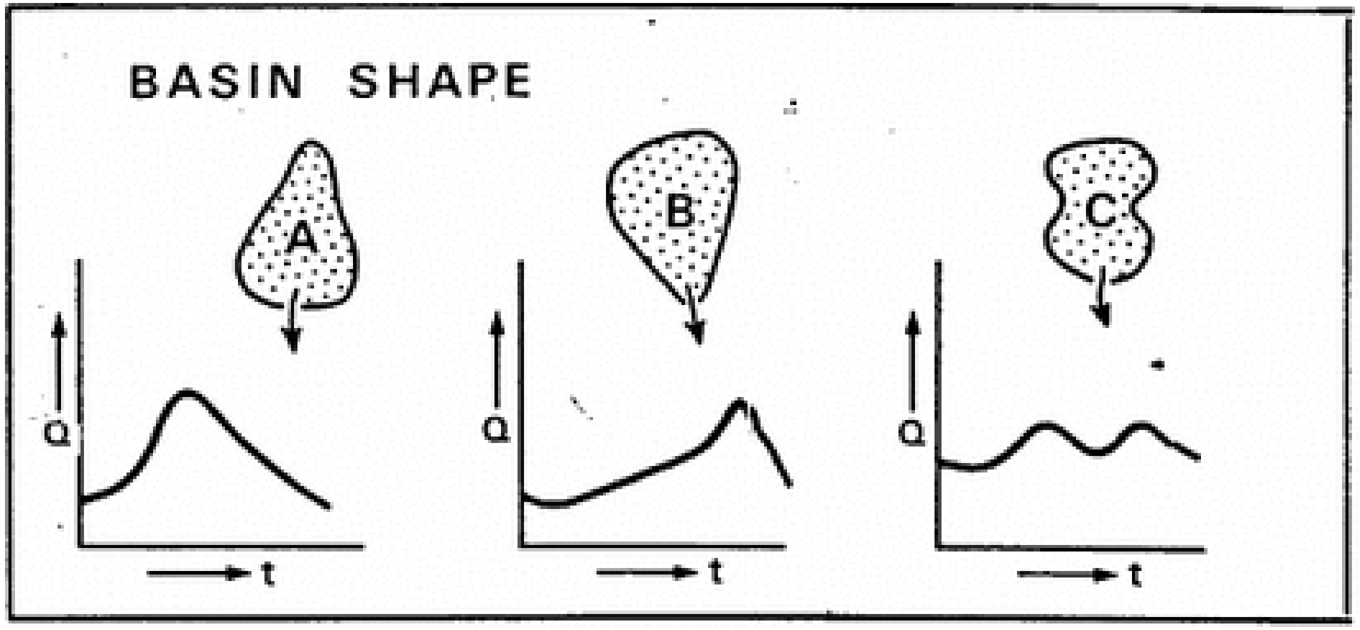
The Optimal Route B & C cited and Proposed:

❑ Investigation, migration into CAD for detail design:

✓ Cut/Fill
✓ Centerline/Road wide (10/20m)
✓ Cross-slope/superelevation/shoulder/road side drainage

❑ Catchment hydrology

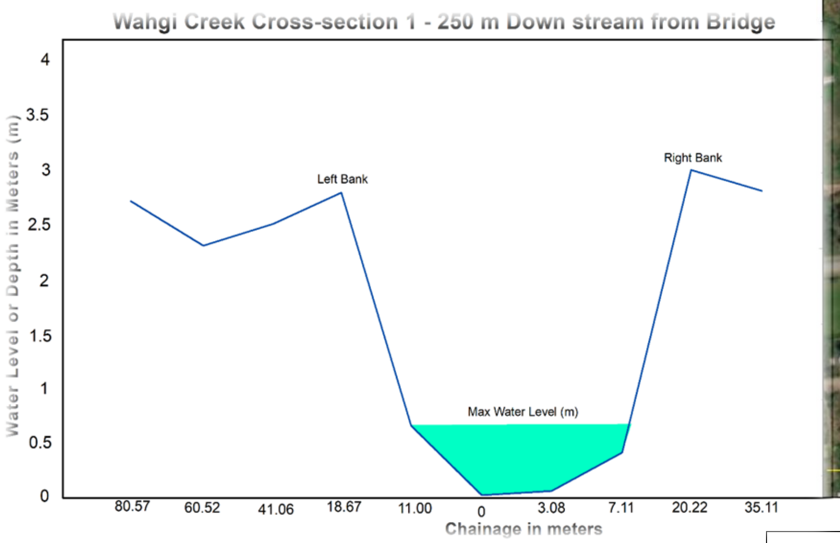
✓ Peak discharge
✓ Rainfall/Flood duration
✓ Drainage Basin/Density/Shape
✓ Site soil Geology

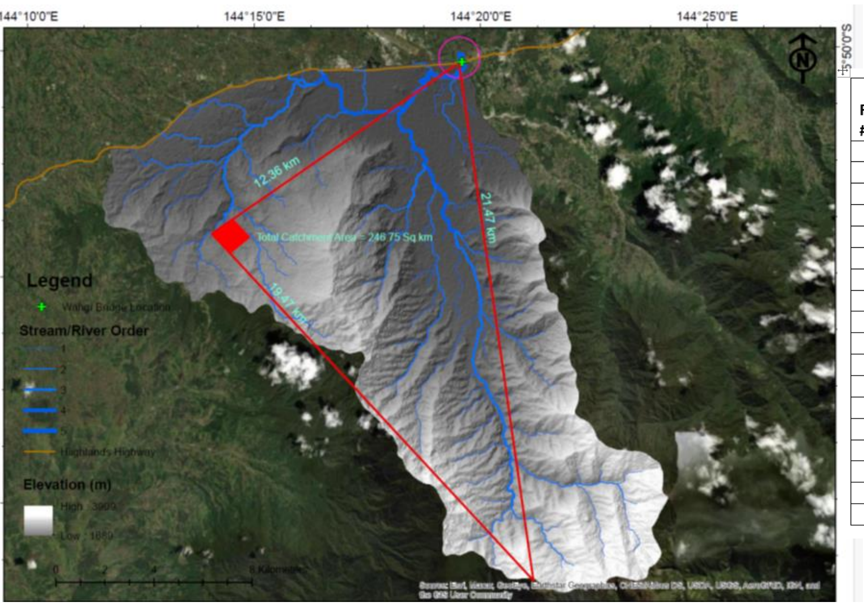


BRIDGE DESIGN WITH HYDROLOGICAL DATA INPUT

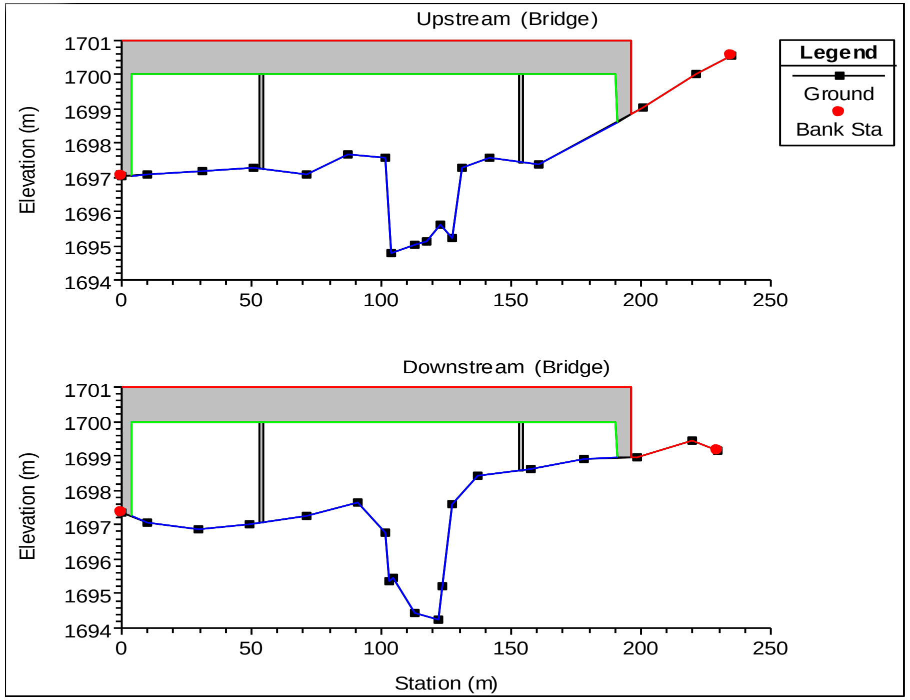
- ❑ Catchment hydrology – Bridges Design

- ✓ Peak discharge
- ✓ Cross section
- ✓ Rainfall/Flood duration
- ✓ HR/Scouring
- ✓ GeoHECRAS – ArcGIS Plugin





Row #	Dist. (m)	RL (m)	WL or Depth (m)	Diff of Distance	Max Water (LW)	Mean Depth	CS Area	Wetted Perimeter (WP)
4	40.39	1698	2.58	16.58				
5	23.81	1698.63	3.21	3.29				
6	20.52	1697.5	2.08	4.39				
7	16.13	1696.5	1.08	3.21				
8	12.92	1698.32	2.9	1.44				
9	11.48	1696.09	0.67	11.48	0.67		3.85	11.50
10	0	1695.42	0	0	0.67		3.03	4.59
11	4.59	1695.44	0.02	4.59	0.67		5.16	7.29
12	11.86	1695.97	0.55	7.27	0.67		0.01	0.18
13	11.99	1696.09	0.67	0.13	0.67			
14	13.71	1697.76	2.34	1.72				
15	23.28	1699.78	4.36	9.57				
16	42.48	1700.2	4.78	19.2				
17								
18	23.47		0.382			0.513	12.04	23.56
19				HR=CA/WP				
20				HR=12.04/23.56				
21	Reduce Level 0 RL=1695.42			HR=0.51				



TAKE AWAY/RECOMMENDATION

- Inland road construction requires careful analysis of site-soil geology, hydrological systems, and topography/slope gradients.
- Integrating geospatial data and tools with engineering practices is essential for effective long-term planning, design, and management of climate-resilient roads.
- Proper measures, such as benching, road basements, revetments, and embankments, should be applied where necessary to ensure stability.
- Periodic maintenance should be supported by an organized inventory database.
- Drainage systems, culverts, and bridges must be designed and constructed based on reliable data.

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THANK YOU

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