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DEPARTMENT OF ROADS

DEVELOPMENT COOPERATION IMPLEMENTATION DIVISION

Strategic Road Connectivity & Trade Improvement Project (SRCTIP)

DETAILED DESIGN OF UPGRADATION OF KAMALA-DHALKEBAR- PATHLAIYA SECTION (130KM) OF MAHENDRA HIGHWAY AND BRIDGES

FINAL DESIGN REPORT

Vol I

Main Report

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ACRONYMS & ABBREVIATIONS

AADT Annual Average Daily Traffic

AC Asphalt Concrete

ACV Aggregate Crushing Value

AIV Aggregate Impact Value

AMSL Average Mean Sea Level

ASL Average Sea level

BBIN Bangladesh, Bhutan, India, Nepal

BC Benefit Cost

BIMSTEC Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation

BoQ Bill of Quantities

BS Bureau of Standard

CAD Computer Aided Design

CALBFAC Speed calibration factor

CBO Community Based Organization

CBR California Bearing Ratio

CBS Central Bureau of Statistics

CFUG Community Forestry Users Group

Ch Chainage

CSB Crushed Stone Base

Cum Cubic Meter

DBM Dense Bituminous Macadam

DBST Double Bituminous Surface Treatment

DCF Discounted Cash Flow

DCP Dynamic Cone Penetration

DEM Digital Elevation Model

DFO District Forest Office

DGPS Differential Global Positioning System

DHM Department of Hydrology and Meteorology

DNPWC Department of National Parks and Wildlife Conservation

DOR Department of Roads (Client/Employer)

DRO	Division Road Office
DTM	Digital Terrain Model
Dwg	Drawing
EA	Environment Assessment
EIRR	Economic Internal Rate of Return
EMP	Environment Management Plan
ESF	Environment Social Framework
ESIA	Environmental and Social Impact Assessment
ESMP	Environmental and Social Management Plan
ESMF	Environmental and Social Management Framework
E-W	East-West Highway
FDR	Final Design Report
FGP	Focus Group Discussion
FI	Flakiness Index
GDP	Gross Domestic Product
GoN	Government of Nepal
GPS	Global Positioning System
GSB	Granular Sub-Base
HDM	Highway Development and Management
HH	House Holds
HMA	Hot Mix Asphalt
IEE	Initial Environmental Examination
IFD	Intensity Frequency Duration
IRR	Internal Rate of Return
ISB	Improved Sub-Base
KDP	Kamala-Dhalkebar-Pathlaiya
LAA	Los Angeles Abrasion test
LCF	Local Consultative Forum
LL	Liquid Limit
MC	Moisture Content
MDD	Modified Dried Density
MoFE	Ministry of Forest and Environment

MSA	Million Standard Axles
NGO	Non-Governmental Organization
NPV	Net Present Value
NSDP	Net State Domestic Product
OD	Origin Destiny
OMC	Optimum Moisture Component
PCC	Plain Cement Concrete
PCI	Per Capita Income
PCU	Passenger Car Unit
PD	Project Directorate
PI	Plasticity Index
PIA	Project Influence Area
PSC	Pre stress Concrete
RCC	Reinforced Cement Concrete
RDA	Roads Development Agency
RL	Reduced Level Project
ROW	Right of Way
RUC	Road User Costs
SAFTA	South Asian Free Trade Area
SCF	Standard Conversion Factor
SRN	Strategic Road Network
TOR	Terms of Reference
VAT	Value Added Tax
WB	World Bank
WMM	Wet Mix Macadam

EXECUTIVE SUMMARY

1. Brief Project Background

The Project Road named as Kamala- Dhalkebar- Pathlaiya section (130 km) of Mahendra Highway was constructed in two stages. The Kamala – Dhalkebar section was constructed with the assistance of Government of India and Dhalkebar – Pathlaiya section was constructed with the assistance from then USSR. Later in 1990's both of these sections were upgraded to two lane standards. The existing bridges of Kamala- Dhalkebar section are provided with two lane standard while, the bridges of Dhalkebar -Pathlaiya section are provided with intermediate lane (5.5 m width) standard and as a result the bridges are now bottlenecks to the traffic. The passenger and freight traffic have been increasing in this highway as a result of trade enhancement due to regional trade agreements such as BIMSTEC, SAFT A, BBIN etc. Further enhancement of trade among the member countries and increasing traffic volume requires an upgrade of this road section

In order to enhance road capacity and efficiency in the road transport, Government of Nepal, Department of Roads (DoR) decided to upgrade the Kamala- Dhalkebar- Pathlaiya Section (KDP), 130 Kms of Mahendra Highway. For the detailed design of Upgradation of Project Road Kamala - Dhalkebar – Pathalaiya Section (130 Km) of Mahendra Highway and 76 Bridges in this section, the Department of Roads (DOR), Development Cooperation and Implementation Branch has awarded a contract under the Strategic Road Connectivity & Trade Improvement Project (SRCTIP) to the joint venture of M/S Eptisa Servicious de Ingeniera and Stup Consultants Private Limited, Madrid Spain in Association as Sub-Consultant with Udaya Consultancy, Geocom International, Sundar Kriti Consultant and Rays Consultant Private Limited. This Project is being financed jointly by the Government of Nepal, Department of Roads and one of the major development partners of the country, the World Bank.

2. Design Standards

The detailed design for upgradation of existing Kamala – Dhalkebar – Pathliaya road to four lane divided road has been carried out considering following codes mainly;

- Nepal Road Standard 2070 (Second Revision-2070)
- IRC:73-1990 “Geometric Design Standards for Rural Highways”
- IRC: SP-84-2019 “Manual of Specifications and Standards for Four Laning of Highways (Second Revision)”

- Nepal Road Design Standards (NRS) 2027 (First Revision-2045)

Also, the design standards for detailed design are adopted considering future growth of traffic, comfort and safety for the road users as well as settlements along the project road.

3. Survey and Investigations

The consultants are engaged for detailed design assignment by the Client. The Consultant have carried out detailed road inventory, condition survey of the existing road, structures, bridges, pavement investigation, drainage capacity assessment and adequacy of existing structures. The Consultant also carried out topographic survey including collection of National Trig. Control Point and National Benchmark from the Department of Surveys (DoS), establishing Control Pillars at every 500m along the alignment, Control survey using DGPS, Traversing, collection of existing features with in Right of Way, levelling to capture existing ground data etc. The Consultant also carried out hydrographical survey for each river bridge, culvert and causeway location, Geotechnical Investigation of Subsoil for the road and bridges; soil and materials investigation including sample collection and testing; road safety audits; collection of secondary data and reports from different sources, etc. The Consultant also carried out Traffic surveys including Continuous Classified Volume Count, Junction Survey, Speed-Delay survey, Axle load survey, Origin-Destination survey at selected stations on the project road.

4. Geology and geotechnical solution

The field study as well as field and laboratory tests as per IS provision were performed for the geotechnical properties of soil along the Kamala – Dhalkebar- Pathlaiya road alignment. The dynamic cone penetration (DCP) tests were performed on the in-situ soil at project site. The laboratory tests were performed for the classification of the sub-grade soil and to determine the optimum moisture content. The results reveal that, most part of the road is aligned through the alluvial river deposits consisting of sand, silt, clay and gravels. The results of the Dynamic Cone Penetration Test show that CBR varies from 2% to 19%.

From the grain size distribution, it is noted that the fractions of brownish colour sand, silt and clay is dominant of low plastic nature and in some stretches; gravels are also intruded in the soil of sub grade level. No landslide and erosion were observed as the road traverses through plain terrain inTerai. However, the problem of floods at the sections nearby to the rivers is prominent.

The entire Project Area is located in Terai region of Nepal where, there is no sloping ground of height more than 2 m, or the entire road is in embankment of average 1.50 m height within

the right of way. Therefore, detailed slope stability analysis for cut slopes for sloping areas/hills and filled slopes for the embankment is not been carried out.

5. Material Investigation

The material survey was conducted to find out the potential sources of construction materials mainly sand and aggregates. Most of thesources are located in the vicinity of the project road. Along the road, the materials are available from Kamala Khola, Ratu Khola, Banke Khola, Maraha Khola, Lakhandehi Khola, Bagmati Khola, Chandi Khola, Lamaha Khola, Dhansar Khola, Bakeiya Khaola and Rapti Khola. The survey for sources of potential materials mostly concentrated for construction materials for base course, sub-base, boulders sand and concrete aggregates to be used in the proposed road construction works. The samples were collected from the excavated trial pits in sufficient quantities, labeled and transported to the laboratory based at Kathmandu. The extent of depths of deposits was also measured during material survey. Based upon the area and the depth of deposits, quantities of material were estimated for each quarry site.

6. Geometric Design

For the Upgrading of the Kamala – Dhalkebar – Pathlaiya road section to four lane divided road, the geometric design standards for plane and rolling section has been adopted as Class II as per NRS 2070. Accordingly, the geometric design standard for design has been followed that for the Class II road as under NRS 2070. Reference of IRC codes, specially IRC SP 84 2019 Manual for Four Laning of National Highway has been made as and when required. For Traffic sign and road marking design, DoR Traffic Manual 2007 has been mainly followed. The design speed of road for plain and rolling section has been adopted as 100 km /hour.

Considering prevailing geometry, land use and proposal for upgradation, the Consultant have adopted total 9 type of Typical Cross Sections for carrying out detailed design. The Consultant have considered and Urban and Semi Urban sections for preparing separate typical cross sections for both type of settlements along the Project Road. The Consultant have prepared schedule of Cross Section w.r.t. final design for entire length of the project road. The Cross Section Schedule is presented vide Table below:

Cross Section Schedule

Sl No	Design Chainage (m)		Length (m)	Cross Section Type / Other Details
	From	To		
1	236+500	236+702	202	Transition Portion
2	236+702	237+342	640	Kamala Bridge
3	237+342	237+500	158	Type-2
4	237+500	237+930	430	Type-2

Sl No	Design Chainage (m)		Length (m)	Cross Section Type / Other Details
	From	To		
5	237+930	238+080	150	Transition Portion
6	238+080	238+125	45	Kamala Canal
7	238+125	238+290	165	Transition Portion
8	238+290	239+280	990	Type-1
9	239+280	239+400	120	Transition Portion
10	239+400	239+900	500	Type-5
11	239+900	240+020	120	Transition Portion
12	240+020	241+430	1410	Type-1
13	241+430	241+584	154	Transition Portion
14	241+584	241+905	321	Charnath Bridge
15	241+905	242+060	155	Transition Portion
16	242+060	242+880	820	Type-1
17	242+880	243+000	120	Transition Portion
18	243+000	243+100	100	Type-5
19	243+100	243+396	296	Type-7
20	243+396	243+404	8	Type-8
21	243+404	243+630	226	Type-7
22	243+630	243+650	20	Type-9
23	243+650	243+836	186	Type-7
24	243+836	243+844	8	Type-8
25	243+844	244+100	256	Type-7
26	244+100	244+220	120	Transition Portion
27	244+220	245+020	800	Type-1
28	245+020	245+172	152	Transition Portion
29	245+172	245+284	112	Baluwa Bridge
30	245+284	245+440	156	Transition Portion
31	245+440	247+380	1940	Type-1
32	247+380	247+500	120	Transition Portion
33	247+500	247+800	300	Type-5
34	247+800	247+920	120	Transition Portion
35	247+920	250+600	2680	Type-1
36	250+600	250+751	151	Transition Portion
37	250+751	250+771	20	Jagdev Branch Bridge
38	250+771	251+068	297	Transition Portion
39	251+068	251+121	53	Jagadev Bridge
40	251+121	251+295	174	Transition Portion
41	251+295	252+195	900	Type-1
42	252+195	252+347	152	Transition Portion
43	252+347	252+613	266	Jalad Bridge
44	252+613	252+770	157	Transition Portion
45	252+770	254+350	1580	Type-1
46	254+350	254+503	153	Transition Portion
47	254+503	254+822	319	Aurahi Bridge
48	254+822	254+980	158	Transition Portion
49	254+980	255+985	1005	Type-1
50	255+985	256+138	153	Transition Portion
51	256+138	256+234	96	Basai Bridge
52	256+234	256+440	206	Transition Portion
53	256+440	258+300	1860	Type-5

Sl No	Design Chainage (m)		Length (m)	Cross Section Type / Other Details
	From	To		
54	258+300	258+420	120	Transition Portion
55	258+420	258+565	145	Type-1
56	258+565	258+712	147	Transition Portion
57	258+712	258+756	44	Sukhajor Bridge
58	258+756	258+910	154	Transition Portion
59	258+910	260+740	1830	Type-1
60	260+740	260+887	147	Transition Portion
61	260+887	260+962	75	Barahari Bridge
62	260+962	261+110	148	Transition Portion
63	261+110	265+090	3980	Type-1
64	265+090	265+229	139	Transition Portion
65	265+229	265+455	226	Ratu Bridge
66	265+455	265+595	140	Transition Portion
67	265+595	266+280	685	Type-1
68	266+280	266+400	120	Transition Portion
69	266+400	268+100	1700	Type-5
70	268+100	268+278	178	Transition Portion
71	268+278	268+353	75	Bhapsi Bridge
72	268+353	268+485	132	Transition Portion
73	268+485	269+210	725	Type-1
74	269+210	269+360	150	Transition Portion
75	269+360	269+389	29	Atabbe Bridge
76	269+389	269+540	151	Transition Portion
77	269+540	270+680	1140	Type-1
78	270+680	270+810	130	Transition Portion
79	270+810	270+935	125	Jangapul-1 Bridge
80	270+935	271+060	125	Transition Portion
81	271+060	271+330	270	Type-1
82	271+330	271+477	147	Transition Portion
83	271+477	271+552	75	Gadhanta Bridge
84	271+552	271+690	138	Transition Portion
85	271+690	274+760	3070	Type-1
86	274+760	274+904	144	Transition Portion
87	274+904	274+944	40	Belgachhi Bridge
88	274+944	275+090	146	Transition Portion
89	275+090	275+470	380	Type-1
90	275+470	275+621	151	Transition Portion
91	275+621	275+641	20	Tuteswor-1 Bridge
92	275+641	275+847	206	Transition Portion
93	275+847	275+867	20	Tuteswor-2 Bridge
94	275+867	276+015	148	Transition Portion
95	276+015	277+050	1035	Type-1
96	277+050	277+201	151	Transition Portion
97	277+201	277+378	177	Maraha Bridge
98	277+378	277+510	132	Transition Portion
99	277+510	278+750	1240	Type-1
100	278+750	278+895	145	Transition Portion
101	278+895	278+933	38	Dholan Bridge
102	278+933	279+085	152	Transition Portion

Sl No	Design Chainage (m)		Length (m)	Cross Section Type / Other Details
	From	To		
103	279+085	280+425	1340	Type-1
104	280+425	280+566	141	Transition Portion
105	280+566	280+586	20	Jarlahi Bridge
106	280+586	280+735	149	Transition Portion
107	280+735	281+825	1090	Type-1
108	281+825	281+975	150	Transition Portion
109	281+975	282+004	29	Batuwa Brdige
110	282+004	282+155	151	Transition Portion
111	282+155	282+560	405	Type-1
112	282+560	282+709	149	Transition Portion
113	282+709	282+811	102	Bhankhe Bridge
114	282+811	282+960	149	Transition Portion
115	282+960	285+565	2605	Type-1
116	285+565	285+712	147	Transition Portion
117	285+712	285+737	25	Amuwa Bridge
118	285+737	285+890	153	Transition Portion
119	285+890	290+030	4140	Type-1
120	290+030	290+150	120	Transition Portion
121	290+150	290+275	125	Phuljor Bridge
122	290+275	290+415	140	Transition Portion
123	290+415	291+705	1290	Type-5
124	291+705	291+855	150	Transition Portion
125	291+855	291+884	29	Kalinjor-1 Bridge
126	291+884	292+035	151	Transition Portion
127	292+035	292+520	485	Type-1
128	292+520	292+671	151	Transition Portion
129	292+671	292+737	66	Kalinjor-2 Bridge
130	292+737	292+890	153	Transition Portion
131	292+890	294+030	1140	Type-1
132	294+030	294+150	120	Transition Portion
133	294+150	294+360	210	Type-5
134	294+360	294+556	196	Type-7
135	294+556	294+564	8	Type-8
136	294+564	294+890	326	Type-7
137	294+890	294+910	20	Type-9
138	294+910	295+066	156	Type-7
139	295+066	295+074	8	Type-8
140	295+074	295+250	176	Type-7
141	295+250	295+350	100	Transition Portion
142	295+350	295+375	25	Dumdume Bridge
143	295+375	295+550	175	Transition Portion
144	295+550	296+300	750	Type-5
145	296+300	296+420	120	Transition Portion
146	296+420	298+980	2560	Type-1
147	298+980	299+100	120	Transition Portion
148	299+100	299+316	216	Type-7
149	299+316	299+324	8	Type-8
150	299+324	299+540	216	Type-7
151	299+540	299+560	20	Type-9

Sl No	Design Chainage (m)		Length (m)	Cross Section Type / Other Details
	From	To		
152	299+560	299+816	256	Type-7
153	299+816	299+824	8	Type-8
154	299+824	300+050	226	Type-7
155	300+050	300+170	120	Transition Portion
156	300+170	300+220	50	Type-1
157	300+220	300+365	145	Transition Portion
158	300+365	300+569	204	Lakhandei Bridge
159	300+569	300+720	151	Transition Portion
160	300+720	301+760	1040	Type-1
161	301+760	301+912	152	Transition Portion
162	301+912	302+022	110	Chapani Bridge
163	302+022	302+170	148	Transition Portion
164	302+170	303+480	1310	Type-1
165	303+480	303+600	120	Transition Portion
166	303+600	303+780	180	Type-5
167	303+780	303+986	206	Type-7
168	303+986	303+994	8	Type-8
169	303+994	304+180	186	Type-7
170	304+180	304+200	20	Type-9
171	304+200	304+386	186	Type-7
172	304+386	304+394	8	Type-8
173	304+394	304+600	206	Type-7
174	304+600	304+800	200	Type-5
175	304+800	304+920	120	Transition Portion
176	304+920	306+480	1560	Type-1
177	306+480	306+600	120	Transition Portion
178	306+600	306+876	276	Type-7
179	306+876	306+884	8	Type-8
180	306+884	307+040	156	Type-7
181	307+040	307+060	20	Type-9
182	307+060	307+296	236	Type-7
183	307+296	307+304	8	Type-8
184	307+304	307+500	196	Type-7
185	307+500	307+732	232	Transition Portion
186	307+732	307+770	38	Rai Bridge
187	307+770	307+920	150	Transition Portion
188	307+920	309+845	1925	Type-1
189	309+845	309+995	150	Transition Portion
190	309+995	310+035	40	Dumajor Bridge
191	310+035	310+185	150	Transition Portion
192	310+185	311+430	1245	Type-1
193	311+430	311+575	145	Transition Portion
194	311+575	311+595	20	Godari Bridge
195	311+595	311+850	255	Transition Portion
196	311+850	312+300	450	Type-5
197	312+300	312+455	155	Transition Portion
198	312+455	312+480	25	Bhagmati East Bridge
199	312+480	312+625	145	Transition Portion
200	312+625	312+785	160	Type-5

Sl No	Design Chainage (m)		Length (m)	Cross Section Type / Other Details
	From	To		
201	312+785	312+936	151	Transition Portion
202	312+936	313+299	363	Bhagmati Bridge
203	313+299	313+450	151	Transition Portion
204	313+450	313+650	200	Type-5
205	313+650	313+801	151	Transition Portion
206	313+801	313+826	25	Bhagmati West Bridge
207	313+826	314+138	312	Transition Portion
208	314+138	314+173	35	Gairi Bridge
209	314+173	314+330	157	Transition Portion
210	314+330	317+500	3170	Type-1
211	317+500	317+653	153	Transition Portion
212	317+653	317+719	66	Paurai Bridge
213	317+719	317+870	151	Transition Portion
214	317+870	319+170	1300	Type-1
215	319+170	319+322	152	Transition Portion
216	319+322	319+342	20	Lachkan Bridge
217	319+342	319+500	158	Transition Portion
218	319+500	323+405	3905	Type-1
219	323+405	323+565	160	Transition Portion
220	323+565	323+590	25	Katha ko pul Bridge
221	323+590	323+750	160	Transition Portion
222	323+750	324+820	1070	Type-1
223	324+820	324+970	150	Transition Portion
224	324+970	325+135	165	Chandi Bridge
225	325+135	325+350	215	Transition Portion
226	325+350	327+300	1950	Type-5
227	327+300	327+420	120	Transition Portion
228	327+420	327+845	425	Type-1
229	327+845	327+995	150	Transition Portion
230	327+995	328+015	20	Jungle Tole Bridge
231	328+015	328+165	150	Transition Portion
232	328+165	329+580	1415	Type-1
233	329+580	329+726	146	Transition Portion
234	329+726	329+751	25	Amu-1 Bridge
235	329+751	329+900	149	Transition Portion
236	329+900	332+630	2730	Type-1
237	332+630	332+782	152	Transition Portion
238	332+782	332+812	30	Kathi Bridge
239	332+812	332+970	158	Transition Portion
240	332+970	333+540	570	Type-1
241	333+540	333+688	148	Transition Portion
242	333+688	333+754	66	Lamaha Bridge
243	333+754	333+900	146	Transition Portion
244	333+900	334+290	390	Type-1
245	334+290	334+443	153	Transition Portion
246	334+443	334+476	33	Kali khola
247	334+476	334+630	154	Transition Portion
248	334+630	339+090	4460	Type-1
249	339+090	339+242	152	Type-3

Sl No	Design Chainage (m)		Length (m)	Cross Section Type / Other Details
	From	To		
250	339+242	339+406	164	Dhansar Bridge
251	339+406	339+560	154	Type-3
252	339+560	342+080	2520	Type-1
253	342+080	342+238	158	Transition Portion
254	342+238	342+263	25	Lamopul
255	342+263	342+420	157	Transition Portion
256	342+420	343+400	980	Type-1
257	343+400	343+550	150	Transition Portion
258	343+550	343+583	33	Bhamara Bridge
259	343+583	343+735	152	Transition Portion
260	343+735	343+920	185	Type-1
261	343+920	344+068	148	Transition Portion
262	344+068	344+088	20	Rampul Bridge
263	344+088	344+250	162	Transition Portion
264	344+250	345+700	1450	Type-5
265	345+700	346+800	1100	Type-6
266	346+800	347+012	212	Transition Portion
267	347+012	347+367	355	Bakeya Bridge
268	347+367	347+520	153	Transition Portion
269	347+520	348+750	1230	Type-1
270	348+750	348+870	120	Transition Portion
271	348+870	348+958	88	Type-5
272	348+958	348+993	35	Unasi Bridge
273	348+993	349+060	67	Type-5
274	349+060	349+180	120	Transition Portion
275	349+180	353+430	4250	Type-1
276	353+430	353+590	160	Transition Portion
277	353+590	353+625	35	Terhakilo Bridge
278	353+625	353+780	155	Transition Portion
279	353+780	354+470	690	Type-1
280	354+470	354+620	150	Transition Portion
281	354+620	354+655	35	Barahakilo Bridge
282	354+655	354+810	155	Transition Portion
283	354+810	356+975	2165	Type-1
284	356+975	357+124	149	Transition Portion
285	357+124	357+289	165	Pasaha Bridge
286	357+289	357+440	151	Transition Portion
287	357+440	358+290	850	Type-1
288	358+290	358+440	150	Transition Portion
289	358+440	358+475	35	Bangandi Bridge
290	358+475	358+625	150	Transition Portion
291	358+625	360+670	2045	Type-1
292	360+670	360+816	146	Transition Portion
293	360+816	360+882	66	Balganga Bridge
294	360+882	361+030	148	Transition Portion
295	361+030	362+690	1660	Type-1
296	362+690	362+839	149	Transition Portion
297	362+839	362+885	46	Baijura Bridge
298	362+885	363+035	150	Transition Portion

Sl No	Design Chainage (m)		Length (m)	Cross Section Type / Other Details
	From	To		
299	363+035	365+540	2505	Type-1
300	365+540	365+688	148	Transition Portion
301	365+688	365+723	35	Tin Bridge
302	365+723	365+870	147	Transition Portion
303	365+870	366+180	310	Type-1
304	366+180	366+300	120	Transition Portion
305	366+300	366+750	450	Type-6
306	366+750	366+887	137	Pathlaiya Jn

The Typical Cross Section wise length has been worked out and summary has been provided in **Table** below for reference.

Length for Typical Cross Sections

TCS Type	Length (in m)
Type-1	86345
Type-2	588
Type-3	306
Type-4	-
Type-5	11455
Type-6	1550
Type-7	4380
Type-8	80
Type-9	100
Transition Portion	19850
Structure Portion	5733
Total Length	130387

The Urban and Semi Urban sections defined along the project road are proposed to be improved with provision of service road either on one or both sides of four lane main carriageway depending up on density of the settlement.

In the rural areas, the road width will be 26 m wide 4-lane section. No service lane is provided in these sections. The cross section features adopted for the design are summarized under.

Urban Section with service lane	
Formation Width	Formation Width : 4x3.5+2x2.5 (shoulder)+4 (Median)+2x0.5 (kerb shy) = 24 m for main Carriage way
Service lane	6.5m on both side = 13m
Shoulders	Paved 2.5 m both side of Main carriageway
Separator	1.2m between Main Carriageway and Service Road
Cycle Track	2m at outer edge of Service Road
Drain cum Footpath	Varies
Pavement Camber	2.5 % on either side from center

Semi Urban section with service lane	
Formation Width	Formation Width : 4x3.5+2x2.5 (shoulder)+4 (Median)+2x0.5 (kerb shy) = 24 m for main Carriage way
Service lane	5.5 m on both side = 11 m
Shoulders	Paved 2.5 m both side of Main carriageway
Separator	1.2m between Main Carriageway and Service Road
Granular Shoulder	1.5m at outer edge of Service Road
Pavement Camber	2.5 % on either side from center
Forest section and Rural section	
Formation Width	Formation Width : Total 4x3.5+2x2.5 (paved shoulder)+2x1 (granular shoulder)+4 (Median)+2x0.5 (kerb shy = 26 m in main Carriage way
Shoulders	Paved 2.5 m both side + Earthen 1.0m on both side
Pavement Camber	2.5% on either side

The median width has been proposed up on decision mutually by DoR and the consultant after detailed discussions held for the same.

7. Traffic Studies and Analysis

The consultant collected traffic data through field survey and forecasted the same considering normal, generated and induced traffic for 10, 15 and 20 years of operation of the upgraded project road. The homogeneous sections were worked out based on the traffic intensity along the project road.

Based on the extrapolation of the normal, generated and induced traffic, the future traffic forecasts for homogeneous sections of Kamala – Dhlakebar – Pathlaiya road is shown in the below Table.

Homogeneous Section	Traffic 2026		Traffic 2031		Traffic 2036		Traffic 2041		Traffic 2046	
	AADT		AADT		AADT		AADT		AADT	
	VPD	PCU	VPD	PCU	VPD	PCU	VPD	PCU	VPD	PCU
Kamala - Dhalkebar	14713	17184	19624	21220	27512	27248	38744	35549	55071	46961
Dhalkebar-Bardibas	15923	18330	21279	22669	29903	29191	42182	38155	60059	50526
Bardibas - Nawalpur	12948	14856	17306	18377	24320	23671	34303	30927	48833	40932
Nawalpur - Chapur	16565	17018	22503	21389	32149	28076	45983	37368	66278	50389
Chapur - Nijgadh	17471	17681	23799	22281	34089	29326	48875	39147	70591	52937
Nijgadh - Pathlaiya	11790	18353	15037	21979	20063	27144	27043	34043	36790	42956

Note: Figures outside pertains to vpd and inside brackets correspond to PCU/day.

Source: Consultant's analysis, 2022.

8. Pavement Design

The Pavement Design is carried out based on the guide line provided in DoR publication "Guidelines for the Design of Flexible Pavement-2014 (Second revision - 2021)" and IRC: 37-2018 "Guidelines for the design of Flexible Pavements (Fourth Revision)". The input parameters for the pavement design are the California Bearing Ratio (CBR) and Design Traffic Loading in terms of Millions Standard Axles (MSA).

The Flexible pavement for main carriageway and service road whereas, rigid pavement has been considered for Bus Bay and Truck Lay byes for carrying out detailed pavement design. During the detailed design and the cost estimating, it was considered to adopt effective CBR, considering obtained CBR of subgrade through laboratory test and CBR of fill material. The effective CBR of 10% has been adopted for carrying out detailed pavement design.

The consultant have proposed three homogeneous sections based on MSA arrived at after Axle load data analysis for detailed pavement design of Main Carriageway. The summary MSA for each homogeneous section is as provided below:

Homogeneous Section Wise MSA Adopted for Main Carriageway

Sections	Section Description	Design traffic (MSA)
Section I:	Kamala (CH 237+300) – Bardibas (Bhabsi River, CH 268+300)	60
Section II	Bardibas (Bhabsi River, CH 268+300) - Nijgadh (Bakaiya River, CH 347+100)	40
Section II:	Nijgadh (Bakaiya River, CH 347+100) - Pathlaiya Junction (CH 367+000)	75

The detailed pavement design has been finalized and thickness for various pavement layers has been recommended up on verifying the same using IITPAVE software produced by IRC. The recommended pavement design for each homogeneous section is as summarized below for reference:

Recommended Pavement Thickness for Main Carriageway

Pavement layer	Design Traffic		
	40 MSA	60 MSA	75 MSA
Wearing Course, AC, mm	40	50	50
Binder Course, DBM, mm	90	90	100
Base course, WMM	250	250	250
Sub-base Course, GSB	200	200	200
Highway Sections	Bardibas, Bhapsi River - Nijgadh, Bakaiya River	Kamal river - Bardibas, Bhapsi River)	Nijgadh, Bakaiya River - Pathlaiya Junction

Pavement layer	Design Traffic		
	40 MSA	60 MSA	75 MSA
Highway Chainages	CH 268+300) - CH 347+200)	CH 236+500 – CH 268+300)	CH 347+200 - CH 366+887

The Design traffic loading of 10 MSA has been considered for service road pavement design. The recommended pavement design for Service Road is as tabulated below:

Recommended Pavement Thickness for Service Road

Pavement layers	Design Thickness, mm	Adopted Thickness, mm	Remarks
AC wearing course	40	40	
DBM binder course	50	50	
WMM base course	150	150	
Granular Sub-base	150	200	same thickness of GSB as of the main carriageway

For Bus Bays and Truck Lay Byes, rigid pavement (Continuous Reinforced Concrete Pavement) has been adopted for the design. The recommended pavement design for bus bay and truck lay bye is as tabulated below:

Recommended Pavement for Bus Bay and Truck Lay Bye

Pavement Quality Concrete PQC (mm)	Dry Lean Concrete DLC (mm)	Granular Sub Base GSB (mm)	Total thickness, (mm)
300	150	200	650

9. Hydrology and Drainage Design

All the existing cross drainage structure for drainage purpose have been evaluated and it has been found total of 142nos, culverts in form of cross drainage structure either in the form of slab culvert, box culvert, pipe culvert or causeway exist on the Project Road. After detailed hydraulic calculations, box culverts with single or multi cell are proposed in lieu of existing pipe, Box or slab culverts.

A detailed hydraulic analysis is further carried out for all existing 21 causeway locations on the Project Road. Based on hydraulic analysis, multicellular box culvert of required size with raised formation level are proposed to replace existing causeways. The Box culverts proposed at existing causeway locations are as tabulated below:

Sr. No.	Chainage (km+m)	Existing Structure Types	Proposed Dimension (Cell No X W X H X Cushion Ht.)	Proposed Structure Types
1	273+223	Causeway	3x6x3.5	Box Culvert
2	273+890	Causeway	2x6x3.5	Box Culvert

Sr. No.	Chainage (km+m)	Existing Structure Types	Proposed Dimension (Cell No X W X H X Cushion Ht.)	Proposed Structure Types
3	276+527	Causeway	2x6x3	Box Culvert
4	279+730	Causeway	3x6x3.5	Box Culvert
5	286+113	Causeway	3x6x4	Box Culvert
6	287+830	Causeway	3x6x4+0.31	Box Culvert
7	288+884	Causeway	3x6x4.5+0.09	Box Culvert
8	297+671	Causeway	3x6x4+0.39	Box Culvert
9	298+696	Causeway	3x6x4+0.41	Box Culvert
10	301+197	Causeway	2x6x4.5+0.746	Box Culvert
11	304+010	Causeway	1x3x3+3.083	Box Culvert
12	304+710	Causeway	1x3x3+0.78	Box Culvert
13	307+370	Causeway	2x3x3+0.822	Box Culvert
14	308+645	Causeway	1x6x3.5	Box Culvert
15	329+360	Causeway	1x6x4.5+0.04	Box Culvert
16	330+347	Causeway	1x6x3	Box Culvert
17	336+205	Causeway	3x6x4+0.47	Box Culvert
18	338+015	Causeway	2x3x3+0.98	Box Culvert
19	344+662	Causeway	2x3x3+1.193	Box Culvert
20	350+172	Causeway	2x3x3+1.05	Box Culvert
21	352+107	Causeway	1x3x3+0.75	Box Culvert

10. Bridges, Culverts and other structures

There are total of 76 bridges provided on the Project Road section. Based on hydraulic calculations total fifteen (15) bridges are converted in to culverts. Also, considering Terms of Reference for the Project, three bridges 1) Kamala, 2) Baekiya and 3) Bagmati are proposed as Signature (special) Bridges. The Department is constructing new four lane bridge across - Dudhaura river at present. Therefore, the proposed Bridges for design are as under:

Proposed Bridge Configuration	No of Bridges
Signature (Special) Bridge	3
Four Lane Bridge under Construction	1
Bridges	57
Bridge converted in Culvert	15
Total Nos.	**76**

The Consultant assessed major intersections based on field surveys and traffic data analysis. The Consultant have proposed flyover at Major junction having significant through and cross movement, the detail is as tabulated below for reference:

List of Proposed Flyovers

S.N.	Chainage (Center of Structure)	Location	Span Configuration	Total Length (m)	Width of structure (m)
1	267+280	Bardibas Junction	29 x30	670	23.4
2	326+560	Chapur Junction	18x30	540	23.4

In addition, the Trumpet Interchange is being separately designed at Merging of Kathmandu – Terai Fast Track (KTFT) with the Project Road near Nijgadh by the Consultant appointed by Nepal Army.

The Consultant conducted joint meetings as well as joint site visit with the representatives of DoR & World Bank and EISA Consultant's team appointed by DoR to assess and finalize locations for flyover, vehicular underpass, pedestrian underpass, tractor/ trolly crossing, cattle crossing, medium size animal crossing and elephant crossing on the project road. The detailed discussion and assessment was made to arrive at mutually agreed various crossing locations during joint site visit and joint meetings held at various venues. The lists of various crossing proposed up on mutual agreement with all above stated stack holders are presented below for reference:

List of Proposed Elephant Crossing Locations

S. N.	Topo Chainage (Bridge Center)	Exiting Structure			Proposed Structure			
		Bridge Name/ Structure	Nos of Span (in no)	Span Arrangement/ Length (in m)	Total Length (in m)	No of Span (in no)	Span Arrangement (in m)	Total Length (in m)
1	329+752	Amu - 1	3	11.34	34.02	1	25	25
2	333+733	Lamaha	2	33	66	2	33	66
3	339+342	Dhansar	8	20.5	164	4	41	164
4	347+209	Bakeya	16	22.2	355.2	4	12.6+82.5+ 165+82.5+ 12.6	352
5	353+628	Terhakilo	4	11.4	45.6	1	35	35
6	357+227	Pasaha	5	33	165	5	33	165
7	360+869	Balganga	3	22	66	3	22	66
8	363+585	Dudhaura	2	45.25	90.5			

List of Proposed Medium Size Animal Crossings

S. No	Topo Chainage (Bridge Center)	Existing Bridge/ Causeway				Proposed Structure for MAC		
		Name of Bridge/ Structure Type	Nos of Span	Span Arrangement/ Length (in m)	Total Length (in m)	No of Span	Span Arrangement (in m)	Total Length (in m)
1	271+514	Gadhanta	5	12.5	62.5	3	25	75

S. No	Topo Chainage (Bridge Center)	Existing Bridge/ Causeway				Proposed Structure for MAC		
		Name of Bridge/ Structure Type	Nos of Span	Span Arrangement/ Length (in m)	Total Length (in m)	No of Span	Span Arrangement (in m)	Total Length (in m)
2	274+925	Belgachhi (DhungreKhola)	4	9.5	38	2	20	40
3	275+630	Tuteshwor-1	2	9.5	19	1	20	20
4	277+266	Maraha	8	15+2*18+2*15+ 2*18+15	132	5	33	165
5	278+913	Dholan	4	9.5	38	1	38	38
6	282+758	Bankhe	6	15+4*18+15	102	3	33+36+33	102
7	285+721	Amuwa	2	9.5	19	1	25	25
8	292+703	Kalinjor - 2	3	22	66	3	22	66
9	317+698	Paurahi	3	22	66	3	22	66
10	322+553	Causeway	1	160	160	1	8	8

List of Proposed Tractor and Cart Crossing

S. N	Topo Chainage (Bridge Center)	Name of Bridge/ Structure	Existing Structure			Proposed Structure		
			No of Span	Span Arrangement/ Length	Total Length	No of Span	Span Arrangement/ Length	Total Length
1	237+022	Kamala	24	26.65	639.6	4	114+206+206+ 114	640
2	241+744	Charnath	15	21.4	321	15	21.4	321
3	245+228	Baluwa	7	16	112	4	32+32+32+16	112
4	252+478	Jalad	10	26.6	266	10	26.6	266
5	254+663	Aurahi	12	26.6	319.2	12	26.6	319.2
6	256+186	Basai	4	21.5+2*26.5+2 1.5	96	4	21.5+2*26.5+2 1.5	96
7	258+735	Sukhajor	2	22	44	2	22	44
8	260+921	Barahari	3	23.5+28+23.5	75	3	23.5+28+23.5	75
9	265+345	Ratu	6	38.5+4*33+38. 5	209	6	38.5+4*33+38. 5	209
10	268+310	Bhapsi	4	12.5	50	2	25	50
11	290+215	Phuljor	7	12.5	87.5	3	30	90
12	291+868	Kalinjor - 1	3	9.5	28.5	1	28.5	28.5
13	300+466	Lakhandei	12	15+4*18+2*15 +4*18+15	204	6	33+36+2*33+ 36+33	204
14	307+753	Rai Bridge	4	9.5	38	1	38	38
15	313+121	Bagmati	11	33	363	4	99+165+99	363
16	314+170	Gairi	3	11.4	34.2	1	22	22
17	325+067	Chandi	5	33	165	5	33	165
18	343+584	Bhamara	1	33	33	1	33	33

List of Proposed Vehicular Underpass / Pedestrian Underpass

Sl. No.	Chainage (Center of Structure) m	Location	Proposed Opening Size for VUP (m)	Proposed Arrangement for PUP (m)	Width of structure (m)
1	243+640	Birendra Bazar	20m (W) x 5.5m (H)	8m (W)x 2.5m (H)	25.9
2	294+900	Lalbandi Bazar	20m (W) x 5.5m (H)	8m (W)x 2.5m (H)	25.9
3	299+545	Nawalpur Junction	20m (W) x 5.5m (H)	8m (W)x 2.5m (H)	25.9
4	304+190	Hariwan Bazar	20m (W) x 5.5m (H)	8m (W)x 2.5m (H)	25.9
5	307+050	Naya Road Junction	20m (W) x 5.5m (H)	8m (W)x 2.5m (H)	25.9

11. Road Safety

The Project Road has been classified as Type II, considering current and forecasted traffic intensity. Accordingly, the road has been designed considering design speed of 100 kmph. The safety requirements for upgraded road are assessed in detail and accordingly necessary safety provisions like safe junctions, U Turn locations in form of proper Median opening, pedestrian level crossing as well as Foot Over Bridge, Vehicular underpass with Pedestrian Underpass in the approaches, separator with pedestrian guard rail/ crash barrier, drain cum footpath at end of service road in urban sections has been provisioned while carrying out detailed design. In addition, road appearances in form of road signs, delineators, chevron signs, w-beam crash barriers, gabion crash barriers, road marking, speed restrictions in busy areas etc. are proposed for safety of road user and pedestrians. The consultant has proposed to develop selected major junctions based on assessment, the list of the same is as provided in **Table** below:

List of Major Junctions Proposed for Development

S.N.	Location	Chainage	Intersection Type
1	Goddar Bazar	239+740	Four Legged
2	Birendra Bazar-1	243+640	VUP+2PUP
3	Bhiman Chowk	246+250	Four Legged
4	Dharapani Chowk	247+650	Four Legged
5	Kanxi Bazar	248+730	Four Legged
6	Puspalpur Chowk	252+050	Four Legged
7	Laalbhiti Chowk	254+000	Four Legged
8	Shreepur Chowk	255+100	Four Legged
9	Dhalkebar	257+250	Roundabout
10	Dhalkebar 400KV Substation Road	258+180	Four Legged
11	Jamunibaas Bus Stop	259+800	Four Legged
12	Bardibas	267+100 to 267+300	At Grade

S.N.	Location	Chainage	Intersection Type
13	Ranigunj Chowk	291+300	Four Legged
14	Laalbandi Chowk-1	294+200	VUP+2PUP
15	Nawalpur Chowk	299+540	VUP+2PUP
16	Hariwan	303+000	Four Legged
17	Hariwan Bazar	304+190	VUP+2PUP
18	Naya Road	307+050	VUP+2PUP
19	Karmaiya Road Junction	311+900	Four Legged
20	Bagmati River Bridge	313+400	Four Legged
21	Chapur	326+560	At Grade
22	Nijgadh	345+000	Four Legged
23	Nijgadh-1	345+300	At Grade
24	Nijgadh-2	346+050	Four Legged
25	Fast Track Junction	348+600	Interchange
26	Dhansar	357+850	T-Junction
27	Pathlaiya Junction	367+000	Roundabout

The Consultant have assessed the requirement of Bus Bay/ Bus Shelter considering adjacent rural or urban area of the project road, the List of the proposed Bus Shelter with or without Bus Bay is as Tabulated below:

List of Proposed Bus Shelter with or without Bay

S. No.	Chainage (m)	Side of Road	Bus Bay/ Bus Shelter
1	238+200	Left	
2	239+600	Left	
3	239+900	Right	
4	243+300	Left	
5	243+350	Right	
6	246+350	Right	Bhiman chowk
7	246+200	Left	Bhiman chowk
8	247+550	Right	
9	247+750	Left	
10	253+800	Left	
11	256+900	Left	
12	257+900	Right	
13	259+750	Left	Jamunibas
14	259+950	Right	
15	261+050	Left	
16	264+900	Left	
17	265+100	Right	
18	266+850	Left	
19	267+400	Right	
20	271+350	Left	Jungle

S. No.	Chainage (m)	Side of Road	Bus Bay/ Bus Shelter
21	279+300	Right	Jungle
22	279+950	Left	Jungle
23	283+200	Left	Jungle
24	290+000	Right	
25	291+200	Left	
26	291+450	Right	
27	294+800	Left	
28	295+050	Right	
29	299+450	Left	
30	299+700	Right	
31	304+100	Left	
32	304+300	Right	
33	307+000	Left	
34	307+200	Right	
35	308+000	Left	
36	309+300	Right	
37	312+800	Left	
38	313+600	Right	
39	314+600	Left	
40	326+500	Left	
41	326+700	Right	
42	339+100	Left	Jungle
43	345+500	Right	
44	345+700	Left	
45	353+150	Left	Jungle
46	354+000	Left	Jungle
47	357+800	Left	Jungle
48	366+500	Left	
49	366+600	Right	

Truck lay-byes have been proposed in the following locations as rest areas for the commercial (truck) traffic. The list of Proposed Truck Lay byes along the Project Road is provided below for reference:

List of Proposed Truck Lay byes

S.N.	Chainage	Sides	Reason for Truck-Layby
1	268+700	Left	Survey and Past trend of parking
2	324+300	Right	
3	327+800	Left	
4	347+800	Right	
5	366+300	Right	

12. Social Aspects

The identification of numerous issues of poor, disadvantaged peoples, gender inequality, accessibility of different facilities and services, status or possibility of HIV/AIDS and human trafficking is being done by separate ESIA Consultant appointed by DoR for the Project. The

linkage between poverty, social exclusion and inadequate or lack of access due to lack of roads or improvement in the transport sector is being recognized by them.

In order to address the above issues like gender inequality, poverty, social risks like HIV/AIDs and human trafficking, child labour, the mitigation measures are being incorporated in enhancement measures and livelihood support programs in Resettlement Action Plan under Livelihood Restoration Programs under preparation by separate ESIA Consultant appointed by DoR for the project road. The project should implement the socialdevelopment component which includes the Complimentary Poverty Reduction Program (CPPR) and Gender Equality and Social Inclusion Plan (GESI) through Project Implementation Unit (PIU) during project implementation.

13. Resettlement Plan

The Government of Nepal (GoN) has legally fixed Right of Way (RoW) of 50 meters for the highways. The issue of right of Way for this road is solved, as the RoW land is owned by the Department of Roads. However, the significant adverse impact of the project will occur due to relocation of private residential structures, which will result in the displacement of people from their original place, seriously affecting their earlier livelihood pattern. Based on the finding of resettlement census carried out during the detail design, an estimated number of 381 households have been expected to be directly affected due to this Sub-project

However, the Resettlement Plan (RP) has been prepared as required by the requirements of the Project.

14. Environmental Assessments

An Initial Environmental Examination of the road project for upgrading of the Kamala - Dhlakebar – Pathlaiya Section of East–West Highway (130 km) has been prepared by the Consultant. This project has been classified as Category -B‖. A separate Poverty and Social Assessment and Resettlement Studies Report have also been prepared by ESIA Consultant separately appointed for the Project. The correlated issues such as safety of community and construction crews, safe passages for public, protection of common physical, cultural, religious, historical, archaeological and public utilities/facilities reinstatement are covered under the mitigation plan. Environmental monitoring is in the implementation of IEE recommendation.

15. Rate Analysis and Cost Estimate

The analysis of rates for various item of works has been carried out adopting weighted average of the labor and material rates collected from five districts named as Dhanusha, Mahottari, Sarlahi, Rautahat and Bara. The equipment rates are taken from the rates of equipment are adopted from the Mechanical Branch of the Department of Roads.

The quantities for various items of works for road works, bridge works, vehicular underpass/ pedestrian underpass/ cattle underpass, protection works, junction improvement works, animal crossings including elephant crossing, road side appurtenances including road marking/ signages/ barriers etc. have been worked out by the team of the Consultant.

The total Civil Cost of the Project excluding VAT @13% arrives at **NPR 36,181.70 Crore** i.e. **NPR 279.42 Crore per km**.

KDP Project Stretch		**TOTAL**
Project length excluding 900m for KTFT interchange		**129.487 Km**
Item No.	**Description of Works**	**Amount (NRs.)**
1	**Part IA: Insurance**	**26,08,58,792**
	Part IB : General Item	52,70,14,702
2	**Part II : Road Works**	
2.01	Site Clearance (Including Dismantling Works)	40,74,74,743
2.02	Earthwork	3,47,57,90,600
2.03	Pavement Works(Main Carriageway)	12,67,15,89,732
2.04	Median	67,10,63,065
2.05	Pavement works (Service Road)	99,50,02,840
2.06	Footpath	17,28,16,695
2.07	Cycle Track	16,44,12,093
2.08	Busbay including shelter	10,04,69,947
2.09	Truck Lay Bye	1,81,29,915
2.10	Major Junction	26,09,77,529
2.11	Minor Junction	32,78,60,954
2.12	Retaining Wall	78,97,42,500
2.13	Toe Wall	16,10,94,905
2.14	Drain	78,18,71,999
2.15	Traffic Furniture	1,24,68,40,687
	Sub-Total Of Part II : Road Works	**22,24,51,38,205**
3	**Part III : Bridge Works**	
3.1	Foundation	3,45,21,40,789
3.2	Sub-Structure	90,15,65,688
3.3	Super-Structure	2,32,08,69,732
3.4	River Training and Protection Works	25,67,91,531
3.5	Miscellaneous Works	4,77,12,824
	Sub-Total Of Part II : Bridge Works	**6,97,90,80,564**
4	**Part III : Bridge to Culvert Works**	**73,64,87,905**
5	**Part IV : Culvert Works**	**2,16,03,63,703**
6	**Part V : VUP & PUP Works**	

KDP Project Stretch		TOTAL
Project length excluding 900m for KTFT interchange		**129.487 Km**
Item No.	**Description of Works**	**Amount (NRs.)**
	A. Structure Works (VUP)	
6.A.1	Foundation	23,13,94,932
6.A.2	Sub-Structure	4,95,86,939
6.A.3	Super-Structure	11,09,15,259
6.A.4	Miscellaneous Works	10,09,379
	Sub-Total Of A	**39,29,06,509**
	B. Structure Works (PUP)	
6.B.1	Foundation	31,89,593
6.B.2	Sub-Structure	16,88,12,971
6.B.3	Super-Structure	64,97,898
	Sub-Total Of B	**17,85,00,462**
	C. RE Wall	**1,05,64,26,239**
	Sub-Total Part V (A+B+C)	**1,62,78,33,210**
7	**Part VII :Cost of Bridge Maintenance & Rehabilitation Works**	**4,06,53,629**
8	**Part X: Performance Based Maintenance Woks and Services**	**1,57,99,08,785**
9	**Part XI : Schedule of Day Works**	**2,43,58,746**
10	**Part XII : Provisional Sums**	**74,23,10,123**
	Total of 1A+1B + 2 + 3 + 4 + 5 + 6 + 7 + 8 + 9 + 10	**36,92,40,08,363**
	Provisional Sum	**74,23,10,123**
	Total excluding Provisional Sum	**36,18,16,98,240**

It has been discussed and agreed with DOR and WB that, the Project Road to be divided in six packages for implementing the upgradation to four lane divided road.

The detail of all six packages cost is as tabulated below for reference

16. Final Detailed Design Report

The Final Detailed Design Report prepared for the subject project road is comprising of different Volumes. Many of the Volumes are divided in to parts depending on size. The List of Volumes of Final Detailed Design Report is provided below for ready reference.

List of Volumes for Final Detailed Design Report

SN	Volume Number	Name of Report / Drawing Volume
1	Vol I	Main Report
		Executive summary
	Chap-1	Introduction and project overview
	Chap-2	Design standards
	Chap-3	Survey and investigations
	Chap-4	Materials investigations
	Chap-5	Traffic surveys and analysis
	Chap-6	Detailed pavement design
	Chap-7	Geometric design
	Chap-8	Hydraulic analysis and drainage design
	Chap-9	Detailed structure designs
	Chap-10	Road safety assessment and improvement proposals
	Chap-11	Bill of quantities and cost estimate
	Chap-12	Social and resettlement issues
	Chap-13	Environment impact assessment
	Chap-14	Procurement
2	Vol I-A	Annexures - Chapter-3: Topographical Survey and Mapping
3	Vol I-B	Annexures - Chapter-3: Road Inventory, Chapert-5: Traffic Survey and Analysis, Chapter-6: Pavement Design Output, chapter-8: Hydraulic Analysis, Drainage design, River training works, Chapter-12: Social and Resettlement Issues
4	Vol I-C	Annexures - Chapter-4: Material Investigations
5	Vol I-D	Annexures - Chapter-3: Bridge and Culvert Inventory and Condition Survey
6	Vol I-E	Cost Estimate (Road and Bridges)
7	Vol II (Part-1)	Detailed Drawings - Road: TCS, Plan and Profile and Miscellaneous Drawings
8	Vol II (Part-2)	Detailed Drawings - Road: Detailed Cross Sections, (CH: 236+470-237+840 and 312+420-313+750)
9	Vol II (Part-3)	Detailed Drawings - Road: Detailed Cross Sections, (CH: 237+840-260+380)
10	Vol II (Part-4)	Detailed Drawings - Road: Detailed Cross Sections, (CH: 260+380-285+200)
11	Vol II (Part-5)	Detailed Drawings - Road: Detailed Cross Sections, (CH: 285+200-312+864)
12	Vol II (Part-6)	Detailed Drawings - Road: Detailed Cross Sections, (CH: 313+750 to CH: 328+750)
13	Vol II (Part-7)	Detailed Drawings - Road: Detailed Cross Sections, (CH: 328+750 to CH: 366+650)
14	Vol II (Part-8)	Road Marking & Signage Plan, Junction Drawings and Drainage Plan and Profile
15	Vol II (Part-9)	Drainage Plan and Profile
16	Vol III-A	Design Report & Drawing of Culverts

SN	Volume Number	Name of Report / Drawing Volume
	Vol-1	Design Calculation Report
	Vol-2	Drawing
17	Vol III-B	Design Report & Drawing of VUP & PUP
	Vol-1	Cover Page + Report, Hydrological Report, Geotech Report, Detail Estimate & Rate Analysis
	Vol-2	Drawings
	Vol-3	Design Calculation Report
18	Vol III-C	Detailed Drawings: Structures - Flyover
	Vol-1	Cover Page + Report, Hydrological Report, Geotech Report, Detail Estimate & Rate Analysis
	Vol-2	Drawings
	Vol-3	Design Calculation Report
19	Vol-IV	Design Report & Drawing of Bridges (57 Bridges)
	Vol-1	Cover Page + Bridge Report, Hydrological Report, Geotech Report, Detail Estimate & Rate Analysis, Site Photograph
	Vol-2	Drawings
	Vol-3	Design Calculation Report
20	Vol-V	Design Basis Report and General Arrangement Drawing for Signature Bridges
		Bagmati
		Bakeya
		Kamala
21	Vol-VI	Report on Rehabilitation of Existing Bridges
22	Vol-VII	Bid Doccument

Chapter 1: Introduction and Project Overview

1.1 Project Background

For the Development of any country and especially for developing countries like Nepal, Transport Network for the transportation of Passengers and Freights play vital role in lifting up the country's economic condition. Long term goal of the 15th 5-years Plan is "Prosperous Nepal, Happy Nepali". One of the objectives for fulfillment of the Goal is Prosperity: "Accessible modern infrastructure and intensive connectivity" and Happiness: "Well-being and decent life".

One of the basic problems of Nepal is its difficult topography, steep slopes, young geology and deep river crossings, which are the hurdles for the construction of road /rail network. Due to fragile topography of the country, which makes it difficult to develop railway transport and expensiveness of air transport; Road Transport is the only practical choice and affordable to common people for mass transportation in Nepal. Roads Transport has been proved to be the most important infrastructure in lifting up the country's economic condition from the beginning. Nepal has made considerable progress in improvement and development of roadways. There are several Highways which link different parts of the country from east to west and from south to North. The most important highway of the country is Mahendra Highway (also known as East -West Highway). This 1028 Km long highway connects Kakarvitta at the east to Gaddhachowki at the west. The 130 Km long Project Road from Kamala (chainage 236+698) to Pathlaiya (chainage 366+773) is a part of this Mahendra Highway.

The Mahendra Highway had been constructed in the past with the assistance of different friendly countries in different parts and in different time period starting from 1970s. For an instance, the Kakarvitta - Dhalkebar section of the road was built with the assistance of the Indian government and the Dhalkebar - Pathlaiya section of the road was built with the assistance of the then USSR government. The highway at that time had been designed and constructed for then nominal traffic capacity. The carriageway width was only 3.5m wide. Similarly, the bridges along the highway from Kamala to Dhalkebar are 7.0m wide and that from Dhalkebar to Pathlaiya are only 5.5m wide and as a result, the bridges have now become bottlenecks to the traffic. In 1990s, when significant rise in the traffic volume was observed and accordingly the carriageway width of the highway was widened to 7m.

In recent years, the passenger and freight traffic have been increasing in this highway as a result of enhancement of agricultural trade with neighbor country (India) and trade enhancement due to regional trade agreements such as BIMSTEC, SAFTA, BBIN etc.

Increasing traffic volume and also enhancement of regional trade among the member countries requires an upgrade of this road section to Asian Highway Standards (Class I).

In order to enhance safety, capacity and efficiency in the road transport and to improve the economic status of the people of Nepal through improvement of road network while redressing regional imbalances and inequalities the Department of Roads (DOR) has taken initiatives for the up-gradation of Mahendra Highway from 2-lane to 4-lane road in different parts. For Kamala – Kanchanpur and in Narayangadh – Butwal sections of the Mahendra Highway, the construction Work has been already been started.

For the detailed design of Upgradation of Project Road Kamala - Dhalkebar – Pathalaiya Section (130 Km) of Mahendra Highway and 76 Bridges in this section, the Department of Roads (DOR), Development Cooperation and Implementation Branch has awarded a contract under the Strategic Road Connectivity & Trade Improvement Project (SRCTIP) to the joint venture of M/S Eptisa Servicious de Ingeniera and Stup Consultants Private Limited, Madrid Spain in Association as Sub-Consultant with Udaya Consultancy, Geocom International, Sundar Kriti Consultant and Rays Consultant Private Limited. This Project is being financed jointly by the Government of Nepal, Department of Roads and one of the major development partners of the country, the World Bank.

1.2 Project Road Description

There are two Asian Highways which pass through Nepal. They are AH2 (from Dhaka, Bangladesh to New Delhi, India) and AH42 (from Lanzhou, China to Barhi, India). The Mahendra Highway is a part of AH2. Therefore, it is logical to develop and upgrade Mahendra Highway to the Asian Highway Standard. This Highway is the main domestic as well as international trade corridor of Nepal providing transportation links between South Asia Association for Regional Cooperation (SAARC) Countries.

The Project Road Kamala – Dhalkebar - Pathlaiya is a part of Mahendra Highway. This Road has a total length of 130 Km. with 34.29% (44.684 Km.) in Urban area, 9.075% (11.825 Km.) in semi-urban area, 45.575% (59.38 Km.) in Forest area and 11% (14.4 Km.) in rural area. and it is 130 Km.

There are 76 bridges and 127 other cross drainage structures and 25 Causeways provided on the Project Road.

The Project Road is located at the northern side of Terai region and Southern side of Chure hill foot. The Project Road passes mainly through plain terrain with cross slope of less than 5% for entire length.

Administratively entire Project Road falls within Madhesh Province of the country. It crosses through 5 districts namely Dhanusha, Mahottari, Sarlahi, Rautahat and Bara and 16 Local Bodies.

Terai region of Nepal is fertile area. Therefore, most of the people along and around the project road area highly depends on agriculture activity for their economy. There are some sugarcane factories in the vicinity of the Project Road. Birgunj – Pathlaiya Industrial corridor also connects to this road at Pathlaiya. The Kathmandu-Terai Fast Track Express way will be connected to the Project Road near Nijagadh. Also, an international airport is planned to be constructed in the vicinity of the Project Road near Nijagadh Bazar.

Major Settlements along the Project Road observed are: Godar, Birendra Bazar, Dharapani, Dhalkebar, Lalgadh, Bardibas, Lalbandi, Nawalpur, Hariwan, Bagmati, Chapur, Nijagadh and Pathalaiya.

There are total 42 major road junctions with other cross/ merging roads. Similarly, the Project Road provides access from adjacent settlements at 344 locations. The Project Road also provides links to major administrative and cultural centers of the country such as Janakpur, Kathmandu, Jaleshwor, Malangwa, Barhathwa, Gaur, Kalaiya, Birgunj and Hetauda.

The present condition of pavement, shoulder, drain, cross drain (pipe culvert, slab culvert and causeway) bridges, retaining structures, utilities along Kamala – Dhalkebar – Pathalaiya Section is described below:

The Road Carriageway width in Project Road section in average is about 7 m ~8 m and shoulder width is about 1 to 2m on both sides. In selected settlement/urban areas, width more than 7m has been provided for the pavement.

The road pavement condition has been observed to be in fair condition with cracks, maintained pot holes and resealed in some stretches. The wearing course at some of the bridges, in Rautahat and Bara districts is in very poor condition which causes bottlenecks to traffic, especially long bridges in these districts.

The retaining structures in form of RRM Walls, Brick masonry walls, Dry stone walls and Gabion walls and road side longitudinal drains along the alignment have been observed in fair condition. All these structures need to be dismantled for the construction of four lane road.

The foundations of some bridges have been found exposed due to scouring and, in some bridges, there is sedimentation problem; which has reduced the vertical clearance under the bridges.

Slab culverts, pipe culverts and causeways have been observed in fair condition for entire length. Few cross-drainage culverts have been found completely buried during inventory.

In general, the right of way along the project road is clear from physical structures. However, there are some small huts, trees (including sacred Pipal tree) etc. at few places which will be required to be removed before the construction of 4 lane divided road.

1.3 Project Objectives

The consultant has already prepared and submitted to the client; a Conceptual Design Report following the inception Report submission. The design for the up-gradation project mainly consists of widening the existing 2-lane highway into four-lane highway and design of bridges accordingly. In urban areas, the design includes the provision for service roads either on the one side or on the both sides depending up on nature of the settlement. This report mainly focuses on the applications of the design standards and basic design principles for upgrading / widening the highway geometry, pavement as well as the bridges and other structures.

The main objectives of the consulting service for the up-gradation of the Project Road from Kamala to Pathlaiya of Mahendra highway (130 km long) are as:

- Conducting detailed engineering survey and design of 130 km road for widening to four-lane width and 76 number of bridges along this section incorporating road safety features and relevant environmental and social measures based on the ESMP,
- Application of innovative design for the highway, pavement as well as bridges and other drainage Structures,
- Identification of locations and Detail design for the wild-fife crossing along the highway section,
- Assessment of conditions of existing bridges and design for remedial maintenance and rehabilitation measures,
- Detail Survey and Design of Intersections, Flyovers, Crossings / Underpasses / foot over crossings and others) at Major Junctions and appropriate design for all other crossings / junctions,
- Conduct alternative analysis for the design of alignment, construction techniques with due considerations of environmental effects,

- Integrate relevant environmental and social measures and recommendations of road safety assessment and audit analysis, e.g., wildlife passes, safety features, etc. into the detailed engineering designs and bid documents,
- Prepare the necessary standard/special Specifications, Cost Estimates, Bill of Quantities, Contract packaging and preparation of Bid documents

1.4 Scope of Work for Detailed Design

The Terms of Reference (TOR) describes the detailed Scopes for the consulting services for Detailed Design Works. The scope of services includes collection and review of available documents, Detailed Survey and investigation works, Detail Design for the improvement / widening of Road, Bridges and other Structures to desired standards, Social and Environmental Assessments, Preparation of detailed costing of construction Works including the cost of social and environmental mitigation measures, Procurement Assistance and Technology transfer and Capacity Development Works.

The scopes of the services comprise of the following activities:

- Study the Feasibility study report carried out for the Upgradation of the Project Road,
- Carry out engineering surveys and investigations, including topographic surveys and mapping, Hydrological survey, Geotechnical Survey, Seismological Study, Material Availability Survey, Traffic Study and Analysis, Axle Load Survey, Condition Surveys for Bridges, Culverts and Structures, Inventory survey of Road and Road Side structures, etc.,
- Assess environmental and social impact, Coordinate, interact and share information with separately appointed ESIA Consultant and Integration of their environmental and social findings and recommendations in detail design in accordance with the ESIA/ESMP, biodiversity management plan and other relevant inputs,
- Use state of art technology in managing the road safety in design for road and bridges. Prepare practical and cost-effective detail design and drawings for the road geometrics (horizontal, vertical, intersection, etc.) and pavement structures (based on projected traffic levels, axle loads and traffic safety), retaining structures, slope protection measures, drains, bridges and other cross drainages structures, intersections, flyovers, noise walls, and all other items necessary for construction of a safe, efficient, and resilient road. Applying sound engineering practices, determine cost-effective improvement options for the road sections, prepare a pavement preservation schedule to forecast future maintenance needs (overlay, crack sealing, etc.) at the right times in order to extend the life of the pavement,

- Conduct detailed geotechnical investigations along the road to investigate the suitability of local construction materials, conduct detailed geotechnical field investigations and lab analyses, provide boring logs, and prepare geotechnical design recommendations for the design of bridges and other structures,
- Conduct hydrological regime study based on the catchment area, rainfall and flood records, engineering field investigations to establish the adequacy of road embankment levels, culverts, and side ditches and design bed and slope protection for the drainage structures and bridges,
- Assess existing pits, ponds, wells in the periphery of road that could be implemented to achieve water harvesting and to improve the road's resilience. Assess possible use of water from road corridor for productive use in safe manner and that could recharge structures like culverts in consultation with local people, especially where roads pass through agriculture areas,
- Assess cross-drainage requirements and propose new structures or improvements to structurally unsound existing structures, if any,
- Prepare standard and special engineering technical specifications for each item of Works,
- Conduct hydrographic survey, utility survey, identification of Underground Structures and Other Obstacles,
- Conduct road safety audit and assessment analysis and incorporate the findings and recommendations into the detailed designs. Assess and make provisions for managing work-zone road safety aspects and traffic management during construction and include the same in the bidding documents,
- Prepare drone survey video of current status of road and bridges. Prepare short animated video of road, bridges and intersections presenting the details of designs features, concepts, traffic flow etc., with voice over and music. Prepare design visualization still images and videos of proposed roadway and bridges,
- Prepare contract packages, taking into account the location of the project roads and specific Project Procurement strategy for Development (PPSD),
- Prepare detailed bills of quantities and calculate engineering and environmental and social management costs estimates for civil works broken down into foreign and local components,
- Prepare a practical and resource-based project schedule showing critical construction activities and floats using CPM/PERT,

Prepare and submit bidding documents for each contract. Conduct capacity development activities for the purpose of knowledge transfer on latest technologies, applied procedure,

methods etc. on road/ bridge design & construction and current international practice on contract administration, contract management, disputes and its resolution etc.

Chapter 2: Design Standards

2.1 Introduction

New roads have mostly to negotiate through plain topography, friendly terrain and pleasant climatic conditions. Therefore, the design of roads to predetermined standards considering importance of safety and free flow of traffic is necessary so that travel is safe and comfortable. The Ultimate aim must be to arrive at an economically viable design, which is in balance with the physical and social environment, which meets future traffic requirements and which encourages consistency and uniformity of operation.

2.2 Design Standards for Road

The newly constructed roads have mostly to negotiate through plain topography, friendly terrain and pleasant climatic conditions. Therefore, the design of roads to predetermined standards considering importance of safety and free flow of traffic is necessary so that travel is safe and comfortable. The Ultimate aim must be to arrive at an economically viable design, which is in balance with the physical and social environment, which meets future traffic requirements and which encourages consistency and uniformity of operation.

This chapter covers briefly, various design standards and considerations adopted in developing four lane facility. As per TOR, the design standard proposed to be adopted for highway designs is Nepal Road Standard 2070 as main guidelines. In addition to NRS-2070, other standards are also reviewed taking into account the site condition, heterogeneous mix of traffic and existing geometry / land constraints. Accordingly, the following design standards and guidelines proposed to be adopted:

- Nepal Road Standard 2070 (Second Revision-2070)
- IRC:73-1990 “Geometric Design Standards for Rural Highways”
- IRC: SP-84-2019 “Manual of Specifications and Standards for Four Laning of Highways (Second Revision)”
- Nepal Road Design Standards (NRS) 2027 (First Revision-2045)

2.3 Highway Geometric Design Standards

2.3.1 Road Classification

NRS-2070 gives road classification based on national importance and Annual Daily Traffic. As per Clause 3(A), the project road is a National Highway connecting East to West of the Country.

As per Clause 3(B), the project road has ADT up to 20000 PCU in 20 years design period. Hence, the project road is classified as Class II, with desirable design speed of 100 Kmph for plain terrain.

2.3.2 Terrain

Terrain (cross country slope) is classified as the percentage slope across the road. Table 6-1, clause 6 (b) of NRS 2070 gives percentage cross slope for various terrain condition. Details of cross slope corresponding to various terrain condition is given in **Table 2.1**.

Table 2.1: Terrain Classification

S.no	Terrain Type	Percent Cross Slope	Degree
1	Plain	0-10	0°-5.7°
2	Rolling	>10-25	>5.7°-14°
3	Mountainous	>25-60	>14°-31°
4	Steep	>60	>31°

The % cross slope of the project road is less than 10% based on the evaluation of contours from Drone Survey data. Hence, the terrain of the project road is classified as Plain Terrain for entire length.

2.3.3 Design Speed

The Design Speed is the basic parameter in the design of all geometric parameters of the project road. Choice of design speed is also governed by the importance of the road (road class), type of terrain, existing road features and constraints. The design speed to be adopted for various classes of roads is given in Class 7 (a), Table 7-1. The summary of Design Speed for various road class and terrain conditions are presented in **Table 2.2**.

Table 2.2: Design Speed for various road class & terrain

Road Class	Plain	Rolling	Mountainous	Steep
I	120	100	80	60
II	100	80	60	40
III	80	60	40	30
IV	60	40	30	20

The Clause 7 (b) also suggests that "in very difficult terrains and unavoidable circumstances", the design speed can be reduced to 75% of the values given in Table 7-1 of NRS 2070.

The Consultant team has carried out inventory of existing road and prepared alignment design for upgradation of project road. Based on the design, there are 5 locations where the design speed of 100 Kmph cannot be accommodated within the available right of way of 50m. The team had discussions with the Client and World Bank team on several occasions and also during the site visit and the DoR advised the consultant to prepare the designs as per NRS standards with 100 Kmph at all locations and with reduced speed of 75 Kmph at locations where the right of way is restricted. These are presented in plan and profile drawings.

2.3.4 Sight Distance

The Sight distance is the distance / length available in different situations, to permit the driver of vehicle enough time and distance to control their vehicles to avoid accidents. There are three types of Sight distances relevant for the design of horizontal and vertical geometry of the highway.

Stopping Sight Distance (SSD): is the clear distance ahead required by the driver of a vehicle to stop the vehicle before meeting a stationary object in his path of the road. It is the minimum distance for which all road sections shall be designed, regardless of any other considerations. SSD for various design speed given in Table 8-1, clause 8.1 (b) of NRS-2070.

Overtaking Sight Distance (OSD): is the minimum sight distance that should be available on a 2-way road (un-divided highway) to enable driver to overtake another vehicle safely. OSD for various design speeds are given in Table 8-2, Clause 8.2 (a) of NRS-2070.

Intermediate Sight Distance (ISD) is normally considered as twice the safe stopping distance and affords reasonable opportunities to drivers overtake vehicle with caution. ISD is not explicitly specified in NRS, but overtaking zones are prescribed as per Clause 8.3 of NRS;

which are used at sections where sufficient OSD cannot be provided due to existing road / site constraints. Some of the considerations in providing overtaking zones are:

- Width of overtaking zones shall be same as that of two-lane road as minimum.
- Length of Overtaking zone shall be at least 3 times the overtaking distance on 2 / multi lane roads.
- Length of Overtaking zone shall be at least 2 times the overtaking sight distance.
- On single lane road, overtaking zones shall be provided at not more than 1 Km interval.
- Appropriate and adequate road signages shall be provided at start and end of overtaking zones.

Summary of SSD and OSD specified in Table 8-1 & Table 8-2 of NTS 2070 are summarized in **Table 2.3.**

Table 2.3: Summary of SSD & OSD

Speed, Km/h	20	30	40	60	80	100	120
Stopping Sight Distance, m	20	30	50	80	130	190	260
Overtaking Sight Distance, m	-	-	165	300	470	640	880

The project road is proposed to be developed as four lane divided carriageway with central median. The vertical design, specially at grade change locations of underpasses, flyovers, animal crossing approaches, bridge locations designed for intermediate sight distance, which is twice the stopping sight distance as providing overtaking sight distance will lead increased approaches which will increase the project cost.

Therefore, in the design of horizontal and vertical geometry, the designs are carried out for Intermediate Sight Distance, which will 2 times the stopping sight distance. The minimum ISD for 100 Kmph is considered as 380m. This is considered as Minimum Desirable Sight Distance.

Absolute minimum sight distance is adopted only on existing road, where further improvement is not possible due to sight condition etc.

2.3.5 Horizontal Curves

The road alignment designed to ensure that the standards of curvature, visibility, super elevation provided to the designated design speed and sight distance criteria. The design of horizontal curves for the project carried out as per Clause 9 and 24.3 of NRS 2070.

In general, horizontal curves should consist of a circular portion flanked by spiral transitions at both ends. Design speed, superelevation and coefficient of side friction affect the design of circular curves. Length of transition curve is determined on the basis of rate of change of centrifugal acceleration or the rate of change of super elevation.

a. Radius of Horizontal Curves

Minimum recommended values of radius of horizontal curves for various design speeds are given in Table 9-1, clause 9.1 (a) of NRS 2070 and summarized in **Table 2.4**. However as far as site conditions permit largest possible values of radius should be used.

Table 2.4: Minimum Radius of Horizontal Curves without Superelevation

Road Class				Design Speed, km/h	Minimum radius of horizontal curves		
					When no superelevation provided (2.5% camber i.e.negative superelevation)	When Maximum Superelevation of 10% provided	From the comfort of passengers (Max lateral force 15% of vertical force)
I				120	1730	600	760
	II			100	870	370	530
		III		80	440	210	340
			IV	60	200	110	190
				40	70	40	90
				30	30	20	50
				20	20	10	30

b. Minimum Radius of Horizontal Curve:

The minimum radius of the curve corresponding worked out based on the following two criteria:

a) The minimum radius of horizontal curve corresponding to design speed of 100 Kmph, lateral friction of 0.12 and maximum superelevation of 7% will be 420m.

b) As per clause 24.3 (g) of NRS 2070, the minimum curve radius of curve considering comfort to passengers will be V2 / 20 and this works out to 500m.

The minimum horizontal curves corresponding to limiting superelevation of 5% and 7% for various design speeds are worked out and presented in **Table 2.5**. For the project, the minimum radius of 500m used in the design.

Table 2.5: Minimum Horizontal Curve Radius

Design Speed, Kmph	**Super - elevation**	100	80	60	40
Minimum Curve Radius, m as per theoretical formula	7%	420	270	150	70
Minimum Curve Radius, m as per empirical formula (Cl 24.3(g)		500	320	180	80
Minimum Curve Radius, m as per theoretical formula	5%	470	300	170	75
Minimum Curve Radius, m as per empirical formula (Cl 24.3(g)		500	320	180	80

<u>Radius of Curve not requiring superelevation</u>

Clause 9.2 (b & c) of NRS 2070 mentions that the curve with radius more than 1000m (defined as large radius) does not require transition curve. This implies that, superelevation (rotation of carriageway to counteract centrifugal force) is not required.

However, as per IRC:73 and IRC:38, the minimum radius of curve required to be provided as per the formula e = V2 / 225R for design speed of 100 Kmph is 1800m.

Therefore, the consultant proposes to adopt 1800m as the minimum curve radius, for not providing superelevation.

2.3.6 Transition Curves

Transition curves are provided for vehicle to pass smoothly from straight section of road to circular section and back to straight section or between curves of different curve radius. The transition curves facilitate gradual application of super-elevation and extra widening (if required), on horizontal curves.

The minimum length of transition curves has been worked out from the following considerations (ref clause 24.4 of NRS 2070):

(a) Length of change of centrifugal acceleration, where

Ls = 0.0215 x V3 x C x R

- Ls : transition curve in m
- V : design speed in Kmph
- C : rate of increase of lateral acceleration given by formula 80/(75+V) with values between 0.5 and 0.8.

(b) Rate of rotation of Carriageway

As per Clause 11.6(e) of NRS 2070, the rate of rotation of outer edge of carriageway shall be 1m for every 150m for road in plain and rolling terrain.

NRS 2070 also provides conditions where transition curves cannot be accommodated between circular and straight portion of the alignment. As per clause 24.4 (b), length of transition curve shall be less than 3.141 times the curve radius. Further, clause 24.4(c) specifies that the transition curve will not be required, if the lateral shift of the horizontal curve (L2/24 times R) is less than 0.25m.

The consultant has adopted rotation of carriageway at rate of 1 in 150 at superelevated sections.

2.3.7 Superelevation

Super elevation is provided on horizontal curves as per clause 11.6 of NRS 2070. The Value of super elevation is calculated using following formula.

$e+f = V^2/127R$

Where,

e-value of super elevation, m/m

R-Radius of horizontal curve

V-Design Speed, km/h

f-co-efficient of lateral friction, depends on the vehicle speed and taken from table

a) Maximum super elevation to be provided is limited to:

- In plain and rolling terrain 7%
- In snow bound areas 7%

- In hilly areas not bound by snows 10%

b) Minimum value of super elevation should be equal to the rate of camber of the pavement.

c) The rate of introduction of superelevation (i.e., longitudinal grade developed at the pavement edge compared to through grade along the centre line) should be such as not to cause discomfort to travelers or to make the road unsightly.

d) Rate of change of the outer edge of the pavement should not be steeper than 1 in 150 in plain and rolling terrain and 1 in 60 in mountainous and steep terrain in comparison with the grade of the centre line.

The alignment design is carried out such that the superelevation is limited to 5% by increasing the radius of the curves. This is considering heterogenous mix of traffic and to provide better comfort to drivers subject to following existing road with minimum shift on curves.

2.3.8 Vertical Alignment

The vertical alignment should provide for a smooth longitudinal profile consistent with category of the road and terrain, Grade changes should not be too frequent as to cause kinks and visual discontinuities in the profile. Desirably, there should be no change in grade within a distance of 150 m. However, these are normally applicable for green field alignment.

The requirements for vertical alignment is given in Clause 10 of NRS 2070. The maximum gradient for various design speed given in Table 10-1 of NRS 2070 is summarized in **Table 2.6**.

Table 2.6: Maximum gradient for various design speed

Design Speed, km/h	20	30	40	60	80	100	120
Maximum Gradient, %	12	10	9	7	6	5	4

The Minimum longitudinal gradients for longitudinal drainage purpose is 0.5%.

For the project, the consultant proposes to carry out the vertical alignment design considering the following at detailed alignment design:

- Follow existing asphalt surface with profile correction with minimum profile corrective course layer and overlay.
- Avoid excessive overlay and profile corrective course to correct the profile, which otherwise would be cost prohibitive.
- Matching of existing bridge deck levels.

2.3.9 Vertical Curves

Vertical curves are provided on the road where two straight sections of different gradient intersect (ref Clause 10.4 of NRS 2070). The curvature shall be large enough to provide comfort for road users and adequate sight distance for safe driving. If the convexity of the curve is upwards, it is called as “Summit / Hog” curve and if the convexity is downwards, then the curve is called “Valley / Sag” curve. The quadratic equation of square parabola satisfies the above conditions and therefore used in computation of length of vertical curves. Length of the curve is derived from ‘K’ value defined as the minimum radius of curvature at the vertex of square parabola and computed as the algebraic difference of grade change.

a) Summit Curves

Summit curves are designed for safe stopping sight distance. The minim length of summit curve is determined from the consideration of safe SSD throughout the length considering height of driver’s eye 1.2m above road level and an object 0.15m above the road surface. The Clause 10.4.1 & clause 24.5 of NRS 2070 provides computation requirements for summit curves for sight distance less than curve length and sight distance more than curve length. The Safe Stopping Distance corresponding to Intermediate Sight Distance is used in computation of summit curve length. Table 10-3 of NRS 2070 provides the minimum K value to be used in computation of summit curve length. Accordingly, K value for design speed of 100 Kmph is 427.

b) Valley Curves

Valley curves are designed for head light sight distance with consideration of visibility to driver during night driving. The head light sight distance is computed considering illumination of road surface with 0.75m mounting above the pavement surface at an inclination of 2 degrees of the headlight. Clause 10.4.2 & clause 24.6 of NRS 2070 provides computation requirements for valley curves for sight distance less than curve length and sight distance more than curve length. The safe stopping distance corresponding to intermediate sight distance is used in computation of valley curve length. Table 10-4 of NRS 2070 provides the minimum K value to be used in computation of valley curve length. Accordingly, K value for design speed of 100 Kmph is 236.

Summary of K values prescribed as per NRS 2070 is given in **Table 2.7**.

Table 2.7: K Values for Vertical Curves

Design Speed, km/h	20	30	40	60	80	100	120
K Value for Summit Curves	2	4	29	94	231	427	807
K Value for Valley Curves	3	6	17	42	111	236	441

The K values given in NRS 2070 for summit curves is based on consideration of Overtaking distance criteria for un-divided road. The consultant has reviewed the vertical curve design requirement w.r.t IRC: SP-84 and IRC: SP:23 guidelines used in similar condition of the project road. The summit curve length obtained from consideration of OSD criteria for grade change of 8% (in case of flyover / underpass approach) works out to 3417m for K value of 427 whereas the approach length around 220m – 250m. Hence, it is practically not possible to fit the curve within the approach. Therefore, the consultant proposes to adopt stopping sight distance criteria wherein the K value for 100 Kmph is 73.6 and corresponding length for grade change of 8% around 295m. In case, the length of the approach is short compared to the length of the curve, the gradient flattened. However, in the extreme case of the alignment not being able to be flattened due to overlap with existing bridge structure, then the vertical curves of the section of the road falling under approaches of flyover / underpass designed for 75 Kmph with appropriate road signage / traffic calming measures.

2.3.10 Grade Compensation on Curves

Grade compensation on vertical curves reviewed as per clause 10.12 of NRS 2070 at road sections, where the vertical grade is more than 4%. Vertical gradient eased by 0.5% for each rise of 500m above MSL. The extent by which the gradient has to be eased will be calculated as (30+R)/R limiting the value to 75/R. This has been carried out on case-to-case basis.

2.3.11 Lateral Clearance

For a single carriageway road that goes through an underpass, whole width of the roadway (carriageway plus shoulder widths) should be cleared in lateral direction.

If footpaths are provided minimum lateral clearance should be width of footpath plus 1.0 m.

On roads with divided carriageway, left hand side lateral clearance should be as given on (a.) and (b.) above.

Right hand side clearance should be 2.0 m (desirable) with 1.5m minimum.

2.3.12 Vertical Clearances

A vertical clearance of 5.0m measured from the crown of the road surface to be provided for whole roadway width on all roads. No obstructions made on this space.

Vertical clearance for high voltage electric cables from the road surface as shown in **Table 2.8**.

Table 2.8: Vertical Clearances for electric wires and cables

Voltage, KV	Minimum Vertical Clearance, m
1	6
110	7
150	7.5
220	8
330	8.5
550	9
720	16

2.4 Cross Section Elements

2.4.1 Right of Way

NRS 2070 (clause 11.9.1 (a)) specifies right of way for various classes of roads. ROW for various road classes are given in **Table 2.9**.

Table 2.9: Right of Way for various Road Classes

Road Type	Total Right of Way, m
National Highways	50
Feeder Roads	30
District Roads	20

As per TOR, the existing right of way for project highway is 50m and the client has informed the consultant during the review meeting that the improvement scheme of 4 lane has to be accommodated within available right of way of 50m as much as possible. Based on the preliminary / concept design, additional land may be required in urban / built up sections / turnings at underpasses (considering turning radius for vehicles) and where service roads along with bus bay / bus shelters is required.

2.4.2 Carriageway

The standard width of main carriageway is 3.5m as per clause 11.1(a), Table 11-1 of NRS 2070 for multi lane road. The total width of pavement to be determined based on the volume of the traffic and capacity of each lane as given in Section 5 of NRS.

2.4.3 Shoulder

A roadside shoulder is a reserved area by the verge of road. Generally, it is kept clear of all traffic movement. In the event of an emergency or break-down of vehicles, a motorist call pull into the shoulder (which is generally hard / paved) to get out of the flow of traffic and get an sense of safety. The shoulders also provide an opportunity to improve sight distance along long cut sections. Shoulder provide better and safer operational conditions and a facility of directly using these as part of carriageway when the road widened.

The requirement for shoulder is given in clause 11.2 of NRS 2070.

a) The width of shoulders on either side of the carriageway at least 0.75m. Recommended width of shoulder for various classes of roads is summarized in **Table 2.10**.
b) For protection of pavement from water percolating under it from shoulder, it is recommended to treat at least a 0.50-0.75m wide strip of shoulder near the edge of the pavement with impervious to water surfacing.
c) If a small gap(<1m) of untreated shoulder is formed between the edge of the pavement and edge of the side drain in hill roads it is recommended to treat this gap with appropriate surface treatment.
d) For mountainous and steep terrain, the shoulder widths can be reduced to a minimum value for a lower class of the road but not less than 0.75m.
e) It is desirable that the color and texture of shoulders be different from those of the carriageway.
f) This contrast serves to clearly define the carriage way at all times, particularly at night and during inclement weather, while discouraging the use of shoulders as additional through lanes.
g) Very wide shoulders (more than 3.75m wide) are also not desirable due to tendency of vehicles misusing it as a carriageway.

Table 2.10: Recommended with of shoulder as per NRS

Road Class	Class I	Class II	Class III	Class IV
Minimum shoulder width, m	3.75	2.5	2.0	1.5

NRS does not categorize the type of shoulder to be provided for multi lane road. On further review of typical cross sections given in clause 11-8 of NRS 2070, it appears that paved shoulders are not specified. Considering the safety and operational condition of the proposed 4 lane highway, paved shoulder for certain width beyond the travel lane is desirable. Therefore, the consultant has referred to the specifications given in IRC:SP-84-2019. As per IRC:SP-84-2019, the total width of shoulder is 4.0m comprising of 2.5m paved shoulder and 1.5m earthen shoulder. This is 1.5m more than the shoulder width specified for Class II road as per NRS. Considering provisions of NRS and IRC as well as various factors, the width of shoulder for the project road has been proposed as given in **Table 2.11**.

Table 2.11: Proposed Width of Shoulder

Type of section	Width of shoulder, m		
	Paved	Earthen	Total
Open country with isolated built up area	2.5	1.5	3.5
Built up area	2.5	-	2.5
Approach to grade separated structures	2.5	-	2.5
Approaches to bridges	2.5	1.5	4.0

The consultant have modified and added Typical Cross Sections subsequent to submission of concept report. Separate Typical Cross Section for Rural section, Urban section and Semi urban section are prepared by the Consultant. In addition, Typical Cross Section for Vehicular Underpass and Flyover stretch in Urban section has been prepared in addition to Typical Cross section for Urban section having at-grade interaction/ service road. The main road and paved shoulder to be continuous in urban sections.

2.4.4 Median/ Central Verge

The project road is proposed for 4 lane divided carriageway separated by central median. The requirements for central median is given in clause 11.3 of NRS 2070. Accordingly,

(a) a minimum median width of 5m is recommended. But a width of 3m can be adopted in areas where land is restricted.

(b) In mountainous and steep terrains maximum possible width of median dictated by the topography should be provided. In such situations, simple barriers may be provided to function as a median or individual carriageways could be designed at different levels.

(c) On long bridges and viaducts, the width of the median may be reduced to 1.5m. However, in no case this should be less than 1.2m.

(d) The median should be of uniform width in a particular section of the highway. However, where changes are unavoidable, a transition of 1 in 20 must be provided.

The consultant has carried out inventory of the project road and reviewed the proximity of bridge structures along the project road. If NRS standards followed, then the width of median varing with 5m in rural section, 3m in urban section where service roads are proposed and 1.5m on bridges. These changes in median at frequent interval along the project road will lead to “haphazard” alignment of travel lanes which is not desirable for the category of road under Class II. Therefore, the consultant proposes 4m wide central median in rural and bridge sections and 1.5m in urban and grade separated sections. The proposed Median width configuration has also been discussed and mutually agreed with the Client and the World Bank.

2.4.5 Camber

Camber / cross fall of pavement following as per clause 11.5 of NRS 2070.

On roads with divided carriageway on straight sections, unidirectional camber provided on either side of carriageway with slope from median edge towards the outer side. The camber for flexible pavement is 2.5% as per Table 11-3 of NRS 2070. The width of paved shoulder follow the camber of main carriageway. The camber of earthen / granular shoulder is 0.5% more than the camber of main carriage way. On superelevated sections, the earthen / granular shoulder on the outer side of the curve provided with reverse camber of 0.5% so that, the soil does not spread on the carriageway which may lead to accidents.

2.4.6 Road Side Slopes

Side slopes of embankment / cut sections for the project road provided as per Clause 11.7 of NRS 2070. Side slopes for embankment provided as per details given **Table 2.12.**

Table 2.12: Recommended Slopes for Fill Sections

Height, m	Side Slope (V:H)
<1.5	1:4

Height, m	Side Slope (V:H)
1.5 to 3.0	1:3
3.0 to 4.5	1:2.5
4.5 to 12.0	1:2
>12.0	To be designed

Recommended slopes in cut sections depends on the type of soil encountered in cutting and provided as per details given in **Table 2.13**.

Table 2.13: Recommended Slopes for Cut Sections

Soil Type	Side Slope (H:V)
Ordinary Soil	1:2 to 1:1
Disintegrated rock	1:1/2 to 1: ¼
Soft rock, shale	1:1/4 to 1: 1/8
Medium rock	1: 1/12 to 1: 1/16
Hard rock	Almost vertical

The summary of land use wise (i.e. urban, semi urban and rural/ forest) Cross Section configuration adopted for geometric design is presented vide Table **Table 2.14 below**.

Table 2.14: Summary of Lan Use wise Cross Section Configuration

Urban Section with service lane		
Formation Width	:	Formation Width: 4x3.5+2x2.5 (shoulder)+4 (Median)+2x0.5 (kerb shy) = 24 m for main Carriageway
Service lane	:	6.5m on both side = 13m
Shoulders	:	Paved 2.5 m both side of Main carriageway
Separator	:	1.2m between Main Carriageway and Service Road
Cycle Track	:	2m at outer edge of Service Road
Drain cum Footpath	:	Varies
Pavement Camber	:	2.5 % on either side from center
Semi Urban section with service lane		
Formation Width	:	Formation Width: 4x3.5+2x2.5 (shoulder)+4 (Median)+2x0.5 (kerb shy) = 24 m for main Carriageway
Service lane	:	5.5 m on both side = 11 m
Shoulders	:	Paved 2.5 m both side of Main carriageway
Separator	:	1.2m between Main Carriageway and Service Road
Granular Shoulder	:	1.5m at outer edge of Service Road
Pavement Camber	:	2.5 % on either side from center

Forest section and Rural section		
Formation Width	:	Formation Width : Total 4x3.5+2x2.5 (paved shoulder)+2x1 (granular shoulder)+4 (Median)+2x0.5 (kerb shy = 26 m in main Carriage way
Shoulders	:	Paved 2.5 m both side + Earthen 1.0m on both side
Pavement Camber	:	2.5% on either side

2.5 Design Standards for Pavement

The pavement design for the Project Road has been carried out adopting various parameters. The parameters are adopted considering provisions / stipulations made in NRS 2070 and IRC 37 -2018 as well as outcome of the discussion held with DoR.

The parameters adopted for the Pavement Design are as stated in **Table 2.15** below:

Table 2.15: Parameters Adopted for Pavement Design

Type of Pavement	Flexible Pavement for Main Carriageway & Service Road Concrete Pavement for Bus Bay and Truck Lay bye
Design Period	20 Years for Flexible Pavement 30 Years for Concrete Pavement
Adopted Homogeneous Sections	Kamala (km 237.300) – Bardibas (km 268.300) Section (HS 1) Bardibas (km 268.300) – Nijgadh (km 247.100) Section (HS 2) Nijgadh (km 247.100) – Pathlaiya (km 367.000) Section (HS 3)
Adopted Design Subgrade Strength	Effective CBR of 10%
Loading Distribution	50% in each Direction
Type of Vehicles Considered for Design Load	Multi Axle Truck, Medium Truck, Mini Truck Large Bus, Mini Bus, Micro Bus
Adopted Design Load (in MSA)	Main Carriageway HS 1 – 60 MSA HS 2 – 40 MSA HS 3 – 75 MSA Service Roads – 10 MSA
Code Consideration for Design	Provisions of NRS 2070 & Verification and Final Pavement Design using IIT Pave i.e. IRC 37 - 2018

2.6 Guidelines and Practices for Other Components

Besides above Design standards for Road, Bridge and Pavement; different guidelines and Codes are used for designing other components like drainage system, embankment protection measures and other auxiliary facilities for road safety. However, generally, provisions made under IRC Codes are adopted besides provisions of NRS 2070 for other component designs.

2.7 Design Standard for Bridges

The design standards adopted for design of bridges including Flyover, Vehicular Underpass, Pedestrian Underpass, Elephant Crossing etc. are described in detail under this section.

2.7.1 Design Life

The design service life for different structures is as considered below for reference:

Table 2.15: Design Life

Bridge Components	Design Service Life (in Years)
Foundations	100
Substructures	100
Superstructure/Deck	100
Bearings	40 (20 years for minor components only)
Expansion Joints	20 (10 years for minor components only)
Railing (Metallic Part)	40
Crash Barrier (Concrete)	100
Drainage System	20

2.7.2 Design Speed

The design speed of vehicles for the purpose of design of structural components is considered as 100 kmph asper TOR. (Cl 3.1.1 Page 74)

2.7.3 Design Load

To consider the self-weight of structure, the unit weights of materials considered as per Clause 203 given in IRC: 6-2017 (Refer Table below)

2.7.3.1 Superimposed Dead Load (SIDL)

Superimposed Dead Load is of two types i.e., Variable SIDL and Fixed SIDL. The load due to wearing coat is of Variable type. The loads due to Crash Barrier, median, are fixed type.

SIDL (Variable Load)

Wearing course shall consist of minimum 50mm thick HIMA (Premix B.C) along with MMA water proofing membrane.

SIDL (Fixed Load)

Crash Barrier

Crash barriers considered are designed as per Clause No 206.6 of IRC 6-2017

2.7.3.2 Live Load

Vehicular Live load
As per Cl. 204.3 of IRC:6-2 017

The Live load combination adopted has been presented vide **Table 2.17** below:

Table 2.16: Live Load Combinations

Sr. No.	Carriageway Width (CW)	No. of Lanes for Design Purposes	Load Combination
1)	5.3 m and above but less than 9.6 m	2	One lane of IRC Class 70R or 2 lanes of IRC Class A
2)	9.6m and above but less than 13.1m	3	One lane of IRC Class 70R (wheeled) for every two lanes and one lane of Class A or 3 lanes of IRC Class A

The Bridges are divided in to four categories for design purpose, the same are as detailed below for reference:

Case 1: For non-urban zone

Total width of the bridge = 11.85 m

Existing carriageway = 8.0 m

Future carriageway = 8.0+0.45+2.50 =10.95 m.

Case 2: For Urban zone

Total width of the bridge = 17.55 m

Existing carriageway = 8.0 m & 6.5 m

For this category, 2 separate 2 lane considered

Case 3: For Urban zone

Total width of the bridge = 9.1 m

Existing carriageway = 8.0 m

For this category, 1 no. 2 lane considered

Case 4: For Urban zone

Total width of the bridge = 27.05 m

Existing carriageway = 2x 8.0 m & 6.5 m

For this category, 3 separate 2 lane considered

The design live load consists of two standard wheeled vehicles,

1) Class 70R vehicle (Wheeled or Tracked) and
2) Class A Train of vehicles.

For longitudinal analysis, 70R Tracked will not govern the design and hence only 70R Wheeled isconsidered.

2.7.4 Congestion Factor

The Congestion Factor as per Clause 204.4 of IRC: 6-2017 considered, as congestion of vehicle is anticipated during the service life of the structure.

2.7.5 Impact Factor

The Impact factor considered for the Longitudinal and Transverse Design of Superstructure as per Clause 208 of IRC: 6-2017.

Impact factor reduced appropriately as per Clause 208.7 of IRC: 6-2017 for design of piers and foundation. Pier cap designed considering 50% of impact value specified above and for design of Pier, impact factor not considered.

2.7.6 Reduction in Longitudinal Effect

The reduction in longitudinal effect has been considered as per Clause 205 of IRC: 6-2017 depending on the number of lanes. This reduction is applicable for live load shear force, bending moment and torsion in longitudinal direction for superstructure and live load vertical loads for substructure and foundation design.

2.7.7 Braking Force/Traction Force

The braking/traction effect has been considered as per Clause 211.2 of IRC: 6-2017 depending on the number of lanes. For seismic case, the braking/traction effect has been considered as 20% of design value as per note below the Clause 219.5.2 of IRC: 6-2017.

2.7.8 Centrifugal Forces

The centrifugal force for structures falling in curve calculated from the following equation and applied accordingly.

$$C = \frac{WV^2}{127R}$$

Where,

C = Centrifugal force acting normally to the traffic (1) at the point of action of the wheel loads or (2) uniformly distributed over every meter length on which a uniformly distributed load acts, in tones.

W = Live load (1) in case of wheel loads, each wheel load being considered as acting over the ground contact length specified in Clause 204 of IRC: 6, in tonnes, and (2) in case of a uniformly distributed live load, in tonnes per linear meter.

V = the design speed of the vehicles in km per hour = 80kmph

R = the radius of curvature in meters,

The centrifugal force has been considered to act at a height of 1.2 m above the level of the carriageway. No increase for impact effect made on the stress due to centrifugal action. The overturning effect of the centrifugal force on the structure as a whole to be also duly considered.

Creep and Shrinkage

Creep and shrinkage effects is considered in accordance with clause 6.4.2.6 & 6.4.2.7 of IRC: 112-2011. The relative humidity of the ambient environment is considered as 70% to arrive at creep coefficient and shrinkage strains.

Creep and shrinkage will depend on many factors like grade of concrete, age of concrete at the time of loading, cross sectional and perimeter of the section under consideration.

Earth Pressure

The effect of earth pressure calculated in accordance with coulombs theory for earth retaining structures. Soil properties for earth pressure load as per the recommendations of geotechnical engineer. All abutments and return walls designed for a live load surcharge equivalent to 1.2m earth fill and the centre of pressure exerted by the backfill at a height of 0.42 times the height of wall above the base as per clause 214.1.1 of IRC: 6-2017.

2.7.9 Wind Load (W)

Design Wind Force on Superstructure

The wind load calculation done as per Clause 209 of IRC: 6-2017. Value of basic wind speed at the location of bridge taken from wind map given in figure 6 of IRC: 6-2017.

Design wind force on the superstructure has been calculated as per Clause 209.3 of IRC: 6- 2017.

Design Wind Force on Live Loads

The transverse wind load per unit exposed frontal area of the live load has been computed using the expression FT given in Clause 4.5.1, except that CD against has been taken as 1.2. The exposed frontal area of live load for the entire length of the superstructure seen in elevation in the direction of wind as defined in Clause 4.5.1 or any part of that length

producing critical response, multiplied by a height of 3.0 m above the road way surface. Areas below the top of a solid barrier neglected.

The longitudinal wind load on live load has been taken as 25 percent of transverse wind load as calculated above. Both loads have been applied simultaneously acting at CG of height of live load above road surface as considered in calculating the force.

Design Wind Force on Substructure

The Wind Load on the substructure has been calculated in accordance with Clause 209.4 of IRC: 6-2017.

Design Wind Force during Construction For construction stages, the hourly mean wind pressure taken as 70 percent of the value as calculated for return period of 100 years, as per Clause 209.2 of IRC: 6-2017.

2.7.10 Temperature Effects

The temperature loads considered as per Cl. 215 of IRC 6-2017. Critical temperature and differential temperature effects are determined and applied. For the purpose of calculating temperature effects, the coefficient of thermal expansion for RCC, PSC and steel structures may be taken as 12.0x 10-6 /°C A temperature variation of +5°C to +42.5°C has been considered for all structures. The Superstructure has also been designed for effects of distribution of temperature across the deck depth as given in Fig. 17a & 17b of IRC6-2017, suitably modified for the surfacing thickness.

Temperature effects considered as follows:

Effects of non-linear profile of temperature combined with 50% live load and full value of ‘E’ considered.

Effects of global fall and rise of temperature combined with 100% live load and full value of ‘E’ considered.

Uniform Temperature

The maximum and minimum air shade temperatures for the site condition obtained from figure 8 and figure 9 of IRC: 6-2017 as 42.5°C and 5°C respectively. The mean of maximum and minimum air shade temperature is equal to 23.75°C.

The difference between maximum and minimum air shade temperature is equal to 37.5oC, which is greater than 20°C.

As per table shown in Clause 215.2 of IRC: 6-2017, the bridge temperature to be assumed when the structure is effectively restrained, is equal to mean of maximum and minimum air shade temperature ±10°C, which corresponds to 13.75°C and 33.75°C. Considering these values as datum values, lowering of bridge temperature is equal to 33.75 to 5.0 = -28.75°C and increasing of bridge temperature is equal to 13.75 to 42.5 = 28.75°C.

Differential Temperature

Effect of temperature difference within the superstructure has been assumed as shown in the Fig. 10 of IRC: 6-2017.

2.7.11 Differential Settlements

Based on the available geotechnical data, rocky profile is anticipated at the project site and hence, differential settlement will not be considered. It is to be noted that viaduct spans are designed as simply supported girders with deck only continuity, the differential settlement load has very less effect, hence will not be considered in design.

2.7.12 Seismic Loads

2.7.12.1 Seismic Force

Seismic force has been considered as per Clause 218

The characteristics of seismic ground motion expected at any location depend upon the magnitude of earthquake, depth of focus, distance of epicentre and characteristics of the path through which the seismic wave travels. The random ground motion can be resolved in three mutually perpendicular directions. The components are considered to act simultaneously, but independently and their method of combination is described in Clause 218.4. Two horizontal components are taken as of equal magnitude, and vertical component is taken as two third of horizontal component.

In zones V the effects of vertical components has been considered for all elements of the bridge.

2.7.12.2 Combination of Component Motions

The seismic forces are assumed to come from any horizontal direction.

For this purpose, two separate analyses has been performed for design seismic forces acting along two orthogonal horizontal directions. The design seismic force resultants (i.e., axial force, bending moments, shear forces, and torsion) at any cross-section of a bridge component resulting from the analyses in the two orthogonal horizontal directions combined as given in fig.18

a) ± r1± 0.3r2

b) ± 0.3r1 ± r2

where,

r1= Force resultant due to full design seismic force along x direction

r2 = Force resultant due to full design seismic force along z direction

When vertical seismic forces are also considered, the design seismic force resultants at any cross-section of a bridge component combined as below:

a) ± r1±0.3 r2±0.3 r3
b) ± 0.3 r1± r2 ±0.3 r3
c) +0.3 r1±0.3 r2 ± r 3

Where r1 and r 2are as defined above and r 3

is the force resultant due to full design seismic force along the vertical direction.

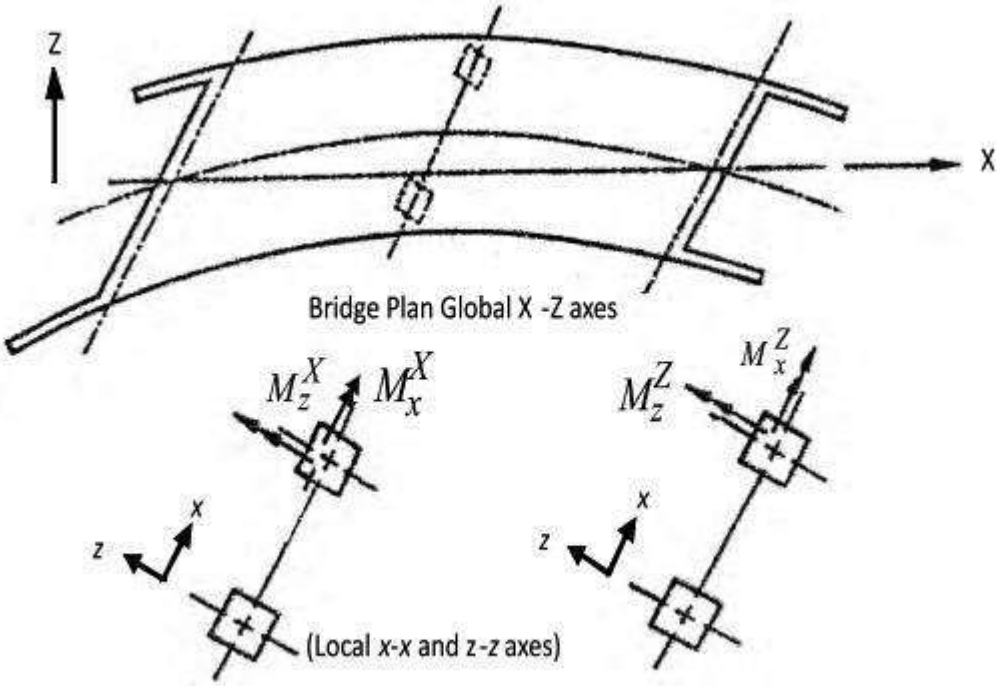

Fig. 18: Combination of Orthogonal Seismic Forces

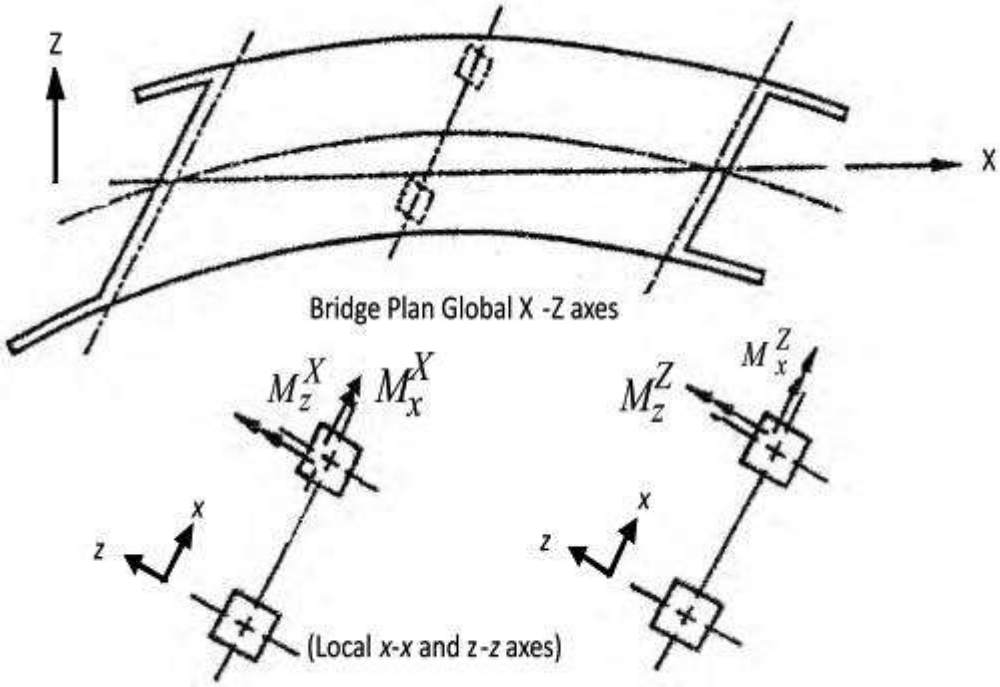

Fig. 18: Combination of Orthogonal Seismic Forces

Table 17: Design Moment for Ground Motion

	Moments for Ground Motion along X-axis	Moments for Ground Motion along Z-axis
Design Moments	$M_x = M_x^X + 0.3\ M_x^Z$	$M_Z = M_z^X + 0.3\ M_z^Z$
	$M_x = 0.3M_x^X + M_x^Z$	$M_Z = 0.3M_z^X + M_z^Z$
	Where, M_x and M_z are absolute moments about local axes.	

2.7.12.3 Horizontal seismic force

The horizontal seismic forces acting at the centres of mass, which are to be resisted by the structure as a whole, computed as follows

$$F_{eq} = A_h \text{ (Dead Load + Appropriate Live Load)}$$

where

F_{eq} = seismic force to be resisted

A_h = horizontal seismic coefficient = $(Z/2) \times (I) \times (S_a/g)$

Appropriate live load shall be taken as per Clause **218.5.2**

Z = Zone factor as given in **Table 16**

I = Importance Factor (see Clause **218.5.1.1**)

T = Fundamental period of the bridge (in sec.) for horizontal vibrations

Design response spectrum for seismic analysis is derived from the figure 19 of IRC 6-2017, considering foundation is resting on soil.

As the bridge is located in seismic zone V, ductile detailing is required. The forces on various members obtained from the elastic analysis of bridge structure are to be divided by Response Reduction Factor for the design of pier and bearing.

For design of foundation, the seismic loads are taken as 1.35 times the forces transmitted to it by concrete substructure as per Clause 219.8 of IRC:6-2017, so as to provide sufficient margin to cover the possible higher forces transmitted by substructure arising out of its over strength.

In accordance with provision of Clause 219.4 of IRC:6-2017, the following seismic combinations have to be considered for the bridge

a. +/- EQx +/- (0.3EQy) +/- (0.3EQz)
b. +/- (0.3EQx) +/- EQy +/- (0.3EQz)

c. +/- (0.3EQx) +/- (0.3EQy) +/- (0.3EQz)

Where,

EQx is seismic in longitudinal direction EQy is seismic in transverse direction EQz is seismic in vertical direction.

Vertical seismic forces has been considered as per IRC SP 114-2018.provisions. The seismic force (modal mass) due to live load are not considered when acting in the direction of traffic, but is considered in the direction perpendicular to traffic. Only 20% of Live Load on the deck has been considered in transverse and vertical seismic case.

Response Reduction Factors

The applicable response reduction factors are as per IRC SP114-2018.

Collision Loads

Vehicle collision load is considered in flyover substructure /pedestrian substructure design as per clause no 222 of IRC 6-2017.

Guidelines for Foundation Design

a. For design of foundation, the seismic loads has been taken as 1.35 times the forces transmitted to it by substructure, so as to provide sufficient margin to cover the possible higher forces transmitted by substructure arising out of its over strength.

b. Since the bridges are located in seismic zone V, hydrodynamic and additional earth pressure forces under seismic condition has been considered as per cl. 219.5.4 of IRC:6-2017.

Buoyancy (B)

For piers and foundation under the influence the water flow, the effects of buoyancy as specified in cl. 213 of IRC: 6-2017 has been considered.

Water Current (WC)

For piers which are parallel to direction of water current, the intensity of pressure has been calculated from the following equation as per cl. 210.2 of IRC: 6-2017.

$$P = 52kv^2_$$

P = Intensity of pressure due to water current (kg/m2)

V = Velocity of the current at the point where pressure intensity is being calculated (m/s)

The square of velocity at a given height calculated as specified in cl. 210.3 of IRC: 6-2017

Jacking Up Condition

The effects of jacking during bearing replacement considered for design of superstructure and substructure.

Bridge structure designed to allow a 20mm vertical jacking at any bridge bearing support with no traffic closure.

However, no special vehicle loading needs to be considered during bearing replacement as well no congestion factor to be considered.

2.7.13 Load Combinations

The load combinations for the design of structural elements are considered as per IRC: 6-2017 limit state design method. The following notations are used for representing load cases in limit states,

G	-	Permanent load
S	-	SIDL Variable load
Q	-	Live load
Fcf	-	Centrifugal load
Fb	-	Braking load
Ff	-	Frictional load
W	-	Wind load
r1	-	Seismic load in long. Direction
r2	-	Seismic load in trans. Direction
r3	-	Seismic load in vertical direction
TG	-	Temperature Gradient load

TU	-	Temperature	Uniform
load P	-	Pre-stress load	

The Ultimate Limit State (ULS)

Under Ultimate Limit State (ULS), loads are required to be combined to check the equilibrium and thestructural strength. The equilibrium of the structure has been checked against overturning, sliding and uplift. It has been ensured that the disturbing loads (overturning, sliding and uplifting) are always less than the stabilizingor restoring actions. The structural strength under ultimate limit state has been estimated in order to avoid internal failure or excessive deformation. The equilibrium and the structural strength has been checked under basic, accidental and seismic combinations of loads.

Equilibrium Combinations

The combinations are considered as per Table B.1 of IRC: 6-2017.

Structural Strength Combinations

The combinations are considered as per Table B.2 of IRC: 6-2017.

Service Limit State (SLS)

Under Service Limit State (SLS), loads are required to be combined to satisfy the serviceability requirements. The serviceability limit state check has been carried out in order to have control on stress, deflection, vibration, crack width, settlement and to estimate shrinkage and creep effects. It has been ensured that the design value obtained by using the appropriate combination is less than the limiting value of serviceability criterion as stated in IRC: 112-2019. The rare combination of loads has been used for checking thestress limit. The frequent combination of loads has been used for checking the deflection, vibration and crack width. The quasi-permanent combination of loads has been used for checking the settlement, shrinkage creep effects and the permanent stress in concrete.

The combinations has been considered as per Table B3 of IRC: 6-2017.

Combination for Design of Foundation

To estimate the structural strength of foundation, the following load combinations has been considered as perTable B4 of IRC: 6-2017.

Combination for Base Pressure Check

To estimate the base pressure under foundation, the loads are considered as per IRC: 78 & load factors are considered as per IRC: 6-2017.

Partial Safety Factor for Material

Partial safety factors for materials are to be taken in accordance with IRC: 112-2019 as provided in **Table 2.18** below:

Table 2.17: Partial Safety Factors for Materials

	γc	γs	γs
Design situation	**for concrete**	**for reinforcing steel**	**for pre stressing steel**
ULS Basic and Seismic	1.5	1.15	1.15
ULS Accidental	1.2	1	1
SLS	1	1	1

2.7.14 Miscellaneous

2.7.14.1 Expansion Joints

Expansion joints are proposed at the end support locations. Strip seal or modular expansion joint are also provided. These joints are designed according to Cl.5.3 of IRC SP: 69.

2.7.14.2 Bearings

Elastomeric /POT cum PTFE / Spherical bearings are provided at end supports as per requirement. These are designed according to the provision of IRC: 83-2015 (Part II)/ (Part-III) / (Part-IV).

Frictional resistance offered to the movement of bearings due to change in temperature calculated as per Clause 211.5 of IRC: 6. The frictional co-efficient for POT / PTFE / Spherical bearings has been taken as 0.05 or 0.03.and the frictional force for free pier taken as FR = 0.05 x Total Reaction (Sumof Dead load, Superimposed dead load & Live load) as per Clause 211.5.1 of IRC: 6.

In case that the reactions at both side of the piers are equal, the frictional forces for EJ piers cancelled and thus no need to be designed, however, in case of unequal reactions, net resultant forces has been accounted.

2.7.14.3 Approach Slab

Approach slab 3.5m minimum length and 300 mm thickness has been provided on approach of the abutment pier. The approach slab is provided over lean concrete of 150mm thickness. The gap between the approach slab and dirt wall is filled with bituminous joint filer with joint sealing compound.

2.7.14.4 Deck Drainage

Drainage spouts is provided in the bridge portion at an interval of 3 m c/c on one side of carriageway in case of uni-camber and on either side of carriageway in case of dual camber in a staggered manner. The water from the drainage spouts has been carried by runner pipes which are connected to down take pipes (clamped to piers) at suitable intervals. However, for details separate drawing has to be referred.

Materials

Concrete

All material properties as per IRC: 112-2011 specifications. The grades of concrete are based on 28 days characteristic compressive cube strength. For Reinforced and Pre-stressed concrete, the preferred nominal aggregate is 20mm

Grade of Concrete

Minimum concrete strength requirements for various components of structure considering exposure condition as “moderate” as per TOR & Table 14.2 of IRC:112-2011 are as presented in **Table 2.19** below:

Table 2.19: Minimum Grade of Concrete

Element	Grade of Concrete
Superstructure (Cast-in-situ / Precast)	M50/M40
Substructure	M50/M40/M35
Foundation (Pile / Pile Cap)	M40/M35
Crash Barrier / Kerb (Cast-in-situ/ Precast)	M40
Element	**Grade of Concrete**
Bearing Pedestals	M40
Approach Slab and Friction Slab	M40

PCC	M15

Young's modulus of Elasticity for normal weight concrete considered as per Table 6.5 of IRC:112- 2011 & Coefficient of thermal expansion for normal concrete is taken as 1.2x10-5/°C.

Steel Reinforcement

Steel for reinforcement shall meet with the requirements of IS 1786 (latest revision) set by Bureau of Indian Standard (BIS). Reinforcements in Thermo mechanically treated reinforcement of Fe 500 D Grade as per IS 1786-2008 manufactured by primary manufacturers viz. TATA, SAIL, TISCO, RASHTRIYA ISPAT NIGAM LTD., JINDAL, ESSAR only. No re-rolled steel use in the Works.

Fusion bonded epoxy coating (FBEC) to reinforcing steel bar as per IS 13620: 1993.The modulus of elasticity (E) is equal to 200,000 MPa.

A. Pre-stressing Steel

The following are defined for the pre stressing system:

1) Multi-strand system comprising the required number of strands in a circular duct.
2) Anchorage and coupling system for the anchoring of the pre stressing forces at the ends or for continuing the force by coupling.
3) Internal tendons comprising of High-density polyethylene (HDPE) sheathing around the strands of bars, external to the concrete used. Once the force is locked off, the orifice is filled with cementatious grout for corrosion protection as well as for bonding of the strands to the concrete to form a bonded system.
4) For pre stressing strands, 7 wire low-relaxation strands complying with IS: 14268-2017 or IRC 112-2020 whichever appropriate used. The following strand types are proposed to be used on the project according to the details and design requirements for various structure types.

Table 2.20: Properties of Pre-Stressing Strands

Material property	Normal Strands
Strand Type	Uncoated stress relieved low relaxation Class II conforming to IS 14268
Yield strength (MPa)	1560
Ultimate strength (MPa)	1770
The breaking strength	0.2 % proof load
Young's Modulus (GPa)	195
Relaxation (After 1000h)	Maximum 4.5%

B. Sheathing Duct

The sheathing duct for internal cables are proposed of corrugated HDPE type satisfying the requirements asspecified in section 13 of IRC: 112-2020

C. Structural Steel

The structural steel to be used is of grade E250 / E350 conforming to IS: 2062 – 2011. Unless otherwise stated, hot rolled and hollow section structural steel E350 (Fe490) having yieldstress 350 MPa for vehicular bridge and for FOB E250 (Fe410 W) B having yield stress 250 MPa gradeconforming to IS 2062-2011. At Foot over Bridge stainless Steel sections used for hand-railing as per requirement employer. All structural steel works and fasteners to be protected in accordance with BS EN ISO 12944 and 14713 where applicable. The first protective maintenance are assumed to beexecuted 15 years as of the works completion.

2.7.15 Codal Reference

The latest revisions of the following Documents in hierarchical order during Detailed Survey and Design of the proposed bridge followed.

A. Nepal Bridge Standards-2067, published by Department of Roads.

B. <u>IRC standards and guidelines</u>

i. IRC: 5-2015 Standard Specification and Code of Practice for Road Bridges

ii. IRC: 6-2017 Standard Specification and Code of Practice for Road Bridges

iii. IRC: 112-2020 Code of Practice for Concrete Road Bridges

iv. IRC: 22-2015 Standard Specifications and Code of Practice for Road Bridges

v. IRC: 24-2010 Standard Specifications and Code of Practice for Road Bridges, Steel Road Bridges (Limit States Method).

vi. IRC: 38-1988 Guidelines for design of horizontal curves for highways and design tables first revision

vii. IRC: 40-2002 Brick, stone and cement concrete block masonry second revision

viii. IRC: 78-2014 Standard Specifications and Code of Practice for Road Bridges

ix. IRC: 83-2015 Standard Specifications and Code of Practice for Road Bridges (Part – I)

x. IRC: 83-2018 Standard Specifications and Code of Practice for Road Bridges (Part – II)

xi. IRC: 83-2018 Standard Specifications and Code of Practice for Road Bridges (Part – III)

xii. IRC: 83-2014 Standard Specifications and Code of Practice for Road Bridges (Part – IV)

xiii. IRC: 45-1972 Recommendation for estimating the resistance of soil below the maximum scour level in the design of well foundation of bridges

xiv. IRC: 87-2011 Guidelines for Formwork, False work and Temporary Structures

xv. IRC: 89-1997 Guidelines for Design and Construction of River Training & Control Works for Road Bridges

xvi. IRC: SP 33-1989 Guidelines on supplemental measures for design, detailing and durability of important bridge structures

xvii. IRC: SP 65-2018 Guidelines for Design and Construction of Segmental Bridges

xviii. IRC: SP 66-2016 Guidelines for Design of Continuous Bridges

xix. IRC: SP 67-2005 Guidelines for Use of External and Unbonded. Prestressing Tendons in Bridge Structures

xx. IRC: SP 70-2016 Guidelines for Use of High-Performance Concrete in Bridges (Including Self Compacting Concrete in Bridges)

xxi. IRC: SP 71-2018 Guidelines for Design and Construction of Precast Pretensioned Girder for Bridges

xxii. IRC: SP 23-1983 Vertical Curves for Highways

xxiii. IRC: SP 64-2016 Guidelines for analysis and design of cast in place voided slab structure

xxiv. IRC: SP:114-2018 Guidelines for Seismic Design of Road Bridges

xxv. IRC: SP: 115-2018 Guidelines for Design of Integral Bridges

C. <u>IS standards</u>

i. IS 1786: 2008 High Strength Deformed Steel Bars and Wires for Concrete Reinforcement - Specification

ii. IS 1893 (Part 1): 2016 Criteria for Earthquake Resistant Design of Structures. Part 1: General Provisions and Buildings.

iii. IS 1893 (Part 2): 2016 Criteria for Earthquake Resistant Design of Structures. Part 3: Bridges and Retaining Walls

iv. IS 2090: 1983 Specification for High Tensile Steel Bars used in Prestressed Concrete (Reaffirmed 2000)

v. IS 2629: 1985 Recommended practice for hot-dip galvanising of iron and steel

vi. (Reaffirmed 1994) + Amendment No.1 (December 1988)

vii. IS 2911 (Part 1 Section 2): 2010 Design and construction of pile foundations – Code of practice. Part 1: Concrete Piles. Section 2: Bored cast in-situ concrete piles

viii. IS 2911 (Part 4) :2013 Code of practice for design and construction of pile foundations. Part 4: Load test on piles

ix. IS 4651 (Part III) 1997 Code of Practice for Planning and Design of Ports and Harbours, Part III: Loading.

x. IS 4759: 1996 Hot-dip zinc coatings on structural steel and other allied products

xi. – Specification (Third revision) (Incorporating Amendment No. 1) (Edition 4.1) (Reaffirmed 2006)

xii. IS 6403: 1983 Code of practice for determination of bearing capacity of shallow foundations (Reaffirmed 2002)

xiii. IS 12070: 1987 Code of practice for design and construction of shallow foundations on rocks (Reaffirmed 2010)

xiv. IS 13620: 1993 Fusion bonded epoxy coated reinforcing bars - Specification

xv. IS 14268: 1995 Uncoated stress relieved low relaxation seven-ply strand for prestressed concrete – Specification (Reaffirmed 2003)

xvi. IS 14593: 1998 Design and construction of bored cast-in-situ piles founded rocks – Guidelines (Reaffirmed 2003)

xvii. IS 8009 (Part II): 1980 Code of practice for settlement of foundation.

xviii. IS 1904: 1986 (reaffirmed 2006) Code of practice for design and construction of foundations in soils: general requirements

xix. IS 816:1969 Code of practice for use of metal arc welding for general construction in mild steel.

xx. IS 2062:2011 Hot rolled medium and high tensile structural steel.

Chapter 3: Survey & Investigations

3.1 Introduction

The Project Road named as Kamala- Dhalkeber – Pathlaiaya section of Mahendra Highway starts from Kamala bridge with 26°52'40.73"N, 86° 8'24.20"E and ends at Pathlaiya roundabout with 27°11'57.66"N, 84°58'50.76"E. The project road traverses through five districts namely Dhanusha, Mahottari, Sarlahi, Rautahat and Bara of Province 2. The total length of road is 130km having plain terrain for entire length. The existing roadway consist of carriage way width of 7.0m average with Bituminous surface and gravel shoulders varying from 1m to 1.2m provided on both sides. The existing pavements is in fair to poor condition with major and minor cracks and potholes observed in many sections. The side drains in form of either earthen or lined, are not provided in embankment section. The lined drain is been observed in selected urban sections. The existing land use pattern is comprising of forest, cultivated land, settlements, markets, rivers and rivulet channels.

3.2 Collection of Secondary Data

A secondary data from different sources has been collected for this project. Major data taken from secondary sources are demographic patterns of the Project Influence Area, economic activities, social activities and other related reports for the desk top study purposes. For carrying out detailed topographic survey works; the consultant purchased trigonometric point data from the Department of Land Survey, which is also a secondary data source. Besides this, for every aspect the consultant have collected necessary secondary data for study and review prior to proceed for Detailed designs.

3.3 Road Inventory

The survey and investigation of road including road inventory and pavement condition survey were carried out by the Teams of the Consultant during Conceptual Design stage of the Project. The road inventory to collect existing feature of the road and relevant components was carried out for entire length of the project road section.

The team comprising of Engineers and Surveyors was deployed at project site to collect existing features along the road for entire length in prescribed format. The existing features collected during Inventory are mainly;

- Carriageway with pavement type and width
- Shoulder with type and width

- Name of settlement/ urban area
- Location and side of Water bodies along the road
- Bus stops/ Bus bays
- Service road with Start & End Chainage and width
- Drain type, width and length with side along the road
- Religoius Structures with dimensions and side on the road
- High Embankment locations
- Crash barrier type, length, condition and side on the road
- Junction type, chainage with name of settlement / urban area
- Type of utility with side, distance from road and length
- Causeway type with length and Condition
- Pedestrian railing with type, length, side and condition

The data collected through road inventory are presented vide **Volume I-B** for reference.

3.4 Pavement Condition Survey

The Pavement Condition survey was carried out by the team of Pavement Engineer and Field Engineers prior to carry out other Pavement investigations. This activity consists primarily of visual observations, supplemented by simple measurements for rut depth using a 3meter straight edge. The following details were collected during pavement condition survey of existing pavement.

- Pavement Composition including layer type and thickness
- Shoulder composition and condition
- Cracking in %
- Revelling in %
- Potholing in %
- Rut depth
- Patching in %
- Pavement edge drop in mm
- Embankment condition

- Road Side drain type, size and condition available, if any

Pavement of the existing road has been found fair, good, poor and very poor along the road. Some major and minor cracks are observed in pavements. Pot holes, alligator cracking, rutting, depression also observed along the road. Near bridge approaches there is poor condition pavement which should be strengthen as soon as possible. In some section there is a pavement overlay after deterioration of pavement surface is observed. Some site photographs are shown in table below.

Poor Pavement condition near Bridge Approaches	**Fair Pavement Condition**
Pavement Overlay	**Very Poor Pavement Condition**

The details collected through Pavement Condition Survey are presented in **Volume I-B** for reference.

3.4.1 Roughness Survey

The existing pavement surface is having several potholes. The most of the length of the project road section is observed free from edge failures or cracks (block, longitudinal or transverse). The depressions and cracks are observed at a few locations mainly in proximity of flat

settlement areas which is due to poor longitudinal and cross drainage conditions. The records of surface roughness for the year 2020 was collected from the Web site of Department of Roads (DOR). The records show that, average IRI value for entire length is 6.67 (m/km). The roughness data collected from DOR web site has been presented in **Table 3.1** for reference.

Table 3.1: IRI and SDI Value of Project Road

S.no	Place		Chainage		Average IRI	Average SDI
	From	To	From	To		
1	Kamala	Dhalkebar	237+000	257+000	7.32	1.95
2	Dhalkebar	Ratu	257+000	265+000	4.18	1.67
3	Ratu	Bardibas	265+000	267+000	7.53	1
4	Bardibas	Banke	267+000	283+000	6.4	2.18
5	Banke	Nawalpur	283+000	299+000	6.96	2
6	Nawalpur	Bagmati	299+000	313+000	8.25	2.07
7	Bagmati	Chapur	313+000	327+000	7.59	2.07
8	Chapur	Dhansar	327+000	340+000	6.29	2
9	Dhansar	Pathlaiya	340+000	367+000	5.55	1.97

Source: DOR/website

3.4.2 Pavement Structural Strength Studies

The Pavement structural strength studies were conducted to determine functional and structural conditions of a highway section either for purposes of routine monitoring or planned corrective action. Functional condition is primarily concerned with the ride quality or safety aspects of a highway section (surface texture, cross slope, splash and spray, etc.). Structural condition is related with the structural capacity of the pavement as measured by deflection, layer thickness, and material properties.

For assessing the utilization of existing pavement, a visual condition survey has been performed. From visual survey alligator cracking, rutting, potholes and gravel exposed are seen in the existing pavement.

There are various methods for pavement evaluation which gives the condition of a pavement (both structurally) & surface characteristics.

- Visual Inspection

Inspecting pavement surface to determine the amount of severity of various types of damages such as rutting, corrugations, raveling, flushing, alligator cracking, pot holes, longitudinal cracking and transverse cracking.

- PSI

A rating system to be carried out by measurement of permanent deformation, riding quality, the extent of cracking and patching.

3.5 Bridge Inventory and Condition Survey

As the Mahendra Highway is going to upgrade to Asian Highway Standards (Class I), the exiting bridges would be usable in any form is one of the major objectives of this project. Kamala to Pathlaiya section of the highway comprises 76 numbers of bridges and 124 culverts of various types. The possible rehabilitation or upgradation of existing bridges and culverts on the project road section providing comfort for financing the project by Funding agency. Therefore, detail inventory and condition survey of all bridges and culverts were conducted by the Team of Bridge Engineers and surveyors.

3.5.1 Inventory

The bridge inventory is the record of bridges, overpass', underpasses. causeway or culverts along a project road section. The bridge inventory includes many features surrounding them, mostly based upon the condition though. Therefore, a team of civil engineers with surveyors were mobilized at site to take the detailed measurements of all possible visible elements of the bridges and culverts. The team traversed from one end of the road project to other end for data collection. The team carried out detail measurements of the structural elements as well as collected data regarding river characteristics during inventory. The details targeted in this inventory for existing bridge/ culvert structures are as listed below.

- Chainage of the bridge/culvert
- Name of Bridge and river
- Length of bridge/culvert
- Span arrangement of bridge
- Skewness of bridge
- Direction of river flow near bridge
- Nearest city or town
- Width of carriage way, footpath, kerbs etc.
- Types of bridge / culverts (RCC, Prestressed, Steel Truss, Steel Plate Girder, Box Girder, T-Girder, I-Girder, etc.)
- Measurements of the structural elements (Deck, Main Girder, Cross Girder, etc.)
- Types of abutments, piers (RCC, Brick masonry, Wall type, Hammer Head Type, frame type etc.)
- Dimensions of abutment and piers (if possible)

- Bearing types, size and size of pedestal
- Water level, bearing level, girder level from bed
- Types and sizes of abutment foundations (If possible)
- Types and sizes of pier foundations (if possible)
- Photographs of visible structure elements

The field work for the inventory was completed as per the fixed schedule by the Team of Engineers. The detail condition assessment needs bridge hydraulics parameters as well as geotechnical parameters. The outcome in form of summary of the inventory is as described below;

Total 46 number of Precast Concrete C-Girder bridges (Inverted C) are noticed, directly supporting the wearing surface. This type of structural form is used for spans between 9.5 and 12.6m. Such type of superstructure constitutes the majority of the bridges (60%).

There are 14 number of Twin fabricated steel plate girder bridges supporting a precast concrete deck slab. This type of structural form is used for span length varying from 22m to 33m.

The existing Lakhandei Bridge consists of continuous precast concrete 'T Girders' supporting a precast concrete deck slab. There are 6 concrete girders having span length of either 15 or 18m. The absence of bearings reveals that, the girders are also integral with the piers/ abutments. Based on the visual inspection, it is believed that the diaphragm was made cast-in-situ in order to achieve the monolithic connection between the girders and the pier stem. Such types of bridges have precast concrete piers erected in a group to form wall type pier. The piers are connected with super structure by cast in situ concrete pier cap.

The bridges with cast-in-situ concrete 'T Girders' supporting a cast-in-situ concrete deck slab have also been encountered during Inventory. The number of concrete girders varies between 2 and 4 nos. depending on the width of road way provided above. This type of structural form is used for spans having length varying from 15.3m to 27.4m. Total of eleven (11) bridges this superstructure form are encountered during bridge inventory. There are also few constructions of RCC T-Girder cast in situ that seems as like C-girder construction observed during bridge inventory by Engineers' team.

It is known during inventory that; the New Ratu Bridge has recently been constructed. The superstructure comprises of three (3) cast-in-situ post-tensioned concrete girders with a total length of approximately 224m consisting of 2 x 38.5m, 4 x 33 spans + 5 x 2.95m gaps. It is

believed that, the gap has been provided to enable the stressing operations of each girder from both ends during construction.

The Dudhaura bridge is under construction through separate construction contract by the Department of Roads at present.

In addition, there are 23 number of causeways noticed on the project road. Most of the Causeways are provided in forest area of the project road. The Causeways are provided with Concrete pavement at or above Ground level at all locations along the project road.

The Bridge Inventory was carried out in specified Format and the same has been presented vide **Volume I-D** for reference.

3.6 Bridge Condition Survey

The Bridge failures can be disastrous, both in terms of human life and economic loss. Reinforced concrete (RC) bridges often deteriorate due to ageing, materials and construction defects, exposure to aggressive environments, lack of ductility, and excessive loads. The distinction among their major degradation causes is purely qualitative since, such mechanisms can act in interaction. The various types of deterioration processes lead to occurrence of different types of defects in the Bridge structure. Therefore, the condition survey of structures has to be performed time to time, especially after ageing effect and or after disaster.

The Condition Survey comprises of carrying out a detailed visual inspection of the structure and subsequently detailed condition surveys of the various components of existing bridge structure. The purpose of the surveys is to determine and document the deterioration in the structure, in order to define detailed investigation and or structural analysis including deterioration. It also provides information about an evaluation of the load carrying capacity of a bridge. There are two stages of bridge condition surveys being performed:

Detailed Visual Inspection

A detailed visual inspection doesn't reveal hidden defects or deterioration in concrete such as delamination's, rebar corrosion and low concrete cover to reinforcing steel. However, the same provides the information on condition of existing structure at a glance.

Detailed Condition Survey

A detailed condition survey is generally carried out only after a concrete component has been identified for rehabilitation. The data collected is then used to establish the rehabilitation

method and to prepare bill of quantities, cost estimate and contract documents. The procedure for carrying out a detailed condition survey involves the observation and recording of surface defects and also involves a delamination survey, a cover meter survey, a corrosion potential survey, coring of concrete components, asphalt sawn samples and physical testing of the concrete cores.

The need for structure rehabilitation is usually driven by the condition of the bridge deck. As most of the bridge decks have an asphalt-wearing surface, it is usually difficult to assess the condition of the concrete beneath the asphalt during an inspection.

Detailed condition survey of a component may not be necessary if the need for replacement of a structurally deficient component is established by an evaluation of the load carrying capacity or by other means. After detailed visual inspection methods of special test for detailed condition survey is established. These can be:

- Ground Penetrating Radar (GPR) survey
- Concrete core Test
- Cover meter test
- Ultra sound Pulse Velocity Test
- Rebound hammer test
- Dynamic parameter evolutions etc.

Common Defects in Materials

The defects and deterioration that commonly occur in the materials used in structures are:

- Common defects in waterproofing membranes;
- inadequate thickness at time of construction;
- Spalling of concrete;
- Cracks in structural member;
- Rusting of reinforcement;
- Deterioration of concrete due to aging or abrasion or any other reason;
- Excessive vibration; etc.

Detailed visual inspection condition survey of all bridges and culverts has been completed by the Bridge team. The analysis of the inventory data and detail visual inspection survey has also been completed. As mentioned in the inventory; heading, detailed condition assessment of individual bridges are associated with hydrological study as well as geological study. As the summary of detailed visual condition assessment following findings were presented.

Findings of the condition survey:

The bridges at Dhalkebar -Pathlaiya section are of 5.5 m width (except newly constructed Dhansar Bridge) which is not sufficient for two lanes traffic. It is found that all steel plate girder bridges having two plate girders has excessive vibrations. Only one continues plate girder bridge having four girders are found in good condign.

Super structure Condition:

In general terms, the following statements could be made to summarize the existing condition of the bridges' superstructures:

a. Surfacing on most bridges is of very poor condition resulting in excessive undulations of travelling vehicles, especially Bardibas to Pathlaiya. This has caused significant vibration particularly on bridges with steel plate girder and some C-Girder bridges. This is accentuated by the fact that heavy trucks constitute a large percentage of travelling vehicles on undulated wearing surface.
b. The expansion joints on most bridges are of very poor condition. This may be the result of poor installation, lack of regular maintenance or due to the excessive vibrations described above. This is also found in bridges between Bardibas to Pathlaiya.
c. Some of the approach slabs appear to have settled. A dip at the abutments is visible at the newly constructed Dhansar River Bridge.
d. The Kamala Bridge concrete girders exhibit shear cracks near the supports and flesural cracks at mid spans. Some girders appear to have been repaired with carbon fiber. However, at the time of writing of this report, no inspection or maintenance records have been made available in order to validate this assumption.

Substructure Condition

In general terms, the substructures appear to be in a fair condition with some requiring minor repairs. Some of piers and abutments between Kamala to Dhalkebar section have already repaired with grouting and shotcreting. Maintenance on wearing surface, expansion joint and greasing on bearings was found. Some of the RCC bridges have honeycombed on girders (as per feasibility report) that have also grouted.

Foundations Condition

Some of the foundations exhibit significant level of scour and are completely exposed. Tuteshwor-1 Bridge Abutment foundation protection appears to be completely exposed. While in Tuteshwor-2, Gairi Bridge and Unasi Bridge excessive scour near piers appears. Gabion

protection work was carried out at those locations. Similarly, abutment and pier foundations are exposed at Lakhandei Bridge.

The data collected through condition survey for all bridges has been prepared in prescribed format and presented in **Volume I-D** for reference.

3.7 Topographic Survey and Mapping

3.7.1 Scope of Works from the ToR

The topographical survey shall collect adequate data to show the following details in the subsequent topographical map:

a. Topography with details such as trees & forest, water bodies, wildlife habitat and movement corridors, sacred/ cultural & religious sites (including natural features with cultural values, e.g. trees, cliffs, etc), existing infrastructures and other land features
b. Existing road details such as formation width, paved area, access roads, bus bays, footpath, parking places, traffic signs, islands, signals, and right of way (RoW) limits (Buildings, Taharas, shops etc.)
c. Details of existing cross-drainage structures such as length, width, and heights of culverts, bridges, spans, pier, abutments, railing and vertical clearances, existing access under the bridge, river training works and river bank structure.
d. Existing power line alignments and elevations (if buried) such as: high-tension poles, low-tension poles, transformers, substations, Streetlights poles, underground electrical supply (if any) etc.
e. Existing telecommunication alignments and elevations (if buried) such as: telephone lines, poles, cabinets, towers, and underground lines (if any)
f. Existing water supply line details such as: supply mains, distribution lines, valves, valve chambers, underground water storage, fire hydrants, etc.
g. Existing sewer line details such as: trunk sewers, branches, manholes, location/position of the septic tank and soak pit of the adjacent building the both sides of the road within the RoW.
h. Existing buildings and structures details such as: religious shrines, tangible cultural heritage, community building, government building, and residential building, type of foundation, and tentative depth of the foundation of the building
i. Existing or potential flood-prone zones/ spots, low laying areas, and river-bank cutting areas
j. Survey and Production of a map of a minimum 100 m wide road corridor in 1:1000 scale and with 0.20m contour interval and clearly showing the centre-line of existing

roads and all features. The consultant may consider and propose wider bandwidth or additional survey areas if necessary for the design.

While conducting Survey works, the survey team should be accompanied by a highway engineer. The Consultant shall acquire the reference coordinate points from the Department of Surveys and referencing of all the survey works made on these references. It should establish benchmarks at a distance of every 500m along the road and on both sides of the riverbanks in the case of bridges.

While conducting the topographical survey for bridge design, the survey area should cover a minimum distance of 500m upstream, 200m downstream, and 200m from the river banks on either side of the river at the proposed bridge site or more if necessary for analysis and design. In the case of the topographical survey of the bridge site, the topographic map should show the following:

I. Contours at 0.2 m intervals;
II. Flood lines on either side of the river in the entire area surveyed;
III. Both banks of the river;
IV. River cross section at 25 m intervals, or less if required for modelling, analysis, and/or design; one cross-section along the proposed bridge axis showing cross profile of 1m interval using suitable method;
V. Details of government and/or public establishments on the river banks, details of existing river training works (if any);
VI. Traverse lines, benchmarks reference lines and/or points with respect to which the present topo map is prepared;
VII. The angle and direction of skew, if the bridge is proposed to be aligned skew;
VIII. The foundation type and zone of influence of the existing foundation of the bridge or any other structures adjacent to the proposed bridge site;
IX. Other information relevant to design, construction and/or maintenance of the bridge;

3.7.2 Topographical Desk Study, Data Collection and Mapping

Location and accessibility

Geographically, the proposed Kamala-Pathlaiya section of East-West high stretches from 26◦52’43.91” to 27◦11’57.73” latitudinally and 86◦08’36.08” to 84◦58’50.06” longitudinally from kamala to Pathalaiya and lies in Mid Terai region of Nepal. The proposed project site is accessible both by bus and airways. Pathlaiya, the starting point of the project is 122 km from Kathmandu via Kulekhani-Hetauda road while Kamala, end point is 220 km. Both Pathlaiya

and Kamala can be accessed by domestic flight from Kathmandu to Simara and Janakpur respectively.

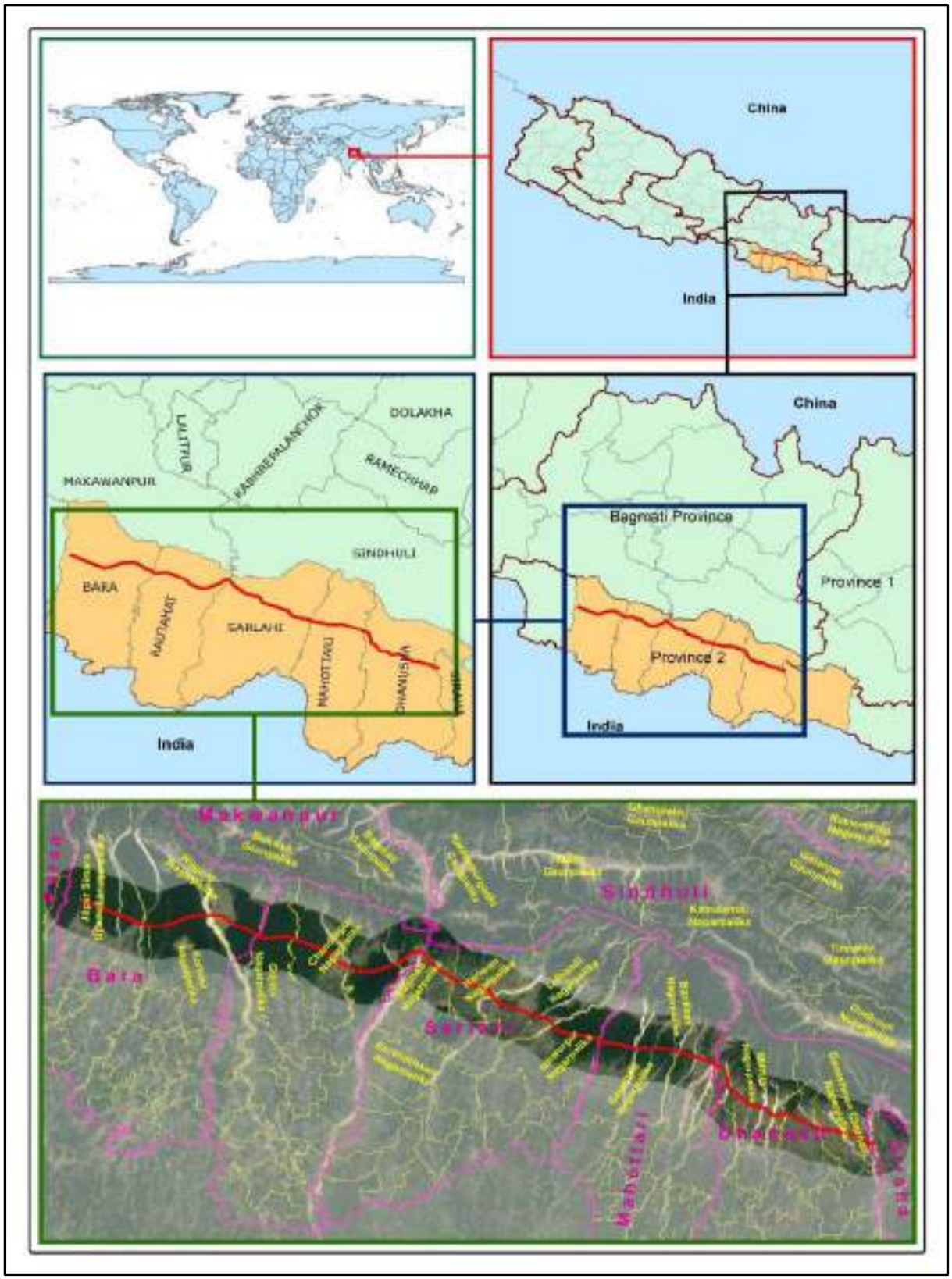

Figure 3.1: Location Map

Land use Study

Land use and land cover alteration within the vicinity of project area is the key in managing and monitoring the natural resources. Geographical Information System is proven tools for assessing the land use and land cover alteration that helps the planners to advance sustainability. The consultant has carried out the study of alteration of land use and land classification of the proposed Kamala to Pathlaiya section of the road by using land use and land cover of ICIMOD as a source in GIS. The land cover such as Water body, built up area, Grassland, Agriculture land Shrub, Forest, Barren land of the source was verified accordingly at site during detail topographic survey.

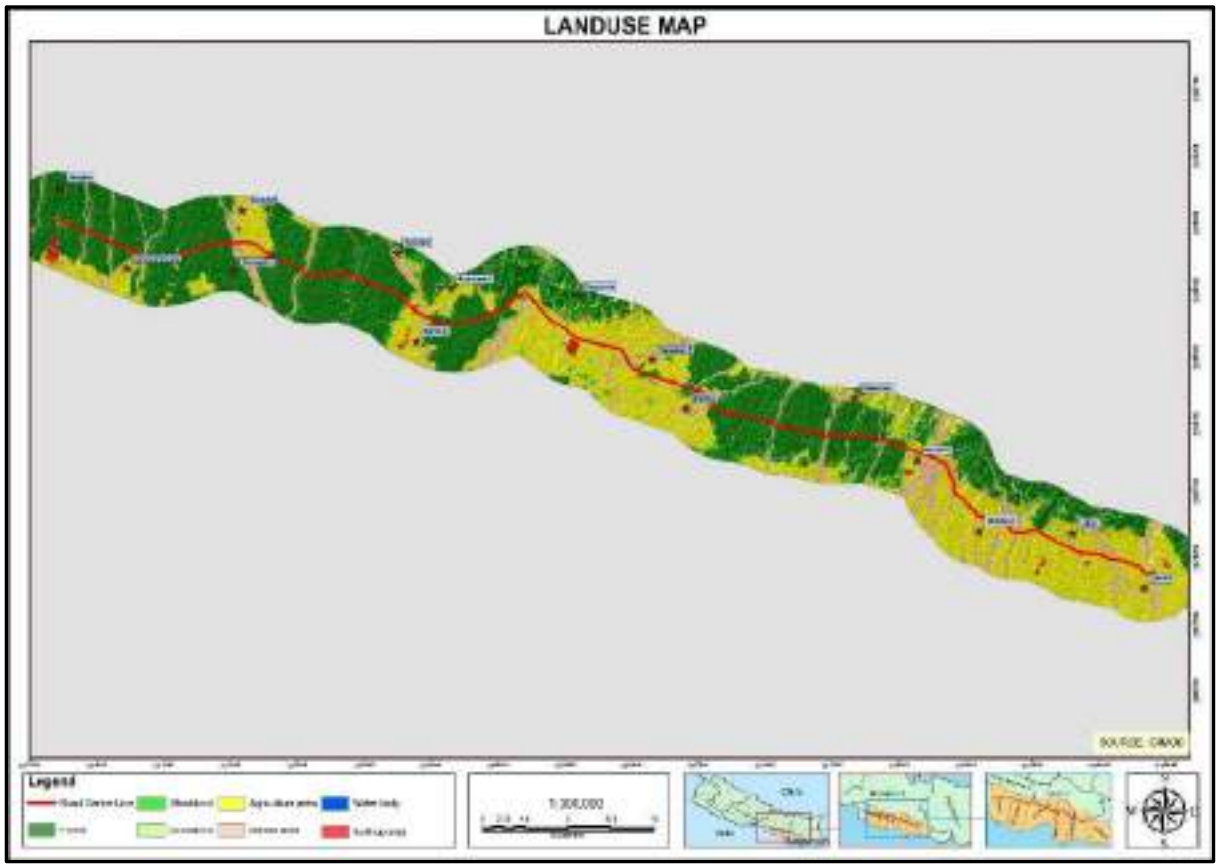

Figure 3.2: Land Use of the Project Area

3.7.3 Methodology

Desk Study

The objective of desk study was to familiarize with project area; review existing project data, information, and applicable guidelines/ norms, identify the data gaps and create an approach for filling data gaps; prepare an updated activity and time schedule with milestones advanced from the proposal stage based on the results of review, and prepare a detailed field plan.

Sources of above information were,

- Geodetic Survey Department of GON;
- Concerned District office;
- Project office; and
- Concerned project bodies and department.
- Concerned Municipal and ward office.

The major activities during the project inception study were as follow:

- Kick-off meeting with the Client;
- Desk-study report collection and review;
- Collection of information, documents, Policies etc.
- Collection of recent topographical maps available for the related area.
- Collecting necessary formats for quality survey work.
- Purchase of benchmarks and national trig points
- Planning for field works; and
- Updating the Work Schedule.

Field Reconnaissance Survey

Reconnaissance survey has been carried out by walking over the proposed project area. Based on studied map and desk study report the recommended area has been focused during field reconnaissance survey.

The team has examined detail of the features and obstacles in the area. Photographs of the various related areas, Permanent features, topography and the river etc. has been taken in the Project area.

This further show:

- General topography of project site;
- Perception of local people regarding the Project;
- Availability of unskilled labour for the project;
- Different Features within Project area; and
- Analysis of various possibilities and Challenges for survey work

With due consideration on the above norms, a reconnaissance survey has been carried out. During the reconnaissance survey the field team have used handheld GPS (Global Positioning System), EDM (Electronic Distance Measurement) and binocular.

Figure 3.3: Road Survey Field Team

GNSS Planning

GNSS receiver receives the GPS signals from the satellite constellation to fix the position of the receiver. The two core satellite constellations are the GPS and the GLONASS, provided by the United States of America and the Russian Federation. The static method of point positioning can be improved by the observing the GNSS Mission planning so that the positional accuracy can be controlled. GNSS mission planning refers to the formation and health of the satellite that contribute the position of receiver. Mission planning also provides the ionosphere data that helps us to determine the time and duration to take the data from the GNSS satellite. The GNSS Mission planning provides elevation of the satellite, number of satellites available, dilution of precision, visibility and ionosphere data. GNSS planning has been performed before moving to site for the best and accurate positioning.

Figure 3.4: DGPS GNSS mission planning before DGPS work start up

Spatial Planning

In order to familiarize/access the prevailing situation of the project area the consultant has used the secondary data source such as Google Earth, Offline Maps, Topo sheets and collected the relevant information for planning and execution of the field works. General topography and boundary of the project was confirmed by overlaying the center line of the proposed road section on Topo sheet and open-source tools.

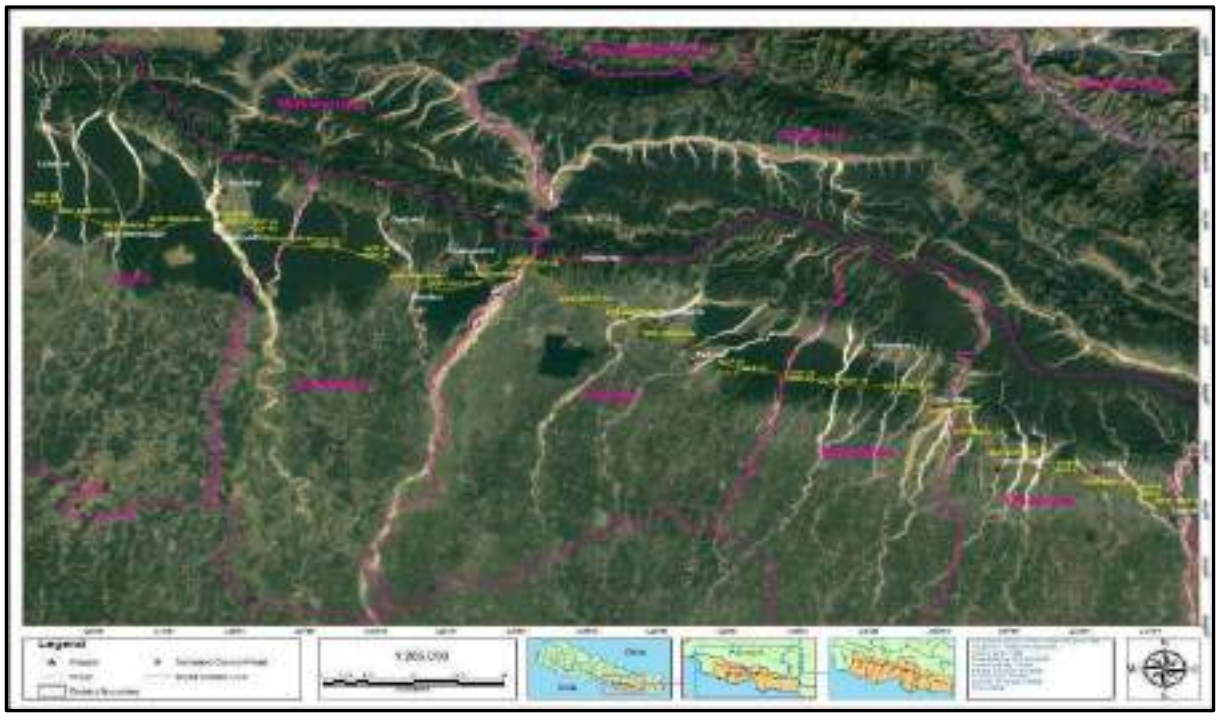

Figure 3.5: Planning of Cross-Sections and Longitudinal Sections

The standardized accuracy and meaningful engineering design is achieved by survey works. Thus, it is of utmost important that all survey to be carried out in the project area should be systematic and accurate. Proper desk study and planning prior to field mobilization is the initiation of Quality Assurance System.

Monumentation of Benchmark

Prior to the field mobilization all relevant information and data has been collected from concerned authorities. The consultant has purchased the National trig control point and national bench mark from DoS, Geodetic Branch. Same Trig point has been searched at site and used as the base point for transfer of ground control point at project site.

Thus, the elevation to the established bench mark has been carried out by transferring the elevation obtained by DGPS placed at different National Benchmarks. Detail of the National trig points and present status at field are presented in tabular form as follows.

Table 3.2: Coordinates and Elevation Data

Grid Sheet/Alignment	Trig/B.M	Easting (m)	Northing (m)	Elevation (masl)	Location	Status
169	**3**	**393243.3**	**2955439**	**N/A**	**Janakpur Airport**	**Found and Used at site**
104	175.1	N/A	N/A	110.94		Found and Used at Site
104	156	N/A	N/A	159.099		Found and Used at Site
104	129	N/A	N/A	171.109		Found and Used at Site
125	26.2			267.656		Found and Used at Site
104	83			142.483		Found and Used at Site
104	44			126.15		Found and Used at Site
104	21			155.193		Found and Used at Site
104	8			147.032		Found and Used at Site
104	1			163.746		Found and Used at Site

Government of Nepal
Ministry of Land Management, Cooperative and Proverty Alleviation
SURVEY DEPARTMENT
(Geodetic Survey Division)

(Department) Tel.: 4106769, 4106842, 4106508, 4106833
Fax No.: 4106757
Email: info@dos.gov.np
(Division) Tel.: 4106614, 4106847, 4106872
Fax No.: 5106614
Email: geodetic@wsn.com.np

Our Ref. No.:
Your Ref. No.: 40
Dispatch No.:

(Data Section)

Date:- 2078/09/18

Innovative Engineering Services.Pvt.Ltd.
Kathmandu, Nepal

Subject:– About the Data and D-Card

We are hereby pleased to provide you the following geodetic Co-ordinate/Level Height/Gravity data as requested by you. These data are not transferable without a written permission from our office, in any form upon completion of the use of control station marker in the ground; please keep the control station marker to keep the point/s well hidden by means of its original cover/soil/stone for its safety. You are also requested to fill in the form attached with this and return to this office either in person or by post which will be helpful in the up keeping and maintenance of the points in the future.

Grid Sheet /Alignment	Trig./B.M. /Gravity No.	Description Card	Co-ordinates		Level Height MSL(M.)	Gravity	Remarks
			Easting	Northing			
104	001 044 083				163.746 126.150 142.483		Provided according to cash receipt no. 28511864 of Survey Department

Surveyor **Survey officer** **Chief Survey Officer**

Government of Nepal
Ministry of Land Management, Cooperative and Proverty Alleviation
SURVEY DEPARTMENT
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(Department) Tel.: 4106769, 4106842, 4106508, 4106833
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Email: info@dos.gov.np
(Division) Tel.: 4106614, 4106847, 4106872
Fax No.: 5106614
Email: geodetic@wsn.com.np

Our Ref. No.:
Your Ref. No.: 3C
Dispatch No.:

(Data Section)

Date:- 2078/09/11

Innovative Engineering Services.Pvt.Ltd.
Kathmandu, Nepal

Subject:– About the Data and D-Card

We are hereby pleased to provide you the following geodetic Co-ordinate/Level Height/Gravity data as requested by you. These data are not transferable without a written permission from our office, in any form upon completion of the use of control station marker in the ground; please keep the control station marker to keep the point/s well hidden by means of its original cover/soil/stone for its safety. You are also requested to fill in the form attached with this and return to this office either in person or by post which will be helpful in the up keeping and maintenance of the points in the future.

Grid Sheet /Alignment	Trig./B.M. /Gravity No.	Description Card	Co-ordinates		Level Height MSL(M.)	Gravity	Remarks
			Easting	Northing			
169	3		2955439.15	393243.29			Provided according to cash receipt no. 28266293 of Survey Department
104	021				155.193		
104	008				147.032		
125	026-2				267.656		

Surveyor Survey officer Chief Survey Officer

Figure 3.6: National trig point and benchmark from Department of survey

The concrete pillar (15x15x55) cm with iron nut bolt at its center has been used to monument the control points. Sufficient control points have been monumented at the various location of the project area. At least three references have been taken and marked with red enamel paints.

Benchmark has been established with due consideration of ground stability, protection against vandalism and disturbances and accessibility for further study and construction. The benchmarks for the rivers have been established outside of the observed High Flood Level. D-Card format has been used to record the description of each individual benchmarks in standardized format which includes photographs, coordinates and three references to the benchmarks. Total 382 number of Control Point has been established at site to facilitate the Bridge and Ground survey whose Description card has been presented in **Volume I-A.**

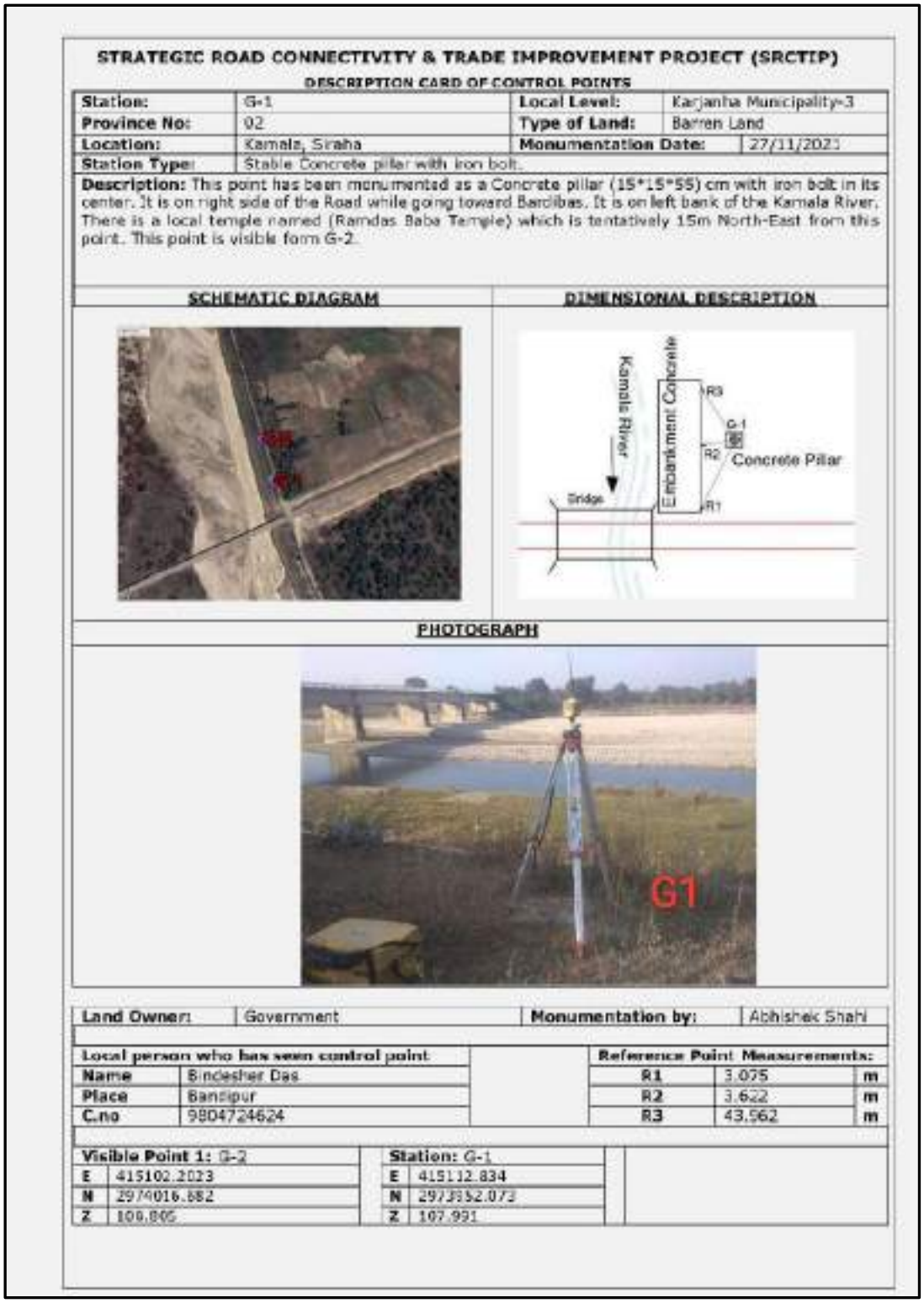
Figure 3.7: Concrete Pillar Loading

Figure 3.8: Concrete Pillar Transportation

Figure 3.9: Establishment of Control Points

Figure 3.10; Control Point Static Measurements

The description card contains detail information about location, Station type, Monumentation date, coordinate of control point, and measurement of reference points, clear photographs etc. A sample of standard D-Cards is presented herein after.



STRATEGIC ROAD CONNECTIVITY & TRADE IMPROVEMENT PROJECT (SRCTIP)

DESCRIPTION CARD OF CONTROL POINTS

Station:	G-1	**Local Level:**	Karjanha Municipality-3
Province No:	02	**Type of Land:**	Barren Land
Location:	Kamala, Siraha	**Monumentation Date:**	27/11/2021
Station Type:	Stable Concrete pillar with iron bolt.		

Description: This point has been monumented as a Concrete pillar (15*15*55) cm with iron bolt in its center. It is on right side of the Road while going toward Bardibas. It is on left bank of the Kamala River. There is a local temple named (Ramdas Baba Temple) which is tentatively 15m North-East from this point. This point is visible form G-2.

SCHEMATIC DIAGRAM | **DIMENSIONAL DESCRIPTION**

PHOTOGRAPH

Land Owner:	Government	**Monumentation by:**	Abhishek Shahi

Local person who has seen control point		**Reference Point Measurements:**		
Name	Bindeshwr Das	**R1**	3.075	m
Place	Bansipur	**R2**	3.622	m
C.no	9804724624	**R3**	43.562	m

Visible Point 1: G-2		**Station:** G-1	
E	415102.2023	**E**	415112.834
N	2974016.682	**N**	2973952.073
Z	108.805	**Z**	107.991

Figure 3.11: Sample of Control point Description card

Control Survey

The control points to the established benchmarks have been transferred from the available trig point. The control points have been transferred by using Static Differential Geographic Positioning System (D-GPS). The observation time has been set based on Climatic Condition and satellite communications availability. The traversing has been done by the DGPS post-processing software. The report of the traversing and post processing is the part of the final survey report.

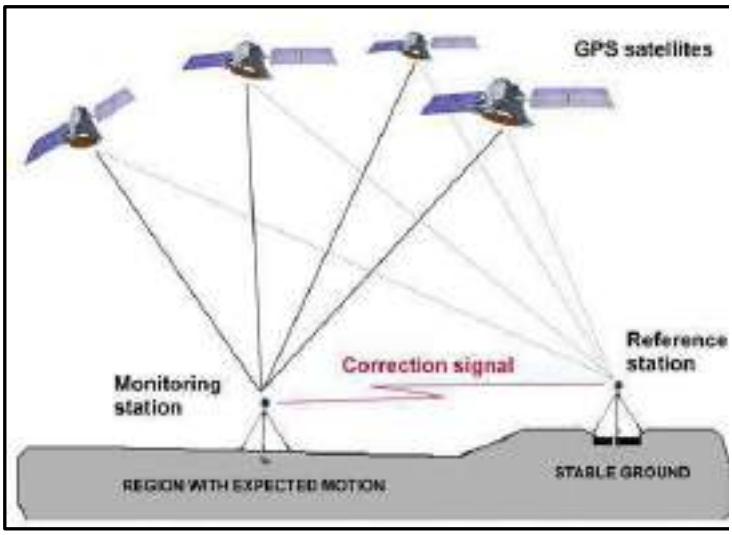


Figure 3.12: DGPS Working Principle

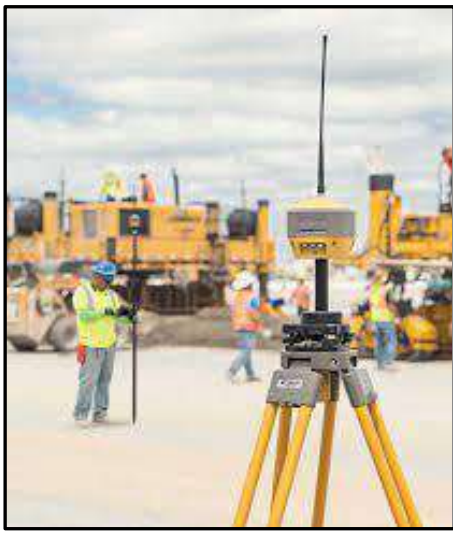


Figure 3.13: Topcon Hiper Hr

Following standard technical specification and procedure for establishing Geodetic Control Network have been considered:

- Static DGPS method have been used with three dual frequency receivers;
- Minimum Observation Time for each baseline have been one hour which can be longer duration based on climatic condition;
- Tripods have been set-up with appropriate optical (laser) plummets and tube bubbles;
- Measurements have been noted to “mm” level accuracy;
- A standard log sheet has been maintained for each station that includes following information:
    - Project Name;
    - Name, Identification number and type of control point;
    - Name of data session file;
    - Date of session, start and stop time of the receiver;
    - Antenna set-up information (orientation, antennae height measurement); and

- o Approximate visibility plot for the station.

Topcon Hiper Hr DGPS have been used for setting out of control points in the project area. GPS includes integrated levelling technology that can minimize the tilt related errors. The GNSS tracking is done through 452 channels with patented universal tracking channel technology. The accuracy of the equipment is mentioned below:

- Static/Rapid Static- H: 3mm + 0.1 ppm/ V: 3.5mm + 0.4 ppm
- RTK- H: 5mm + 0.5 ppm/ V: 10mm + 0.8 ppm
- Data Update/ Output Rate- Up to 100 Hz

The control points are based on Everest 1830 (1937 Adjustment) ellipsoid and are provided in Modified UTM with three different meridians (81, 84 and 87 Degree). The summary of the DGPS control point calculation is the part of main survey report.

- DGPS-Static

Static GPS survey procedures allow various systematic errors to be resolved when high-accuracy positioning is required. Static procedures are used to produce baselines between stationary GPS units by recording data over an extended period of time.

The major control points have been established with abbreviation “G ” followed by a number and alphabet (E.g. G-1, G-2, ….G-20 etc.).

The following chart shows the principle of determining the observation time.

Table 3.3: DGPS Observation planning sheet

Sl.No	Baseline Length	No for Satellite Available	Time of Observation
1	1 to 10 Km	6	45 Minutes
		4	60 Minutes
62	10 to 20 Km	6	50 Minutes
		4	90 Minutes
3	More then 20 Km	6	1 hour 30 Minutes
		4	2 hour

Table 3.4: Static Survey Specifications

Specification	Static
General Network Design	
Minimum number of reference station to control the project.	1 previous control point.
Maximum distance between the survey project boundary and network reference control stations	50 km
Minimum number of all baselines contained in a loop	100%
Field	
Maximum PDOP during station occupation	5(75% of time)
Minimum observation time on station	1 hr
Maximum epoch interval for data sampling	1 sec
Minimum satellite mask angle above the horizon	15 degrees
Office	
Fixed integer solution for all baselines	Yes
Ephemeris	Broadcast
Maximum loop length	50 km
Maximum misclosure per loop, in terms of loop length	15 ppm
Maximum misclosure per loop in any one component (x,y,z) not to exceed	5 cm
Repeat baseline difference in any component (x,y,z) not to exceed	10 ppm
Maximum length misclosure allowed for a baseline in a properly-weighted, least squares network adjustment	50 ppm
Maximum allowable residual in any one component (x,y,z) in a properly weighted, least squares network adjustment	5 cm

Figure 3.14: Control Point Transfer from National Benchmarks

Figure 3.15: post-processing and traversing by DGPS

Since, major control points have been established by DGPS approach, no traversing is required. However, some minor traversing has been done for detail topographical survey where major control points could not cover the whole survey area.

Table 3.5: Control point processing summary

Loop	dHz (m)	dU (m)	Horz Tolerance (m)	Vert Tolerance (m)	dHz (ppm)	dU (ppm)	Length (m)	dHz relative	dU relative	Check	dN (m)	dE (m)
BM-104_175.1-TRIG_169-3(12/16/2021 3:44:25 PM)	0.0009	0.003	0.366	0.396	0.01	0.05	67202.9	1:74105929.4	1:22169779.7	Pass	0.0006	0.0007
BM-104_175.1-G42(12/16/2021 3:47:00 PM)												
G42-TRIG_169-3(12/16/2021 3:47:00 PM)												
BM-104-56-G58(12/17/2021 2:43:44 PM)	0.0107	0.0237	0.0801	0.1101	1.07	2.37	10011.41	1:934416.9	1:422323.6	Pass	0.0017	0.0106
BM-104-56-G42(12/17/2021 2:41:43 PM)												
G42-G58(12/17/2021 2:43:44 PM)												
G113-G114(12/26/2021 11:29:00 AM)	0.0097	0.0369	0.0899	0.1199	0.81	3.08	11983.19	1:1236424.3	1:324675.5	Pass	0.0097	0.0004
G96-G113(12/26/2021 11:29:00 AM)												

Loop	dHz (m)	dU (m)	Horz Tolerance (m)	Vert Tolerance (m)	dHz (ppm)	dU (ppm)	Length (m)	dHz relative	dU relative	Check	dN (m)	dE (m)
G96-G114(12/26/2021 11:26:54 AM)												
G143-G156(12/26/2021 9:21:50 AM)	0.0034	0.0062	0.0733	0.1033	0.39	0.71	8664.291	1:2532903.6	1:1405258.1	Pass	0.0017	0.003
G143-G144(12/26/2021 9:23:58 AM)												
G144-G156(12/26/2021 9:23:58 AM)												
G15-G42(12/17/2021 10:03:32 AM)	0.0073	0.0013	0.1277	0.1577	0.37	0.07	19539.09	1:2681797.9	1:15370764.9	Pass	0.0071	0.0017
G15-G16(12/17/2021 10:04:11 AM)												
G16-G42(12/17/2021 10:04:11 AM)												
G170-G221(12/25/2021 4:11:45 PM)	0.0023	0.0113	0.1245	0.1545	0.12	0.6	18905.77	1:8362308.3	1:1666148.0	Pass	0.0022	0.0004
G170-G231(12/25/2021 4:11:22 PM)												

Loop	dHz (m)	dU (m)	Horz Tolerance (m)	Vert Tolerance (m)	dHz (ppm)	dU (ppm)	Length (m)	dHz relative	dU relative	Check	dN (m)	dE (m)
G221-G231(12/25/2021 4:11:45 PM)												
G180-G244(12/20/2021 9:51:55 AM)	0.0024	0.0027	0.0677	0.0977	0.32	0.36	7544.165	1:3150646.7	1:2800682.0	Pass	0.0009	0.0022
G179-G180(12/20/2021 9:51:55 AM)												
G179-G244(12/20/2021 9:50:40 AM)												
G197-G244(12/20/2021 12:43:17 PM)	0.0089	0.0054	0.1283	0.1583	0.45	0.28	19660.85	1:2202490.7	1:3629982.6	Pass	0.0034	0.0083
G197-G198(12/20/2021 12:44:29 PM)												
G198-G244(12/20/2021 12:44:29 PM)												
G244-G245(12/19/2021 3:29:01 PM)	0.0083	0.0024	0.1743	0.2043	0.29	0.08	28866.27	1:3497398.9	1:12281544.9	Pass	0.002	0.008
G170-G244(12/19/2021 3:28:35 PM)												

Loop	dHz (m)	dU (m)	Horz Tolerance (m)	Vert Tolerance (m)	dHz (ppm)	dU (ppm)	Length (m)	dHz relative	dU relative	Check	dN (m)	dE (m)
G170-G245(12/19/2021 3:29:01 PM)												
G244-G256(12/20/2021 4:57:18 PM)	0.0076	0.0146	0.1549	0.1849	0.3	0.58	24975.69	1:3291887.1	1:1714465.0	Pass	0.0047	0.0059
G244-G253(12/20/2021 4:52:11 PM)												
G253-G256(12/20/2021 4:57:18 PM)												
G256-G271(12/21/2021 11:26:56 AM)	0.0216	0.0291	0.2404	0.2704	0.51	0.69	42082.77	1:1951437.4	1:1445074.3	Pass	0.0167	0.0137
G256-G291(12/21/2021 11:15:46 AM)												
G271-G291(12/21/2021 11:26:56 AM)												
G256-G292(12/21/2021 9:05:49 AM)	0.02	0.0239	0.2405	0.2705	0.48	0.57	42105.11	1:2101712.1	1:1762756.2	Pass	0.0168	0.0109
G256-G271(12/21/2021 11:26:56 AM)												

Loop	dHz (m)	dU (m)	Horz Tolerance (m)	Vert Tolerance (m)	dHz (ppm)	dU (ppm)	Length (m)	dHz relative	dU relative	Check	dN (m)	dE (m)
G271-G292(12/25/2021 8:38:10 AM)												
G256-G318(12/21/2021 2:29:56 PM)	0.0113	0.0258	0.1672	0.1972	0.41	0.94	27439.69	1:2430136.3	1:1061958.3	Pass	0.0026	0.011
G256-G319(12/21/2021 2:27:04 PM)												
G318-G319(12/21/2021 2:29:56 PM)												
G256-G333(12/21/2021 4:06:08 PM)	0.0013	0.0078	0.1144	0.1444	0.07	0.46	16883.1	1:13462957.7	1:2172702.6	Pass	0.0003	0.0012
G256-G334(12/21/2021 4:06:30 PM)												
G333-G334(12/21/2021 4:06:30 PM)												
G271-G292(12/25/2021 8:38:10 AM)	0.0043	0.0114	0.0552	0.0852	0.86	2.27	5036.829	1:1167363.5	1:441437.9	Pass	0.0024	0.0036
G271-G272(12/25/2021 8:37:57 AM)												

Loop	dHz (m)	dU (m)	Horz Tolerance (m)	Vert Tolerance (m)	dHz (ppm)	dU (ppm)	Length (m)	dHz relative	dU relative	Check	dN (m)	dE (m)
G272-G292(12/25/2021 8:38:10 AM)												
G27-G42(12/17/2021 11:29:00 AM)	0.0018	0.0045	0.0803	0.1103	0.18	0.45	10066.34	1:5668322.4	1:2212843.9	Pass	0.0002	0.0018
G27-G28(12/17/2021 11:29:00 AM)												
G28-G42(12/17/2021 11:24:56 AM)												
G292-G293(12/23/2021 3:20:35 PM)	0.0037	0.0001	0.0339	0.0639	4.69	0.14	785.3741	1:213027.5	1:7372439.2	Pass	0.0017	0.0033
G292-G294(12/23/2021 3:19:33 PM)												
G293-G294(12/23/2021 3:20:35 PM)												
G292-G351(12/24/2021 10:05:09 AM)	0.0156	0.0029	0.2197	0.2497	0.41	0.08	37936.64	1:2435907.6	1:13080723.0	Pass	0.0139	0.007
G292-G352(12/24/2021 10:05:22 AM)												

Loop	dHz (m)	dU (m)	Horz Tolerance (m)	Vert Tolerance (m)	dHz (ppm)	dU (ppm)	Length (m)	dHz relative	dU relative	Check	dN (m)	dE (m)
G351-G352(12/24/2021 10:05:22 AM)												
G292-G364(12/24/2021 2:12:36 PM)	0.0434	0.1205	0.1741	0.2041	1.51	4.18	28822.19	1:663435.1	1:239246.1	Pass	0.0065	0.043
G292-G363(12/24/2021 2:11:42 PM)												
G363-G364(12/24/2021 2:12:36 PM)												
G2-G42(12/17/2021 8:37:18 AM)	0.0018	0.0088	0.1767	0.2067	0.06	0.3	29331.73	1:15880243.9	1:3333616.0	Pass	0.0016	0.0009
G1-G2(12/17/2021 8:37:18 AM)												
G1-G42(12/17/2021 8:35:58 AM)												
G305-G306(12/22/2021 4:37:22 PM)	0.0041	0.0002	0.0767	0.1067	0.44	0.02	9335.419	1:2251142.7	1:60587033.5	Pass	0.0041	0.0001
G292-G305(12/22/2021 4:37:22 PM)												

Loop	dHz (m)	dU (m)	Horz Tolerance (m)	Vert Tolerance (m)	dHz (ppm)	dU (ppm)	Length (m)	dHz relative	dU relative	Check	dN (m)	dE (m)
G292-G306(12/22/2021 4:37:09 PM)												
G348-G350(12/22/2021 3:14:31 PM)												
G292-G348(12/22/2021 3:14:31 PM)	0.005	0.0373	0.1303	0.1603	0.25	1.86	20065.42	1:3982101.8	1:537957.3	Pass	0	0.005
G292-G350(12/22/2021 3:14:10 PM)												
G77-G78(12/18/2021 8:09:08 AM)												
G42-G77(12/18/2021 8:07:49 AM)	0.0005	0.0013	0.1229	0.1529	0.03	0.07	18586.44	1:36706167.9	1:14547417.5	Pass	0	0.0005
G42-G78(12/18/2021 8:09:08 AM)												
G95-G96(12/18/2021 9:34:51 AM)												
G42-G95(12/18/2021 9:34:51 AM)	0.0159	0.0602	0.1752	0.2052	0.55	2.07	29030.01	1:1828964.3	1:482433.5	Pass	0.0126	0.0096
G42-G96(12/18/2021 9:33:38 AM)												

Loop	dHz (m)	dU (m)	Horz Tolerance (m)	Vert Tolerance (m)	dHz (ppm)	dU (ppm)	Length (m)	dHz relative	dU relative	Check	dN (m)	dE (m)
G96-G126(12/19/2021 9:28:12 AM)	0.0251	0.0439	0.1345	0.1645	1.2	2.1	20891.78	1:833398.6	1:475736.7	Pass	0.0101	0.023
G96-G125(12/19/2021 9:28:53 AM)												
G125-G126(12/19/2021 9:28:53 AM)												
G96-G156(12/18/2021 2:25:30 PM)	0.0041	0.0132	0.244	0.274	0.09	0.31	42802.92	1:10567800.9	1:3244191.9	Pass	0.0006	0.004
G96-G155(12/18/2021 2:35:00 PM)												
G155-G156(12/18/2021 2:35:00 PM)												
G96-G165(12/18/2021 4:11:59 PM)	0.003	0.0107	0.297	0.327	0.06	0.2	53395.16	1:17935730.1	1:4979114.4	Pass	0.0012	0.0027
G96-G170(12/18/2021 4:13:00 PM)												
G165-G170(12/18/2021 4:13:00 PM)												

DGPS- Real Time Kinematics (RTK)

RTK enabled is one of the best and most reliable features of this DGPS device and we can take many advantages of this feature. The majority of civilian users' single frequency receivers are used. The public ranging modulation is currently only on the L1 signal. The only ranging signal on L2 is encrypted. The exceptions are survey and scientific systems that use expensive receivers with methods to work around the L2 encryption. The single-frequency user must deal with the error produced as the signals go through the ionosphere. The second frequency was put on the GPS satellites to allow real time removal of the ionosphere error. It does this to an accuracy better than 1 cm. Hyper HR is (L1 + L2) DGPS so the accuracy is greater than the (L1) DGPS.

So, to transfer coordinates or to perform detail point survey from longer distance and for the smaller distances (up to 5 Km Radial) loop /Control point /BM/TP also fixed by RTK Principle. All of those point should be free from obstruction of satellite signal. Total station can be used for those places where there is obstruction of satellite signal. This is advance and the latest technology in surveying. which overcome the errors of Total station causes due to multiple time shifting of its occupied point and back point.

RTK principal is based on the real time GNSS solution that has the accuracy of about (H: 5mm+0.5 PPM) in horizontal and (V: 10mm+ 0.8 PPM) in vertical. We can setup base station at known station and rover station can have used in our desired point. Then the data can be observed in real time on Palmtop controller having magnet field software inside it. Diagrammatic description of RTK principle is attached below.

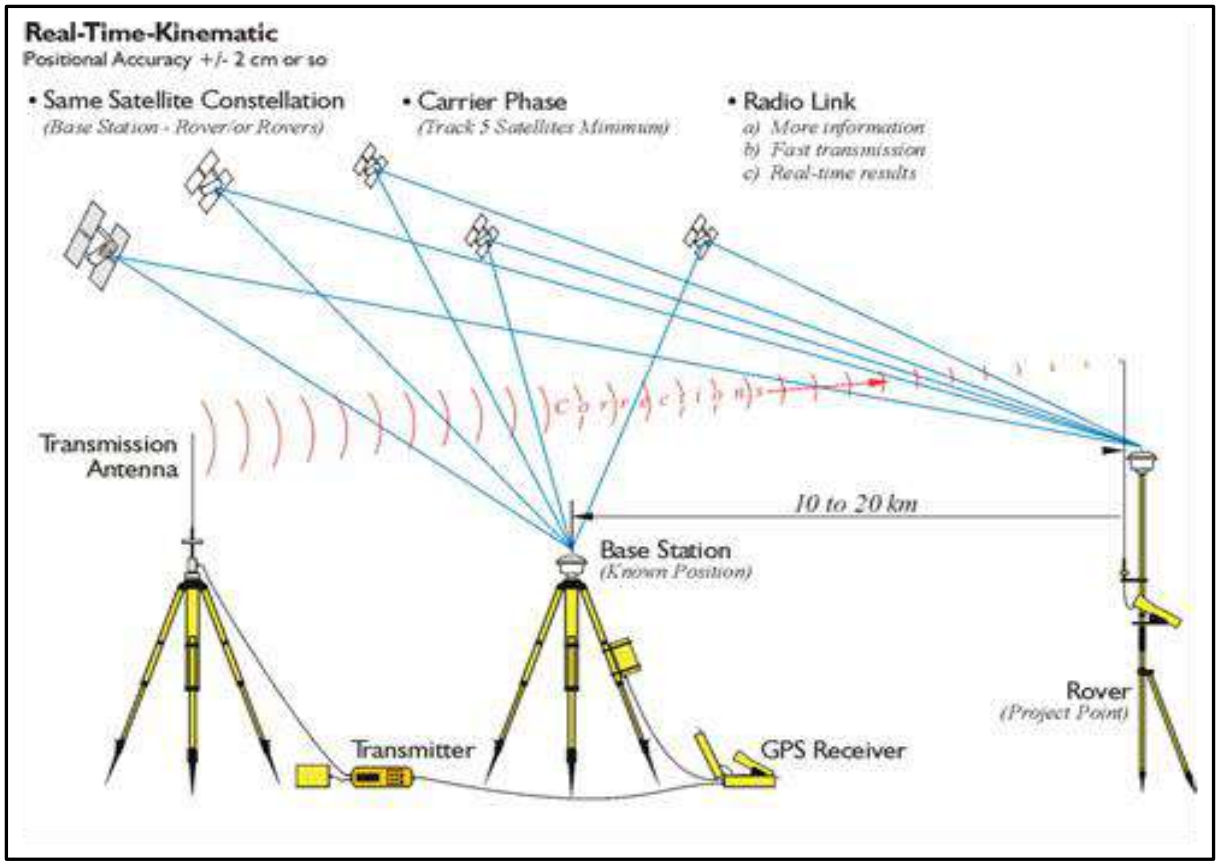


Figure 3.16: DGPS RTK Working Principle

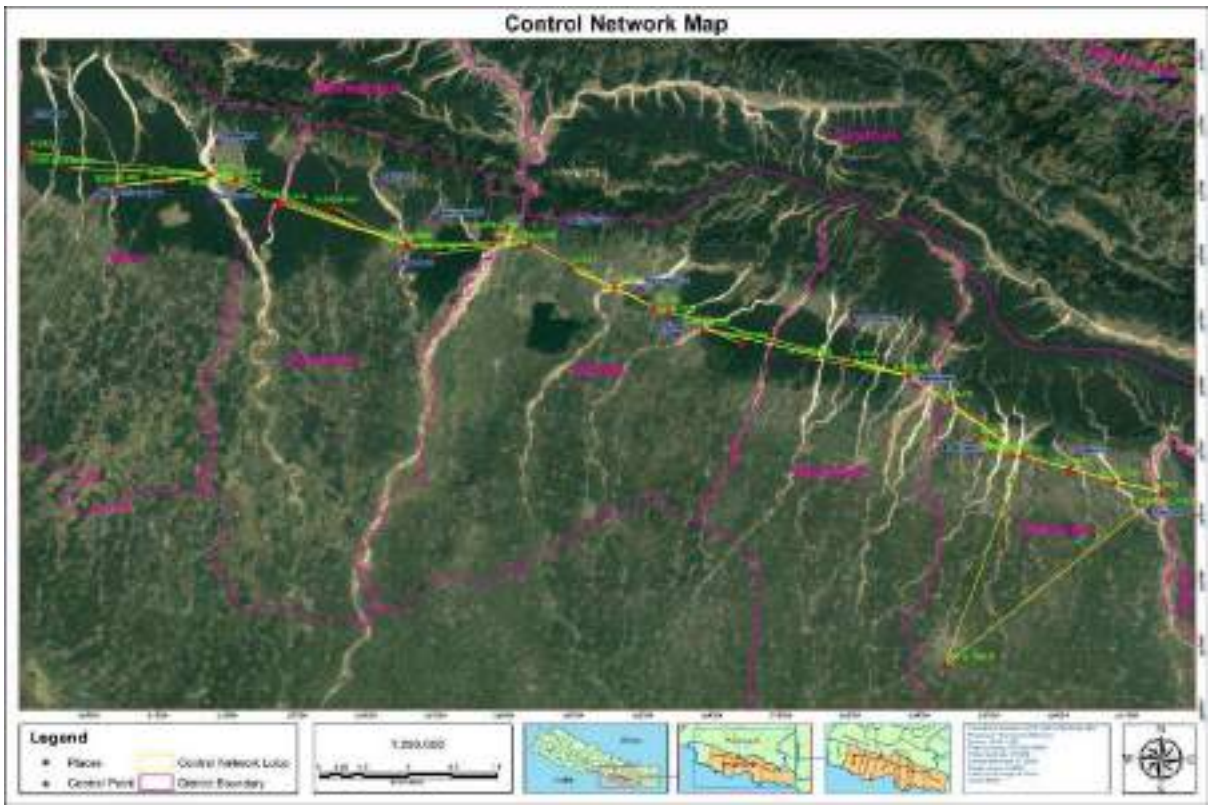


Figure 3.17: Major Control Network Map

Levelling

Levelling is the most widely used method of obtaining the elevations of ground points relative to a reference datum and is usually carried out as a separate procedure to those used in fixing planimetric position. The basic concept of levelling involves the measurement of vertical distance relative to a horizontal line of sight. Hence it requires a graduated staff for the vertical measurements & an instrument that provides a horizontal line of sight.

The level calculation sheet has been attached in the **Volume I-A.**

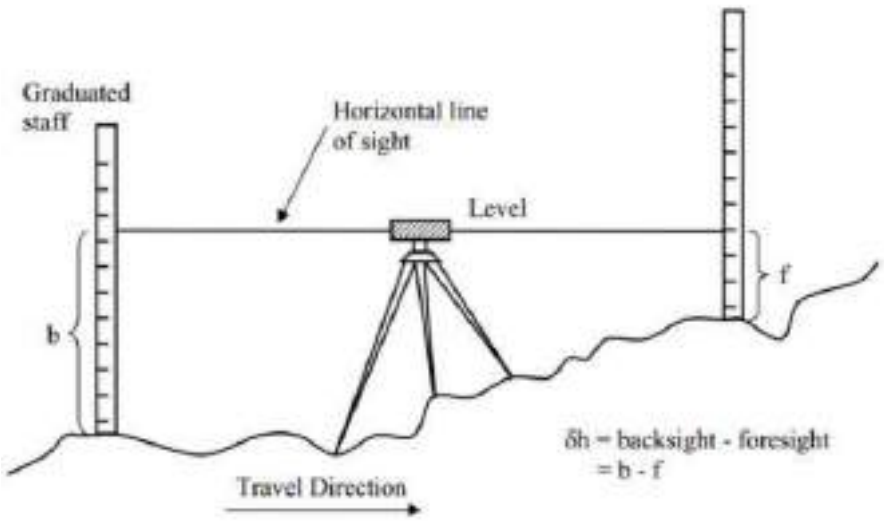


Figure 3.18: Levelling

Levelling procedures

a) Setting up

Backsight and foresight distances should be approximately equal to avoid any errors due to collimation, refraction or earth curvature. Distances must not be so great as to not be able to read the graduations accurately. The points to be observed must be below the level of the instrument, but not lower than the height of the staff.

b) Elimination of parallax

Parallax is the apparent movement of the image produced by movement of the observer's eye at the eyepiece. It is eliminated by focusing the telescope on infinity and then adjusting the eyepiece until the cross-hairs appear in sharp focus. The setting will remain constant for a particular observer's eye.

c) Booking

Level books or loose-leaf levelling sheets numbered and indexed in a register. Details of the site, work, date, observer, chainman, booker, weather, wind, instrument and any other relevant items entered. Enter the first observation (which is on a known point) in the Backsight column, and sufficient detail in the Remarks column to identify it. Enter the point's R.L. zero from the site register or plate on the BM, etc. Identify them in the Remarks column as above. Enter the foresight on a further line in the Foresight column. Change the instrument to the next setup. Enter the following backsight on the same line as the previous foresight but in the Backsight column.

Type of leveling used: Differential Levelling (Direct levelling)

Differential levelling is one of the direct levelling types in which the difference in elevation of two points irrespective of the horizontal position is calculated. It is also commonly known as fly levelling.

Types of Booking Method: Rise Fall

Rise fall booking method uses the arithmetic check formula:

Sum of Backsight Reading-Sum of Foresight Reading= Last Reduced level – First Reduced Level=Sum of Rising-Sum of Fall

Station	*BS*	*IS*	*FS*	*Rise*	*Fall*	*RL*	*Remarks*
A	1.35					200.00	Benchmark
		0.80		0.55		200.55	E_1
	1.40		1.65		0.85	199.70	CP_1
		0.70		0.70		200.40	E_2
	1.30		1.70		1.00	199.40	CP_2
			1.85		0.55	198.85	B
	Σ BS = 4.05		Σ FS = 5.20	Σ Rise = 1.25	Σ Fall = 2.40		
Check: Σ BS – Σ FS = –1.15			Σ Rise – Σ Fall = –1.15			RL of last point – RL of first point = –1.15	

Figure 3.19: Rise fall booking method

Computation of coordinates

The coordinates received from GPS receiver were in the WGS 84 reference system that has to be processed to get the refined values from Topcon Magnet tools software. These coordinates were transformed to MUTM - 84 (North) coordinate system using the transformational parameters. The commercial software magnet office has been used for the post-processing. The list of ground control points is presented in tabular form.

Table 3.6: Ground Control Points Coordinates in MUTM UTM & WGS 84

S.N.	MUTM 84				UTM45		WGS84	
	Easting	Northing	Elevation	Remarks	Easting	Northing	Longitude	Latitude
1	415112.834	2973952.073	107.991	G1	414882.952	2973341.467	86.143	26.879
2	415102.202	2974016.682	108.805	G2	414872.323	2973406.057	86.143	26.88
3	414470.217	2973769.369	108.098	G3	414240.522	2973158.816	86.137	26.878
4	414411.604	2973735.353	103.639	G4	414181.927	2973124.81	86.136	26.877
5	413768.151	2974131.969	111.616	G5	413538.661	2973521.311	86.13	26.881
6	413803.191	2974075.698	111.071	G6	413573.691	2973465.056	86.13	26.88
7	413387.993	2974577.514	114.036	G7	413158.614	2973966.726	86.126	26.885
8	413322.801	2974615.548	114.343	G8	413093.441	2974004.749	86.125	26.885
9	412633.506	2974809.788	118.202	G9	412404.348	2974198.932	86.118	26.887
10	412592.25	2974773.016	117.787	G10	412363.104	2974162.171	86.118	26.886
11	411823.824	2974961.7	119.125	G11	411594.902	2974350.8	86.11	26.888
12	411870.313	2975059.691	118.812	G12	411641.378	2974448.762	86.11	26.889
13	411249.595	2975152.834	121.553	G13	411020.841	2974541.878	86.104	26.89
14	411202.122	2975176.456	121.789	G14	410973.382	2974565.493	86.104	26.89
15	410323.408	2975300.766	123.84	G15	410094.924	2974689.767	86.095	26.891
16	410422.181	2975293.06	124.881	G16	410193.668	2974682.063	86.096	26.891
17	409634.474	2975669.619	126.714	G17	409406.191	2975058.512	86.088	26.894
18	409667.9	2975662.716	126.435	G18	409439.608	2975051.611	86.088	26.894
19	408849.845	2975702.541	134.291	G19	408621.791	2975091.425	86.08	26.895
20	408897.798	2975653.891	133.4	G20	408669.73	2975042.789	86.08	26.894
21	408059.037	2975760.158	137.188	G21	407831.214	2975149.025	86.072	26.895
22	408076.217	2975843.48	137.171	G22	407848.389	2975232.323	86.072	26.896
23	407281.324	2975853.409	138.45	G23	407053.728	2975242.249	86.064	26.896
24	407151.477	2975883.794	139.697	G24	406923.919	2975272.625	86.063	26.896
25	406446.249	2976236.118	144.086	G25	406218.897	2975624.846	86.056	26.899
26	406441.947	2976308.638	144.452	G26	406214.596	2975697.345	86.056	26.9
27	405786.681	2976608.327	150.41	G27	405559.522	2975996.946	86.049	26.903
28	405862.797	2976574.267	149.648	G28	405635.615	2975962.896	86.05	26.902
29	405148.395	2976873.225	152.788	G29	404921.422	2976261.767	86.043	26.905
30	405082.832	2976908.996	153.261	G30	404855.878	2976297.528	86.042	26.905
31	404513.336	2977272.215	154.943	G31	404286.548	2976660.641	86.036	26.909
32	404447.783	2977308.29	154.62	G32	404221.015	2976696.705	86.035	26.909

S.N.	MUTM 84				UTM45		WGS84	
	Easting	Northing	Elevation	Remarks	Easting	Northing	Longitude	Latitude
33	403758.458	2977642.534	156.436	G33	403531.891	2977030.852	86.029	26.912
34	403737.449	2977543.762	155.237	G34	403510.888	2976932.109	86.028	26.911
35	403110.053	2977966.135	158.981	G35	402883.675	2977354.358	86.022	26.915
36	403069.82	2978015.918	159.422	G36	402843.454	2977404.127	86.022	26.915
37	402560.669	2978290.022	162.409	G37	402334.452	2977678.151	86.016	26.918
38	402518.354	2978299.579	162.545	G38	402292.149	2977687.705	86.016	26.918
39	401788.478	2978058.953	161.3	G39	401562.486	2977447.149	86.009	26.915
40	401742.121	2978065.669	161.58	G40	401516.143	2977453.863	86.008	26.915
41	401091.901	2978005.739	159.349	G41	400866.112	2977393.951	86.002	26.915
42	401044.162	2978026.713	159.08	G42	400818.387	2977414.919	86.001	26.915
43	400349.177	2977985.617	158.299	G43	400123.605	2977373.835	85.994	26.915
44	400304.899	2978017.225	158.774	G44	400079.34	2977405.434	85.994	26.915
45	399787.52	2978386.506	161.138	G45	399562.112	2977774.607	85.988	26.918
46	399833.06	2978396.154	160.579	G46	399607.639	2977784.252	85.989	26.918
47	399484.887	2978919.953	165.734	G47	399259.568	2978307.898	85.985	26.923
48	399421.73	2978952.076	166.096	G48	399196.429	2978340.012	85.985	26.923
49	398810.484	2979185.352	166.986	G49	398585.361	2978573.22	85.979	26.925
50	398719.867	2979224.789	166.901	G50	398494.771	2978612.645	85.978	26.926
51	398111.049	2979212.895	166.688	G51	397886.131	2978600.755	85.972	26.926
52	398148.903	2979261.225	167.068	G52	397923.974	2978649.071	85.972	26.926
53	397447.013	2979438.487	170.291	G53	397222.289	2978826.281	85.965	26.928
54	397553.354	2979396.776	167.634	G54	397328.598	2978784.582	85.966	26.927
55	396842.295	2979539.787	169.332	G55	396617.747	2978927.551	85.959	26.928
56	396905.606	2979522.758	169.149	G56	396681.04	2978910.527	85.959	26.928
57	396386.962	2979933.091	173.566	G57	396162.547	2979320.741	85.954	26.932
58	396378.923	2979789.99	172.514	G58	396154.51	2979177.681	85.954	26.931
59	396126.053	2980355.106	175.662	G59	395901.714	2979742.632	85.951	26.936
60	396114.308	2980335.72	175.827	G60	395889.973	2979723.252	85.951	26.936
61	395601.606	2980840.337	175.794	G61	395377.42	2980227.722	85.946	26.94
62	395652.611	2980777.787	176.114	G62	395428.411	2980165.19	85.947	26.94
63	395319.581	2981294.822	182.545	G63	395095.478	2980682.074	85.943	26.944
64	395320.202	2981329.947	182.895	G64	395096.099	2980717.189	85.943	26.944
65	394810.467	2981642.294	187.334	G65	394586.512	2981029.445	85.938	26.947
66	394843.909	2981631.771	187.224	G66	394619.945	2981018.925	85.938	26.947
67	410785.79	2975165.115	123.018	G67	410557.171	2974554.155	86.099	26.89
68	410773.236	2975129.783	123.225	G68	410544.621	2974518.834	86.099	26.89
69	394281.153	2981893.33	185.177	G69	394057.353	2981280.408	85.933	26.949
70	394323.933	2981861.587	186.345	G70	394100.12	2981248.674	85.933	26.949
71	394084.288	2982121.896	185.864	G71	393860.545	2981508.907	85.931	26.952
72	394036.868	2982227.66	186.918	G72	393813.139	2981614.64	85.93	26.952
73	393958.568	2982626.952	190.93	G73	393734.862	2982013.816	85.929	26.956
74	393908.983	2982651.077	191.346	G74	393685.292	2982037.933	85.929	26.956

S.N.	MUTM 84				UTM45		WGS84	
	Easting	Northing	Elevation	Remarks	Easting	Northing	Longitude	Latitude
75	393955.033	2983165.442	194.084	G75	393731.328	2982552.148	85.929	26.961
76	393968.963	2983209.427	194.504	G76	393745.254	2982596.12	85.93	26.961
77	393774.864	2983764.138	201.564	G77	393551.212	2983150.67	85.927	26.966
78	393765.079	2983798.603	201.885	G78	393541.43	2983185.125	85.927	26.967
79	393566.795	2984319.791	206.065	G79	393343.204	2983706.16	85.925	26.971
80	393575.927	2984287.904	205.332	G80	393352.333	2983674.283	85.925	26.971
81	393466.226	2984823.228	210.358	G81	393242.664	2984209.45	85.924	26.976
82	393447.427	2984910.657	209.824	G82	393223.871	2984296.854	85.924	26.977
83	393121.227	2985299.365	215.779	G83	392897.766	2984685.449	85.921	26.98
84	393140.99	2985251.117	215.621	G84	392917.523	2984637.215	85.921	26.98
85	392365.367	2985627.28	219.574	G85	392142.127	2985013.268	85.913	26.983
86	392326.11	2985657.018	219.792	G86	392102.881	2985042.997	85.913	26.983
87	391984.087	2985700.651	220.995	G87	391760.958	2985086.617	85.909	26.984
88	391965.672	2985682.18	218.969	G88	391742.548	2985068.152	85.909	26.983
89	391376.424	2985984.509	223.022	G89	391153.472	2985370.393	85.903	26.986
90	391462.764	2985956.899	225.41	G90	391239.787	2985342.791	85.904	26.986
91	390908.451	2986246.698	221.28	G91	390685.636	2985632.505	85.898	26.988
92	390846.837	2986269.793	220.469	G92	390624.04	2985655.593	85.898	26.989
93	390101.754	2986605.344	217.801	G93	389879.175	2985991.047	85.89	26.992
94	390054.651	2986573.262	216.372	G94	389832.085	2985958.974	85.89	26.991
95	389472.735	2986719.652	210.49	G95	389250.339	2986105.321	85.884	26.993
96	389420.894	2986695.688	209.62	G96	389198.513	2986081.364	85.883	26.992
97	388822.045	2986937.326	210.22	G97	388599.839	2986322.932	85.877	26.995
98	388878.514	2986919.379	210.125	G98	388656.292	2986304.99	85.878	26.994
99	387704.039	2987327.595	209.67	G99	387482.16	2986713.087	85.866	26.998
100	387735.698	2987317.309	209.447	G100	387513.809	2986702.804	85.866	26.998
101	388329.056	2987168.986	208.324	G101	388106.994	2986554.524	85.872	26.997
102	388373.293	2987154.144	208.696	G102	388151.218	2986539.686	85.873	26.996
103	386995.616	2987543.475	207.588	G103	386773.943	2986928.904	85.859	27
104	386948.903	2987558.542	209.508	G104	386727.244	2986943.967	85.858	27
105	386268.233	2987786.31	212.478	G105	386046.773	2987171.668	85.852	27.002
106	386234.313	2987798.879	211.447	G106	386012.863	2987184.233	85.851	27.002
107	385733.405	2988017.884	210.14	G107	385512.101	2987403.175	85.846	27.004
108	385682.401	2988031.697	210.02	G108	385461.112	2987416.984	85.846	27.004
109	384947.544	2988162.436	207.815	G109	384726.469	2987547.684	85.838	27.005
110	384906.688	2988160.001	207.882	G110	384685.625	2987545.25	85.838	27.005
111	384263.06	2988120.783	204.393	G111	384042.185	2987506.044	85.831	27.005
112	384236.624	2988125.216	204.485	G112	384015.757	2987510.475	85.831	27.005
113	383655.983	2988172.731	202.222	G113	383435.285	2987557.977	85.825	27.005
114	383614.91	2988174.269	202.089	G114	383394.224	2987559.514	85.825	27.005
115	382974.656	2988044.995	195.74	G115	382754.157	2987430.278	85.818	27.004
116	382913.084	2988042.703	196.048	G116	382692.603	2987427.987	85.818	27.004

S.N.	MUTM 84				UTM45		WGS84	
	Easting	Northing	Elevation	Remarks	Easting	Northing	Longitude	Latitude
117	382304.066	2988146.358	192.191	G117	382083.763	2987531.611	85.812	27.005
118	382265.552	2988152.476	190.294	G118	382045.26	2987537.728	85.811	27.005
119	381579.859	2988273.788	192.173	G119	381359.768	2987659.004	85.804	27.006
120	381552.27	2988272.589	192.631	G120	381332.187	2987657.806	85.804	27.006
121	380798.279	2988092.793	192.189	G121	380578.416	2987478.062	85.796	27.004
122	380774.349	2988101.819	192.459	G122	380554.493	2987487.086	85.796	27.004
123	380063.751	2988307.068	191.434	G123	379844.102	2987692.275	85.789	27.006
124	380032.174	2988318.537	191.384	G124	379812.534	2987703.74	85.789	27.006
125	379174.339	2988522.415	188.257	G125	378954.95	2987907.559	85.78	27.008
126	379139.647	2988540.172	188.686	G126	378920.268	2987925.311	85.78	27.008
127	378459.218	2988744.652	188.957	G127	378240.038	2988129.731	85.773	27.01
128	378427.901	2988750.216	188.787	G128	378208.73	2988135.293	85.772	27.01
129	377533.216	2988876.758	187.787	G129	377314.306	2988261.799	85.763	27.011
130	377501.397	2988880.895	187.858	G130	377282.496	2988265.934	85.763	27.011
131	376813.213	2989005.474	184.886	G131	376594.513	2988390.477	85.756	27.012
132	376783.816	2989010.346	185.176	G132	376565.125	2988395.348	85.756	27.012
133	376098.102	2989060.148	179.031	G133	375879.611	2988445.135	85.749	27.013
134	376067.548	2989056.701	178.428	G134	375849.066	2988441.689	85.749	27.013
135	375396.544	2989204.307	181.492	G135	375178.258	2988589.252	85.742	27.014
136	375309.916	2989261.718	181.884	G136	375091.655	2988646.646	85.741	27.014
137	374813.121	2989624.33	181.451	G137	374595.005	2989009.153	85.736	27.018
138	374769.025	2989669.329	181.019	G138	374550.922	2989054.138	85.735	27.018
139	374132.388	2989908.555	177.121	G139	373914.471	2989293.295	85.729	27.02
140	374101.669	2989915.252	176.994	G140	373883.761	2989299.99	85.729	27.02
141	373452.309	2990016.515	172.444	G141	373234.591	2989401.223	85.722	27.021
142	373422.412	2990017.67	172.065	G142	373204.702	2989402.378	85.722	27.021
143	372653.341	2990132.863	168.434	G143	372435.856	2989517.537	85.714	27.022
144	372623.173	2990141.289	167.811	G144	372405.697	2989525.961	85.714	27.022
145	371961.117	2990256.682	166.055	G145	371743.834	2989641.32	85.707	27.023
146	371913.596	2990264.314	165.78	G146	371696.327	2989648.95	85.707	27.023
147	371261.743	2990367.163	165.833	G147	371044.664	2989751.769	85.7	27.024
148	371213.871	2990374.624	165.842	G148	370996.806	2989759.228	85.7	27.024
149	370484.926	2990457.614	163.723	G149	370268.074	2989842.194	85.692	27.025
150	370461.604	2990462.062	163.904	G150	370244.759	2989846.64	85.692	27.025
151	369859.123	2990596.49	161.747	G151	369642.454	2989981.029	85.686	27.026
152	369824.201	2990613.63	161.742	G152	369607.542	2989998.164	85.686	27.026
153	369193.871	2990996.996	160.025	G153	368977.396	2990381.418	85.679	27.029
154	369172.173	2991019.315	160.128	G154	368955.704	2990403.731	85.679	27.03
155	368691.267	2991693.501	160.562	G155	368474.939	2991077.72	85.674	27.036
156	368643.315	2991772.762	160.442	G156	368427.001	2991156.958	85.674	27.036
157	368248.786	2992353.777	161.473	G157	368032.587	2991737.803	85.67	27.042
158	368214.359	2992378.948	161.405	G158	367998.17	2991762.967	85.669	27.042

S.N.	MUTM 84				UTM45		WGS84	
	Easting	Northing	Elevation	Remarks	Easting	Northing	Longitude	Latitude
159	367465.413	2992710.487	157.103	G159	367249.443	2992094.409	85.662	27.045
160	367378.138	2992733.624	156.111	G160	367162.193	2992117.54	85.661	27.045
161	366678.973	2993025.542	155.065	G161	366463.232	2992409.373	85.654	27.048
162	366609.959	2993042.13	154.082	G162	366394.239	2992425.956	85.653	27.048
163	365924.959	2993224.64	151.219	G163	365709.439	2992608.413	85.646	27.049
164	365881.889	2993231.613	150.896	G164	365666.381	2992615.383	85.646	27.049
165	365144.589	2993545.882	148.375	G165	364929.296	2992929.561	85.638	27.052
166	365101.227	2993560.517	148.094	G166	364885.947	2992944.192	85.638	27.052
167	364411.618	2993737.685	146.724	G167	364196.539	2993121.308	85.631	27.054
168	364370.992	2993752.286	146.225	G168	364155.925	2993135.905	85.63	27.054
169	363740.196	2994006.041	144.773	G169	363525.314	2993389.586	85.624	27.056
170	363731.589	2993969.033	145.062	G170	363516.709	2993352.588	85.624	27.056
171	349801.053	3002592.85	135.822	G171	349590.241	3001973.889	85.482	27.132
172	349769.537	3002606.876	136.087	G172	349558.734	3001987.911	85.482	27.132
173	349493.198	3002861.195	135.445	G173	349282.476	3002242.156	85.479	27.135
174	349514.543	3002887.704	135.727	G174	349303.815	3002268.657	85.479	27.135
175	348814.24	3002923.089	131.583	G175	348603.716	3002304.032	85.472	27.135
176	348763.556	3002917.442	131.682	G176	348553.047	3002298.387	85.472	27.135
177	348038.873	3002610.092	136.891	G177	347828.576	3001991.127	85.465	27.132
178	347992.067	3002588.946	137.27	G178	347781.783	3001969.987	85.464	27.132
179	347525.599	3002059.723	134.827	G179	347315.451	3001440.918	85.46	27.127
180	347499.499	3002019.916	134.329	G180	347289.359	3001401.123	85.459	27.127
181	346856.65	3001478.501	128.726	G181	346646.698	3000859.866	85.453	27.122
182	346832.013	3001460.399	129.225	G182	346622.068	3000841.769	85.453	27.122
183	346228.412	3001171.281	126.559	G183	346018.643	3000552.736	85.447	27.119
184	346205.727	3001164.278	126.542	G184	345995.965	3000545.735	85.446	27.119
185	345741.809	3000984.635	125.697	G185	345532.182	3000366.144	85.442	27.117
186	345716.055	3000973.068	126.38	G186	345506.436	3000354.581	85.441	27.117
187	345047.514	3000753.283	129.234	G187	344838.09	3000134.86	85.435	27.115
188	345014.44	3000735.463	129.123	G188	344805.025	3000117.045	85.434	27.115
189	344308.293	3000467.985	127.9	G189	344099.085	2999849.645	85.427	27.112
190	344274.137	3000454.195	128.486	G190	344064.939	2999835.859	85.427	27.112
191	343607.571	3000214.079	124.307	G191	343398.567	2999595.814	85.42	27.11
192	342945.669	2999978.647	123.424	G193	342736.858	2999360.45	85.414	27.108
193	342219.622	2999881.677	125.005	G195	342011.023	2999263.509	85.406	27.107
194	342172.824	2999873.008	124.995	G196	341964.239	2999254.842	85.406	27.107
195	341428.452	2999785.515	121.628	G197	341220.084	2999167.375	85.398	27.106
196	341339.917	2999784.263	121.677	G198	341131.575	2999166.123	85.397	27.106
197	340626.378	2999903.04	123.384	G199	340418.245	2999284.866	85.39	27.107
198	363237.302	2994129.086	140.355	G200	363022.566	2993512.595	85.619	27.057
199	363323.933	2994107.592	142.016	G201	363109.172	2993491.107	85.62	27.057
200	362443.17	2994404.614	141.648	G202	362228.666	2993788.042	85.611	27.06

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	Easting	Northing	Elevation	Remarks	Easting	Northing	Longitude	Latitude
201	362431.107	2994412.287	141.511	G203	362216.607	2993795.713	85.611	27.06
202	361930.475	2994580.677	139.967	G204	361716.121	2993964.054	85.606	27.061
203	361842.176	2994637.839	140.002	G205	361627.848	2994021.199	85.605	27.062
204	361172.216	2994916.468	139.794	G206	360958.083	2994299.747	85.598	27.064
205	361129.099	2994883.229	139.702	G207	360914.979	2994266.518	85.597	27.064
206	358457.854	2997362.123	142.078	G208	358244.514	2996744.688	85.57	27.086
207	358428.011	2997370.057	141.971	G209	358214.68	2996752.62	85.57	27.086
208	357819.651	2997529.104	145.028	G210	357606.497	2996911.621	85.564	27.087
209	357756.551	2997537.806	143.621	G211	357543.416	2996920.32	85.563	27.087
210	357183.436	2997775.258	144.338	G212	356970.468	2997157.703	85.557	27.089
211	357229.634	2997761.155	144.352	G213	357016.653	2997143.604	85.558	27.089
212	360683.049	2995040.843	139.385	G214	360469.059	2994424.086	85.593	27.065
213	360645.07	2995046.462	139.685	G215	360431.091	2994429.703	85.593	27.065
214	360196.654	2995417.799	141.716	G216	359982.806	2994800.932	85.588	27.068
215	360148.34	2995431.984	141.491	G217	359934.506	2994815.113	85.588	27.069
216	359760.999	2996026.467	137.58	G218	359547.278	2995409.422	85.584	27.074
217	359745.748	2996013.872	138.026	G219	359532.032	2995396.831	85.583	27.074
218	359721.101	2996371.774	137.786	G220	359507.392	2995754.628	85.583	27.077
219	359778.607	2996286.375	138.101	G221	359564.881	2995669.254	85.584	27.076
220	359364.477	2997076.142	140.644	G222	359150.872	2996458.791	85.579	27.083
221	359332.93	2997125.402	140.591	G223	359119.335	2996508.036	85.579	27.084
222	358901.247	2997254.422	140.473	G224	358687.778	2996637.019	85.575	27.085
223	358880.939	2997252.44	140.521	G225	358667.476	2996635.037	85.575	27.085
224	356632.18	2997819.38	144.271	G226	356419.373	2997201.812	85.552	27.09
225	356679.037	2997808.744	144.323	G227	356466.216	2997191.179	85.552	27.09
226	356088.573	2997959.885	139.454	G228	355875.925	2997342.276	85.546	27.091
227	356065.437	2997956.945	139.311	G229	355852.796	2997339.337	85.546	27.091
228	355192.875	2998179.125	137.782	G230	354980.488	2997561.452	85.537	27.093
229	355269.259	2998159.486	138.032	G231	355056.85	2997541.819	85.538	27.093
230	354488.883	2998363.535	138.338	G232	354276.702	2997745.809	85.53	27.094
231	354515.802	2998341.855	138.268	G233	354303.613	2997724.135	85.53	27.094
232	353506.597	2999139.143	133.687	G234	353294.703	2998521.19	85.52	27.101
233	353821.975	2998828.653	135.285	G235	353609.989	2998210.791	85.523	27.099
234	353888.692	2998772.623	135.935	G236	353676.686	2998154.777	85.524	27.098
235	353493.374	2999143.963	136.271	G237	353281.484	2998526.009	85.52	27.101
236	352796.808	2999688.378	135.137	G238	352585.121	2999070.265	85.513	27.106
237	352828.618	2999670.514	134.781	G239	352616.922	2999052.406	85.513	27.106
238	352217.891	2999989.051	133.724	G240	352006.373	2999370.85	85.507	27.109
239	352254.054	2999965.181	133.702	G241	352042.526	2999346.987	85.507	27.109
240	351692.356	3000423.454	130.059	G242	351480.992	2999805.126	85.502	27.113
241	351683.339	3000443.933	129.967	G243	351471.977	2999825.6	85.502	27.113
242	351101.602	3000957.083	128.681	G244	350890.41	3000338.6	85.496	27.118

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	Easting	Northing	Elevation	Remarks	Easting	Northing	Longitude	Latitude
243	351139.069	3000922.727	128.873	G245	350927.866	3000304.254	85.496	27.117
244	350580.869	3001522.809	132.124	G246	350369.829	3000904.161	85.49	27.123
245	350571.188	3001542.145	131.569	G247	350360.151	3000923.491	85.49	27.123
246	350073.633	3002292.677	134.649	G248	349862.742	3001673.804	85.485	27.129
247	350071.569	3002223.886	134.88	G249	349860.678	3001605.033	85.485	27.129
248	340568.831	2999913.577	123.793	G250	340360.714	2999295.4	85.39	27.107
249	339832.056	3000123.893	123.346	G251	339624.154	2999505.654	85.382	27.109
250	339790.235	3000139.826	123.411	G252	339582.346	2999521.583	85.382	27.109
251	338874.823	3000525.05	125.066	G253	338667.201	2999906.694	85.372	27.112
252	338819.692	3000572.55	124.762	G254	338612.086	2999954.18	85.372	27.113
253	338672.15	3000715.745	125.212	G255	338464.587	3000097.334	85.37	27.114
254	338675.385	3000772.956	122.349	G256	338467.821	3000154.528	85.37	27.114
255	337956.709	3000961.709	128.806	G257	337749.355	3000343.226	85.363	27.116
256	337973.719	3000995.198	128.378	G258	337766.36	3000376.705	85.363	27.116
257	337345.691	3001401.164	132.36	G259	337138.516	3000782.553	85.357	27.12
258	337355.596	3001445.132	132.415	G260	337148.418	3000826.508	85.357	27.12
259	336841.525	3001901.978	133.25	G261	336634.497	3001283.221	85.352	27.124
260	336806.996	3001941.678	133.376	G262	336599.978	3001322.909	85.351	27.125
261	334840.801	3003408.693	141.779	G263	334634.357	3002789.496	85.331	27.138
262	334807.139	3003421.984	141.968	G264	334600.705	3002802.783	85.331	27.138
263	334258.457	3003630.145	143.343	G265	334052.183	3003010.883	85.326	27.14
264	334225.476	3003644.539	143.375	G266	334019.212	3003025.273	85.325	27.14
265	336414.83	3002415.49	135.617	G267	336207.926	3001796.583	85.347	27.129
266	336400.773	3002435.463	135.883	G268	336193.874	3001816.55	85.347	27.129
267	320851.779	3008196.715	154.589	G269	320649.42	3007576.122	85.19	27.179
268	320821.886	3008159.81	153.653	G270	320619.536	3007539.228	85.189	27.179
269	321444.719	3007806.679	153.803	G271	321242.187	3007186.2	85.196	27.176
270	321490.582	3007775.421	153.585	G272	321288.037	3007154.951	85.196	27.176
271	322163.394	3007237.065	152.17	G273	321960.652	3006616.752	85.203	27.171
272	322212.629	3007206.384	151.941	G274	322009.873	3006586.08	85.204	27.17
273	323362.591	3006517.509	149.724	G277	323159.499	3005897.406	85.215	27.164
274	323382.492	3006514.388	149.768	G278	323179.394	3005894.286	85.215	27.164
275	335902.408	3002867.527	139.284	G279	335695.654	3002248.488	85.342	27.133
276	335944.855	3002840.992	139.159	G280	335738.089	3002221.961	85.343	27.133
277	335363.727	3003200.251	141.478	G281	335157.13	3002581.115	85.337	27.136
278	335388.85	3003188.413	141.431	G282	335182.246	3002569.28	85.337	27.136
279	300750.192	3010490.794	163.186	G283	300553.703	3009869.534	84.987	27.197
280	300724.902	3010509.885	163.072	G284	300528.42	3009888.619	84.986	27.197
281	319680.143	3008357.04	153.821	G289	319478.126	3007736.4	85.178	27.181
282	319710.512	3008357.558	153.848	G290	319508.487	3007736.918	85.178	27.181
283	319031.489	3008267.695	154.657	G291	318829.662	3007647.081	85.171	27.18
284	319028.195	3008296.838	154.829	G292	318826.369	3007676.216	85.171	27.18

S.N.	MUTM 84				UTM45		WGS84	
	Easting	Northing	Elevation	Remarks	Easting	Northing	Longitude	Latitude
285	318655.067	3008360.784	156.239	G293	318453.35	3007740.143	85.167	27.18
286	318652.961	3008382.76	156.386	G294	318451.244	3007762.113	85.167	27.181
287	318023.439	3008320.222	154.197	G295	317821.906	3007699.593	85.161	27.18
288	317987.865	3008310.387	154.196	G296	317786.342	3007689.761	85.161	27.18
289	316990.871	3008245.753	156.187	G297	316789.64	3007625.146	85.151	27.179
290	317105.045	3008257.784	155.135	G298	316903.78	3007637.174	85.152	27.179
291	316415.352	3008245.737	155.192	G299	316214.289	3007625.13	85.145	27.179
292	316368.358	3008245.018	154.289	G300	316167.308	3007624.411	85.144	27.179
293	315706.482	3008073.076	152.985	G301	315505.626	3007452.52	85.138	27.177
294	315757.503	3008089.674	153.206	G302	315556.632	3007469.113	85.138	27.178
295	315138.109	3007841.24	152.799	G303	314937.419	3007220.751	85.132	27.175
296	315126.445	3007831.119	152.682	G304	314925.758	3007210.633	85.132	27.175
297	314429.623	3007603.467	151.614	G305	314229.139	3006983.048	85.125	27.173
298	314411.236	3007601.194	151.676	G306	314210.758	3006980.776	85.125	27.173
299	313966.53	3007425.522	150.675	G307	313766.182	3006805.155	85.12	27.171
300	313938.897	3007423.792	150.531	G308	313738.557	3006803.425	85.12	27.171
301	313306.822	3007195.719	149.881	G309	313106.666	3006575.419	85.114	27.169
302	313295.305	3007186.499	149.809	G310	313095.152	3006566.202	85.114	27.169
303	324054.688	3006290.462	151.351	G311	323851.394	3005670.425	85.222	27.162
304	324081.284	3006281.025	151.847	G312	323877.982	3005660.991	85.223	27.162
305	324705.341	3006054.752	151.914	G313	324501.857	3005434.784	85.229	27.16
306	324715.274	3006031.36	151.744	G314	324511.787	3005411.399	85.229	27.16
307	325254.523	3005764.479	147.967	G315	325050.878	3005144.595	85.234	27.158
308	325272.287	3005754.928	147.954	G316	325068.637	3005135.047	85.235	27.158
309	325753.636	3005395.905	149.192	G317	325549.846	3004776.129	85.239	27.155
310	325774.093	3005368.754	148.403	G318	325570.297	3004748.986	85.24	27.154
311	325983.462	3005098.798	146.978	G319	325779.605	3004479.109	85.242	27.152
312	326022.244	3005106.333	147.496	G320	325818.375	3004486.641	85.242	27.152
313	326771.174	3004890.091	145.144	G321	326567.086	3004270.462	85.25	27.15
314	326811.393	3004892.846	145.014	G322	326607.294	3004273.217	85.25	27.15
315	327618.345	3004976.244	147.328	G323	327414.01	3004356.59	85.258	27.151
316	327643.886	3004978.756	146.718	G324	327439.544	3004359.101	85.259	27.151
317	328496.627	3005085.269	147.96	G325	328292.036	3004465.583	85.267	27.152
318	328518.828	3005071.168	148.479	G326	328314.23	3004451.486	85.267	27.152
319	329366.214	3005158.64	148.185	G327	329161.369	3004538.933	85.276	27.153
320	329385.88	3005159.119	148.396	G328	329181.029	3004539.412	85.276	27.153
321	330187.351	3005159.415	144.689	G329	329982.266	3004539.707	85.284	27.153
322	330217.877	3005155.614	145.402	G330	330012.783	3004535.908	85.285	27.153
323	330616.774	3005046.697	140.314	G331	330411.564	3004427.022	85.289	27.152
324	330637.338	3005031.884	140.432	G332	330432.122	3004412.214	85.289	27.152
325	331254.716	3004800.475	138.283	G333	331049.319	3004180.872	85.295	27.15
326	331306.238	3004779.989	138.006	G334	331100.826	3004160.392	85.296	27.15

S.N.	MUTM 84				UTM45		WGS84	
	Easting	Northing	Elevation	Remarks	Easting	Northing	Longitude	Latitude
327	332028.119	3004498.144	145.791	G335	331822.497	3003878.629	85.303	27.147
328	332035.112	3004543.576	145.401	G336	331829.488	3003924.048	85.303	27.148
329	332755.005	3004217.832	145.197	G337	332549.17	3003598.399	85.31	27.145
330	332792.316	3004202.365	145.475	G338	332586.47	3003582.936	85.311	27.145
331	333581.85	3003893.841	144.511	G339	333375.774	3003274.502	85.319	27.142
332	333607.226	3003886.649	144.5	G340	333401.142	3003267.313	85.319	27.142
333	312618.266	3006923.431	149.829	G341	312418.311	3006303.211	85.107	27.167
334	312672.66	3006953.502	149.337	G342	312472.689	3006333.273	85.107	27.167
335	311673.506	3006733.231	144.283	G343	311473.827	3006113.066	85.097	27.165
336	311608.825	3006748.239	143.849	G344	311409.165	3006128.07	85.096	27.164
337	310161.533	3006749.305	141.168	G345	309962.295	3006129.136	85.082	27.165
338	310237.679	3006731.077	140.824	G346	310038.419	3006110.913	85.083	27.165
339	309242.297	3007065.542	144.415	G347	309043.328	3006445.281	85.073	27.167
340	309233.594	3007039.481	143.214	G348	309034.627	3006419.227	85.073	27.167
341	309094.596	3007187.647	144.335	G349	308895.67	3006567.35	85.071	27.169
342	309088.874	3007167.631	144.606	G350	308889.95	3006547.34	85.071	27.168
343	300216.147	3010773.65	166.373	G351	300019.814	3010152.307	84.981	27.2
344	300223.407	3010771.015	166.472	G352	300027.072	3010149.673	84.981	27.2
345	301253.299	3010339.307	163.827	G353	301056.663	3009718.091	84.992	27.196
346	301313.298	3010309.333	163.432	G354	301116.645	3009688.126	84.992	27.196
347	302115.459	3009936.01	161.157	G355	301918.571	3009314.912	85	27.192
348	302135.329	3009920.479	160.786	G356	301938.435	3009299.385	85.0005	27.192
349	303109.931	3009456.395	155.238	G357	302912.753	3008835.436	85.011	27.188
350	303133.559	3009483.918	155.709	G358	302936.374	3008862.951	85.011	27.188
351	303328.037	3009450.172	158.182	G359	303130.795	3008829.215	85.013	27.188
352	303313.972	3009455.778	157.715	G360	303116.734	3008834.82	85.013	27.188
353	303888.131	3009256.471	158.321	G361	303690.726	3008635.571	85.018	27.186
354	303949.867	3009235.292	157.939	G362	303752.444	3008614.398	85.019	27.186
355	304633.278	3008977.477	155.177	G363	304435.655	3008356.658	85.026	27.184
356	304631.428	3008984.332	155.129	G364	304433.805	3008363.511	85.026	27.184
357	305737.299	3008447.388	149.787	G365	305539.353	3007826.724	85.037	27.179
358	305812.073	3008418.807	150.613	G366	305614.106	3007798.151	85.038	27.179
359	306611.029	3008161.759	151.368	G367	306412.828	3007541.178	85.046	27.177
360	306629.775	3008160.099	151.34	G368	306431.569	3007539.518	85.046	27.177
361	307940.747	3007593.452	147.452	G369	307742.158	3006973.037	85.06	27.172
362	308048.238	3007547.687	147.372	G370	307849.618	3006927.285	85.061	27.172
363	399141.753	2979013.548	165.059	G371	398916.534	2978401.466	85.982	26.924
364	399137.876	2978988.692	164.935	G372	398912.658	2978376.617	85.982	26.924
365	400796.777	2977986.278	157.884	G373	400571.075	2977374.496	85.999	26.915
366	400785.45	2977951.418	157.949	G374	400559.751	2977339.646	85.999	26.914
367	402052.697	2978233.862	160.643	G375	401826.628	2977622.007	86.011	26.917
368	402082.19	2978258.347	162.517	G376	401856.112	2977646.485	86.012	26.917

S.N.	MUTM 84				UTM45		WGS84	
	Easting	Northing	Elevation	Remarks	Easting	Northing	Longitude	Latitude
369	320309.199	3008331.733	155.787	G377	320106.999	3007711.101	85.184	27.18
370	320265.156	3008340.851	155.243	G378	320062.969	3007720.216	85.184	27.18
371	310836.902	3006614.115	142.307	G379	310637.467	3005993.985	85.089	27.164
372	310886.503	3006613.987	142.346	G380	310687.054	3005993.857	85.089	27.164
373	307272.825	3007856.036	149.084	G381	307074.431	3007235.544	85.053	27.174
374	307298.386	3007894.314	149.837	G382	307099.985	3007273.811	85.053	27.175
375	302507.606	3009829.8	161.059	G383	302310.604	3009208.733	85.004	27.191
376	302538.261	3009818.189	161.068	G384	302341.25	3009197.125	85.005	27.191
377	305063.89	3008748.939	154.767	G385	304866.141	3008128.187	85.03	27.182
378	305083.076	3008740.211	154.675	G386	304885.322	3008119.461	85.031	27.182
379	308520.688	3007397.212	145.267	G387	308321.93	3006776.854	85.065	27.17
380	308548.973	3007390.873	145.235	G388	308350.206	3006770.517	85.066	27.17
381	312033.787	3006799.618	145.78	G389	311834.003	3006179.434	85.101	27.165
382	312103.672	3006814.842	146.902	G390	311903.867	3006194.653	85.102	27.166

Road Survey

Due to rapid, accurate, easy data logging, real-time data, and fast downloading facility, the use of DGPS is very popular nowadays. Fast RTK is one of the revolutions in the field of survey for detailing more accurately where there is no obstruction to satellite signals. All the data can be seen from the Palmtop Controller consisting magnet Field and other information like the position of points in the map, Satellite signal, Horizontal and Vertical accuracy, etc.

For those locations where there is an obstruction to satellite signals total station is the best option for detailing. The total station offers flexible options to set the instrument in known and unknown stations as well. If the instrument is set at some unknown position, its coordinates can be determined automatically with the instrument, by observing at least three known stations by the method of resection. Therefore, with the various advantages, we used total station for the detailing purpose.

In the detailed survey, the position both in plan and elevation of all natural and manmade features of the area like road edge, waterways,trees, cultivation road track, river bank , high flood levels, etc, has been depicted from the ground and subsequently have been shown in topographical maps by means of cartographically correct conventional symbols. All hills and valleys within the area have been surveyed and plotted on a map by a certain scale.

Sufficient details of the existing topography have been surveyed and noted. The details include not limited to roads, footpaths, houses, physical and man-made features,

A rough sketch of the surveyed points has been sketched so that it might be useful while plotting the maps.

Control Point Monumentation

Static Point Positioning

Levelling

Road Survey

Roadside Survey

Kholsi Survey

Bridge Survey

A Bridge survey has been carried out for the particular bridges specified by the client. The topographical survey of the bridge includes 700m upstream, 300m downstream, and 200m from the edge of the river bank. The survey includes the topography and the bridge components. Total station and DGPS have been used for taking the spatial location of the features.

Table 3.7: Code Description

SN	CODE	DESCRIPTION
1	AB-T,B	ABUTMENT WALL
2	AMINALFARM	AMINALFARM
3	AQUEDUCT	AQUEDUCT
4	ATM	ATM
5	BADMINTON COURT	BADMINTON COURT
6	BAMBO COTTAGE	BAMBO COTTAGE
7	BAMBOO	BAMBOO
8	BDL	BED LEVEL
9	BENCH	BENCH
10	BGR	BAGAR
11	BIO GAS	BIO GAS
12	BL	BED LEVEL
13	BLOCK	BLOCK
14	BLOCK WALL	BLOCK WALL
15	BLOCKAREA	BLOCKAREA
16	BORE WELL	BORE WELL
17	BOU	BOUNDARY
18	BRG	BRIDGE
19	BRG_BLOCK	BRIDGE BLOCK
20	BRG_FOUNDATION	BRIDGE FOUNDATION
21	BRICK WALL	BRICK WALL
22	BUS WAITING STATION	BUS WAITING STATION
23	CW	CAUSEWAY
24	C-DRN	CONCRETE WALL
25	CGI HC	CGI HC
26	CHURCH	CHURCH
27	CL	CENTERLINE

SN	CODE	DESCRIPTION
28	CLVT-T,B	CULVERT
29	CNL-T,B	CANAL
30	CONCRETE SLAB	CONCRETE SLAB
31	CONCRETE WALL	CONCRETE WALL
32	CONCRETE BLOCK	CONCRETE BLOCK
33	CONCRETE POLE	CONCRETE POLE
34	COURT	COURT
35	CRUSHER AREA	CRUSHER AREA
36	CRUSHER WEIGHT DEVICE	CRUSHER WEIGHT DEVICE
37	DECK	DECK LEVEL
38	DELINEATOR	DELINEATOR
39	DIVIDER	DIVIDER
40	DRN	DRAINAGE
41	DRN SLAB	DRAINAGE SLAB
42	E_CNL-T	EARTHEN CANAL
43	E-DRN	EARTHEN DRAINAGE
44	EMB	EMBANKMENT BUTTOM
45	EP	ELECTRIC POLE
46	EP WIRE CROSSING	ELECTRIC WIRE CROSSING
47	FACTORY	FACTORY
48	FACTORY AREA	FACTORY AREA
49	FARM	FARM
50	FL	FENCE LINE
51	FLAG PILLER	FLAG PILLER
52	FOOTBALL GOAL POST	FOOTBALL GOAL POST
53	FOOTBALL GROUND	FOOTBALL GROUND
54	FOUNDATION	FOUNDATION
55	FT	FOOT TRACK
56	GARAGE	GARAGE
57	GARDEN AREA	GARDEN AREA
58	GATE	GATE
59	GBN	GABIN WALL
60	GOAL POST	GOAL POST
61	GRAVE	GRAVE
62	GROUND AREA	GROUND AREA
63	HAND PUMP	HAND PUMP
64	HC	HOUSE CORNER
65	HEALTH POST	HEALTH POST
66	HFL	HIGH FLOOD LEVEL
67	HIGH TENSION STATION	HIGH TENSION STATION
68	HOSPITAL	HOSPITAL
69	H-PUMP	HAND PUMP

SN	CODE	DESCRIPTION
70	HUME PIPE	HUME PIPE
71	HUT	HUT
72	I-LAND	I-LAND
73	INFORMATION BOARD	INFORMATION BOARD
74	INSCRIPTION	INSCRIPTION
75	INTAKE	INTAKE
76	JUNCTION	JUNCTION
77	JUNGLE	JUNGLE
78	KC	KHOLSI CENTRE
79	KE	KHOLSI EDGE
80	KILOMETER POST	KILOMETER POST
81	LADDER	LADDER
82	LAY-BY	LAY-BY
83	MH	MANHOLE
84	MILL	MILL
85	MONASTERY	MONASTERY
86	MW	MACHINERY WALL
87	NIJGADH INTERNATIONAL AIRPORT	NIJGADH INTERNATIONAL AIRPORT
88	NS	NATURAL SURFACE
89	NTC TOWER	NTC TOWER
90	OPEN SHED	OPEN SHED
91	PARAPET WALL	PARAPET WALL
92	PARK	PARK
93	PARKING AREA	PARKING AREA
94	PCC	PLAIN CEMENT CONCRETE
95	PETROL PUMP	PETROL PUMP
96	PIER	PIER
97	PIG FARM	PIG FARM
98	PIGEON NEST	PIGEON NEST
99	PILLAR	PILLAR
100	PIPE	PIPE
101	POLICE STATION	POLICE STATION
102	POLUTRY FARM	POLUTRY FARM
103	POND	POND
104	RA	RECIDENTIAL AREA
105	RC	ROAD CENTRE
106	RCC-FOUNDATION	REINFORCEMENT CEMENT CONCRETE FOUNDATION
107	RE	ROAD EDGE
108	RELYING	RELYING
109	RESTING PLACE	RESTING PLACE
110	RICEMILL	RICEMILL

SN	CODE	DESCRIPTION
111	RIVER	RIVER
112	ROAD CURB	ROAD CURB
113	ROAD DIVIDED	ROAD DIVIDED
114	ROAD INFORMATION BOARD	ROAD INFORMATION BOARD
115	RW	RETAINING WALL
116	SAFETY TANK	SAFETY TANK
117	SALT TRADE	SALT TRADE
118	SCHOOL	SCHOOL
119	SEP	SOLAR ELECTRIC POLE
120	SLAB	SLAB
121	SP	SOLAR POLE
122	STAIR	STAIR
123	STAIRCASE	STAIRCASE
124	STATUES	STATUES
125	STONE	STONE
126	STREAM	STREAM
127	STREAM CENTRE	STREAM CENTRE
128	SUGAR FACTORY WASTEWATER	SUGAR FACTORY WASTEWATER
129	TANK	TANK
130	TAP	TAP
131	TF	TRANSFOTMER
132	THC	TILE HOUSE
133	TICK-DRN	TICK-DRAINAGE
134	TICKET COUNTER	TICKET COUNTER
135	TLT	TOILET
136	TMPL	TMPL
137	TRANSFORMER	TRANSFORMER
138	TRANSMISSION LINE	TRANSMISSION LINE
139	TRANSMISSION WIRE	TRANSMISSIONWIRE
140	TREE	TREE
141	VIEW TOWER	VIEW TOWER
142	VOLLEYBALL COURT	VOLLEYBALL COURT
143	WAITING STATION	WAITING STATION
144	WALL	WALL
145	WATER JUNCTION TANK	WATER JUNCTION TANK
146	WATER TANK	WATER TANK
147	WELL	WELL
148	WHC	WOODEN HOUSE CORNER
149	WING WALL	WING WALL
150	WIRE CROSSING	WIRE CROSSING
151	WIRESUPPROTINGPOLE	WIRESUPPROTINGPOLE

SN	CODE	DESCRIPTION
152	WL	WATER LEVEL
153	WORKSHOP	WORKSHOP
154	TMPL	TEMPLE
155	V-O-W-C	VEHICLE OVERLOAD WEIGHT CHECKING
156	RP	RICE MILL
157	ROAD SIGN	ROAD SIGN
158	S-SFT-B	STEEL SAFETY BAR
159	SEF-B	SAFETY BAR
160	SHC	STEEL HOUSE(TEEN HOUSE)
161	T-SHOP	TEA SHOP
162	CRE	CONCRETE ROAD RDGE
163	BB	EMBANKMENT BUTTOM
164	TB	EMBANKMENT TOP
165	ERE	EARTHEN ROAD EDGE
166	S-F-W-W H-PIPE	FACTORY WASTE WATER PIPE
167	S-F-W-W	FACTORY WASTE PIPE OPENING
168	GRE	GRAVEL ROAD EDGE
169	LP	LIGHTING POLE
170	NT-O-F	NEPAL TELECOM OPTICAL FIBER
171	NTC TOWER	NTC TOWER
172	NCELL TOWER	NCELL TOWER
173	POND	POND
174	PW	PARAPET WALL
175	P-PUMP	PETROL PUMP
176	TULSI WORSHIP	TULSI-W
177	TILE CURING	TILE CURING

3.8 Hydrological Survey

Hydraulic analysis is a critical component for design of up-gradation of highway. The alignment of KDP up-gradation project crosses many rivers, streams and water courses through bridges, culverts and causeways. Hydraulic analysis is carried out to obtain velocity and depth of flow at crossing and its vicinity during design flood event. The Low and high chords of bridge, bridge waterway, foundation level and river training works are fixed based on hydraulic analysis of river at bridge site. Design flood is estimated using hydrological analysis of the catchment of the river. Similarly, Conservation of the natural drainage system around the road alignment is one of the most important concerns during design and construction of roads. For this purposes network of side drains and cross drains along with other related structures are proposed for

the project. Design of the components of drainage structures also requires information on design peak flows, depth and velocity of flow. Adequacy of capacity of existing and proposed new side drains and cross drains are assessed using standard underlying hydraulic principles.

3.8.1 Scope

Hydraulic analysis includes the works of field investigation, field measurement (Cross Sectional and L-Sectional surveys) , secondary data collection (Data of Hydro-Metrological Stations), Rainfall Runoff Analysis, Frequency Analysis, Design Discharge Calculations, Water Surface profile Calculation (HFL, LWL) Scour Calculation and recommendation on the basis of study for the design of bridge, culverts, river training works and drainage networks. These scopes of works have been listed in ToR as

For determination of all design data the consultant shall carry out a detailed hydrological survey and study of the river and bridge sites, which shall include the following:

a. Catchment area of the river up to bridge site;

b. Nature, size and quantities of debris carried by the river;

c. Intensity, duration and distribution of rain in the catchment;

d. Existing bridge or other hydraulic structures across the river in the vicinity of the proposed bridge site with their details as much as possible;

e. General slope of the river from the critical point (origin) of the river up to bridge site and general slope of the catchment in both sides of the river;

f. Cross sections covering 100m on either side. Beyond flood lines of the river at proposed bridge site, at about 500m. uls and about 200m dis. wherein HFL, LWL, LBL, area of the cross section, wetted perimeter and geological profile with silt factor of each strata (at proposed bridge site only) indicated. (Horizontal and vertical scale of the cross section shall be the same.);

g. Bed slope of the river which must start from 100m up of the U/S cross section and end at 100 m. down of the dis. cross section;

h. Maximum discharge calculated by established formulas with different return periods and the peak discharge observed over a period of 100 years;

i. Velocity and depth of flow at the time of survey;

j. Shifting of the river in the past at proposed bridge site and in its vicinity;

k. River-bed degradation or aggradation (covering 500 m upstream and 500 m downstream);

l. Use of river as migration corridor of wildlife and fisheries;

m. Other information required for river control, design, construction and maintenance of the bridge;

The hydrological survey shall collect secondary data, preferably from the governmental sources, to determine the following:

a. Unit hydrograph for the catchment of River for bridge construction

b. Size of the opening and location of cross drainage structure

c. Minimize modification to the natural drainage pattern

After the selection of the proposed bridge site with alternatives and preparation of topographic maps, the Consultant shall discuss the collected hydrological and other data and decide the following points with the client for final decision of the bridge site:

a. Design discharge

b. Scour depth, Maximum Scour depth

c. Linear waterway needed to be provided

d. Anticipated soil condition for foundation

e. The most feasible proposed bridge site

f. River- training & approach roads

g. Type of proposed foundation, substructure and superstructure

The Consultant shall also carry out a detailed hydrological survey and study along the road alignments and identify catchment, discharge in drain, cross drainage, seepage area etc.

3.8.2 Methodology

Following methodologies were adopted to complete the objectives of hydraulic analysis and drainage design:

- Collection of rainfall data for representative stations around the vicinity of catchments from Department of Hydrology and Meteorology (DHM).
- Delineation of catchment areas at drainage crossing sites by using digital topographical maps and verifying by Google Earth Pro and GIS using SRTM data.
- Rainfall analysis (estimating rainfall of design frequency) at stations having more than 25 years of data by applying Cumfreq software.
- Determination of floods of design frequency by using rainfall-runoff models and statistical approach if the river is gauged.
- Comparison of floods by different methods and determination of the design flood for each river/stream/drain.
- Determination of HFL, water surface profile, average and maximum velocities using hydraulic modeling.
- Determination of general scour at crossing using regime equations and Blench zero bed approach
- Comparison of general scour by different methods and determination of the design scour.
- Determination of maximum scours at structural components of crossings.
- Preparation of networks of side and cross drains and determination of design discharge, depth and velocity at different strategic location to ascertain the required dimension of related structures.
- Design of required river training works at the vicinity of the proposed bridge based on survey data and field verification.

3.9 Geotechnical Investigations

The study of properties of Earth soil by invasive or non-invasive method is termed as geotechnical investigation of the soil. This can be conducted for Road, bridges, Dams and embankment, levees and slope stabilization etc. Geotechnical investigation mainly comprises of field test and lab test.

Field test consists of Drilling of 4inch to 6inch of borehole to get samples from SPT (Standard Penetration test and Dynamic Penetration test (DCPT Heavy for Bridges) and (DCPT light for road). These are primary done in field and provide data for further analysis in the lab.

3.9.1 For Bridges:

The Scope of work of Geotechnical investigation is inclusive of mobilization of plant and personnel, including shifting & erecting the same from one location to the other and demobilization after completion of field work. The work also included setting out, digging Bore holes up to specified depths at predetermined locations and conducting Standard Penetration Tests in the bore holes at suitable intervals as per IS Code of practice, collection of undisturbed and disturbed soil samples, measurement of ground water table collection of water samples and carrying out various laboratory tests on soil and water samples collected in the field.

The Subsoil exploration (Drilling) is done using Rotary or Percussion Drilling in Case of Bridge. The borehole will typically be of 4 inch and goes to the depth of 16m to 20m Depending upon the soil strata of the area. Field tests such as SPT or DCPT is conducted at the site to determine the penetration resistance of the soil strata. Water Table is also measured in the Field for 24 hours to confirm the depth of water table. The disturbed and Undisturbed sample were collected for further lab analysis.

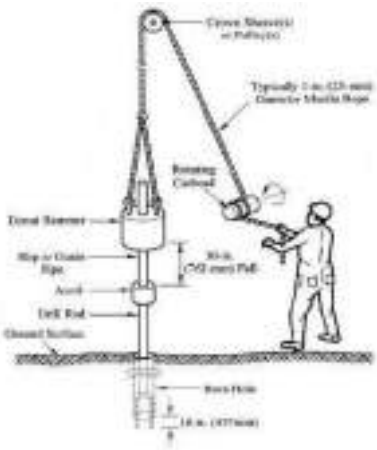


Figure 3.20: Standard Penetration Test (SPT) with 63.5 kg of Hammer (In Bridge)

<u>Field Investigation;</u>

The scope of work for field investigation includes the following:

- Drilling of Bore holes of 150mm dia. at each Bank of the river and pier locations defined by the Bridge Designer. The digging of bore hole to be carried out w.r.t. specifications provided in IS: 1892.
- To conduct Standard Penetration Tests/ Dynamic Cone Penetration Test in the bore holes at 1.50 m interval in depth & at every change of strata, whichever is earlier.

- To Collect disturbed soil samples from bore holes at regular interval and at every identifiable change of strata to supplement the boring records.
- Recording the depth of ground water table in all the bore holes if, observed up to the depth of exploration during boring work as per specifications.
- Conducting the laboratory tests on selected disturbed / undisturbed soil samples collected from various bore holes, Preparation and submission of reports.

Standard Penetration Tests: It consists of driving a Split Spoon sampler with an outside dia. of 50 mm into the soil at the base of borehole. Driving is accomplished by a drop of hammer weighing 63.5 kg falling freely through a height of 750 mm onto the drive head. First of all, the spoon is driven 150 mm into the soil at the bottom of the borehole. It is then driven further 300 mm and the number of blows (N values) required to drive this distance is recorded. Standard Penetration Tests (SPT) were conducted in the boreholes at 1.5 m intervals. The tests were conducted in accordance with IS: 2131-1981.

Dynamic Cone Penetration Test (DCPT): It consists of driving a cone by blows of hammers. The number of blows for driving the cone through a specified distance is a measure of the dynamic cone resistance. Dynamic Cone Penetration test are performed by a 50 mm cone. The method for DCPT is similar to that of SPT. First of all, the cone is driven 100 mm into the soil at the bottom of the bore hole. It is then driven further 200 mm and the number of blows (Ncbr values) required to drive this distance is recorded.

The result i.e., Nc values first corrected to the Standard Penetration Test (SPT) value (N) and that provides and estimation of degree of compaction of soil strata, values of angles of internal friction (¬) and allowable bearing capacity. The dynamic cone resistance is correlated with the SPT (N) as given below.

Nc = 1.5 N for depth up to 3 m

= 1.75 N for depth 3 to 6 m

= 2 N for depth greater than 6 m

And DCPT Light are done for road to get the bearing capacity of soil. At every 1.5m depth SPT/DCPT tests is conducted to provide field N value. The soil sample from SPT and Undisturbed sample is transported to lab for further property analysis.

Soil Sampling

(i) Disturbed Sample:

The disturbed samples were collected from the split immediately after conducting Standard Penetration Test. Before any sample was taken, the borehole was cleaned up of loose disturbed soil deposited during boring operation. The samples, which were obtained from bailer and in the SPT tube were preserved as representative disturbed samples for finding out index properties. The samples thus obtained were placed in airtight double plastic bags, labeled properly for identification and later transported to the lab for analysis.

(ii) Undisturbed Sample:

The undisturbed Sample were extracted by means of thin wall tube (Shelby tube). The tubes were pushed into the ground and the samples are recovered mechanically. The tubes were sealed with wax and wrapped with airtight polythene sheets and then bound by adhesive tapes and properly labelled. The tubes were properly packed in a wooden box so as to minimize the disturbances during transportation to the laboratory and avoided the changes of moisture content of sample. These sample are used for the determination of strength and consolidation parameters.

Ground Water Table

The prediction of depth of ground water table requires the installation of piezometers and regular monitoring of those for at least one year time period. However, the time frame and the installation are beyond the scope of the work and also the time frame is short; the visual examination was performed to find the depth. The Ground Water Table (GWT) was monitored at every 1.5 m depth during the drilling work carried out at all bridge sites.

Laboratory Tests

The laboratory tests were conducted on selected representative disturbed and undisturbed samples collected in core boxes, were transported to the laboratory established at Kathmandu, Nepal. All of the tests were conducted confirming to the specifications as per IS codes. The following tests were conducted on the collected soil samples.

Table 3.8: Laboratory Tests

SN	Type of Test	IS Code Referred	Remarks
1	Bulk and dry density	By Calculations	
2	Moisture content	IS:2720 (Part-2)-1992	

SN	Type of Test	IS Code Referred	Remarks
3	Grain size/ Hydrometer analysis	IS:2720 (Part-4)-1992	
4	Atterberg Limits	IS:2720 (Part-5)-1992	
5	Specific Gravity	IS:2720 (Part-3)-1992	
6	Unconfined Compression Test	IS 2720(Part 10):1991	
7	Consolidation Test	IS 2720(part 15): 1986	
8	Direct shear test	IS 2720(Part 13):1986	
9	California Bearing Ratio Test (Soaked and Unsoaked)	IS-2720-PART-16-1979	
10	Material testing (Los Angeles Abrasion Test)	IS 10070 (1982)	

The Geotech team of the consultant collected all samples from each bridge sites, transported at laboratory located at Kathmandu and performed all necessary tests on the same. The geotechnical reports containing test results, recommendation for foundation types, depth and capacity have been prepared for each bridges and being submitted under **Volume-IV**.

3.10 Seismological Study of the Area

Nepal is a seismically active country lying between collisions of Indian to the Eurasian plates and moving continuously, resulting in frequent and often devastating earthquakes within this region. A recent devastating earthquake was occurred on 25th April, 2015 with its epicenter lying at Gorkha in Nepal. Considering such geological movement, the Bridges and other structures require special attention while carrying out seismic resistant design.

Geologically Nepal is divided into 5 sub divisions, namely Indo-Gangatic Plain (Terai), Siwalik (Churia), Lower Himalayas, Upper Himalayas and Tibetan Tethys Himalayas. According to geological survey, the road alignment passes through sediments of Indo-Gangetic Plain. The Lower Siwaliks Formation is represented by mudstone embedded with sandstone. The Indo-Gangatic Plain contains thick boulder-gravel beds as well as gravel to thick sand beds. The alignment passes through alluvial deposits including mix of alluvial and residual soil deposits.

Seismicity

Nepal lies in the active seismic zone V and ranks at 11th position in terms of seismic risk. Historical data shows that, the occurrence of destructive great earthquakes has happened in the past along the major active faults. Nepal is divided by level of shaking hazard, into three major seismic zones from south to north, separated by major thrusts and faults. These zones are elongated in a general east-west direction, with the middle part of the country slightly more prone to shaking than the northern and the southern parts. The road alignment falls in the seismic moderate hazard area of the Nepal Himalaya. The seismic zoning Map and Seismic Hazard Map of Nepal are provided in **Figure 3.21** and **Figure 3.22** below for reference.

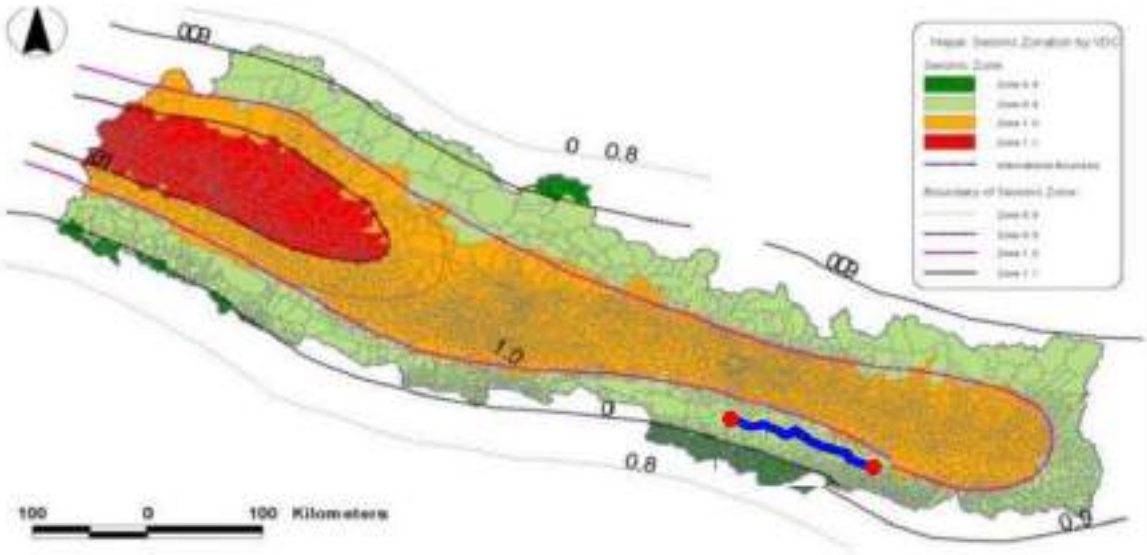


Figure 3.21: Seismic Zoning Map of Nepal

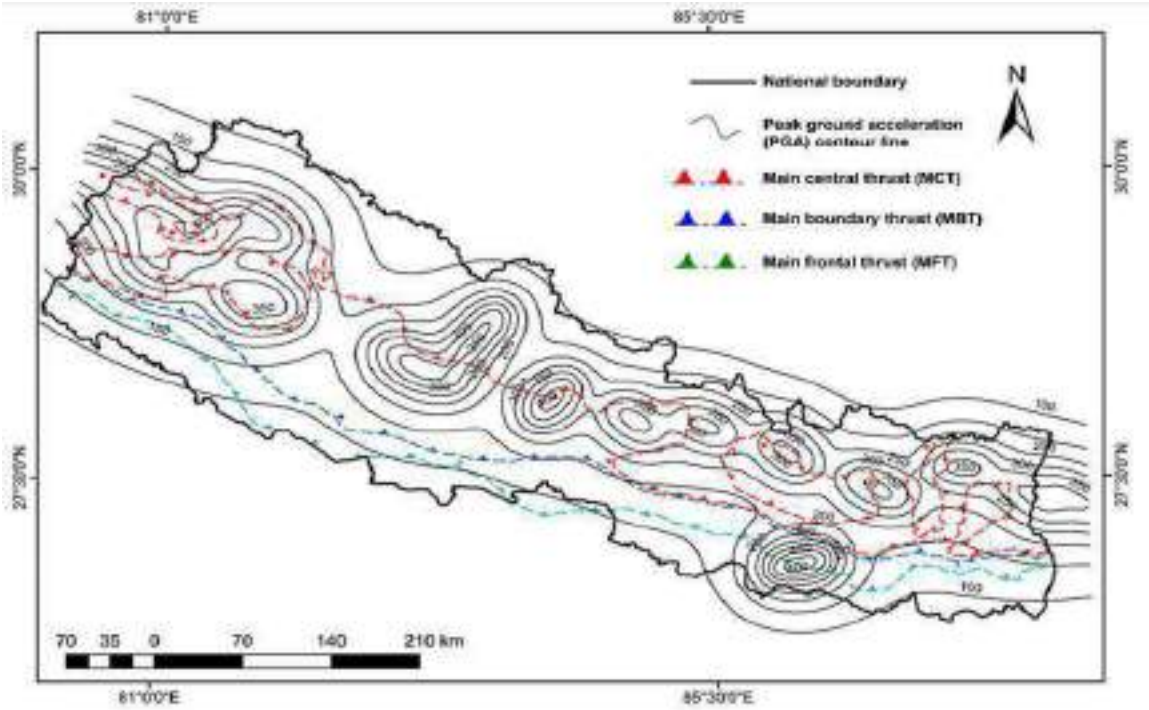


Figure 3.22: Seismic Hazard Map of Nepal

The above figures show the distribution of Peak Horizontal Acceleration at bedrock that has a 10% probability of being exceeded over 50 years prepared by Department of Mines and Geology, National Seismological Centre, Nepal. The one third section of the road in Eastern side falls in the area with the peak ground acceleration (PGA) distribution more than 200 gal

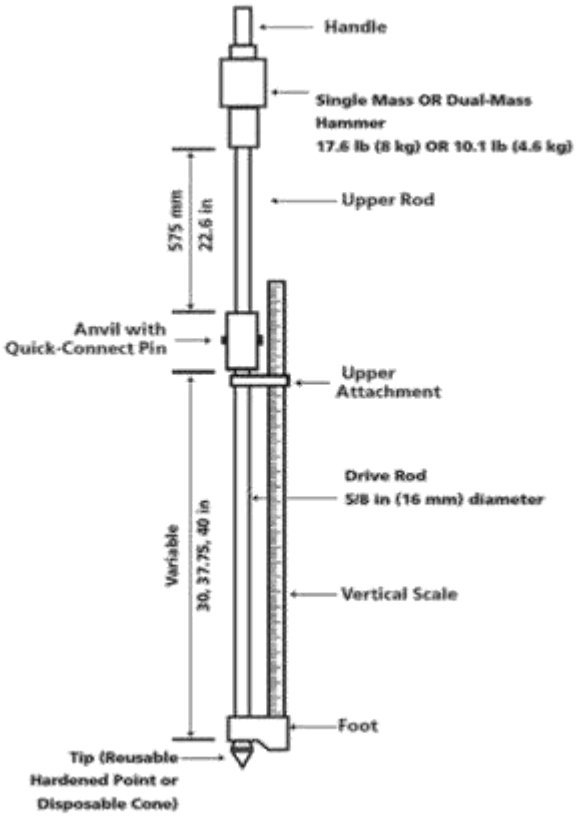
Chapter 4: Material Investigations

4.1 General

The Soil Samples were collected from Trial Pits created of size 1m×1m up to the full depth of pavement at every 500m interval. The texture and type were as described and pit log was made at test location. The samples of 30 to 40 kg were collected from each trial pit along the Project Roads. The Dynamic Cone Penetrometer (DCP) was carried out at the bottom end of the pit up to about 1.0 m below subgrade level to determine in-situ CBR. The samples of the encountered sub grade material were as collected and transported for laboratory testing at PLANET TEST Laboratory at Shantinagar, Kathmandu to find out the properties of existing sub-grade soil.

4.2 Investigation of Subgrade of Existing Pavement

The subsurface investigations along the road alignment were carried out to evaluate the sub-grade characteristics from Dynamic Cone Penetrometer Tests (DCP). The investigation of existing sub-grade was carried out using Dynamic Cone Penetrometer (DCP) equipment to find out the in-situ CBR value of the sub grade. The DCP test was carried out at each trial pit location. The test was conducted by allowing 8kg hammer to free fall from 57mm. The penetration per number of blow was recorded.



The penetration record for 1m depth was recorded. The test was stopped after encountering no penetration for 5 nos. of blow. The test reports have been presented in **Volume I-C** for reference.

4.3 Investigation at Toe of Existing Road Embankment/ New Formation/ Widening Portion of Existing Road

The trial tests pits of the size of 0.7m x 0.7m were dug at every km between the large pits in staggering left / right pattern along the pavement shoulder interface. Similarly, some of those pits were excavated at the toe of the road embankment/ new formation and widening portion of existing road. The samples were brought to Kathmandu for carrying out the laboratory test.

4.4 Laboratory Testing for Sub-Grade Characteristics and Strength

The soil samples extracted to present the different strata from pits tests along the road alignment were subject to standard laboratory soil testing for evaluation and analysis in accordance with AASHTO standard methods and specification to specify them for their engineering values. All tests performing in following standard procedures:

- Particle Size Distribution
- Determination of OMC and MDD
- California Bearing Ratio

The bulk samples taken from test pits on the existing sub-grade were subjected to Procter Test under AASHTO-T80 testing procedure. Method B or D was adopted depending on the gradation of the soil or aggregate material. A (4.54Kg) hammer was used. Five trials were performed for each compaction test.

The sub-grade, sub-base, base strength and other engineering characteristics were determined using the California Bearing Ratio (CBR) tests. The three points CBR method was adopted, where the specimens were soaked for 96 hours duration. The method allows interpolating the CBR values at various dry densities of soil. Three points obtained from CBR test represented the different compaction energies at 10, 30 and 65 blows using 4.54 Kg hammer dropped at a height of 0.457m for five layers of soil in the compaction cylinder mold.

The field study as well as laboratory tests were performed for the geotechnical properties of soil along the Kamala-Dhalkebar-Pathlaiya road alignment. The dynamic cone penetrometer (DCP) test was performed in the in-situ soil. Laboratory test were performed for the classification of the sub-grade soil, and to determine the optimum moisture content. Results reveal that most part of the road is aligned through the alluvial river deposits consisting of sand, silt, clay and gravels. The results of the Dynamic Cone Penetration Test show that minimum CBR varies from 5% to 20%. The results of the compaction tests show that maximum dry densities which ranges from 1.783 to 2.068 gm/cc for most of the samples, were obtained

at 8.9-13.9 optimum moisture content and CBR value ranges from 7% to 23 %. From the grain size distribution, it is noted that the fractions of brownish color sand, silt and clay is dominant of low plastic nature and in some stretches, gravels are also intruded in the soil at subgrade level. No landslides and erosion were observed as the road aligns through terai/plain terrain. However, the occurrence of the flood at the sections nearby to the river are prominent.

The chainage wise details of the gradation and compaction characteristics of subgrade soil in field and laboratory is shown in **Table 4.1** below.

Table 4.1: Chainage wise details of the gradation and compaction

CHAINAGE	Grain Size Analysis			Natural Moisture Content (%)	Field Density (kN/m^3)	Compaction		Laboratory CBR (%)	Least CBR value from DCP
	Gravel (%)	Sand (%)	Silt+Clay (%)			OMC (%)	MDD (kN/m^3)		
0	39.6	32.1	28.27	7.1	18.91	11.3	19.1	14.1	5
0+500									6
1+000	18.1	79.1	2.84	7.76	18.88	13.2	18.7	9.3	2
1+500									2
2+000	59.4	23.6	16.97	5.15	17.63	11.9	18.99	6.2	3
2+500									2
3+000	32.7	49.5	17.78	7.04	17.51	15.6	17.83	6	4
3+500									8
4+000	32.7	49.5	17.78	5.69	19.09	13	19.43	7.1	6
4+500									5
5+000	37.5	60.6	1.96	6.67	17.67	12.2	19.04	8.1	4
5+500									9
6+000	36.3	45.3	18.49	7.1	17.81	13.2	18.84	6	4
6+500									3
7+000	49.5	40.6	9.88	7.76	18.88	13.3	18.96	10.1	9
7+500									2
8+000	22.9	72.8	4.35	5.25	18.3	13.3	19.2	9.1	19
8+500									19
9+000	40	40	20.05	6.84	17.34	13.1	18.48	13.4	11
9+500									12
10+000	40.7	51.7	7.65	6.12	18.4	13.5	18.7	13.7	12
10+500									5
11+000	31.8	54.7	13.57	3.16	18.52	13.1	19.19	10.5	2
11+500									3
12+000	32.1	61.3	6.62	4.31	18.9	13.1	19.19	7.2	2
12+500									2
13+000	22.3	72.9	4.74	2.22	18.3	8.3	18.77	12.2	1
13+500									4
14+000	28.1	67.4	4.57	2.92	17.86	13.1	19.19	12.6	8

CHAINAGE	Grain Size Analysis			Natural Moisture Content (%)	Field Density (kN/m³)	Compaction		Laboratory CBR (%)	Least CBR value from DCP
	Gravel (%)	Sand (%)	Silt+Clay (%)			OMC (%)	MDD (kN/m³)		
14+500									6
15+000	24.2	68.8	6.95	4.41	18.53	10.3	19.21	12.4	3
15+500									4
16+000	17.8	71.1	11.11	3.16	18.53	9	19.13	9.9	6
16+500									2
17+000	25.2	63.4	11.41	4.31	18.89	11.5	19.02	8.5	3
17+500									9
18+000	25	68.1	6.9	3.22	19.41	13.2	19.65	8.8	2
18+500									2
19+000	31.8	54.7	13.57	2.98	18.52	13.1	19.56	8.1	4
19+500									6
20+000	29.6	60	10.44	5.41	18.68	12.3	19.67	11.9	6
20+500									3
21+000	37.9	54.3	7.81	2.56	17.8	18.9	11.2	12.2	2
21+500									3
22+000	45.9	49.4	4.69	4.13	18	19	13.2	9	5
22+500									2
23+000	41.1	56.3	2.57	5.4	18.43	19	12.8	9.5	2
23+500									4
24+000	23.1	74.5	2.37	4.54	17.69	18.6	12	10.9	8
24+500									4
25+000	25	72.3	2.63	3.33	17.69	18.4	13.2	14.1	5
25+500									4
26+000	57.4	40.9	1.73	6.52	18.4	18.5	12.2	9.5	2
26+500									5
27+000	47.8	42.8	9.34	4.13	19.01	19.3	10.8	13.9	3
27+500									2
28+000	41.8	45.4	12.84	5.4	18.96	19	11.3	10.3	2
28+500									2
29+000	34.6	56	9.43	4.54	17.64	18.5	12.9	11.1	2
29+500									3
30+000	16.3	64.9	18.78	3.33	17.94	18.8	13.7	11.1	2
30+500									6
31+000	32.7	55	12.27	3.68	17.72	18.5	12.8	9.1	5
31+500									3
32+000	23	68.9	8.01	3.45	17.97	18.9	12.8	10.1	4
32+500									4
33+000	46	51	3.04	3.56	19.21	20.2	9.7	13.9	3
33+500									5
34+000	35.2	59.6	5.15	4.41	18.86	19.5	12	12.3	3

CHAINAGE	Grain Size Analysis			Natural Moisture Content (%)	Field Density (kN/m³)	Compaction		Laboratory CBR (%)	Least CBR value from DCP
	Gravel (%)	Sand (%)	Silt+Clay (%)			OMC (%)	MDD (kN/m³)		
34+500									3
35+000	31.8	54.7	13.57	4.68	19.15	19.4	10.5	14.6	2
35+500									3
36+000	26.8	57.1	16.07	3.42	18.91	19.4	10.1	15.3	5
36+500									2
37+000	20.7	65.4	13.85	3.56	18.6	19.2	11.5	12.7	2
37+500									3
38+000	28.1	62.3	9.64	4.24	18.46	18.9	12.8	13.3	2
38+500									2
39+000	11.7	75.6	12.71	3.45	18.78	19.1	12.3	11.7	2
39+500									2
40+000	28	61.7	10.25	3.45	18.95	19.5	12.7	11.2	3
40+500									3
41+000	22.2	65.8	11.94	3.66	17.54	18.6	13.3	13.6	6
41+500									3
42+000	20.7	67.8	11.54	5.26	18.05	18.6	13.7	10.3	4
42+500									5
43+000	31.8	54.7	13.57	4.56	19.08	19.4	11	13.3	2
43+500									3
44+000	28.1	60.4	11.46	3.66	18.27	18.8	13.7	11.7	2
44+500									2
45+000	25.6	62.1	12.34	5.18	18.02	18.6	12.1	13.7	5
45+500									9
46+000	31	55.8	13.28	4.56	18.34	19.3	12.4	6.8	6
46+500									12
47+000	30.3	58.5	11.18	3.66	17.91	18.6	12.8	9.8	6
47+500									2
48+000	32.7	53.7	13.53	5.16	18.49	19	11.6	11.4	19
48+500									32
49+000	30.9	60.3	8.78	6.56	18.59	19.1	12.4	12.1	2
49+500									2
50+000	23.4	64.8	11.8	6.65	18.98	19	11.2	10.5	10
50+500									5
51+000	33	56.9	10.05	3.56	18.03	18.9	13.9	13.2	6
51+500									1
52+000	23.5	67.1	9.46	4.18	18.89	19.4	11.7	13.3	2
52+500									3
53+000	29.1	62.7	8.23	5.16	18.53	19.1	13.1	12.4	1
53+500									5
54+000	32.3	59.7	8.03	3.66	18.78	19.3	13.5	11.1	8

CHAINAGE	Grain Size Analysis			Natural Moisture Content (%)	Field Density (kN/m³)	Compaction		Laboratory CBR (%)	Least CBR value from DCP
	Gravel (%)	Sand (%)	Silt+Clay (%)			OMC (%)	MDD (kN/m³)		
54+500									6
55+000	38.2	53.9	7.96	5.66	19.18	19.3	12.4	13.7	5
55+500									4
56+000	38.8	50.9	10.26	4.56	17.94	18.9	12.7	11.5	9
56+500									9
57+000	29	62.8	8.2	4.56	18.05	18.9	12.1	11.6	15
57+500									3
58+000	32.9	60.3	6.82	3.66	17.88	18.7	12.8	12.6	9
58+500									2
59+000	39.5	52	8.49	5.16	18.49	19.2	13.3	13.7	19
59+500									9
60+000	35.8	55.1	9.08	6.56	18.41	18.8	13.2	10.4	19
60+500									12
61+000	29	61.9	9.13	5.73	18.81	19	13.6	9.8	6
61+500									2
62+000	36.1	54.5	9.44	5.3	18.25	18.7	13.4	11.3	5
62+500									19
63+000	40.2	49.8	9.94	4.6	18.47	19	12.5	8.7	15
63+500									2
64+000	38.3	53.4	8.28	4.23	17.41	18.3	9.1	12	2
64+500									10
65+000	41.8	50.3	7.9	4.03	18.96	19.2	13.1	14.6	14
65+500									8
66+000	40.4	50.7	8.94	5.23	19.66	19.7	8.1	18.4	4
66+500									4
67+000	40.9	51.5	7.63	3.6	17.84	18.6	13	13.6	3
67+500									5
68+000	35.7	55.9	8.34	5.3	18.62	19	11.9	11.2	2
68+500									4
69+000	30.6	60.3	9.08	3.68	18.17	18.9	12.4	12.1	7
69+500									2
70+000	37.5	55.4	7.05	4.53	20.16	20.3	10.9	12.5	2
70+500									3
71+000	45.1	46.8	8.08	5.57	18.73	19.2	10.9	12.3	2
71+500									4
72+000	34.7	56	9.31	4.26	19.47	19.7	10.8	12.2	7
72+500									3
73+000	34	58.8	7.27	4.56	18.64	19.2	11.2	10.1	5
73+500									4
74+000	41.5	49.5	9.07	4.73	17.66	18.4	10.8	13.5	9

CHAINAGE	Grain Size Analysis			Natural Moisture Content (%)	Field Density (kN/m³)	Compaction		Laboratory CBR (%)	Least CBR value from DCP
	Gravel (%)	Sand (%)	Silt+Clay (%)			OMC (%)	MDD (kN/m³)		
74+500									7
75+000	38.4	53.7	7.89	4.34	18.94	19.4	11.7	11.2	5
75+500									5
76+000	42.3	50.6	7.11	3.85	18.57	19.3	12.2	9	9
76+500									2
77+000	39.3	51.2	9.46	6.56	18.62	19.1	11.5	11.5	15
77+500									11
78+000	41.6	51.9	6.57	5.26	17.73	18.3	12.7	14.3	9
78+500									9
79+000	37.6	55.5	6.96	4.06	18.19	19.1	12.8	13.5	5
79+500									2
80+000	39.6	52.3	8.06	5.73	18.64	19.1	11.8	9.7	19
80+500									5
81+000	29	66.9	4.04	3.68	18.27	19	12.1	9.5	2
81+500									2
82+000	34.8	56.6	8.59	5.23	18.69	19.3	11.6	10.9	10
82+500									10
83+000	41.3	52.5	6.22	5.23	19.36	19.5	10.6	12.1	5
83+500									10
84+000	42.1	52.3	5.58	5.77	18.94	19.6	10.6	18.66	4
84+500									4
85+000	35.9	59.9	4.23	5.8	18.65	19.3	11	11.7	3
85+500									3
86+000	42.2	47.9	9.92	5.4	19.62	19.6	11.2	11.4	5
86+500									4
87+000	33.8	58.6	7.56	4.63	18.27	19.2	13.1	12	4
87+500									6
88+000	32.4	61.5	6.08	4.58	18.4	19.2	12.2	11.9	2
88+500									2
89+000	41.1	52.1	6.79	5.62	18.58	18.9	12.2	12.4	3
89+500									3
90+000	35.7	55.4	8.82	5.36	18.75	19.2	11.8	11.6	4
90+500									8
91+000	38.1	54.5	7.39	4.49	18.5	19.1	11.9	10.5	6
91+500									5
92+000	31.4	59.2	9.42	5.26	19.39	19.7	11	17.5	4
92+500									7
93+000	37	57.2	5.74	4.52	18.97	19.8	10.1	13.1	11
93+500									3
94+000	38.2	56.9	4.89	4.52	18.87	19.5	11.7	12.3	8

CHAINAGE	Grain Size Analysis			Natural Moisture Content (%)	Field Density (kN/m³)	Compaction		Laboratory CBR (%)	Least CBR value from DCP
	Gravel (%)	Sand (%)	Silt+Clay (%)			OMC (%)	MDD (kN/m³)		
94+500									2
95+000	34.1	60.6	5.29	4.63	19.12	19.8	10.6	13.6	19
95+500									11
96+000	36.3	56.7	7.02	4.39	18.4	19.2	11.1	13.5	6
96+500									12
97+000	38.4	55.5	6.04	4.49	18.5	19.3	10.8	12.2	3
97+500									6
98+000	41.7	49.3	9.02	4.56	18.32	19.1	11.4	13.6	2
98+500									5
99+000	36.4	54.1	9.56	4.1	18.55	19.1	12.3	12.5	4
99+500									3
100+000	33.8	59.9	6.26	4.56	18.87	19.5	11.9	10.4	2
100+500									6
101+000	34.2	57	8.8	5.53	18.9	19.3	12.5	10.9	8
101+500									9
102+000	39.4	55.9	4.69	5.36	18.98	19.4	11.9	12.1	5
102+500									5
103+000	36.9	56.9	6.18	5.3	18.66	19.2	11.8	11.1	4
103+500									3
104+000	38.3	50.4	11.2	5.46	18.57	19.2	11.7	11.4	5
104+500									2
105+000	28	59.8	12.18	4.56	18.75	19.4	12.7	12.9	3
105+500									9
106+000	31.5	59.9	8.65	5.62	18.49	19.1	12.7	15.3	6
106+500									4
107+000	33.8	57.5	8.66	4.56	18.34	19.1	9.9	15.5	4
107+500									7
108+000	38.2	50.6	11.15	5.03	18.44	19.1	11.5	11.4	3
108+500									5
109+000	40.4	52.6	6.99	5.62	19.33	19.5	12	14.8	11
109+500									3
110+000	37.8	56.2	6.04	3.56	19.07	19.9	11.4	13.1	3
110+500									2
111+000	24.4	64.6	11.04	4.25	18.89	19.5	10.5	12	5
111+500									4
112+000	36.2	58.2	5.67	5.26	19.37	19.7	10.9	11.8	3
112+500									4
113+000	24	70	6.04	5.26	19.09	19.6	11.3	10.5	6
113+500									7
114+000	31.8	62.7	5.57	4.87	18.8	19.3	11.9	13.9	4

CHAINAGE	Grain Size Analysis			Natural Moisture Content (%)	Field Density (kN/m³)	Compaction		Laboratory CBR (%)	Least CBR value from DCP
	Gravel (%)	Sand (%)	Silt+Clay (%)			OMC (%)	MDD (kN/m³)		
114+500									5
115+000	30.5	63.2	6.29	4.56	19.28	19.7	10.9	13.3	8
115+500									8
116+000	27.4	65.3	7.33	5.28	18.89	19.6	11	11.5	5
116+500									29
117+000	27.8	65.3	6.9	5.45	18.81	19.2	11.4	11.9	8
117+500									11
118+000	32.5	61.8	5.69	4.87	18.1	18.9	10.7	15.8	10
118+500									15
119+000	13	78.2	8.79	5.58	18.71	19.3	12.3	12.6	12
119+500									12
120+000	23.9	67.8	8.26	4.68	18.56	19.2	12	10.2	11
120+500									5
121+000	31.5	60.8	7.72	5.6	19.24	19.6	10.2	10.5	5
121+500									4
122+000	18.1	74.5	7.39	5.23	18.92	19.7	10.1	11	9
122+500									2
123+000	17.3	74	8.75	5.26	18.86	19.8	10.5	12	6
123+500									6
124+000	20.7	72.5	6.82	5.28	19.58	19.4	10.5	10.9	7
124+500									7
125+000	27.4	67.9	4.7	5.14	19.24	19.5	12.4	11.4	4
125+500									7
126+000	29.5	64	6.45	6.28	18.92	19.6	10.2	11	9
126+500									7
127+000	28.4	67.5	4.12	5.24	19.39	20	11.1	13.7	7
127+500									5
128+000	35.8	60.8	3..46	5.26	18.79	19.4	12	12.3	2
128+500									6
129+000	24.3	69.3	6.39	4.89	18.86	19.3	11.7	11.7	2
129+500									2
130+000	20	75.5	4.42	5.64	18.56	19.2	11.1	12.5	2

The comparison of CBR test performed in the field and CBR test performed on the collected sample at Laboratory is presented vide **Figure 4.1** below.

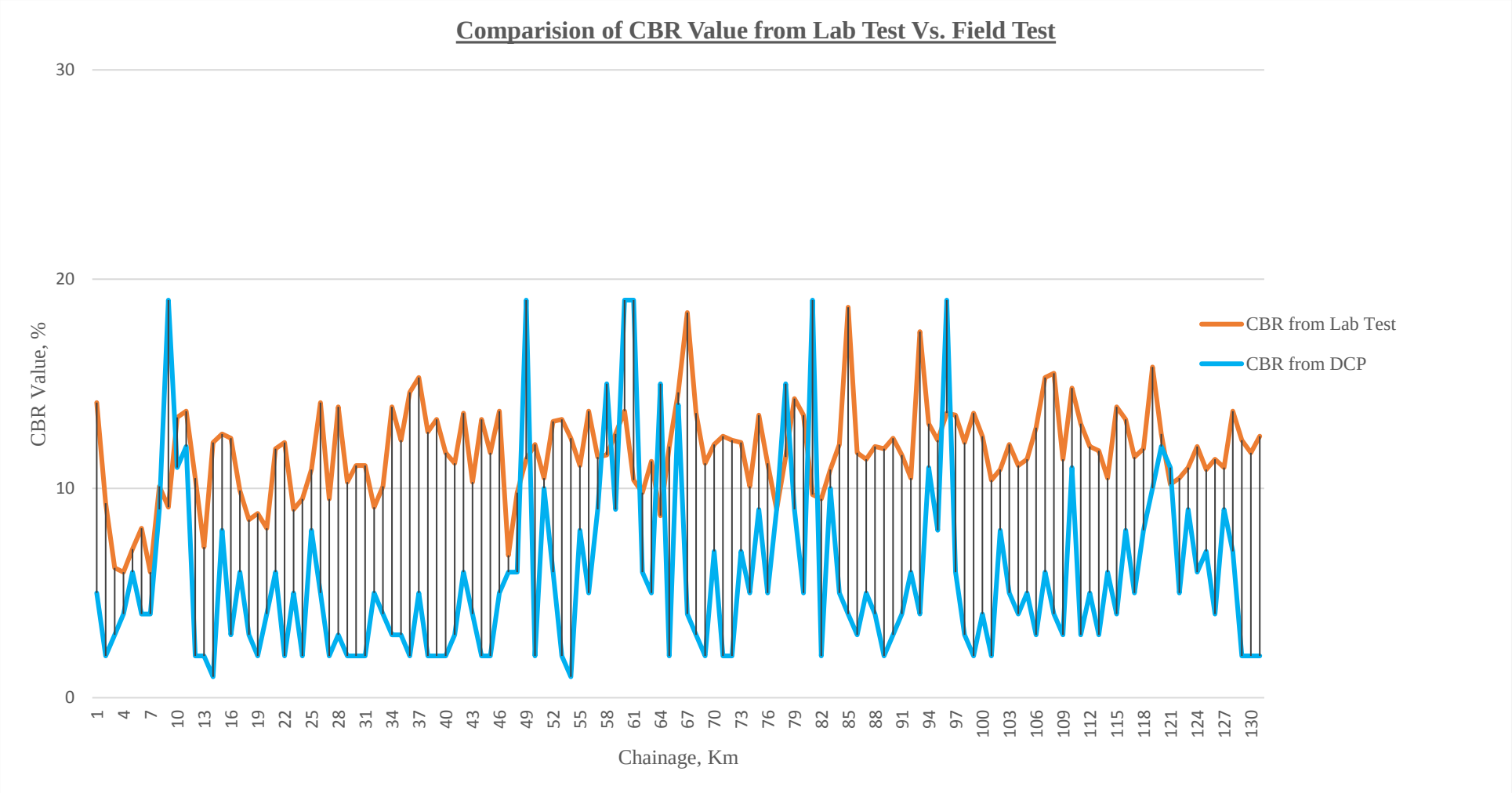


Figure 4.1: Comparison of CBR Value from Lab Test Vs. Field Test

4.5 Information of Borrow Places and Results of Site Survey

The borrow pits for material investigation works were surveyed at eleven selected places along the existing road. The borrow pit investigation was carried out a total of eleven river location to the naked eye between Kamala-Dhalkebar and Pathlaiya road section. These points were selected considering transport distance (lead), quality and approximate amount of the Material. Therefore, before commencement of the Construction, the constructor has to carry out detailed investigations at recommended places for the quantitative and qualitative determination. The information of borrow places along the Project Road is shown in the **Table 4.2** below.

Table 4.2: Information of borrow places

Place	Location	From Existing Road			Description of Materials	Remarks
		Road Left/Right		Offset		
Start Area Zone	1	Kamala River (Chisapani)	Right	7000m on U/S of bridge	Material for sand and aggregate is of good quality	
	2	Ratu Khola	Left/Right	1000 m on both side of bridge	Material is of good quality	As the material is to be used as concrete material it suitable for purpose.
	3	Banke Khola	Left/Right	1000 m on both side of bridge	Material is of good quality	
	4	Maraha Khola	Left/Right	1000 m on both side of bridge	Material is of good quality	
Middle Area Zone	5	Lakhandehi Khola	Left/Right	1000 m on both side of bridge	Material is of good quality	
	6	Bagmati River	Left/Right	1000 m on both side of bridge	Material is of good quality	
	7	Chandi Khola	Left/Right	1000 m on both side of bridge	Material is of good quality	
	8	Lamaha	Left/Right	1000 m on both side of bridge	Material is of good quality	
	9	Dhansar	Left/Right	1000 m on both side of bridge	Material is of good quality	
End Area Zone	10	Bakaiya Khola	Left/Right	1000 m on both side of bridge	Material is of good quality	
	11	Rapti	Left/Right	1000 m on both side of bridge	Material is of good quality	

4.6 Sub-Base, Base Materials, Embankment Filling Samples

The samples from six different quarry sites i.e., Ratu Khola, Banke Khola, Mahara Khola, Bagmati River, Bakaiya River and Rapti River were collected during field investigation for the sub-base, base materials. The following test were performed following IS code testing method on the sample collected from site.

a) California Bearing ratio test
b) Standard Proctor compaction test
c) Gradation test
d) Atterberg limit tests
e) Moisture Content test

4.6.1 California Bearing Ratio (CBR)

The California Bearing Ratio test conducted to ascertain the bearing strength of the proposed sub grade. The CBR in combination with the expected traffic intensity of the proposed road and other parameters used to design the road pavement thickness (comprising of capping layer, the Sub-base, Base course and the Asphalt layer).

The summary of the Lab CBR value adopted for KDP Project and the summary of test results is in **Table 4.1** vide **para 4.4** above.

4.6.2 Standard Proctor Compaction Test

The standard proctor compaction carried out to study the degree of compaction that could be possibly achieved on the in-situ sub-grade material. According to K.B. Woods following indicates value of the sub grade material mainly soil:

Density (Kg/m^3)	Soil Eng. Properties
2000 & above	Excellent Soil
Between 2000 & 1900	Good Soil
Between 1900 & 1650	Fair Soil
Less than 1600	Poor Soil

The sub-grade material for the proposed KDP project used with the category of fair to good indicating that the sub grade soil would yield reasonably good degree of compaction if proper compacting equipment is deployed during the preparation of sub-grade. There are, however, weak stretches having soft soil since the road alignment falls on low land areas of Terai where

the pavement designer is required to review the both CBR as well as proctor compaction result to make provision for the capping layers. Generally, compacted/consolidated sub-grade should have CBR of > 6 for construction of sub grade. Otherwise, a provision of capping material of one or more-layer, total thickness consisting of 200 to 300 mm is required to strengthen the sub-grade prior placement of any pavement layers.

The summary of the Proctor compaction and the summary of test report is shown in **Table 4.1 vide para 4.4 above.**

4.6.3 Material Gradation (Sieve Analysis)

The secondary data of sieve analysis of sub-base/base material was observed with a view to find the following:

- That whether the naturally occurring material could be used as sub-base materials with some modifications.
- That whether the sub-grade material has the grading envelope acceptable as sub-grade material.

The summary of various tests performed on Base and Sub base material collected from the selected quarry sites is provide vide **Table 4.3** below:

Table 4.3: Summary of Test Results on Sub-base, base materials

S.N	Types of Test	Name of Quarry Sites					Remarks
		Ratu Khola	Mahara Khola	Bagmati River	Bakaiya River	Rapti River	
1	California Bearing Ratio (CBR) Value at 98% of MDD	84.8	79.4	94.5	77.2	75.2	
2	Optimum Moisture Content (OMC), %	6.46	6.7	7	7.5	7.55	
3	Maximum Dry Density Unit Weight (MDD), KN/m^3	2.27	2.26	2.26	2.25	2.28	
4	Liquid Limit (%)	22.1	-	15.98	24.57	19.55	
5	Plastic Limit (%)	-	-	-	-	-	

The result of sieve analysis test performed on Base and Sub base material are presented in the **Table 4.4** below.

Table 4.4: Sieve Analysis test results on Sub-base, Base materials

S.N	Name of Quarry Sites	Sieve Analysis Results			Remarks
		Silt + Clay (%)	Sand (%)	Gravel (%)	
1	Ratu Khola	5.90	43.20	50.90	
2	Banke Khola	2.00	21.00	76.00	
3	Maraha Khola	5.90	37.70	56.40	
4	Bagmati River	6.90	40.60	52.40	
5	Bakaiya River	4.60	45.40	50.10	
6	Rapti River	2.80	50.10	47.00	

In addition, samples collected from the sites selected for Embankment filling were collected and various tests were performed in the Laboratory. The summary of various tests performed on samples collected for Embankment filling purpose is provide vide **Table 4.5** below:

Table 4.5: Summary of Test Results on Embankment filling materials

Location	Grain Size Analysis			Atterberg Limits		Compaction		Laboratory CBR (%)
	Gravel (%)	Sand (%)	Silt+Clay (%)	LL (%)	PL (%)	OMC (%)	MDD (g/cc)	
Lakhandehi Khola	26.4	58.2	15.4	-	-	7.6	1.88	41.3
Lamaha Khola	5.9	75.2	18.9	22.5	-	7.5	2.02	30.6
Dhanushar Khola	30.2	62.9	6.9	-	-	7.8	1.98	39.2
Chandi Khola	17.9	73.9	8.3	-	-	10.5	1.83	26.50

The detailed material test results for all type of samples have been presented in annexure **Volume I-C** for reference.

4.7 Boulder Materials

The road alignment of Kamala-Dhalkebar-Pathlaiya passes through the Indo-Gangetic plain which consists mostly cobbles, pebbles, gravel with fine sediments. So, it is very difficult to find the boulder material along the alignment. However, during the monsoon the river transport the large quantities of debris from the Siwalik, Mahabharat range and brings the boulder mass. Mostly, the flooded boulder mass can be collected in the river such as Kamala, Ratu, Bagmati, Bakaiya Rivers. Those are not the permanent source for boulders. Apart from that, the boulder required for the construction can be collected from Rapti River in Pathlaiya-Hetauda Road.

4.8 The Stone /Aggregate Quarry Materials

The samples from five different quarry sites Ratu Khola, Mahara Khola, Bagmati River, Bakaiya River and Rapti River were collected during field investigation for the stone/aggregate

materials. The following test were performed following IS code testing method on the sample collected from site.

a) Aggregate Impact Value
b) Los Angeles Abrasion Value
c) Gradation test
d) Flakiness test
e) Specific gravity test and water absorption test
f) Soundness test

4.8.1 Stone/aggregate Impact value (AIV) test

These tests are required to ascertain the pounding impact due to dynamic moving traffic. The results should confirm to the following requirement as per IS 2386 –part IV.

<10%	Exceptionally strong
10 – 20%	Strong
10 – 30%	Satisfactory for road surfacing
30%	For cement concrete sub-base and other works
31 – 35%	Suitability to be decided in conjunction with other test parameters
>35%	Weak for road surfacing

4.8.2 Los Angeles Abrasion (LAA) tests

LAA test is conducted to check the wear and tear properties of the rocks /stone aggregates. The test is simulated to field condition of wear and tear in the laboratory. The results should confirm to the following requirement as per IS 2386 –part IV. The requirement of LAA Test as per IS 2386-part IV has been provided in **Table 4.6** below.

Table 4.6: IS requirements for LAA tests

1.	Water bound Macadam (WBM) sub-base course	60%
2.	WBM base course with Bituminous surfacing	50%
	Bituminous Macadam base course	
	Built Up spray grout base course	
3.	WBM Surfacing course	40%
	Bituminous Macadam Binder course	
	Bituminous penetration macadam	

	Built up spray grout binder course	
4.	Bituminous carpet surface course	35%
	Bituminous surface dressing, single or two coats	
	Bituminous Surface dressing, using precoated aggregate	
	Cement concrete surface course [as per IRC)	
5.	Bituminous/asphaltic concrete surface course	30%
	cement concrete pavement surface course [as per ISI]	

4.8.3 Water absorption and specific gravity test

These tests are conducted to check if the stone used for pavement construction are dense, compact and that the water absorption is within the acceptable limit, and are particularly useful to judge the quality of the material for bituminous works.

4.8.4 Grading on naturally occurring gravelly materials

The naturally occurring materials were collected from number of locations along the existing road and well as from the proposed (new) road alignment. The materials were analyzed for grading envelope among other tests to confirm if these materials could be used as sub-base materials. The results are attached under **Table 4.7** below.

Table 4.7: Laboratory Test Results on stone quarry/Natural Quarry materials

Quarry Site	Grain Size Analysis			Flakiness (%)	AIV	LAA	Sp. Gr.	Water Absorption (%)
	Gravel (%)	Sand (%)	Silt+Clay (%)					
Ratu Khola	50.9	43.2	5.9	23.52	21.53	29.67	2.68	0.47
Banke River	76	21	2	20.34	12.57	26.98	2.65	0.57
Maraha Khola	56.4	37.7	5.9	23.14	13.69	26.62	2.74	0.88
Bagmati River	52.4	40.6	6.9	24.42	19.4	30.7	2.73	1.02
Bakaiya	50.1	45.4	4.6	22.83	13.16	24.04	2.72	0.4
Rapti	47	50.1	2.8	24.17	24.12	32.4	2.67	0.33

4.9 The Natural Sand Materials

The samples from five different quarry sites Ratu Khola, Mahara Khola, Bagmati River, Bakaiya River and Rapti River were collected during field investigation for the sand materials. The following test were performed on sand samples following IS code testing method.

a) Sieve analysis
b) Fineness modulus
c) Silt content

The summary of Fitness Modulus test and Silt Content test performed on the material collected from Quarry sites is presented vide **Table 4.8** below.

Table 4.8: Laboratory Test Results on sand quarry samples

S.N	Types of Test	Name of Quarry Sites						Remarks
		Kamala River	Ratu Khola	Maraha Khola	Bagmati River	Bakaiya River	Rapti River	
1	Fineness Modulus	2.66	2.76	2.93	4.13	2.29	2.89	
2	Silt Content		Absent	Absent	Absent	Absent	Absent	

The approximate quantity available for utilizing as Sub grade material at selected river sources is provided vide **Table 4.9** below.

Table 4.9: Quantity Available for Sub-grade Construction

S.N	Name of River	Volume of Filling Materials (m^3)/Year
From Kamala (East) (CH-0+000)		
1	Ratu Khola	4,50,000.00
2	Maraha Khola	1,65,600.00
3	Lakhandehi Khola	1,80,000.00
4	Bagmati River	8,10,000.00
5	Chandi Khola	1,44,000.00
6	Lamaha Khola	58,500.00
7	Dhanusar Khola	1,44,000.00
8	Lalbakaiya River	7,87,500.00
	Total	**27,39,600.00**

4.10 Embankment Filling Materials

The specific sites for the embankment filling materials cannot be specified at Design Stage as the same has to be identified and selected by the Contractor during execution. There are abundant materials at the quarry site such as Ratu River, Maraha Khola, Bagmati River, Lal

bakaiya River, Rapti River for construction material as well as embankment filling materials only after mixing with clayey soil. Apart from above listed sites there are few other sites where, the embankment filling materials can be extracted such as: Barahari Khola, Chandi River, Lamaha River, Dhanusar River, and Lakhandehi River etc.

The embankment filling materials at most of the quarry sites consists of more than half of coarse fraction of sub-grade materials smaller than 4.75 mm. Hence, the sub-grade materials are poorly graded sands or gravelly sand with little or no fines, which is categorized as fair to good materials as per IRC:36-2010.

During this study, it is observed that the current under-construction project such as Railway project, alignment of which passes through parallel to KDP Project has no defined source for embankment filling materials. The contractors have been using the filling materials available on the right of way of the Railway project. However, it is not recommended to excavate the embankment materials from within the existing Right of Way. Instead, the contractor can obtain (purchase) these materials from private land within the distance of 1 km from the road alignment. The summary of Laboratory tests performed on the material collected from the sources selected for embankment filling is as provided vide **Table 4.10** below.

Table 4.10: Laboratory Test Results of Embankment Filling Materials

S.N	Name of Source	Grain Size Analysis				Atterberg's Limit Test			Remarks
		Clay %	Silt %	Sand %	Gravel %	LL	PL	PI	
1	Lamaha Khola	0	18.9	75.2	5.9	21.5	-	-	
2	Chandi Khola	0	8.3	73.9	17.9	23.87	-	-	
3	Lakhendehi Khola	0	15.4	58.2	26.4	24.45	-	-	
4	Lamaha Khola	0	18.9	75.2	5.9	21.5	-	-	

4.11 Water

Fresh Water is a very precious natural resource and it is widely reported that the world reserve of fresh water is fast depleting. Life on earth is not possible without water. Water is one of the most important elements in construction but people still ignore quality aspect of this element. The water is required for preparation of mortar, mixing of cement concrete and for curing work etc. during construction work. The quality and quantity of water has much effect on the strength of mortar and cement concrete in construction work.

The water used for mixing and curing should be clean and free from injurious quantities of alkalis, acid, oils, salt, sugar, organic materials, vegetable growth and other substances that may be deleterious to bricks, stone, concrete or steel. Potable water is generally considered satisfactory for mixing. The pH value of water should be not less than 6. During the study it was observed that water available throughout length of alignment.

The water for the construction works along the Kamala-Dhalke-Pathlaiya is found in enough volume.

4.11.1 Specification of Water for Construction

Water used for all construction works like masonry work, making concrete, mortar, bricks, or for other plain or reinforced general construction, should be clean and free from objectionable quantities of suspended materials, vegetables, or organic impurities like alkalis, salts, and other deleterious substances.

Because such deleterious materials cause efflorescence or are likely to interfere with setting of mortar or prove harmful to construction works. Clear and potable water is considered quite satisfactory for all purposes.

NOTE: In any case, salty water must not be used for construction works.

Deleterious Materials in Water

The following considerations are assumed to rectify maximum permissible limits of deleterious materials in water.

1. Limits of Acidity
2. Limits of Alkali
3. Percentage of solids

Limits of Acidity

To neutralize 200 ml of sample water, required caustic soda solution should not be more than 2 ml of 0.1 N. The details of its test are given in I.S. 3025-1964.

Limits of Alkali

To neutralize 200 ml sample of water, required hydrochloric acid should not be more than 0.1 ml of 0.1 N. The details of its test are given in I.S. 3025-1964.

Percentage of solids

The percentage of solids should not exceed the following limits when tested in accordance with I.S. 3025-1964.

4.12 Flyash

The Fly ash is an useful component of modern concerts, due to its pozzolanic nature, it acts as a useful material of cement. The fly ash is a heterogeneous by-product material produced in the combustion process of coal used in power stations. It is a fine grey colored powder having spherical glassy particles that rise with the flue gases. As fly ash contains pozzolanic materials components which reach with lime to form cementitious materials. Thus, fly ash is being used in concrete, mines, landfills and dams.

The fly ashes are broadly classified worldwide into two chemical types for their industrial applications, mostly in cement industries, namely class C and class F.

Class C

Class C fly ash, with its higher levels of calcium oxide, generally has self-cementing properties. In terms of global fly ash composition, fly ash from India on average contains higher levels of silicon dioxide, than that from the US and China. In terms of particle size, fly ash more often is poorly graded than well-graded; fly ash from India in particular tends to be poorly graded.

The following test to be performed following IS code testing method on the sample collected from the relevant industry. The results should confirm to the following requirement as per IS 1727-1967 and meet the standards presented vide **Table 4.11** below:

Table 4.11: Standard range of test value for flyash

S. N	Types of Tests	Standard Range of Test Value
1	Optimum moisture content (OMC), %	11 to 53%
2	Maximum dry density, g/cm^3	1.01 to 1.78 g/cm^3
3	Shrinkage limits	38 to 65
4	Permeability, cm/s	10^{-4} to 10^{-7} cm/s
5	Angle of friction, Ø^0	25^0 to 40^0

The fly ash is easily available in Birgunj, Parsa which is about 24 Km south from Pathlaiya, end point of Kamala-Dhalke-Pathlaiya Road Project.

4.13 Construction Materials like Cement, Steel, Bitumen

The external construction materials like cement, steel, Bitumen are easily available nearby the project site of Kamala-Dhalkebar-Pathlaiya Road. The cement and Steel is found in abutment quantity along the project location namely in towns such as Bardibas, Harion, Chandranigahapur, Nijgadh, Pathlaiya. Similarly, Arvind Emporium P. Ltd (AEPL), Nepal Bitumen and Barrel Udyog Ltd. (NBBUL), Kathmandu Bitumen Co. Pvt. Ltd etc are the major suppliers of bitumen in Nepal and have warehouse in Birgunj, Parsa which is about 24 Km south from Pathlaiya, end point of Kamala-Dhalke-Pathlaiya Road Project. All the external construction materials shall be tested during construction phase as per the specification given in "STANDARD SPECIFICATIONS FOR ROAD AND BRIDGE WORKS, 2073".

4.14 Lead Chart for All Construction Materials

The consultant visited various sources selected for construction of various pavement layers and gather detail regarding available quantities, collected samples to verify suitability and assessed lead from the project site during material investigation. The Lead Chart containing required data has been prepared and presented vide **Table 4.12** below.

Table 4.12: Lead chart for construction materials

Place		Name of Source	Location	Available Materials	Estimated Quantities	Remarks
Start Area Zone	**Dhanusa District (Section between Kamala River to Ratu Khola)**					
	1	Kamala River (Chisapaani)	7 km U/S from Chainage 0+000 Starting point (Kamala) and 35.5 Km away from Chainage 28+500 ending point (Ratu)	Sand & Natural Aggregates, Cobble	1260000 m^3	3 km Black top and 4km Earthen Road from Chainage 0+000 Starting point (Kamala)

Place		Name of Source	Location	Available Materials	Estimated Quantities	Remarks
	2	Ratu Khola	28 km away from Chainage 0+000 Starting point (Kamala River)	Boulders, Cobbles, Sand, Sub-base, base & Embankment filling	560000 m^3	28 km Black top and 200 m Earthen Road from Chainage 0+000 Starting point (Kamala) & 101.5 km Black top and 200 m Earthen Road from Chainage 130+000 ending point (Pathlaiya)
Middle Area Zone	**Mahottari District (Section Between Ratu Khola to Banke Khola)**					
	2	Ratu Khola	200m away from Chainage 28+500 (Ratu Khola)	Boulders, Cobbles, Sand, Sub-base, base & Embankment filling	560000 m^3	200 m Earthen Road away from Chainage 28+500 (Ratu Khola)
	3	Maraha Khola	11+400 km away from Chainage 28+500 (Ratu Khola)	Cobbles, Pebbles, Sand& Embankment filling	320000 m^3	11.4 km Black top and 500 m Earthen Road away from Chainage 28+500 (Ratu Khola)
	4	Banke Khola	17.48 km away from Chainage 28+500 (Ratu Khola)	Boulders, Cobbles, Sand, Sub-base, base & Embankment filling	500000 m^3	17.48 km Black top and 500 m Earthen Road away from Chainage 28+500 (Ratu Khola) & 84.02 km Black top and 500 m Earthen Road from Chainage 130+000 ending point (Pathlaiya)
	Sarlahi District (Section Between Banke Khola to Bagmati River)					
	4	Banke Khola	500m away from Chainage 45+980 (Banke Khola)	Boulders, Cobbles, Sand, Sub-base, base & Embankment filling	500000 m^3	500 m Earthen Road away from Chainage 45+980 (Banke Khola) & 45.98 Km Black topped and 500 m Earthen Road away from Chainage 0+000 from starting point (Kamala)

Place		Name of Source	Location	Available Materials	Estimated Quantities	Remarks
Middle Area Zone	5	Lakhandehi Khola	17.89 Km away from Chainage 45+980 (Banke Khola)	Sand & Embankment filling	250000 m^3	17.89 Km Black top and 300m Earthen Road from Chainage 45+980 (Banke Khola)
	6	Bagmati River	30.23 km away from Chainage 45+980 (Banke Khola)	Boulders, Cobbles, Sand, Sub-base, base & Embankment filling	550000 m^3	30.3 Km Black top and 500m Earthen Road from Chainage 45+980 (Banke Khola) & 53.5 Km Black top and 500m Earthen Road from Ending point (Pathlaiya)
	Rautahat District (Section Between Bagmati River to Dhansar River)					
	6	Bagmati River	500 away from Chainage 75+500 (Bagmati River)	Boulders, Cobbles, Sand, Sub-base, base & Embankment filling	550000 m^3	500m Earthen Road from Chainage 75+500 (Bagmati River)
	7	Chandi Khola	12.27 Km away from Chainage 75+500 (Bagmati River)	Sand & Embankment filling	250000 m^3	12.27 Km Black top and 500m Earthen Road away from Chainage 75+500 (Bagmati River)
	8	Lamaha Khola	20.90 Km away from Chainage 75+500 (Bagmati River)	Sand & Embankment filling	350000 m^3	20.90 Km Black top and 500m Earthen Road away from Chainage 75+500 (Bagmati River)

Place		Name of Source	Location	Available Materials	Estimated Quantities	Remarks
	9	Dhansar Khola	26.39 Km away from Chainage 75+500 (Bagmati River)	Sand & Embankment filling	300000 m^3	26.39 Km Black top and 500m Earthen Road away from Chainage 75+500 (Bagmati River) & 26.7 Km Black top and 300m Earthen Road from Ending point (Pathlaiya)
End Area Zone	**Bara District (Section Between Dhansar River to Pathlaiya)**					
	9	Dhansar Khola	300 m away from Chainage 102+600 (Dhansar Khola)	Sand & Embankment filling	300000 m^3	300m Earthen Road from Chainage 102+600 (Dhansar Khola)
	10	Bakaiya Khola	7.79 Km away from Chainage 102+600 (Dhansar Khola)	Boulders, Cobbles, Sand, Sub-base, base & Embankment filling	120000 m^3	7.79 Km Blacktop Road and 300m Earthen Road from Chainage 102+600 (Dhansar Khola) &19.5 Km Black top and 300m Earthen Road from Ending point (Pathlaiya)
	11	Rapti	33 km away from Chainage 130+000 Ending point (Pathlaiya)	Boulders, Cobbles, Sand& Embankment filling	850000 m^3	32.5 Km Black top and 500m Earthen Road from Ending point (Pathlaiya)

4.15 Site Photographs

Trial pit test	Trial pit test
DCP test	Conducting DCP test

Compaction test	CBR reading taken
Grain Size Analysis fine aggregate	LAA test work

Chapter 5: Traffic Surveys & Analysis

5.1 General

Traffic gets generated as a result of several inter-connected factors, encompassing the prevailing socio-economic conditions such as population, gross domestic product, vehicle ownership, sectoral economic activities etc. Traffic demand estimation, therefore, requires detailed studies and investigations concerning these factors as well as the magnitude and characteristics of the existing traffic flows and its past trend in respect of nature, composition and growth. Towards this end, the Consultants have undertaken detailed traffic studies and the same are presented in this chapter. The entire process of the traffic study is carried out in the following sequence:

- Collection of secondary data
- Field survey
- Analysis
- Design recommendations

5.1.1 Road Network

The project area is in the plain (Terai area). The project road is an important section of the East -West highway in terms of traffic volume. The highway alignment passes through the urbanized settlements, sparsely populated areas, forests, and agricultural lands. The road network in the study area mainly comprises the East -West highway (NH01), Postal Road (NH05), and some national highways in the North-South direction. Most of the sections of the Postal highway are under construction or planned highways at present. Therefore, the traffic flow along this highway is not significant for the consideration of the traffic analysis for the study. The National Highways in the North-South direction mainly feed the traffic to the project road. The location of the project road and schematic diagram of the project area and road network is shown in the **Figure 5.1 and Figure 5.2.** The National highways in the project area either connecting or diverging from the Project Road or running parallel to Project are listed below:

- Postal Highway (NH05) alignment passes through Janakpur- Thalahi – Malangawa – Kailashpur – Kalaiya – Birgunj,
- Dhalkebar - Janakpur – Jatahi (NH22) Highway,
- Bhittamod – Jaleshwor – Bardibas (NH28) Highway,
- Nawalur – Malangawa – Sonbarsha (NH32) Highway,

- Manmat – Kalaiya – Matiarwa (NH36) Highway
- Chandranigahapur – Gaur (NH35) Highway,
- Sisiya – Pathalaiya (NH41) Highway,
- Kathmandu – Terai Fast Track (Expressway) (NH33),
- Bardibas – Sindhuli – Khurkot – Dhulikhel (BP Highway- NH13) highway

5.1.2 Homogenous Roads Sections

The Highway network in the project area consists of National Highways, Provincial roads and, local roads. The project road can be divided into homogenous sections depending upon the nature of the roadside activities, traffic generation through radial roads and roadside land-use. Traffic analysis and forecast can be simplified by adopting the concept of homogenous sections along the project road. Kamal – Dhalkebar - Pathlaiya section of the East -West Highway. Based on urban areas with merging/ diverging important roads and land use the Project Road can be divided into the following Homogenous Sections as tabulated vide **Table-5.1**.

Table 5.1: Homogenous sections of the Project Road

S/N	Homogenous Sections	Description	Land Use in between
1	Kamala - Dhalkebar	at Dhalkebar (NH22)	Cultivated land, Sparse to dense settlement
2	Dhalkebar - Bardibas	At Bardibas: Highway link NH28 and NH13	Cultivated land, Sparse to dense settlement
3	Bardibas - Nawalpur	At nawalpur junction with NH 32 from Malangawa	Mainly Forest area
4	Nawalpur to Chapur	At Chapur Junction with NH 36 from Gaur	Cultivated land, Sparse to dense settlement as well as forest
5	Chapur - Nijgadh	At Nijgadh junction with Fast Track NH 33	Forest and settlement area
6	Nijgadh – Pathlaiya	At Pathlaiya Junction with NH 41 from Birgunj	Mainly Forest

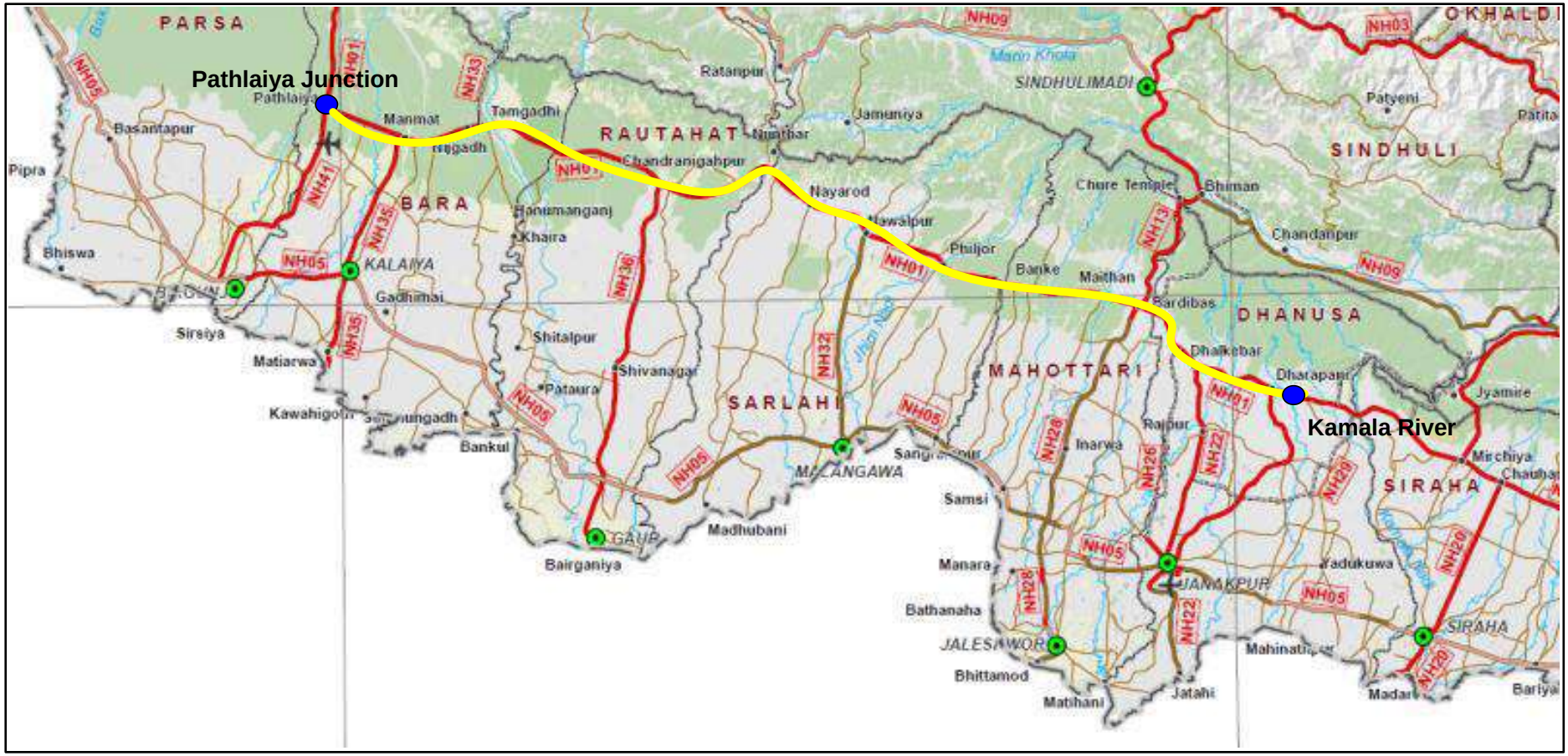


Figure 5.1: Project Road Alignment

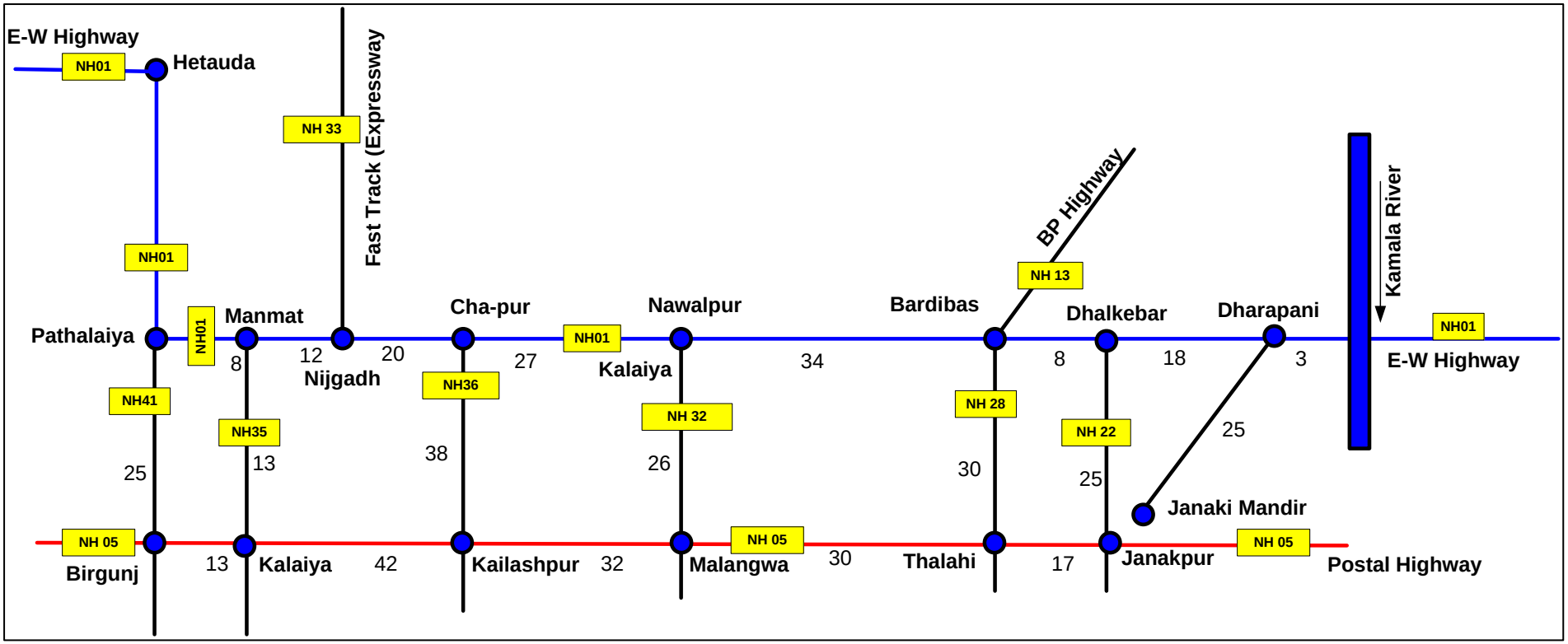


Figure 5.2: Road Network Diagram

5.1.3 Secondary data Collection and review

Traffic engineering principles and a variety of traffic data are considered as the basis for the entire design process for the highway geometry including the pavement and bridge as well as other cross drainage structures. Similarly, the traffic data are vital for the intersection design and other pedestrian roadside facilities. Most importantly, the highway cross-section determined as per the prevailing traffic type and intensity. In addition to these aspects, traffic engineering data are vital for determining the road safety features and the design of traffic control devices. Several traffic engineering/study reports, specifications, guidelines, standards, and others have been reviewed in this project. Most of them are as below:

Previous traffic count data collected by DoR is one of the major part of the secondary data for the development of the initial scenario on the traffic flow for the Project. The results of the historic traffic count data were analyzed for estimating the traffic growth rates for a particular type of vehicle. As the Feasibility Study for the same project road section has been completed and approved recently, the outcome in terms of growth rate and other parameters are taken in consideration for arriving at Traffic Forecast for Detailed Design i.e., current assignment.

The road traffic design and safety aspects have been based on the following guidelines and standards or the code of practices in highway design and traffic engineering.

- **Feasibility Study Report for up-gradation of Kamal – Dhalkebar – Pathlaiya (KDP) Section of Mahendra Highway, January 2020**: The report was taken as the basis of the traffic analysis and forecast procedure. The traffic study and other analyses included in this report were assumed as the departure of the detailed traffic engineering analysis.
- **Previous traffic volume count data from DoR (website references)**: the previous classified traffic count data were considered for the analysis of traffic growth scenarios at the traffic count stations located along the project road. Traffic forecast and traffic analysis are based on the previous traffic count data and results of the field survey (conducted in this study). The traffic growth rates observed from 2011 to 2021 have been reviewed and refined for the current analysis.
- **Nepal Road Standard, 2070 (second revision)**: The standard was adopted for establishing traffic engineering parameters such as Equivalence Factors for (Passenger Car Unit-PCU) for classified traffic count, expected Capacity of the road, anticipated Level of Service (LOS), and others. The Standards were taken as the basis of the entire geometric design of the project.

- **Study Report:** TA-9604 NEP: Consulting Services of Transaction Technical Assistance for Institutional Strengthening of Road Safety and Gender Equality: Some relevant parts of this study report were referred in the design and recommendations for Road Safety Features for the KDP road project. The recommended design approaches for the development of Roadside Service /Rest Areas were reviewed and redeveloped the designs for the project.
- **iRAP Nepal Strategic Road Network Assessment, Draft Results Report, 11 Jan 2022**: The recently conducted iRAP field survey has his report has been considered as the conceptual framework for the development of road safety measures for this project.
- **Road Safety Guidelines (IRC 88: 2019)**: The guidelines is useful for the design stage audit of the project road. It has included the step-by-step procedure for the Road Safety Audit.
- **IRC: 108-2015 Guidelines for Traffic forecast on Highways**: The traffic forecast models recommended in these guidelines have been modified and accepted for the estimation of future traffic on the Project Road.
- **Indo Highway Capacity Manual, 2017**: The document is very important for the capacity analysis and determining the Level of Service of the four-lane highway and improvement of the intersections on with the road project.
- **Traffic Sign Manual, 1997, Department of Roads**: This manual is important as the legal framework for the road signs and markings in Nepal.
- **Code of practices for Road Signs: IRC-67:2012**: The latest version of the IRC-67 has been taken for the application of recent practices in Road Signs along the four-lane highway with a central median.
- **Code of Practices for Road Marking IRC: 35-2015**: The detailed pavement marking and object painting standards have been adopted as per this document.
- **Manual Specifications and Standards for Four Laning of Highways, IRC: SP: 84: 2019**: The road safety measures, cross-sectional elements, and traffic control devices have been referred from these specifications.
- Based on the secondary documents the following category of vehicles have been adopted in the project, please refer **Figure 5.2**.

Table 5.2: Vehicle Category

Motorized traffic			Non-Motorized traffic
Multi-axle truck	Micro Bus	Three-Wheeler	Rickshaw
Heavy Truck	Car	Four Wheel Drive	Bullock Cart
Light truck	Motorcycle	Power Tiller	Bicycle
Big Bus	Utility vehicles		
Mini Bus	Tractor		

5.1.4 Existing Urban areas/ Settlements

Traffic study has been carried out considering prevailing land use and specifically significant urban settlements. The urban areas/ settlement areas along the highway have a great impact on the through traffic. The major settlements with length along the Project Road observed during inventory / surveys are shown in **Table 5.3**. The total length of the settlement area (densely populated or sparsely built-up areas) are found about 43 km. Therefore, it is obvious that, the traffic operation along this highway is significantly affected by the local traffic including the pedestrian movements.

Table 5.3: Urban Areas/ Settlement along the Road Project

S.N.	Name of Urban Area/ Settlement	Approximate Length (km)
1	Goddard Bazar	1.0
2	Ganesh Nath	1.6
3	Ganesh Nath-5	0.20
4	Bhiman Bus stop	0.30
5	Dharapani Chowk	2.20
6	Puspalpur Chowk	0.80
7	Dalmatia	0.70
8	Ram-Laxman Chowk	0.22
9	Radha Krishna Mandir Road	0.70
10	Dhalkebar	1.20
11	Dhalkebar Substation Road	1.60
12	Jamunibaas Bus stop	1.0
13	Dhumasan Road	0.20
14	Laalgadh	2.40
15	Bardibas	2.40
16	Gaushala	0.20
17	Banke station	0.40
18	Phuljhor	0.30

S.N.	Name of Urban Area/ Settlement	Approximate Length (km)
19	Ranigunj Chowk	1.40
20	Laalbandi Chowk	2.60
21	Nawalpur Chowk	1.40
22	Ganesh Chowk	0.60
23	Ganesh Chowk-2	0.60
24	Harion	3.80
25	Naya Road	2.80
26	Purano Chauki	1.00
27	Karmaiya Road Junction	0.35
28	Kali Mandir	0.35
29	Chandrapur	2.60
30	Chandranigahapur	2.60
31	Nijgadh	3.40
32	Dhansar	0.30
33	Pathalaiya	1130
	Total Length (in m)	**42.60**

5.1.5 Major Road Junctions

The project highway section crosses several National, Provincial, and Local roads. Similarly, the highway meets with many accesses from the adjacent land plots including the private properties. The major junctions (four-leg and three-legs) have been identified during inventory and detailed reconnaissance of the Project Road at the initial stage. After the traffic survey and analysis for the Project Road, the consultant has recommended the major junctions to be improved considering provisions of relevant codes for the four-lane divided highway category. The Major Junctions on the Project Road are identified based on important cross roads and traffic intensity, the same are presented vide **Table 5.4**. The intersection types have mainly been decided to be four lagged and T-type. Furthermore, the urban area with the significant level of local traffic the highway upgradation has been proposed for the provision of Vehicle and pedestrian underpass.

Table 5.4: Major Junctions on the project road

Sr No	Name of Location	Chainage (km+m)	Intersection Type	Remarks
1	Goddar Bazar	239+740	Four Legged	
2	Bhiman Chowk	246+250	Four Legged	
3	Dharapani Chowk	247+650	Four Legged	
4	Kanxi Bazar	248+720	Four Legged	

Sr No	Name of Location	Chainage (km+m)	Intersection Type	Remarks
5	Puspalpur Chowk	252+050	Four Legged	
6	Laalbhiti Chowk	254+000	Four Legged	Staggered
7	Shreepur Chowk	255+100	Four Legged	
8	Dhalkebar 400KV Substation Road	258+180	Four Legged	
9	Jamunibaas Bus Stop	259+800	Four Legged	
10	Bardibas-1	268+880	Three Legged	Right
11	Bardibas-2	270+350	Three Legged	Right
12	Bardibas-3	271+380	Four Legged	
13	Bardibas-4	281+500	Three Legged	Left
14	Ishworpur-1	283+180	Three Legged	Left
15	Ishworpur-2	289+230	Three Legged	Left
16	Ishworpur-3	290+000	Three Legged	Left
17	Ranigunj Chowk	291+300	Four Legged	Staggered
18	Lalbandi-1	294+900	Four Legged	Staggered
19	Lalbandi-2	295+700	Four Legged	
20	Lalbandi-3	300+760	Three Legged	Right
21	Hariwon-1	301+620	Four Legged	
22	Harion-2	303+000	Four Legged	
23	Bagmati-1	309+380	Three Legged	
24	Bagmati-2	309+850	Three Legged	
25	Bagmati-3	310+400	Four Legged	
26	Karmaiya Road Junction	311+900	Four Legged	
27	Bagmati River Bridge	313+400	Four Legged	
28	Chandrapur-1	314+720	Three Legged	Left
29	Chandrapur-2	317+400	Three Legged	Right
30	Chandrapur-3	324+540	Three Legged	
31	Nijgadh-1	339+100	Three Legged	Left
32	Nijgadh-2	342+120	Three Legged	Left
33	Nijgadh-3	343+180	Three Legged	Right
34	Nijgadh-4	346+000	Three Legged	Right
35	Nijgadh-5	346+720	Three Legged	Right
36	Nijgadh-6	347+600	Three Legged	Left
37	Nijgadh-7	350+950	Three Legged	
38	Nijgadh-8	353+150	Three Legged	

Sr No	Name of Location	Chainage (km+m)	Intersection Type	Remarks
39	Nijgadh-9	353+950	Three Legged	Left
40	Jitpur, Simara-1	355+900	Three Legged	Left
41	Jitpur, Simara-2	357+830	Three Legged	Left
42	Jitpur, Simara-3	362+080	Three Legged	Left

5.2 Traffic Survey

The main objective of carrying out various types of traffic surveys is to formulate the traffic prediction model for the Design Period. Based on the predicted traffic at the end of the design year, traffic analysis for the Level of Service (LOS) and capacity analysis has been performed. The types of traffic surveys carried out by the Consultant's team are as:

a. Continuous Classified Volume Count,
b. Turning Movement Count at Junction
c. Origin -Destination (O-D) Survey,
d. Speed and Delay Survey,
e. Axle load Survey.

5.2.1 Continuous Classified Volume Count

The collection of traffic data plying on the Project Road is comprised of continuous classified traffic volume count. This was carried out at the identified important locations along the project road. The classified count data for the mid-block sections as well as the turning movements at the major junctions have been manually counted from the video captured at the project site. The continuous classified volume count was carried out for continuous 72 hours (three days) duration at identified important locations.

The traffic data collected from the field survey are taken as the base year data for carrying out traffic forecast for Design Period. Similarly, the traffic count data with the separate turning movement at the junctions are considered for carrying out the junction capacity analysis. The locations selected for conducting Continuous Classified Volume Count survey on the Project Road are as stated below:

- Pathlaiya – From 22.12.21 to 24.12.21
- Chandranigahapur – From 15.12.21 to 17.12.21
- Nawalpur – From 15.12.21 to 17.12.21

- Bardibas – From 22.12.21 to 24.12.21
- Dhalkebar – From 19.12.21 to 21.12.21

Three-day continuous traffic count data has been recorded through Videography at above locations. The video images of the respective locations were manually counted by the team of Traffic Engineers at the office. The traffic count has been managed by recording all types of vehicles as per their turning movement at the junctions. The vehicle count data (traffic stream) has been summarized in terms of Average Daily Traffic (ADT) and Passenger Car Unit (PCU). The traffic count carried out in the prescribed format, which is shown in **Table 5.5.**

Table 5.5: Classified Traffic count format

Department of Roads																																			
Development Cooperation Implementation Division																																			
Strategic Road Connectivity and Trade Improvement Project (SRCTIP)																																			
Deatil Design of upgradation of Kalama - Dhakebar -Pathlaiya Section of Mahendra Highway and Bridges																																			
Seasonal Factor: 0.94																																			
Year: 2021/22								**Station;**																											
Leg:	**Pat hilaiya**							**A:**	**From**												**C:**	**To**													
Start Time	**End Time**	**Truck**						**Bus**						**Car**		**Motor Cycle**		**Utility Vehicles**		**4Wheel Drive**		**Tractor**		**3-Wheeler**		**Power Triller**		**Bicycle**		**Rickshaw**		**Bullock Cart/ Hand Cart/ Tanga**	
		Multi axle		**Heavy**		**Light**		**Big**		**Mini**		**Micro**																							
		a	**c**	**a**	**c**	**a**	**c**	**a**	**c**	**a**	**c**	**a**	**c**	**a**	**c**	**a**	**c**	**a**	**c**	**a**	**c:**	**a**	**c**	**a**	**c**	**a**	**c**	**a**	**c**	**a**	**c**	**a**	**c**
Day1 (Date : ….....)																																			
Sub-Total																																			
Day1 (Date : ….....)																																			
Sub-Total																																			
Day 3 (Date: ….....)																																			
Sub-Total																																			
Total																																			
Average Daily Traffic (ADT)																																			
PCU Factors		3	3	3	3	1.5	1.5	3	3	3	3	1.5	1.5	1	1	0.5	0.5	1.5	1.5	1	1	2	1.5	1.5	1.5	1.5	2	0.5	0.5	1.5	1.5	6	6
Average Daily Traffic (ADT), PCU																																			
Average Annual Daily Traffic (AADT), PCU																																			
Total AADT, PCU for a																																			
Total AADT, PCU for c																																			

The classified traffic count at the junctions was managed by recording the traffic flow with the turning movement by noting down the data (classified count) for the 15-minute duration.

5.2.2 Origin – Destination (O-D) Survey

The OD survey was carried out for determining diverted traffic to the consecutive routes. Improvement of road network may cause the existing traffic to divert to an alternative route if, it any other parallel road becomes fast or cheaper than the existing route currently being used. The benefits arising from such diverted traffic are calculated separately from the normal and generated traffic, and are based on the difference in total journey costs on the alternative routes. The field data under the O-D survey was collected at the two junctions namely at Dhalkebar and Pathlaiya. The existing traffic diversion at the Daklebar and Pathlaiya are objects of the O-D study. The major traffic flow to be analyzed is the traffic volume from the southern part of the country to Kathmandu. Therefore, traffic diversion to the alternative routes (BP Highway, Fast Track, and Hetauda route to Kathmandu) using KDP upgraded four-lane highway was analyzed in the route choice analysis. The road network for diversion analysis (OD survey and analysis) is based on the schematic diagram shown in **Figure 5.2**. A detailed analysis of the O-D data was performed by the team of Traffic Engineers, which has been described in relevant para below. The format adopted for carrying out O-D Survey has been presented vide **Table 5.6** below.

Table 5.6: Format of the OD Survey

Kamala - Dhalkebar - Pathlaiya Road Undrading Project												
Origin-Destination Survey												
Station:		Nagdhunga					**Day & Date:**		28-Dec-21			
Road		Tribhuwan Rajpath					**Surveyor:**		Shyam/Rajan			
Pavement		Bituminous pavement					**Direction:**		Naubise			
S/N	**Arrival Time**	**Vehicle Class**	**Origin**		**Destination**		**Travel Time**	**Pax. No**	**Freight**			
			Place	**District**	**Place**	**District**			**Type s of Mode**	**Load Wt.**	**Volu me (E/P/**	
1												
2												

5.2.3 Speed and delay survey

The speed and delay survey of the existing traffic flow along the project road is important for considering the base year traffic flow pattern and the overall performance of the existing traffic along the KDP road. The speed and video recording were carried out by using the GPS fitted Dashboard video camera on the moving vehicle. Two movements to-and-from Pathlaiya to

Kamala were recorded for the analysis of operating speed and causes of the delay along the Project Road.

As the result of the initial analysis, the reduction of operating speed may be caused due to:

- The traffic flow condition: increased volume, mixed traffic conditions (especially local traffic)
- Build-up highway sections: urbanized centers and market areas,
- Narrow roadway sections: especially at the bridge approaches,
- Traffic control: Traffic police posts record the vehicular entry and exit from major market areas,
- Physically deteriorated roadway sections: damaged pavement edge and shoulder conditions create the hurdle to the overtaking and passing movements along the highway,
- Diversion of traffic flow at the construction sites: the bridge construction sites, highway maintenance sections, and
- Stops of public transport,

The speed and delay survey was conducted from extracted data of the field video information. The speed survey data was collected in the form of following table as shown in **Table 5.7**. The average speed of the specific sections have been recorded and the causes of the speed reduction has been identified.

Table 5.7: Speed Delay study data format

Distance		Distance (m)	Speed variation in Nawalpur- Chapur					Land use/ Roadside activity
From	To		Average Speed	Standard deviation	Top speed	Median Speed	Lowest Speed	

The video records have been analyzed using the dash board camera software (Mivue manager) as shown in **Figure 5 3**.

Figure 5.3: Speed and Delay study analyzing the video clip on the desktop platform (MiVue Manager)

5.2.4 Axle load Survey

The movement of commercial vehicles and respective loading patterns were collected by the axle load survey. The axle load survey was carried out at Pathlaiya and Dhalkebar junctions of the Project Road. The axle load survey was carried out by using analog-type weighing pads. The load of each wheel configuration (single and double) was recorded for each axle of the commercial vehicles. The axle load intensity is important for the design of pavement layers. The axle load was measured for each type of vehicle in full, partial, and empty loading conditions. The analysis of the axle load survey is concluded for the determination of equivalence factors for each axle of the commercial vehicle. The format utilized for carrying out Axle Load survey has been presented as **Table 5.8** below. The photograph of Analog type Axle load measurement pad used for the survey is provided vide **Figure 5.4** and photograph of the Axle load survey in progress at Pathlaiya is presented as **Figure 5.5.**

Table 5.8: Axle Load Survey format

Axle Load Survey																			
Project: Detailed Design of Upgradation of Kamala-Dhalkebar Pathlaiya										Date of Survey				Time of Weighing: from …….. To ……					
										Direction: from …… to ……									
Survey Station: **Pathlaiya**																			
SN	Vehicle Class	Load, Ton								Total Load Axle - 1, ton	Total Load Axle - 2, ton	Total Load Axle - 3, ton	Total Load Axle - 4, ton	GVW, ton	Commodity	Loading intensity: F/P/E	Origin	Destination
		Axle-1		Axle-2		Axle-3		Axle-5										
		Left wheel Load, Ton	Right wheel Load, Ton	Left wheel Load, Ton	Right wheel Load, Ton	Left wheel Load, Ton	Right wheel Load, Ton	Left wheel Load, Ton	Right wheel Load, Ton									

Figure 5.4:Analog type Axle Load measuring pad

Figure 5.5:Axle Load measurement at Pathlaiya

5.3 Traffic Survey Data Analysis

The traffic survey results as well as analysis are very important in the decision of the overall geometric as well as safety parameters. Therefore, the analyses of the results are directly related to the specific parameter of the design. Furthermore, the forecasting traffic is one of the important and foremost steps of the design of highways. The base year results as the primary data and forecasting are essential for describing the future scenario in terms of Level of Service and the expected.

5.3.1 Classified traffic Count Survey

The Traffic count data collected for continuous three days at five locations was calculated for each day and included in the prescribed format presented vide **Table 5.5** above. The Average Daily Traffic (ADT) arrived at up on process of data for each location (including the Nijgadh) has been provided vide **Table 5.9, Table 5.10, Table 5.11, Table 5.12, Table 5.13 and Table 5.14** for reference.

Table 5.9: Traffic count result at Kamala – Dhalkebar, ADT, VPD

S/N	Vehicle type	ADT, VPD
1	MA Truck	1277
2	Heavy Truck	731
3	Mini-truck	133
4	Large-bus	560
5	Mini-bus	100
6	Micro-bus	659
7	Car	707
8	Motorcycle	6694
9	Utility vehicle	676
10	Four-wheel drive	927
11	Tractor	165

Table 5.10: Traffic count result at Dhalkebar - Bardibas, ADT, VPD

S/N	Vehicle type	ADT, VPD
1	Multi-axle Truck	1244
2	Heavy-Truck	795
3	Mini-truck	146
4	Large-bus	680
5	Mini-bus	104
6	Micro-bus	562
7	Car	719
8	Motorcycle	7365
9	Utility vehicle	813
10	Four-wheel drive	1061
11	Tractor	160

Table 5.11: Traffic count result at Bardibas - Nawalpur, ADT, VPD

S/N	Vehicle type	ADT, VPD
1	Multi-axle Truck	851
2	Heavy-Truck	576
3	Mini-truck	213
4	Large-bus	716
5	Mini-bus	134

S/N	Vehicle type	ADT, VPD
6	Micro-bus	371
7	Car	696
8	Motorcycle	5994
9	Utility vehicle	670
10	Four-wheel drive	754
11	Tractor	139

Table 5.12: Traffic count result at Nawalpur - Chapur, ADT, VPD

S/N	Vehicle type	ADT, VPD
1	Multi-axle Truck	866
2	Heavy-Truck	682
3	Mini-truck	229
4	Large-bus	663
5	Mini-bus	163
6	Micro-bus	335
7	Car	722
8	Motorcycle	8779
9	Utility vehicle	622
10	Four-wheel drive	736
11	Tractor	284

Table 5.13: Traffic count result at Chapur - Nijgadh, ADT, VPD

S/N	Vehicle type	ADT, VPD
1	Multi-axle Truck	865
2	Heavy-Truck	731
3	Mini-truck	312
4	Large-bus	661
5	Mini-bus	188
6	Micro-bus	283
7	Car	722
8	Motorcycle	9481
9	Utility vehicle	531
10	Four-wheel drive	652
11	Tractor	402

Table 5.14: Traffic count result at Nijgadh - Pathlaiya, ADT, VPD

S/N	Vehicle type	ADT, VPD
1	Multi-axle Truck	796
2	Heavy-Truck	741
3	Mini-truck	461
4	Large-bus	791
5	Mini-bus	138
6	Micro-bus	180

S/N	Vehicle type	ADT, VPD
7	Car	882
8	Motorcycle	3188
9	Utility vehicle	449
10	Four-wheel drive	711
11	Tractor	133

5.3.1.1 Equivalent Factor for Passenger Car Unit

The traffic count results have been separately managed to express in terms of mid-block traffic volume, turning movements at the junction. The three days traffic count was converted into the Annual Average Daily Traffic (AADT) for each stream of traffic flow. The traffic count data has been interpreted for each homogenous section of the KDP section of E-W Highway. Equivalence factors for working out PCU

The Continuous Classified Volume Count numbers of the vehicles are converted into the Passenger Car Unit (PCU) by taking the following equivalence factors. The Equivalent Factors are considered as mentioned in Nepal Road Standard, Second Revision, the same are presented in **Table 5.15** below.

Table 5.15: Vehicle type and equivalence factors (Nepal Road Standards, 2070)

Sr	Vehicle Type	Equivalence Factor
1	Bicycle, Motorcycle	0.5
2	Car, Auto-Rickshaw, SUV, Light Van and Pick up	1.0
3	Light (Mini) Truck, Tractor, Rickshaw	1.5
4	Truck, Bus, Minibus, Tractor with trailer	3.0
5	Non-motorized Carts	6.0

5.3.1.2 Annual Average Daily Traffic (AADT)

Annual Average Daily Traffic has been worked out using seasonal variation factor as obtained using seasonal variation factor described in para below.

5.3.1.3 Seasonal variation

The Average Daily Traffic (ADT) was worked out by averaging the three days Traffic Volume Count data. Furthermore, the ADT has been converted into the Annual Average Daily Traffic (AADT) by using the seasonal factor. The seasonal factor for this highway was taken as 0.94. This seasonal factor has been adopted from the previous traffic count studies conducted by

DOR. The Continuous Classified Volume Count data has been converted in terms of AADT in PCU.

The homogeneous sections adopted for Traffic survey and analysis has been presented vide **Figure 5.6**. The homogeneous section wise variation in Annual Average Daily Traffic (AADT) in terms of PCU has been presented vide **Figure 5.7**. The summary of base year traffic converted in terms of AADT (in Vehicles per-day and PCU) has been shown in the **Table 5.16 and Table 5.17** below.

Table 5.16: Summary of Annual Average Daily Traffic (AADT), (Vehicles per day)

Highway Sections (KDP)	Truck			Bus			Car	Motor Cycle	Utility Vehicles	4Wheel Drive	Tractor	3-Wheeler	Power Triller	Bicycle	Rickshaw	Bullock Cart/ Hand
	Multi axle	Heavy	Light	Big	Mini	Micro										
Kamala - Dhalkebar	1200	687	125	526	94	620	665	6293	635	872	155	237	0	1038	0	0
Dhalkebar- Bardibas	1169	747	137	639	97	529	676	6923	764	997	150	301	0	1171	0	0
Bardibas - Nawalpur	800	542	201	673	126	348	655	5634	630	708	131	401	0	1003	0	0
Nawalpur - Chapur	814	641	216	623	153	315	679	8252	585	692	267	1287	0	1296	0	0
Chapur - Nijgadh	813	687	294	621	176	266	679	8912	499	613	378	1687	0	1162	0	0
Nijgadh - Pathlaiya	748	697	434	744	129	170	829	2996	422	668	125	221	0	124	8	0

Table 5.17: Summary of Annual Average Daily Traffic (AADT), (PCU)

Highway Sections (KDP)	Truck			Bus			Car	Motor Cycle	Utility Vehicles	4Wheel Drive	Tractor	3-Wheeler	Bicycle	SUM
	Multi axle	Heavy	Light	Big	Mini	Micro								
Kamala - Dhalkebar	3601	2062	188	1579	282	930	665	3146	953	872	233	355	519	15386
Dhalkebar- Bardibas	3508	2242	206	1917	292	793	676	3462	1146	997	225	452	586	16502
Bardibas - Nawalpur	2399	1625	301	2018	379	523	655	2817	945	708	196	602	501	13669
Nawalpur - Chapur	2441	1924	323	1869	458	473	679	4126	877	692	400	1930	648	16840
Chapur - Nijgadh	2440	2062	440	1863	529	400	679	4456	748	613	566	2530	581	17909
Nijgadh - Pathlaiya	2244	2091	650	2231	388	254	829	1498	633	668	188	331	62	12067

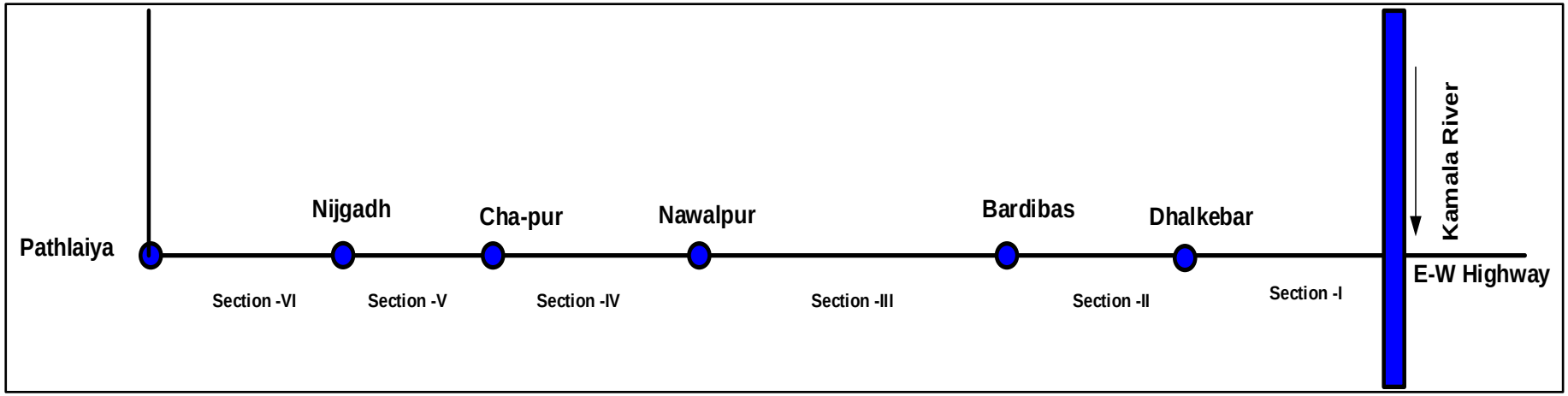


Figure 5.6: Homogenous Sections of the Project Road

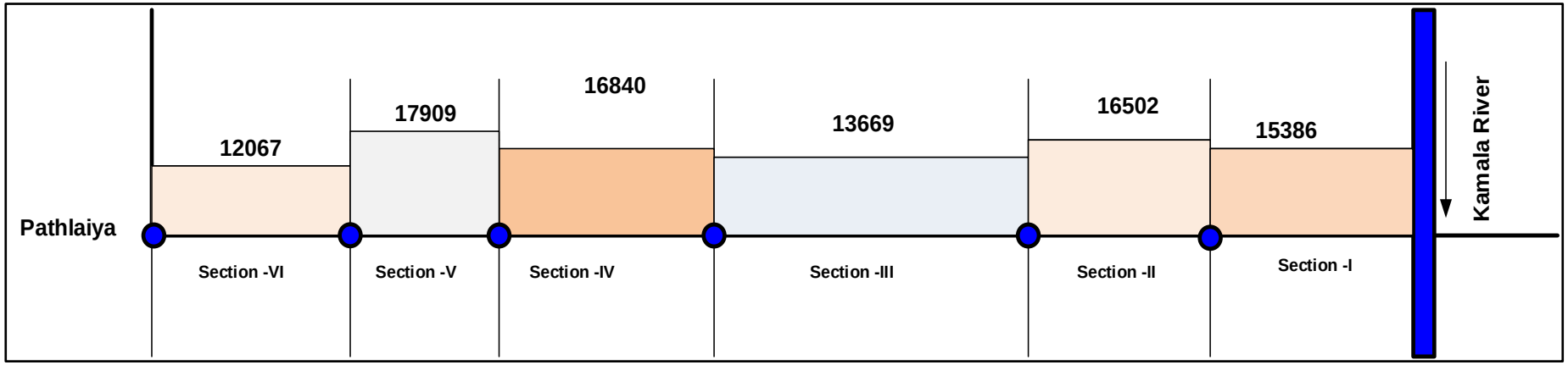


Figure 5.7: Section wise Traffic Volume Variation (AADT, PCU)

5.3.1.4 Traffic Composition

The **Table 5.18** below shows the summary of composition of traffic for each homogeneous section for reference.

Table 5.18: Homogeneous Section vise Traffic Composition

S/N	Vehicle type	Kamala - Dhalkebar	Dhalkebar - Bardibas	Bardibas- Nawalpur	Nwalpur - Chapur	Chapur - Nijgadh	Nijgadh - Pathlaiya
1	MA Truck	1277	1244	851	866	865	796
2	Truck	731	795	576	682	731	741
3	Minitruck	133	146	213	229	312	461
4	Large bus	560	680	716	663	661	791
5	Mini bus	100	104	134	163	188	138
6	Micro bus	659	562	371	335	283	180
7	Car	707	719	696	722	722	882
8	Motorcycle	6694	7365	5994	8779	9481	3188
9	Utility vehicle	676	813	670	622	531	449
10	Four wheel drive	927	1061	754	736	652	711
11	Tractor	165	160	139	284	402	133

The representation of Traffic composition worked out in Graphical form has presented for each homogeneous section vide **Figure 5.8 to Figure 5.13** for reference. Similarly, the proportions of the freight, passenger and utility vehicles for each station is given in **Figure 5.14, Figure 5. 15, Figure 5.16, Figure 5.17, Figure 5.18 and Figure 5.19**

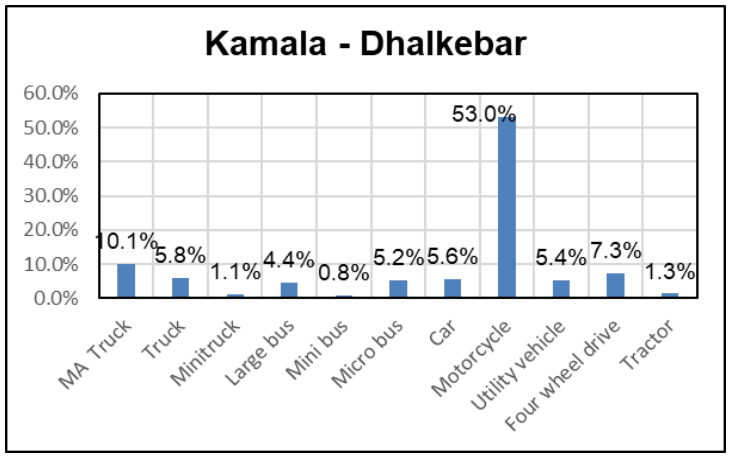


Figure 5.8: Traffic Composition (Kamala – Dhalkebar)

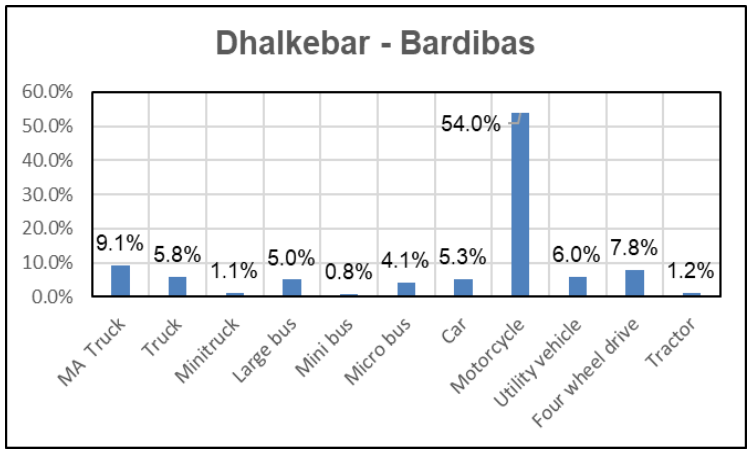


Figure 5.9: Traffic Composition (Dhalkebar – Bardibas)

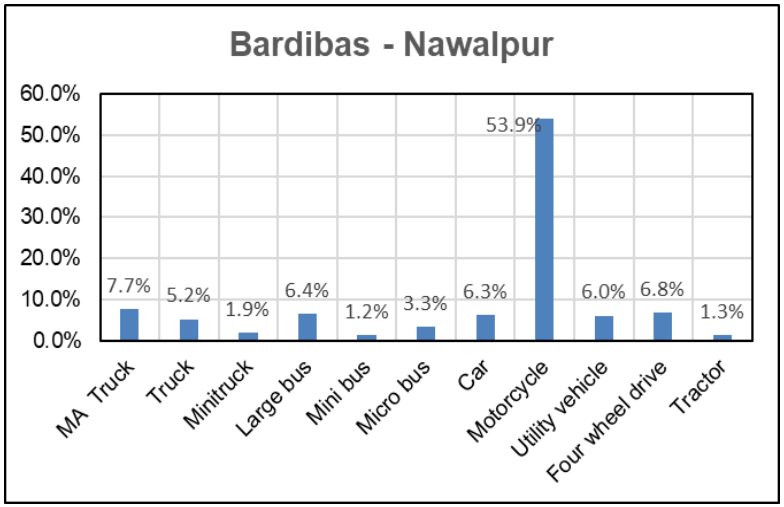


Figure 5.10: Traffic composition (Bardibas – Nawalpur)

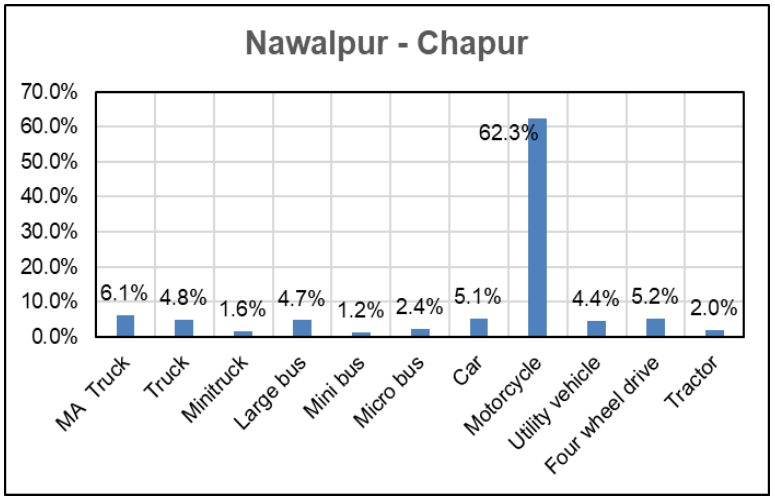


Figure 5.11: Traffic Composition (Nawalpur – Chapur)

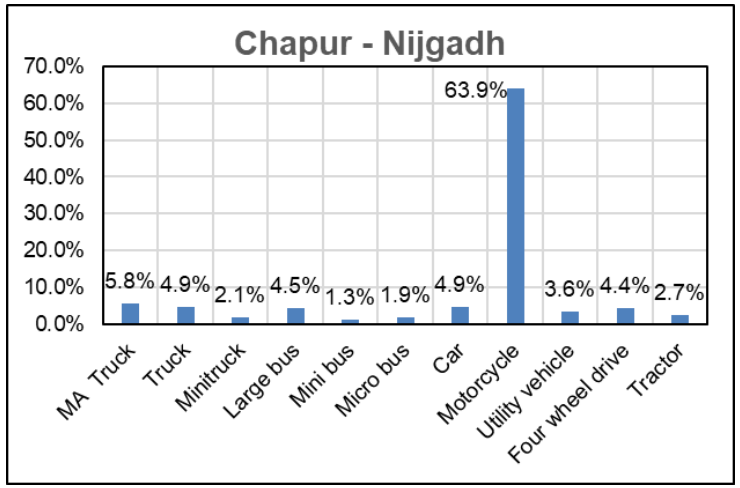


Figure 5.12: Traffic composition (Chapur- Nijgadh)

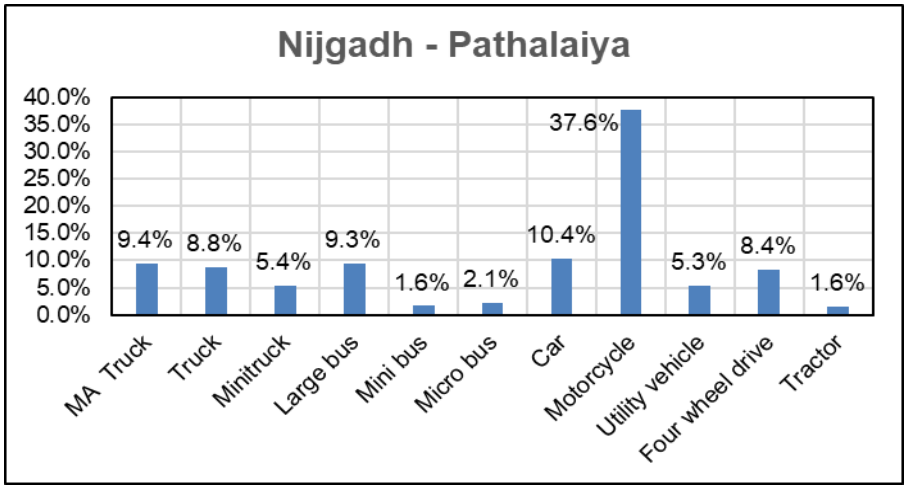


Figure 5.13: Traffic composition (Nijgadh – Pathlaiya)

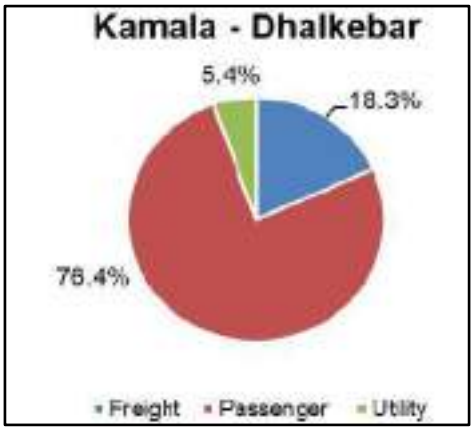


Figure 5.14: Proportion of vehicles (Kamala – Dhalkebar)

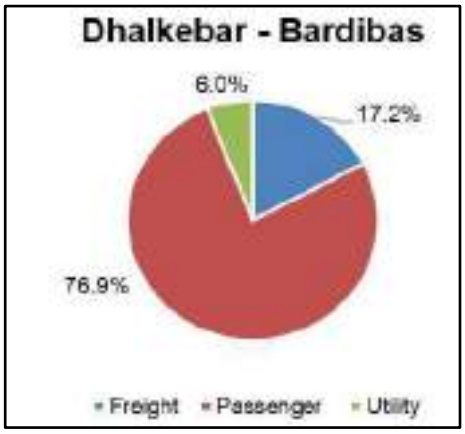


Figure 5.15: Proportion of vehicles (Dhalkebar – Bardibas)

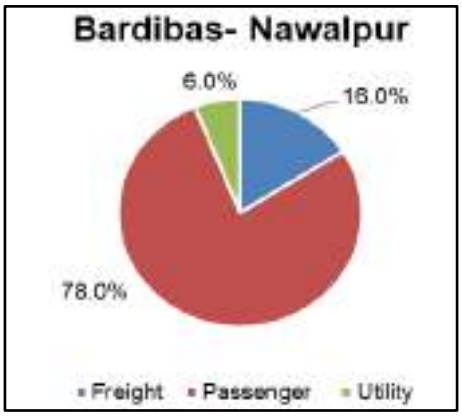


Figure 5.16: Proportion of vehicles (Bardibas- Nawalpur)

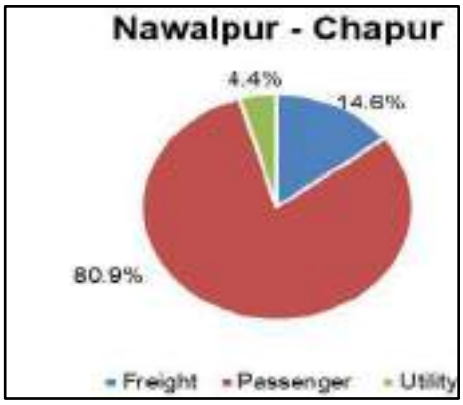


Figure 5.17: Proportion of vehicles (Nawalpur – Chapur)

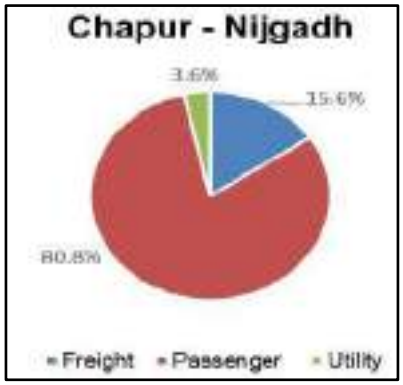


Figure 5.18: Proportion of vehicles (Chapur – Nijgadh)

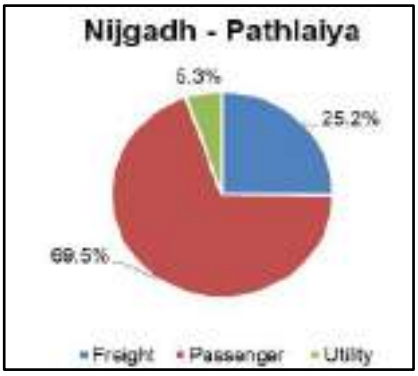


Figure 5.19: Proportion of vehicles (Nijgadh – Pathalaiya)

5.3.2 Turning Movement Count at Junction

The turning movement count was conducted at five major junctions on the project road namely, Dhalkebar, Bardibas, Nawalpur, Chandranigahpur, and Pathlaiya. The traffic counts

at the major junctions have been recorded as per the turning movement in prescribed format for each arm of the Junction. The turning traffic movement in PCU (AADT) at the junctions is presented in **Figure 5.20, Figure 5.21, Figure 5.22, Figure 5.23 and Figure 5.24**.

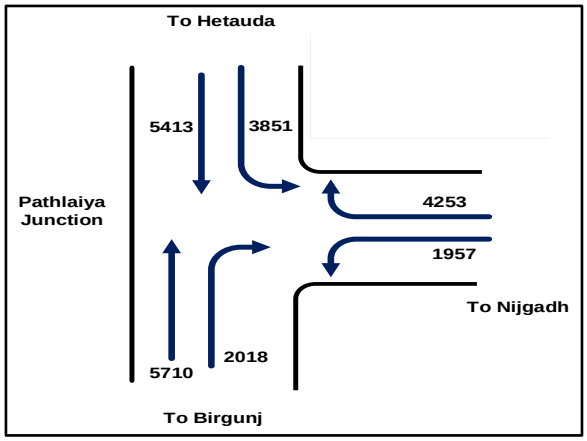


Figure 5.20: Turning Movement at Pathlaiya

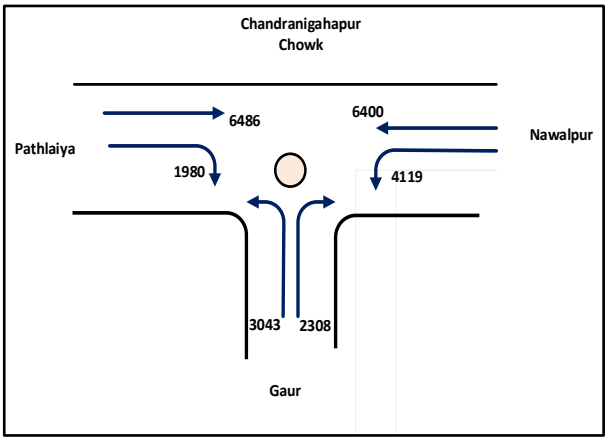


Figure 5.21: Turning Movement at Chapur

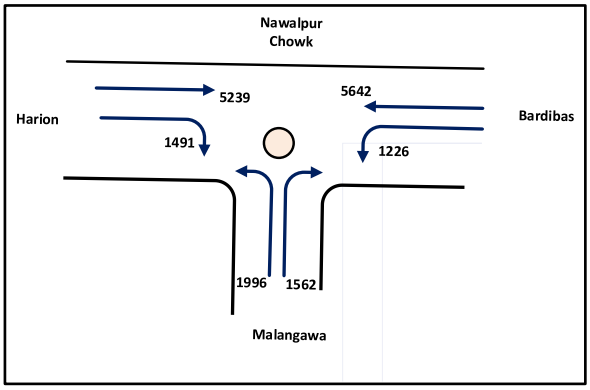


Figure 5.22: Turning Movement at Nawalpur

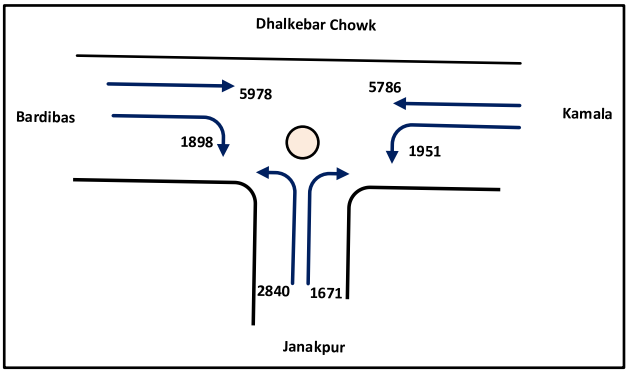


Figure 5.23: Turning Movement at Dhalkebar

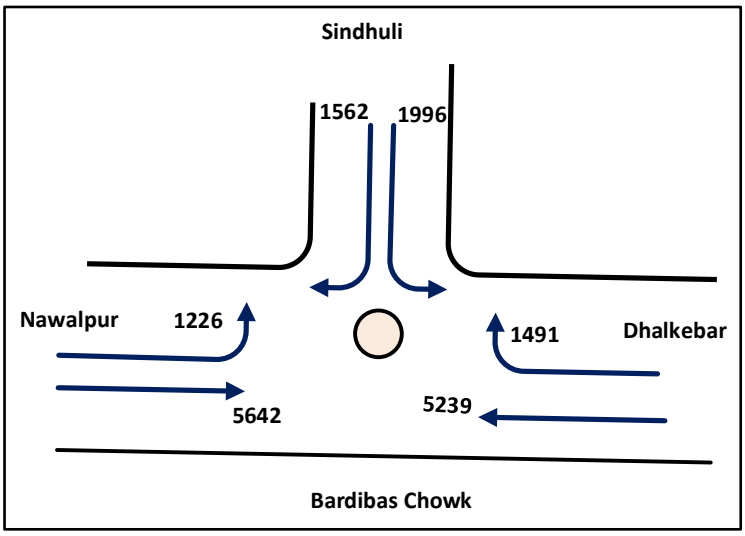


Figure 5.24: Turning movement at Bardibas junction

5.3.3 Origin – Destination (O-D) Survey

The Origin - Destination survey data collected from the field were analyzed for the determination of traffic generation through diversion after the completion of project road upgradation as well as the completion of the Kathmandu Terai Fast Track (KTFT) Expressway Road project by the Consultant. The determination of the percentage diversion for the respective origin and destination worked out is presented in **Table 5.19** and in **Table 5.20** below.

Table 5.19: Traffic destinations from the origin of Bardibas East (consultant's survey)

Destination	Origin: Bardibas East						
	Multi-axle	Heavy	Light	Big	Mini	Micro	Car
Narayangadh-west	13.65%	3.40%	4.60%	4.54%	5.60%	0%	2.49%
Pokhara-muglin	8.36%	2.50%	8.40%	6.67%	3.40%	0%	12.73%
Kathmandu	21.62%	77.44%	47.37%	44.50%	34.88%	70.71%	54.83%
Narayangadh	8.36%	3.61%	4.80%	14.08%	6.24%	0%	9.27%
Bara (Nijgadh, Amlekhgunj)	7.90%	3.70%	3.60%	8.96%	10.10%	0%	0.34%
Hetauda	7.80%	3.60%	8.90%	4.92%	8.39%	0%	10.51%
Birgunj	2.60%	1.70%	6.80%	6.84%	9.45%	0.20%	6.64%
Sarlahi/Rautahat	22.60%	2.70%	7.23%	2.91%	7.46%	0%	1.31%
Bardibas Chowk Area	3.70%	0.70%	5.70%	2.69%	7.12%	29.09%	1.11%
Sindhuli	3.40%	0.65%	2.60%	3.88%	7.36%	0%	0.76%

Table 5.20: Traffic destinations from the origin at Hetauda west (consultant's survey)

Destination	Vehicle Category	Origin							
		Bardibas-East	Birgunj/Raxaul	Sarlahi/Rautahat	Nijgadh	Parsa	Bara	Hetauda	Total
Narayangadh-West	**Truck**	27.7%	20.7%	17.2%	9.7%	17.4%	20.0%	15.6%	20.2%
	Bus	11.3%	8.7%	6.8%	0.0%	0.0%	2.4%	13.5%	9.3%
	Car	11.0%	7.3%	4.4%	3.6%	1.8%	4.4%	11.4%	7.1%
Pokhara-Muglin	**Truck**	18.2%	11.5%	22.1%	8.1%	15.4%	15.6%	18.1%	16.0%
	Bus	14.5%	14.5%	13.0%	33.3%	54.6%	16.7%	23.0%	15.8%
	Car	28.3%	19.2%	25.3%	16.4%	10.7%	20.9%	17.6%	21.5%
Kathmandu	**Truck**	31.1%	45.8%	37.2%	41.9%	32.2%	31.1%	49.7%	40.7%
	Bus	58.4%	61.5%	58.6%	16.7%	18.2%	69.1%	41.9%	58.2%
	Car	40.3%	51.0%	53.0%	61.8%	51.8%	46.5%	47.7%	48.6%
Narayangadh	**Truck**	23.0%	22.0%	23.4%	40.3%	35.0%	33.4%	16.7%	23.2%
	Bus	15.8%	15.3%	21.6%	50.1%	27.3%	11.9%	21.6%	16.7%

Destination	Vehicle Category	Origin							
		Bardibas-East	Birgunj/Raxaul	Sarlahi/Rautahat	Nijgadh	Parsa	Bara	Hetauda	Total
	Car	20.5%	22.5%	17.3%	18.2%	35.7%	28.2%	23.3%	22.9%

The result of the OD survey data from the field survey has been utilized for the determination of the diverted traffic for the new road network. The future estimation of the traffic diversion to the newly developed transport links such as Fast Track (merging at Nijgadh to KDP) has been performed on the basis of the O-D survey results.

5.3.3.1 Speed and Delay Survey

The Speed and Delay Study has been carried out for the determination of existing impedances to the traffic flow. The continuous speed has been recorded using the dash board camera fitted with the GPS. The speed and the types of the roadside obstruction to the vehicular movement has been analyzed in the video-clips at office. The entire project alignment has been analyzed for the six homogenous sections.

Most of the project road alignment is comprised of low to highly populated market areas. The significant speed has been observed along the critical locations such as densely populated areas, narrow bridges as well as crossings of the major roads. The speed variations along the various roadside features have been recorded and the graphical interpretations of the speed has been taken to describe the critical as well as normal highway sections with respect to the operating speed. The graphical representation of the speed variation shows the locations of the respective instant speed values. All six homogenous sections have been analyzed with the help of these graphs.

After the observation of the video clips of the speed-delay survey; the major causes of speed reduction were found as:

- Narrow bridge section (while commercial vehicles are coming from the opposite direction),
- Road pavement conditions: poorly maintained pavement conditions (bridge as well as highway carriageway) cause the reduction in speed,
- Market and settlement area (where the significant local vehicular and pedestrian traffic)

- Junctions of the crossing roads
- Presence of local non-motorized as well as two wheelers traffic including the pedestrian,
- Disturbances of parked vehicles,
- Physical barriers created for the traffic checking posts by the Police,
- Absence of the overtaking zones along some highway sections,
- Highway crossing (walking) by the cattle as well as monkeys,
- Detour of the Road construction or maintenance works.

The speed variation graphs for each homogenous section is presented in **Figure 5.25 Figure 5.26, Figure 5.27, Figure 5.28, Figure 5.29, and Figure 5.30.** This graph shows the critical location of the speed reduction and normal road sections with the higher operation speed. The average speed of the running vehicle could represent the average travel time for the existing KDP section. It could justify the improvement of the highway speed after the upgradation.

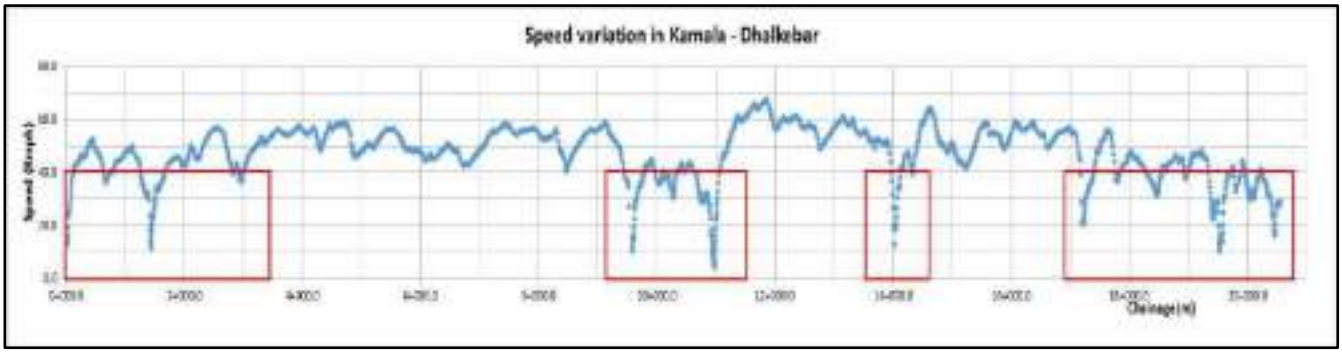


Figure 5.25: Speed variation for Kamala – Dhalkebar section (From kamala)

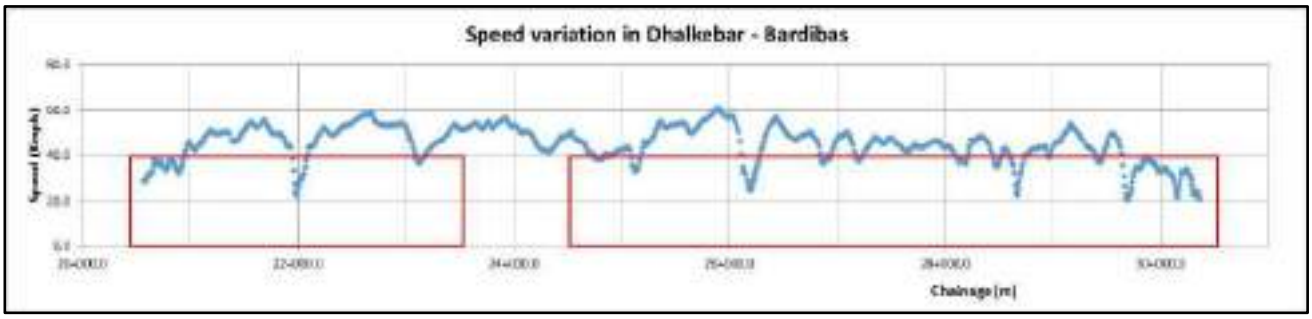


Figure 5.26: Speed variation for Dhalkebar – Bardibas section (From kamala)

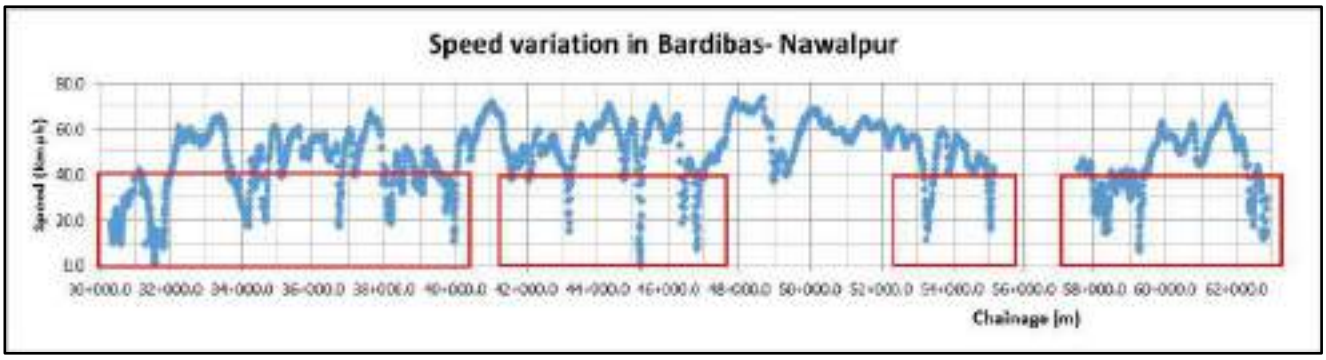


Figure 5.27: Speed variation for Bardibas - Nwalpur section (From kamala)

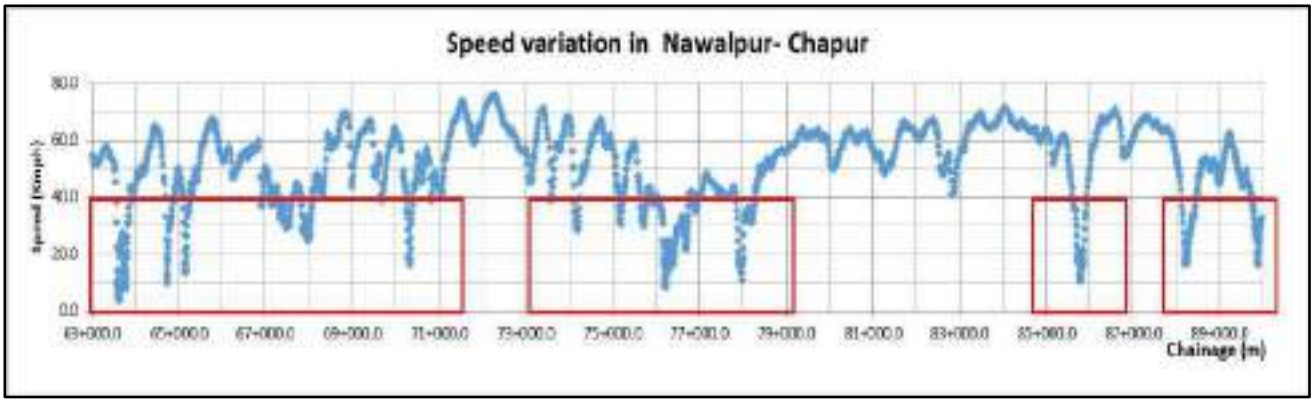


Figure 5.28: Speed variation for Nawalpur – Chapur Section (From kamala)

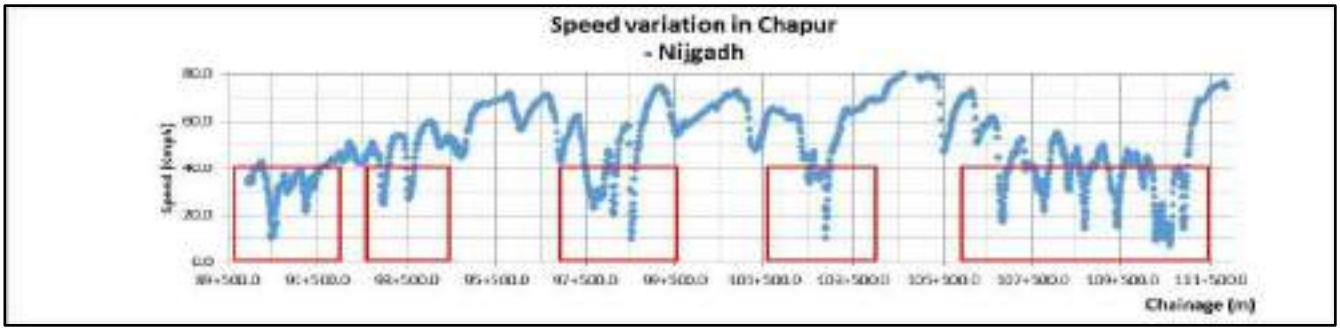


Figure 5.29: Speed variation for Chapur – Nijgadh Section (From kamala)

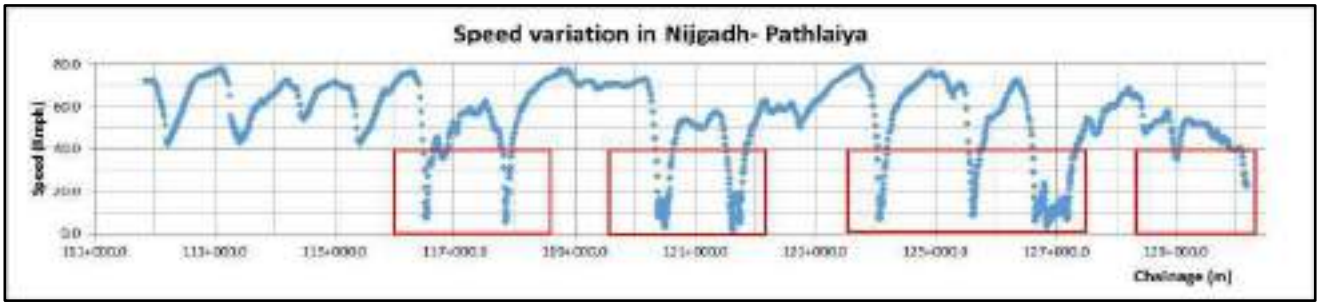


Figure 5.30: Speed variation for Nijgadh – Pathlaiya Section (From kamala)

The average speed at the critical locations has been significantly reduced the various reasons as mentioned above. The normal section of the highway has shown the higher operating speed. The anticipated Level of Service (LoS) of upgraded highway can be estimated after having the improvement of those friction factors of the speed reduction. The speed variation of six homogenous sections of the KDP project road has been shown in **Table 5.21**.

Table 5.21: Average Speed (km/ph) for Homogeneous Sections

S.N.	KDP Sections	Speed at Critical Sections (km/h)	Speed at Normal Sections (km/h)
1	Kamala- Dhalkebar	29.98	50.68
2	Dhalkebar- Bardibas	33.38	48.24
3	Bardibas - Nawalpur	25.69	53.99
4	Nawalpur - Chapur	26.47	55.44
5	Chapur - Nijgadh	28.01	56.67
6	Nijgadh - Pathlaiya	17.24	59.90

The most critical section of the project is identified the Nijgadh – Pathlaiya section. The critical section of this location is the under-construction bridge site where, the speed decreases drastically due to diversion in form of earthen narrow road. The speed of traffic flow at the diversion was observed very low due to the poorly maintained temporary roadway. Similarly, the higher speed was also observed in this section due to the undisturbed roadway traffic in the stretch of forest area.

5.3.3.2 Axle Load Survey

The axle load survey was conducted at two locations for two days duration by the survey team of the Consultant. The four set of data collected through survey (separate data for each direction at both locations) has been analyzed for the determination of prevailing axle load intensity. Furthermore, the results of each set of data were averaged to determine the average equivalent factors for each category of vehicles.

The major findings of the truck loading along the existing highway is described as below:

- The axle load analysis was performed for the axle configuration of:
    - Axle configuration: 1.2 two axle trucks having dual wheel at the rear axle.
    - Axle configuration: 1.22 three axle trucks having tandem wheel configuration,
    - Axle configuration: 1.1.22 four axle trucks with the single wheel lift axle in between the front axle and rear tandem axle,
    - Axle configuration: 1.2.22 four axle truck with the dual wheel axle in between front and rear tandem axle.

- The commodity and the maximum loading of the freight vehicles:
  - The most heavily loaded 1.22 tandem trucks were found as the commodity of construction material transport from the quarry sites and average loading of 29 tonnes of gross vehicle weight (survey sample of Pathlaiya to Nijgadh section),
  - The axle load group of 1.2.22 types of truck were found average loading of 47.3 tonnes (sample from Pathlaiya),
  - Most heavily load trucks were found with the commodity of construction materials such as sand, aggregates and stones, coals, iron rods, cement and LPG Cylinders

The analysis of collected data was carried out to achieve Vehicle Damage Factor (VDF) for each category of vehicle at each test locations. The calculation sheets of VDF are attached under **Volume I-B** for reference.

The result of analysis of the axle load pattern for all types of axle group is shown in **Table 5.22**.

Table 5.22: Results of the location wise Vehicle Damage Factor (VDF)

S/N	Axle Survey Station	Axle configuration	VDF
1	Pathlaiya station day 1	MA Truck (1.1.22 and 1.2.22)	6.90
		Heavy (1.2 & 1.22)	6.13
		Mini truck	1.35
		Large Bus	0.68
		Minibus	0.04
		Microbus	0.00
2	Pathlaiya station day 2	MA Truck (1.1.22 and 1.2.22)	7.21
		Heavy (1.2 & 1.22)	6.51
		Mini truck	1.48
		Large Bus	0.62
		Minibus	0.52
		Microbus	
3	Dhalkebar day 1	MA Truck (1.1.22 and 1.2.22)	7.25
		Heavy (1.2 & 1.22)	4.57
		Mini truck	0.35
		Large Bus	0.68
		Minibus	0
		Microbus	0
4	Dhalkebar day 2	MA Truck (1.1.22 and 1.2.22)	
		Heavy (1.2 & 1.22)	5.49
		Mini truck	1.03
		Large Bus	1.19
		Minibus	0.05
		Microbus	0

The final VDF was derived from the above results are presented in **Table 5.23.** These values were taken as the design Vehicle Damage Factors (VDF) for the calculating Equivalent Standard Axles (in Million) which is one of the important parameters for the Pavement Design.

Table 5.23: Adopted Vehicle Damage Factor (VDF)

Vehicle Type	EF
MA Truck (1.1.22 and 1.2.22)	7.12
Heavy (1.2 & 1.22)	5.67
Mini truck	1.05
Large Bus	0.66
Minibus	0.20

5.4 Traffic Forecast

5.4.1 Past Traffic trend

The previous traffic count results of the DoR have been considered for the analysis of the trend of current traffic flow along the project road. The continuous classified volume count result at the specific count stations were tabulated for consideration. The traffic count stations along the project road and other connecting highways under consideration by the Department for traffic count at regular time interval were collected and are shown in **Figure 5.31**.

The Continuous Classified Volume Count in terms of Annual Average Daily Traffic (AADT) for each station along the project road are taken into consideration for assessing current traffic trend. Then data was averaged of three days of continuous count managed by the DoR. The Seasonal correction factors and the Passenger Car Unit (PCU) factors have been considered for calculating AADT. The locations of the traffic count stations along the project road adopted by DOR are Dhalkebar East (Station 30), Bardibas East (Station 31), Karmaiya (Station 38) and, Pathlaiya East (Station 41).

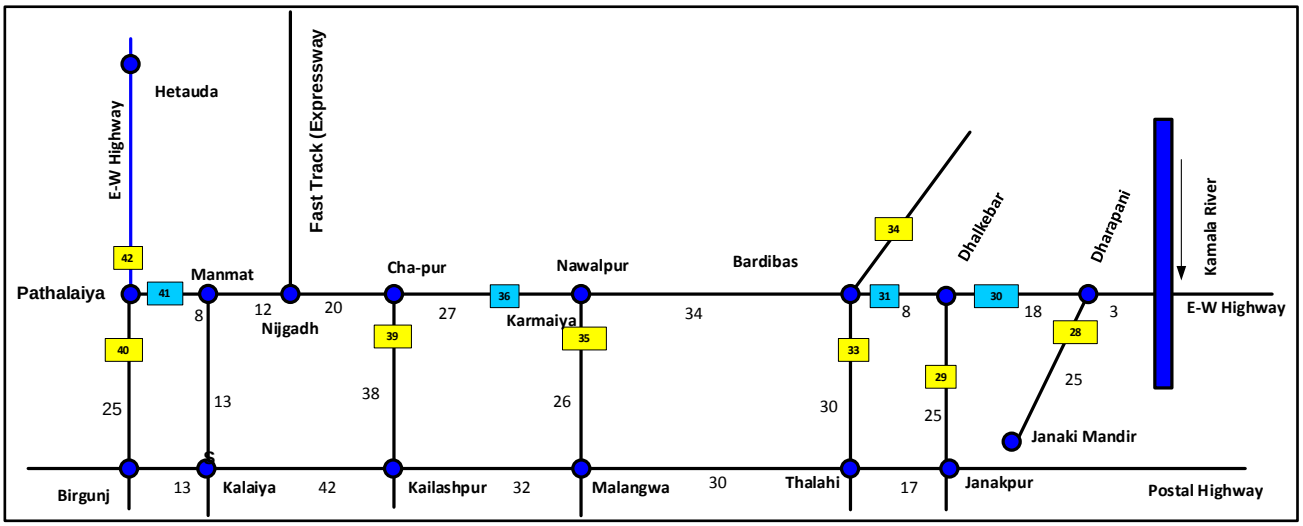


Figure 5.31: Traffic count stations in the project area

The analysis of the previous traffic data was considered for the period from 2011/12 to 2020/21 (7 years). The continuous classified volume count data for each traffic count station collected from authentic web site and is shown as Past Traffic Trend in **Table 5.24, Table 5.25, Table 5. 26, and Table 5.27**.

Table 5.24: Past Traffic Trend at Dhalkebar East (Station: 30)

Categories	Classified Volume Study (VPD) at Dhalkebar east						
	2011/12	**2012/13**	**2014/15**	**2015/16**	**2016/17**	**2018/19**	**2020/21**
Multi-axle truck	358	244	90	205	45	676	1149
Heavy Truck	293	392	311	332	502	580	874
Light truck	65	80	329	211	194	36	41
Big Bus	474	402	613	469	343	539	488
Mini Bus	77	110	36	64	84	390	101
Micro Bus	32	147	221	174	300	1050	734
Car	122	188	165	173	255	788	598
Motorcycle	1349	2663	1100	1538	2544	6929	7073
Utility vehicles	67	178	85	100	258	663	701
Tractor	105	204	81	120	78	154	167
Three-Wheeler	100	67	21	54	41	131	200
Four Wheel Drive	354	285	225	296	404	878	935
Power Tiller	9	0	0	2	4	0	0
Rickshaw	2	87	5	32	9	0	0
Bullock Cart	20	32	4	18	5	0	0
AADT (PCU)	**5468**	**6013**	**5433**	**5086**	**5489**	**15668**	**14481**

(Source: http://ssrn.aviyaan.com/traffic_controller)

Table 5.25: Past Traffic Trend at Bardibas East (Station: 31)

Categories	Classified Volume Study (VPD) at						
	2011/12	2012/13	2014/15	2015/16	2016/17	2018/19	2020/21
Multi-axle truck	239	232	96	158	365	2	1306
Heavy Truck	284	310	280	285	743	1397	604
Light truck	51	72	272	161	397	135	184
Big Bus	353	435	1201	892	708	533	563
Mini Bus	91	141	95	104	184	247	114
Micro Bus	24	96	107	84	560	333	511
Car	113	171	148	148	498	527	683
Motorcycle	1760	1591	2036	1799	4259	7301	5666
Utility vehicles	106	134	186	171	597	831	777
Tractor	146	135	111	123	129	217	167
Three-Wheeler	110	118	130	116	164	954	283
Four Wheel Drive	294	360	120	233	856	514	1057
Power Tiller	1	0	0	0	10	0	0
Rickshaw	34	57	0	22	12	0	0
Bullock Cart	13	3	1	5	7	32	0
AADT (PCU)	4867	5192	7666	5961	11056	14591	14115

(Source: http://ssrn.aviyaan.com/traffic controller)

Table 5.26: Past Traffic Trend at Karmaiya (Station No: 36)

Categories	Classified Volume Study (VPD) at							
	2011/12	2012/13	2014/15	2015/16	2016/17	2018/19	2019/20*	2020/21
Multi-axle truck	524	420	33	249	111	14	65	944
Heavy Truck	366	464	756	575	1355	1301	1229	1197
Light truck	93	100	146	126	585	111	344	18
Big Bus	699	576	821	736	536	467	687	694
Mini Bus	124	155	99	120	340	251	352	1
Micro Bus	63	165	310	237	262	502	187	334
Car	98	241	139	151	343	311	459	659
Motorcycle	1691	1060	2985	2230	2424	4554	6632	3045
Utility vehicles	99	132	135	136	560	556	653	337
Tractor	118	125	62	87	97	136	158	67
Three-Wheeler	57	129	43	50	37	154	1066	99
Four Wheel Drive	387	351	587	441	563	363	778	356
Power Tiller	0	0	17	14	51	0	1	0
Rickshaw	37	49	7	20	4	1	380	0
Bullock Cart	9	7	33	17	0	50	0	0
AADT (PCU)	7385	6684	8706	7151	10164	11488	14701	11468

(Source: http://ssrn.aviyaan.com/traffic_controller)

Table 5.27: Past Traffic Trend at Pathlaiya East (Station No: 41)

Categories	Classified Volume Study (VPD) at							
	2011/12	2012/13	2014/15	2015/16	2016/17	2018/19	2019/20*	2020/21
Multi-axle truck	647	429	96	0	50	38	51	1509
Heavy Truck	466	379	280	1091	1810	1334	1708	1041

Categories	Classified Volume Study (VPD) at							
	2011/12	2012/13	2014/15	2015/16	2016/17	2018/19	2019/20*	2020/21
Light truck	84	93	272	34	217	104	262	129
Big Bus	943	566	419	754	761	627	1033	447
Mini Bus	168	191	165	118	232	302	272	337
Micro Bus	38	15	150	31	33	151	70	39
Car	185	178	308	168	211	453	544	416
Motorcycle	1871	1022	2036	1551	1809	2676	2569	2519
Utility vehicles	132	73	260	228	296	512	453	333
Tractor	155	206	133	166	326	126	78	115
Three-Wheeler	39	11	228	25	116	108	148	165
Four Wheel Drive	477	411	199	241	545	894	830	586
Power Tiller	0	1	128	5	5	1	0	0
Rickshaw	62	32	0	0	1	0	130	0
Bullock Cart	14	2	1	0	0	0	0	0
AADT (PCU)	8,931	6,050	6,466	6,702	10,041	12,450	13,532	12749

(Source: http://ssrn.aviyaan.com/traffic_controller)

The graphical presentation of the past traffic trend in terms of Annual Average Daily Traffic (PCU) for Dhalkebar East (Station 30), Bardibas East (Station 31), Karmaiya (Station 38), and Pathlaiya East (Station 41) count stations is shown in **Figure 5.32**, **Figure 5.33**, **Figure 5.34** and **Figure 5.35**

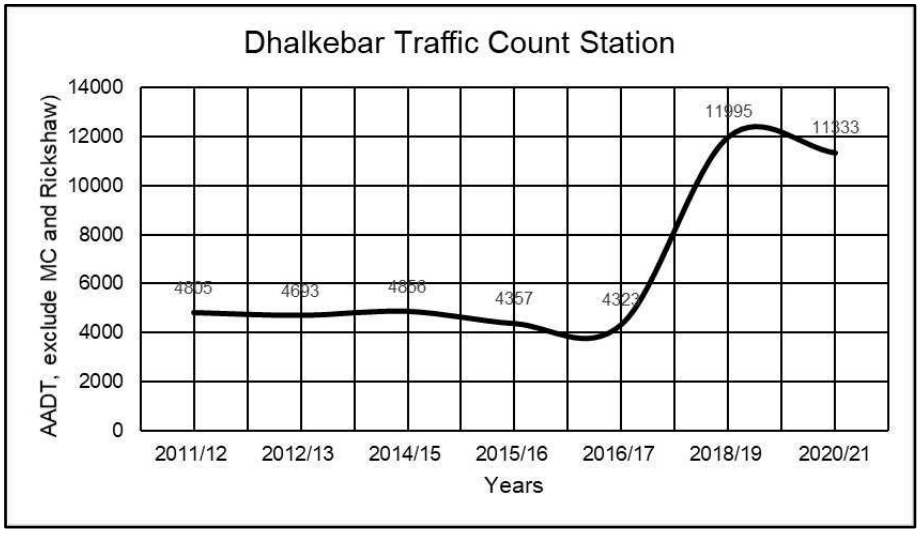


Figure 5.32: Past Traffic Trend at Dhalkebar East (Station: 30)

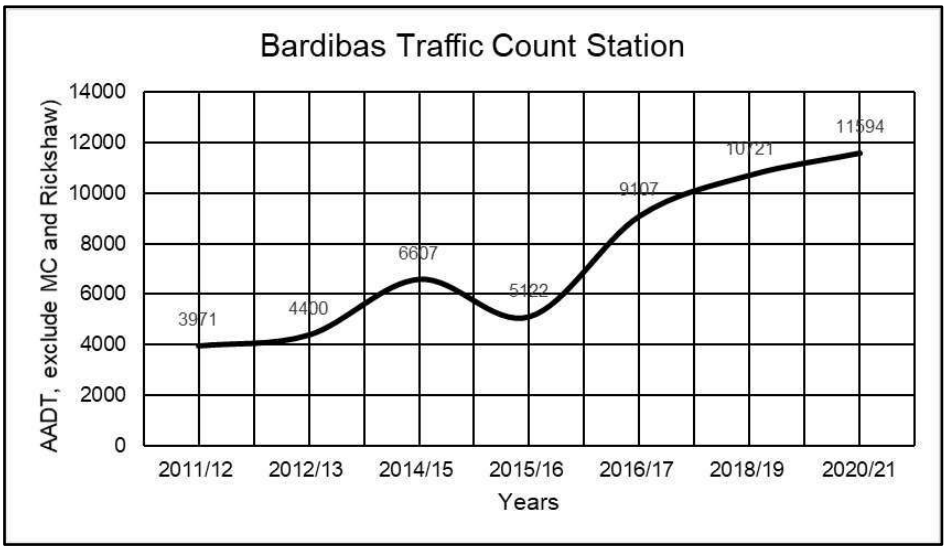


Figure 5.33: Past Traffic Trend at Bardibas East (Station: 31)

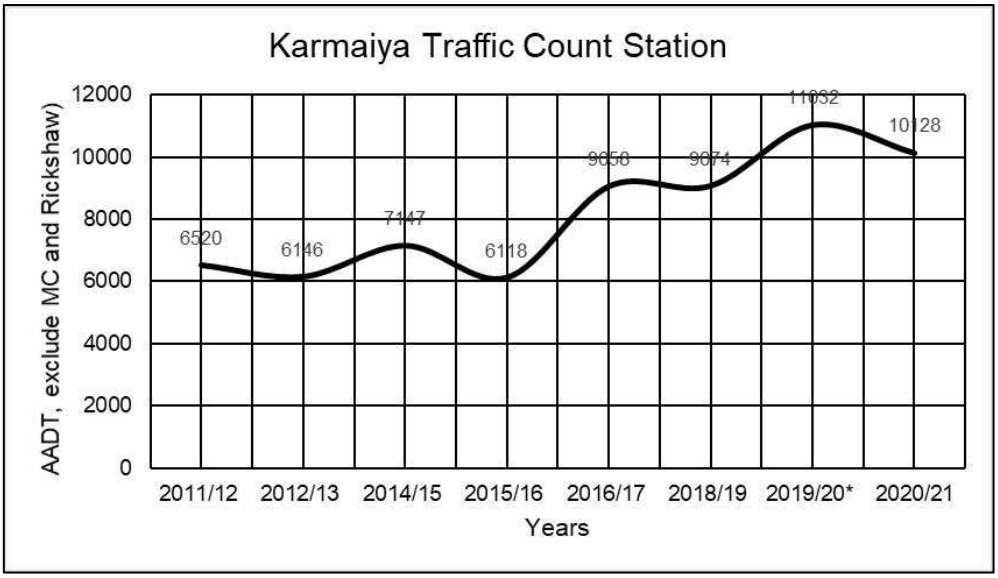


Figure 5.34: Past Traffic Trend at Karmaiya (Station No: 36)

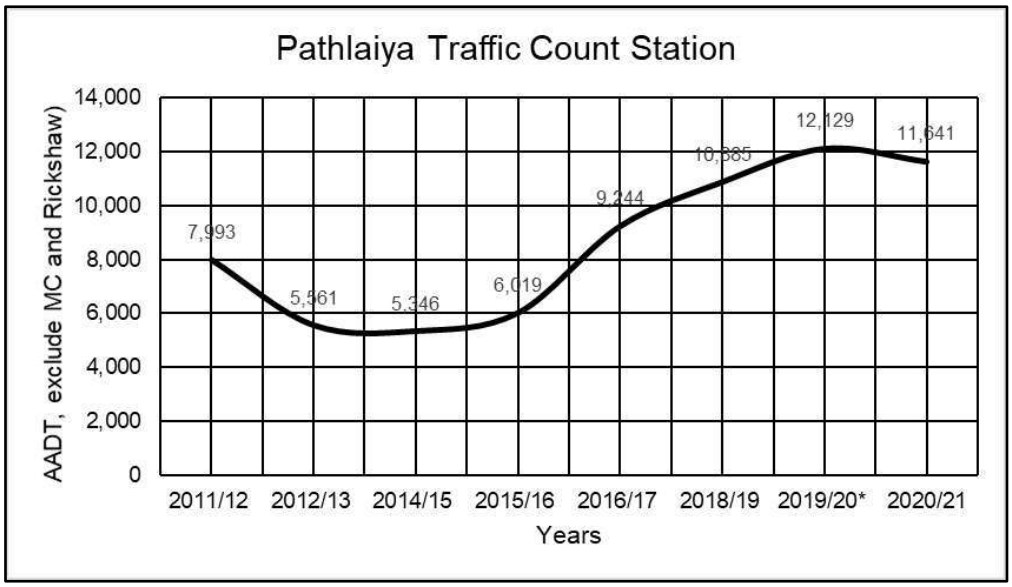


Figure 5.35: Past Traffic Trend at Pathlaiya East (Station No: 41)

The change in the percentage of the traffic volume in terms of Annual Average Daily Traffic (PCU) from the previous year for each station of the classified count worked out by the Consultant has been presented in **Table 5.28** below.

Table 5.28: Percentage (%) change in Annual Average Daily Traffic (PCU)

Years	Stations		Years	Stations	
	30	31		36	41
2011/12-2012/13	9.97%	6.68%	2011/12-2012/13	-9.49%	-32.26%
2012/13-2014/15	-9.65%	47.65%	2012/13-2014/15	30.25%	6.88%
2014/15 - 2015/16	-6.39%	-22.24%	2014/15 - 2015/16	-17.86%	3.65%
2015/16 - 2016/17	7.92%	85.47%	2015/16 - 2016/17	42.13%	49.82%
2016/17 - 2018/19	185.44%	31.97%	2016/17 - 2018/19	13.03%	23.99%
2018/19 - 2020/21	-7.58%	-3.26%	2018/19- 2019/2020*	27.97%	8.69%
			2019/2020*- 2020/21	-21.99%	-5.79%

It is revealed from above Table that, the growth trend of the traffic volume for past 6 year's time period is absurd and cannot be considered as base for traffic forecasting. The count results of those traffic survey do not have regular trend of increase. However, the overall growth trend is observed as the positive. The growth rates of the separate class of vehicles (such as freight vehicles and passenger vehicles) are in a regular trend without huge fluctuation in the growth rate. This drastic change in the growth rate may be explained by the inconsistency of the traffic count season and the effect of the local traditional cultural festivals. Moreover, the traffic growth rate after the year 2016 has increased significantly. The overall economic growth and increase in per capita income have resulted in a higher growth rate after 2015 in Nepal.

5.4.2 Growth Rate Analysis

The traffic growth rate analysis is one of the vital issue for traffic forecast. The growth rate assumption needs to be properly backed up with sufficient vehicle registration data, socio-economic and demographic data. However, the socio-economic and demographic data as well as vehicle registration data are not being properly maintained in the Country. Therefore, the Consultant followed the different process for carrying out traffic growth rate analysis, which is summarized below:

- Review of the historical growth at DoR count stations that lie within/ in the vicinity of the project roads identified previously: The data collected and analysed as described in para above. It is already mentioned that, the trend of the past traffic data does not have uniform growth pattern. Therefore, the DoR count data could not be used directly for the analysis of traffic growth rates for the project road,
- Extrapolation of the growth-rate based on elasticity of transport demand with respect to gross domestic product (GDP) or per capita income (PCI) through regression analysis;
- Extrapolation of the growth-rate based on elasticity of transport demand with respect to petroleum consumption; and
- Review of the elasticity factors and growth-rate adopted in other road projects including the feasibility study of KDP project.

Generally, the estimation of the traffic growth rate is mainly performed by the analysis of elasticity, the GDP, PCI and Vehicle Registration data in the country. The elasticity of transport demand was calculated through regression analysis using GDP figures for the freight vehicles and the PCI figures for commercial and private vehicles. The elasticity of transport demand with respect to a parameter (e.g. GDP, travel-time savings or travel cost, etc.) is the change in the transport demand for a corresponding change in that parameter. An elasticity factor of -0.55 for transport demand with respect to travel cost signifies that for every 1% increase in the cost of travel, there is 0.55% decrease in the travel demand based on the arc-elasticity method.

The growth rate of the vehicle registration was taken as proxy for traffic growth and compared with the GDP/ PCI growth observed in Nepal over the years. There is certain distortion in the corresponding traffic growth-rate that is result based on this assumption as the vehicle registrations in Nepal. There is no data on vehicle-travel with in the road networks of Nepal. Taking all these of limitation into consideration, the distortion in the growth-rate was ignored

and the following formula was adopted to derive the future growth-rates for different time periods.

For passenger and private vehicles, $G = E * [(1 + Gp)x(1 + Gpci) - 1]$

Where, E= elasticity of transport demand; Gp= population growth-rate; Gpci= per-capita income growth-rate; G= traffic growth-rate

For freight vehicles $G = E * G_{gdp}$

Where, E= elasticity of transport demand;

G_{GDP}= gross domestic product growth-rate

G= freight vehicle growth-rate

The elasticity factor of vehicle travel with respect to petroleum consumption in Nepal that was calculated through liner regression in the feasibility was adopted. This analysis was based on historical data on petroleum consumptions and some limited vehicle travel survey conducted in the past.

The elasticity factors were compared with the corresponding factors used in other road projects to ensure consistency. In general, the correlation between the vehicle registration with GDP or PCI was stronger than based on the correlation between vehicle travel and petroleum consumptions with some exception. In the conclusion, the final growth-rate was adopted considering all the growth-rate that was derived from all methods including historical traffic growth observed along the project roads. After the various view point on the traffic growth rate analysis, the consultant decided to adopt the growth rates as shown in **Table 5.29**.

Table 5.29: Adopted Traffic Growth Rate for the Project

Vehicle types	2022 -2026	2027 -2032	2033 - 2038	2038 - 2043	2043- 2048
MAV Truck	3.68	2.88	3.09	3.62	3.5
Truck	3.68	2.88	3.09	3.62	3.5
Mini truck	3.68	2.88	3.09	3.62	3.5
Large bus	2.49	2.67	3.14	3.04	3.03
Mini bus	2.49	2.67	3.14	3.04	3.03
Micro bus	2.49	2.67	3.14	3.04	3.03
Car	4.68	5.03	5.91	5.72	5.69
Motorcycle	6.91	7.73	8.74	8.47	8.44
Utility vehicle	2.22	2.39	2.81	2.72	2.71
Four wheel drive	6.68	5.03	5.91	5.72	5.69
Tractor	3.17	3.40	3.99	3.85	3.83

5.4.3 Traffic Components

5.4.3.1 Normal Traffic

The normal traffic is that portion of traffic that currently plying on the project highway regardless, whether the project road is upgraded or not.

5.4.3.2 Generated Traffic

The traffic forecast is mainly related to the generated traffic after the upgradation of the existing highway. It mainly consists of the traffic results after the improvement of the road due to reduction in the time and the cost of travel. It reflects the additional trips that, occur apart from the normal traffic due to shorter travel time or cheaper cost of travel up on road improvement/ upgradation.

Generated traffic is generally based on the price elasticity of transport demand. The Price elasticity of transport demand is the change in transport demand with respect to the change in the price of travel. For passenger vehicles, the fare reflects the cost of travel while it is the time cost and fuel cost for private vehicles. To simplify the analysis, the elasticity of transport demand with respect to travel-time savings was taken to be analogous to the price elasticity of transport demand. This is logical since the transport demand tends to increase with a decrease in the travel time, which, in turn usually triggers a reduction in the cost of travel.

For the project highway section, an elasticity of transport demand for generated traffic based on the average of values of -0.1 and a factor of -0.5 adopted globally. The actual traffic generated was the product of the average elasticity of transport demand calculated and the travel-time savings that result after the project-highway section is upgraded.

5.4.3.3 Diverted Traffic

The Project Road shall have significant influence of the diverted traffic after the construction of Kathmandu – Terai Fast Track Expressway originating from Kathmandu and merging at the Nijgadh with the Project Road. The diverted traffic results from the current traffic diverting from other routes to the project road. This traffic results when there are competing routes along the project road and the diversion is assumed to be in proportion to the travel-time savings, which, is logical based on the travel characteristics. The Commuter will take the route, which is the quickest unless the cost of travel along the route in question is not very high. After the having Network Analysis and collecting O-D survey data from the Site, the consultant has determined the diverted traffic to the Project Road.

5.4.3.4 Induced Traffic

Induced traffic occurs, when new economic opportunities emerge after the road improvement. This component is different from generated traffic, but it is often difficult to accurately assess this traffic in Nepal owing to lack of data and the fact that some portion of this component is already included in the generated traffic. Therefore, induced traffic has not been considered for the project highway section in light of this difficulty and to avoid double counting.

5.4.3.5 Base year Traffic and forecast

The data collected through the traffic count survey at various locations of the Project Road have analyzed as previously described in terms of AADT PCU and Vehicle per day. The results of the analysis for determining the traffic flow along the KDP highway sections are described earlier.

Further, traffic forecast was performed based on the predetermined growth rates. The Pathlaiya – Nijgadh section of the Project Road has been analyzed for the diverted traffic and Final Traffic Forest has been presented for each Homogeneous section vide **Table 5.30, Table 5.31, Table 5.32, Table 5.33, Table 5.34and Table 5.35** for reference.

Table 5.30: Traffic forecast for Kamala- Dhalkebar Section

Vehicle type	Traffic Jan, 2022 VPD	AADT Jan, 2026 VPD	AADT Jan, 2031 VPD	AADT Jan, 2036 VPD	AADT Jan, 2041 VPD	AADT Jan, 2046 VPD
MA Truck	1200	1387	1599	1861	2224	2656
Truck	687	794	916	1066	1273	1521
Mini truck	125	145	167	194	232	277
Large bus	526	581	663	773	898	1043
Mini bus	94	104	118	138	160	186
Micro bus	620	684	780	911	1058	1228
Car	665	798	1020	1360	1796	2372
Motorcycle	6293	8221	11929	18136	27232	40892
Utility vehicle	635	694	781	897	1026	1173
4 wheel drive	872	1129	1443	1923	2539	3354
Tractor	155	176	208	253	306	369

Table 5.31: Traffic forecast for Dhalkebar- Bardibas Section

Vehicle type	Traffic Jan, 2022 VPD	AADT Jan, 2026 VPD	AADT Jan, 2031 VPD	AADT Jan, 2036 VPD	AADT Jan, 2041 VPD	AADT Jan, 2046 VPD
MA Truck	1169	1351	1557	1813	2166	2588
Truck	747	864	995	1159	1384	1654
Mini truck	137	159	183	213	254	304
Large bus	639	705	804	939	1090	1266
Mini bus	97	108	123	143	166	193

Vehicle type	Traffic Jan, 2022 VPD	AADT Jan, 2026 VPD	AADT Jan, 2031 VPD	AADT Jan, 2036 VPD	AADT Jan, 2041 VPD	AADT Jan, 2046 VPD
Micro bus	529	583	665	777	902	1048
Car	676	812	1037	1382	1825	2411
Motorcycle	6923	9045	13124	19954	29962	44990
Utility vehicle	764	834	939	1079	1233	1411
4 wheel drive	997	1292	1651	2200	2905	3837
Tractor	150	170	201	244	295	357

Table 5.32: Traffic forecast for Bardibas - Nawalpur Section

Vehicle type	Traffic Jan, 2022 VPD	AADT Jan, 2026 VPD	AADT Jan, 2031 VPD	AADT Jan, 2036 VPD	AADT Jan, 2041 VPD	AADT Jan, 2046 VPD
MA Truck	800	924	1065	1240	1481	1769
Truck	542	626	721	840	1004	1199
Mini truck	201	232	267	311	371	444
Large bus	673	742	847	988	1148	1333
Mini bus	126	139	159	186	215	250
Micro bus	348	384	439	512	595	691
Car	655	786	1005	1339	1768	2335
Motorcycle	5634	7361	10681	16239	24384	36614
Utility vehicle	630	688	774	889	1016	1162
4 wheel drive	708	918	1173	1563	2064	2726
Tractor	131	148	175	213	257	310

Table 5.33: Traffic forecast for Navalpur - Chapur Section

Vehicle type	Traffic Jan, 2022 VPD	AADT Jan, 2026 VPD	AADT Jan, 2031 VPD	AADT Jan, 2036 VPD	AADT Jan, 2041 VPD	AADT Jan, 2046 VPD
MA Truck	814	940	1084	1262	1507	1801
Truck	641	741	854	994	1188	1419
Mini truck	216	249	287	334	399	477
Large bus	623	687	784	915	1063	1235
Mini bus	153	169	192	224	261	303
Micro bus	315	348	397	463	538	624
Car	679	815	1042	1388	1833	2421
Motorcycle	8252	10780	15643	23783	35711	53624
Utility vehicle	585	638	718	825	943	1079
4 wheel drive	692	896	1145	1526	2015	2661
Tractor	267	302	357	435	525	634

Table 5.34: Traffic forecast for Chapur – Nijgadh Section

Vehicle type	Traffic Jan, 2022 VPD	AADT Jan, 2026 VPD	AADT Jan, 2031 VPD	AADT Jan, 2036 VPD	AADT Jan, 2041 VPD	AADT Jan, 2046 VPD
MA Truck	813	940	1083	1261	1507	1800
Truck	687	794	916	1066	1273	1521
Mini truck	294	339	391	455	544	650
Large bus	621	685	782	912	1060	1231
Mini bus	176	195	222	259	301	350

Vehicle type	Traffic Jan, 2022 VPD	AADT Jan, 2026 VPD	AADT Jan, 2031 VPD	AADT Jan, 2036 VPD	AADT Jan, 2041 VPD	AADT Jan, 2046 VPD
Micro bus	266	294	335	391	455	528
Car	679	815	1042	1389	1834	2422
Motorcycle	8912	11642	16894	25684	38567	57912
Utility vehicle	499	545	613	704	805	921
Four wheel drive	613	794	1015	1353	1786	2359
Tractor	378	428	506	615	743	897

Table 5.35: Traffic forecast for Nijgadh - Pathlaiya Section

Vehicle type	Traffic Jan, 2022 VPD	AADT Jan, 2026 VPD	AADT Jan, 2031 VPD	AADT Jan, 2036 VPD	AADT Jan, 2041 VPD	AADT Jan, 2046 VPD
MA Truck	748	1397	1610	1875	2240	2660
Truck	697	1205	1389	1617	1932	2294
Mini truck	434	637	735	855	1022	1213
Large bus	744	1044	1191	1390	1614	1874
Mini bus	129	224	255	298	346	402
Micro bus	170	253	289	337	392	455
Car	829	1533	1960	2612	3449	4548
Motorcycle	2996	3914	5680	8636	12967	19445
Utility vehicle	422	527	593	682	779	891
4-wheel drive	668	914	1168	1557	2056	2711
Tractor	125	142	167	204	246	297

Chapter 6: Detailed Pavement Design

6.1 Pavement Design Standards/Criteria

6.1.1 Introduction

The KDP section of the E-W highway is an existing two-lane road with a bituminous pavement with a granular base and sub-base layers. The highway alignment mainly passes through the forest area, cultivated plots, and settlements including the urbanized market areas. The existing roadway is comprised of the carriageway (bituminous pavement) and granular shoulders on both sides. In some urban areas, the high has been developed as a four-lane carriageway. The widening of the roadway shall be managed within the demarcated or defined Right of Way (RoW). The proposed road up-gradation project is intended to build a four-lane highway with a central median. Similarly, the road up-gradation activities shall consist of service lanes and other pedestrian facilities on both sides of the urban as well as dense settlements. The design of cross-section, as well as pavement structure, mainly depends on the method of widening of the roadway i. e. concentric or eccentric type. The up-gradation is intended to develop the cross-section with the entire width of the RoW. Therefore, the concentric widening would be more proper for this project. In such case of the widening and the existing pavement would mainly be occupied by the central median. Therefore, the pavement design for this project would consider the geotechnical investigation of the existing roadway as well as the bearing capacity of the ground strips on both sides.

6.1.2 Selection of Pavement types

Pavement design mainly consists of the determination of the type of pavement and thickness of the layers to be constructed over the sub-grade. There are mainly rigid and flexible types of road pavement. The selection of appropriate type is an important and foremost step of the pavement design procedure for identifying the most favorable type of pavement structure for a given set of traffic, subgrade soils, climate, and other factors. The type selection process could be carried out based on multi-criteria methods which may consider various factors with the relative weights for indicating the importance for given conditions.

The selection of the pavement type for the KDP project explained by the following factors:

- Traffic: the basic principle of pavement design is to consider the extent of the commercial vehicle per day (CVPD). The traffic count survey in this study has found that, the commercial vehicle per day ranges from 4000 to 5000 per day along this

section of the E-W highway. The range of the traffic for the selection of pavement type is appropriate for both types of pavements.

- Soil characteristics: The load-carrying capability of a native soil, which forms the sub-grade for the pavement structure, is a dominant factor in pavement performance. The uniform character of the soil even in a small area can exhibit different behavior due to the influence of different weather factors such as precipitation, temperature, etc. by considering the existing roadway and ground conditions within the Right of Way, the flexible pavement is preferred pavement type for the project.
- Construction considerations: Upgrading of the entire KDP roadway is the highway in operation. The traffic flow shall not be blocked by the construction activities while upgrading the existing two lane road. The flexible type of pavement is suitable in such cases of construction. Other considerations such as speed of construction, accommodating traffic during construction, ease of replacement, anticipated future widening, seasons of the year when construction must be accomplished, and perhaps others may have a strong influence on paving type selections in specific cases.
- Recycling: The opportunity to recycle the pavement material from an existing roadway section or other sources may dictate the use of one pavement type. The concentric widening of existing two lane road with median in center and construction of new pavement on both sides has been decided at Conceptual Design Stage. Therefore, recycling of existing two lane pavement has not been taken in to consideration. Similarly, the opportunity of recycling in the future may also be considered. The existing pavement layer materials could be utilized to some extent for the pavement layers.
- Cost of construction: Where there are no overriding factors and several alternate pavement types would serve satisfactorily, cost comparison can be used to assist in determining pavement type. The cost of construction of the rigid and flexible pavement could be taken as a major factor for the selection of pavement type.
- Considering these factors and the performance of the existing bituminous pavement are leading factors for adopting the construction of flexible pavement for this project road.

6.1.3 Design controls and criteria

The design of flexible road pavement is based on the principles adopted in the prevailing Pavement Design Guidelines. The design approaches and criteria for a country should consider the local conditions i.e. climatic, socio-economic and technological development and so on. The flexible pavement has been modeled as a three-layered structure and stresses and

strains at critical locations to be computed using the linear elastic model. In other words, the aspects of performance, three types of pavement distress resulting from the repeated (cyclic) application of traffic loads are considered:

- Vertical compressive strain at the top of the sub-grade, which can cause sub-grade deformation resulting in permanent deformation at the pavement surface.
- Horizontal tensile strain or stress at the bottom of the bituminous layer, which can cause fracture of the bituminous layer.
- Pavement deformation within the bituminous layer.

The permanent deformation within the bituminous layer can be controlled by meeting the mix-design requirements as per the Standards Specifications for Road and Bridge Works (DoR, 2073). Thicknesses of granular and bituminous layers are selected by using the analytical design approach so that strains at the critical points are within the allowable limits. For calculating tensile strains at the bottom of the bituminous layer, the stiffness of the dense bituminous macadam (DBM) layer made with the suitable type of bitumen.

The performance criteria are major issues in the design of the pavement layers. The Design Guidelines for Flexible Pavement (second revision) have indicated that, the sub-grade rutting criteria and fatigue criteria of bituminous layers considered for the reliability of 80 % 90%. As the project road section is of the National Highway category, the higher traffic volume to be considered and accordingly the pavement design has been carried out considering reliability of 90 %.

An average rut depth of 20 mm or more, measured along the wheel paths, is considered in these guidelines as a critical or failure rutting condition. The equivalent number of standard axle load (80 kN) repetitions that can be served by the pavement, before the critical average rut depth of 20 mm or more occurs, is checked by the relationship:

$$N_R = 1.4100 * 10^{-8} \left[\frac{1}{\varepsilon_v} \right]^{4.5337}$$ **……Equation 1**

Where,

N_R: sub-grade rutting life (cumulative equivalent number of 80 kN standard axle loads that can be served by the pavement before the critical rut depth of 20 mm or more occurs.

ε_v : vertical compressive strain at the top of the sub-grade calculated using linear elastic layered theory by applying standard axle load at the surface of the selected pavement system.

The fatigue cracking on the pavement surface, whose total area in the section of the road under consideration is 20 % or more than the paved surface area of the section, is considered as the critical or failure condition. The equivalent number of standard axle (80 kN) load repetitions that can be served by the pavement, before the critical condition of the cracked surface area of 20 % or more occurs. The relationship equation considered for the design is as presented below:

$$N_f = 0.5161 * C * 10^{-4} \left[\frac{1}{\varepsilon_t}\right]^{3.89} \left[\frac{1}{M_{Rm}}\right]^{0.854}$$ ……. **Equation 2**

Where,

$$C = 10^M \text{ and } M = 4.84\left[\frac{V_{be}}{V_a + V_{be}} - 0.69\right]$$

V_a = percent volume of air void in the mix used in the bottom bituminous layer,

V_{be} = percent volume of effective bitumen in the mix used in the bottom bituminous layer,

N_f = fatigue life of bituminous layer (cumulative equivalent number of 80 kN standard axle loads that can be served by the pavement before the critical cracked area of 20 % or more of the paved surface area occurs)

ε_t = maximum horizontal tensile strain at the bottom of the bottom bituminous layer (DBM) calculated using linear elastic layered theory by applying standard axle load at the surface of the selected pavement system.

M_{RM} = resilient modulus (MPa) of the bituminous mix used in the bottom bituminous layer, selected as per the recommendations made in these guidelines

The factor 'C' is an adjustment factor used to account for the effect of variation in the mix volumetric parameters (effective binder volume and air void content) on the fatigue life of bituminous mixes and was incorporated in the fatigue models to integrate the mix design considerations in the fatigue performance model. The strains on different pavement layers due to vehicle loading has been illustrated in **Figure 6.1** below:

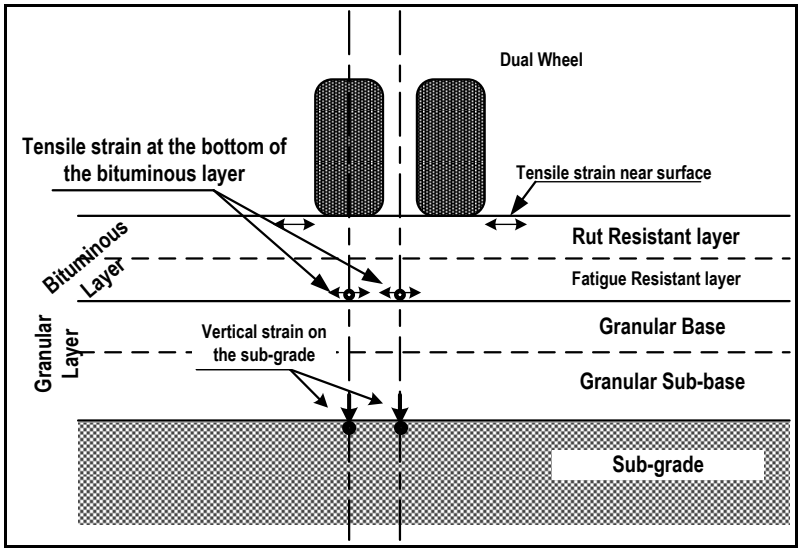


Figure 6.1: The critical points for the analysis of pavement layers

6.1.4 Traffic considerations

Pavement design is mainly guided by the anticipated traffic volume of commercial vehicles. The traffic calculations for the design of pavement are performed in the steps:

- The Continuous Classified Volume count survey has been carried out. As per the prevailing practice for the traffic count survey, the Traffic survey for three days has been carried out.
- Axle load survey for the determination of Vehicle Damage Factor has been carried for the various types of commercial vehicles.
- The base year calculation of the daily numbers of repetition of standard axle has been made for the design lane and direction. The calculations to be performed to determine the proper growth rate of the commercial vehicle. The Guidelines for the design of flexible pavement recommend the 5 % growth rate for all types of commercial vehicles. The same growth rate has been adopted for all types of Commercial vehicles.
- The cumulative traffic Loading (the cumulative number of standard axles) for the design period to be determined for the analysis of the pavement layers.

The Design Traffic Loading in terms of the cumulative number of standard axles is computed as:

$$N = \frac{365*[(1+r)^n - 1]}{r} * A * D * F$$

Where,

- N = the cumulative number of standard axles to be catered for in the design in terms of Million Standard Axles (MSA)
- A = Initial traffic in the year of completion of construction in terms of number of commercial vehicles per day
- D = Lane distribution factor,
- F = Vehicle damage factor,
- n = Design life in years,
- r = annual growth rate of commercial vehicle (in the absence of detail traffic study r can be taken as 5% i.e 0.05)
- The traffic in the year of completion is estimated using the following formula: $A = P(1+r)^x$
- Where, P is the number of commercial vehicles as per the last traffic count; x is the number of years between the last traffic count and the year of completion of construction.

Pavement design is mainly guided by the design traffic loading in terms of cumulative number of standard axles for the Design Period. The axle load survey and the analysis of the loading intensity as well as wheel configurations were performed for the determination of design traffic. The equivalent factors for the conversion of anticipated traffic into the axle load repetition were determined for the specific types of commercial vehicles

6.1.5 Evaluation of existing pavement

The sub-grade strength is important for the design of the pavement. The existing pavement including the earth surface along the RoW (to be widened) has been evaluated through respective geotechnical investigations including the determination of the existing pavement structure, sub grade soil analysis etc. The existing bituminous pavement layers (carriageway), shoulders (unpaved) on the embankment have been tested in the laboratory as well as in the field. The type of tests conducted on soil are as listed below:

- Grain size distribution,
- Moisture content,
- Field density,

- Compaction (OMC and MDD)
- Laboratory CBR tests.
- DCP test has been carried out and the corresponding CBR has been determined.

Furthermore, the existing pavement layer survey has been carried out by the excavation of the pit along the edge of the carriageway. The field CBR test values of the soil in the existing embankment in almost cases was found more than 5 %. However, the CBR value for the ground far from the embankment was found in the range of value of the existing sub-grade varies from 5 % to 40% along the KDP road. The pit test for the determining existing pavement crust were dug at every 500m along the road. The thickness observed for each layer of existing pavement are presented in the **Table 6.1** below:

Table 6.1: Existing pavement layers and respective thickness (consultant's field survey)

Chainage	wearing course, cm	Base course, cm	Sub Base, cm	Total Depth, cm	Chainage	Wearing course, cm	Base course, cm	Sub Base, cm	Total Depth, cm
000+000	10	15	25	50	066+000	9	15	25	49
000+500	9	15	25	49	066+500	9	15	25	49
001+000	8	15	25	48	067+000	9	14	25	48
001+500	8	15	25	48	067+500	8	15	25	48
002+000	9	15	30	54	068+000	9	15	25	49
002+500	10	15	30	55	068+500	8	15	25	48
003+000	10	15	30	55	069+000	10	15	25	50
003+500	10	14	30	54	069+500	9	15	25	49
004+000	10	15	30	55	070+000	10	15	25	50
004+500	10	15	30	55	070+500	9	15	25	49
005+000	10	14	25	49	071+000	8	15	25	48
005+500	10	15	25	50	071+500	8	15	25	48
006+000	10	15	25	50	072+000	9	15	30	54
006+500	8	15	25	48	072+500	10	15	25	50
007+000	10	15	30	55	073+000	10	15	25	50
007+500	9	15	25	49	073+500	10	15	30	55
008+000	10	15	25	50	074+000	9	15	30	54
008+500	10	14	25	49	074+500	9	15	30	54
009+000	10	15	25	50	075+000	9	14	25	48
009+500	10	15	30	55	075+500	8	15	25	48
010+000	8	14	30	52	076+000	10	15	25	50
010+500	10	15	30	55	076+500	10	15	25	50
011+000	9	15	30	54	077+000	10	15	30	55
011+500	10	15	25	50	077+500	10	15	25	50
012+000	8	15	25	48	078+000	10	15	25	50
012+500	8	15	25	48	078+500	10	15	30	55
013+000	9	15	30	54	079+000	9	15	30	54
013+500	8	15	30	53	079+500	10	15	25	50
014+000	8	15	25	48	080+000	8	14	25	47
014+500	8	15	25	48	080+500	8	15	25	48

Chainage	wearing course, cm	Base course, cm	Sub Base, cm	Total Depth, cm	Chainage	Wearing course, cm	Base course, cm	Sub Base, cm	Total Depth, cm
015+000	8	15	25	48	081+000	8	15	25	48
015+500	8	15	25	48	081+500	8	15	25	48
016+000	9	15	25	49	082+000	8	15	25	48
016+500	9	15	25	49	082+500	9	15	25	49
017+000	9	14	25	48	083+000	8	15	25	48
017+500	8	15	25	48	083+500	8	15	25	48
018+000	9	15	25	49	084+000	9	15	25	49
018+500	8	15	25	48	084+500	9	15	25	49
019+000	9	15	25	49	085+000	10	15	25	50
019+500	9	15	25	49	085+500	8	15	30	53
020+000	10	15	25	50	086+000	8	15	25	48
020+500	9	15	25	49	086+500	8	15	25	48
021+000	8	15	25	48	087+000	10	14	25	49
021+500	8	15	25	48	087+500	10	15	25	50
022+000	9	15	30	54	088+000	10	15	25	50
022+500	10	15	25	50	088+500	9	15	25	49
023+000	10	15	25	50	089+000	8	15	30	53
023+500	10	15	30	55	089+500	10	15	25	50
024+000	9	15	30	54	090+000	10	15	25	50
024+500	9	15	30	54	090+500	8	15	25	48
025+000	9	14	25	48	091+000	10	15	25	50
025+500	8	15	25	48	091+500	10	15	25	50
026+000	10	15	25	50	092+000	10	15	25	50
026+500	10	15	25	50	092+500	10	14	30	54
027+000	10	15	30	55	093+000	8	15	30	53
027+500	10	15	25	50	093+500	10	15	25	50
028+000	10	15	25	50	094+000	9	15	25	49
028+500	10	15	30	55	094+500	9	14	25	48
029+000	9	15	30	54	095+000	8	15	25	48
029+500	10	15	25	50	095+500	8	15	25	48
030+000	8	14	25	47	096+000	9	15	25	49
030+500	8	15	25	48	096+500	10	15	25	50
031+000	8	15	25	48	097+000	10	15	25	50
031+500	8	15	25	48	097+500	10	15	30	55
032+000	8	15	25	48	098+000	9	15	30	54
032+500	9	15	25	49	098+500	8	15	30	53
033+000	8	15	25	48	099+000	8	14	25	47
033+500	8	15	25	48	099+500	8	15	25	48
034+000	9	15	25	49	100+000	10	15	25	50
034+500	9	15	25	49	100+500	10	15	25	50
035+000	10	15	25	50	101+000	10	15	25	50
035+500	8	15	30	53	101+500	10	15	25	50
036+000	8	15	25	48	102+000	10	15	25	50
036+500	8	15	25	48	102+500	10	15	30	55
037+000	10	14	25	49	103+000	10	15	30	55
037+500	10	15	25	50	103+500	10	15	30	55
038+000	10	15	25	50	104+000	10	15	30	55
038+500	9	15	25	49	104+500	10	15	30	55
039+000	10	15	30	55	105+000	10	14	25	49
039+500	10	15	25	50	105+500	10	15	25	50

Chainage	wearing course, cm	Base course, cm	Sub Base, cm	Total Depth, cm	Chainage	Wearing course, cm	Base course, cm	Sub Base, cm	Total Depth, cm
040+000	10	15	25	50	106+000	10	15	25	50
040+500	8	15	20	43	106+500	8	15	25	48
041+000	10	15	25	50	107+000	10	15	30	55
041+500	10	15	25	50	107+500	9	15	25	49
042+000	10	15	25	50	108+000	10	15	25	50
042+500	10	14	30	54	108+500	10	14	25	49
043+000	8	15	30	53	109+000	10	15	25	50
043+500	10	15	25	50	109+500	10	15	30	55
044+000	9	15	25	49	110+000	8	14	30	52
044+500	9	14	25	48	110+500	10	15	30	55
045+000	8	15	25	48	111+000	9	15	30	54
045+500	8	15	25	48	111+500	10	15	25	50
046+000	9	15	30	54	112+000	8	15	25	48
046+500	10	15	30	55	112+500	8	15	25	48
047+000	10	15	30	55	113+000	9	15	30	54
047+500	10	15	30	55	113+500	8	15	30	53
048+000	10	15	30	55	114+000	8	15	25	48
048+500	10	15	30	55	114+500	8	15	25	48
049+000	10	14	25	49	115+000	8	15	25	48
049+500	10	15	25	50	115+500	8	15	25	48
050+000	10	15	25	50	116+000	9	15	25	49
050+500	9	15	25	49	116+500	9	15	25	49
051+000	8	15	25	48	117+000	9	14	25	48
051+500	8	15	25	48	117+500	8	15	25	48
052+000	9	15	30	54	118+000	9	15	25	49
052+500	10	15	30	55	118+500	8	15	25	48
053+000	10	15	30	55	119+000	9	15	25	49
053+500	10	14	30	54	119+500	9	15	25	49
054+000	10	15	30	55	120+000	10	15	25	50
054+500	10	15	30	55	120+500	9	15	25	49
055+000	10	14	25	49	121+000	8	15	25	48
055+500	10	15	25	50	121+500	8	15	25	48
056+000	10	15	25	50	122+000	9	15	30	54
056+500	8	15	25	48	122+500	10	15	25	50
057+000	10	15	30	55	123+000	10	15	25	50
057+500	9	15	25	49	123+500	10	15	30	55
058+000	10	15	25	50	124+000	9	15	30	54
058+500	10	14	25	49	124+500	9	15	30	54
059+000	10	15	25	50	125+000	9	14	25	48
059+500	10	15	30	55	125+500	8	15	25	48
060+000	8	14	30	52	126+000	10	15	25	50
060+500	10	15	30	55	126+500	10	15	30	55
061+000	9	15	30	54	127+000	10	15	30	55
061+500	10	15	25	50	127+500	10	15	25	50
062+000	8	15	25	48	128+000	10	15	30	55
062+500	8	15	25	48	128+500	10	15	30	55
063+000	9	15	30	54	129+000	9	15	30	54
063+500	8	15	30	53	129+500	10	15	30	55
064+000	8	15	25	48	130+000	10	15	25	50
064+500	8	15	25	48					

Chainage	wearing course, cm	Base course, cm	Sub Base, cm	Total Depth, cm	Chainage	Wearing course, cm	Base course, cm	Sub Base, cm	Total Depth, cm
065+000	8	15	25	48					
065+500	8	15	25	48					

The typical layout of data collected by the Consultant's team during surveys in the field is presented as **Figure 6.2** below for reference.

Location: 1+000
Sample No.: 3 Tested by : Binod Giri

Material	Depth	Range
Black Top	8.00 cm	0 ~ 8 cm
Base	15.00 cm	8 – 23 cm
Sub Base	25.00 cm	23 – 48 cm
Subgrade sand mixed soil with gravel		
Total Depth	48.0 cm	

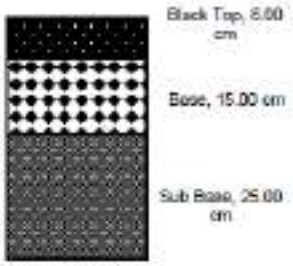


Figure 6.2: A typical field survey report of the existing pavement structure

The pavement design is to be carried out considering the effective CBR (Resilient modulus) of the Sub-grade. The effective CBR is a combination of CBR value for existing subgrade and CBR value of borrow soil to be used for constructing an embankment. The effective CBR of the subgrade has been determined by using the empirical charts provided in the Guidelines for Pavement Design.

Furthermore, the Resilient Modulus of soils can be determined in the laboratory by conducting the repeated tri-axial test as per the procedure detailed in AASHTO T307-99. However, the Resilient Modulus of subgrade soil (MRS) can be estimated from its CBR value by using the following equations.

$$M_{RS} = 10.0 * CBR \qquad \textbf{(for CBR} \leq 5\%)$$

$$M_{RS} = 17.6 * (CBR)^{0.64} \qquad \textbf{(for CBR} > 5\%)$$

Where,

- MRS = Resilient Modulus of sub-grade soil (in MPa).
- CBR = California bearing ratio of sub-grade soil (in %)

6.1.6 Design of Bituminous Layers

Bituminous pavement (flexible pavement) surfacing generally consists of either a wearing course or a binder course with a wearing course depending upon the traffic to be carried. For

high traffic volume roads with design traffic of 50 Million Standard Axles (MSA) or more, Bituminous Concrete is recommended for surfacing courses for durable, aging resistant, and crack resistant surface courses.

Dense Bituminous Macadam (DBM) mix with VG40 binder and confirming to Standard Specifications (Clause 1208), shall be the material used for base/binder courses for roads with 20 MSA or higher design traffic. Dense Bituminous Macadam (DBM)/Bituminous Macadam (BM) can be used as base/binder courses for roads with design traffic less than 20 MSA. The recommended alternatives for the design of the bituminous layer are shown in the **Table 6.2** below: -

Table 6.2: Recommended options for the bituminous layers (Pavement design guidelines)

S/N	Traffic Level	Surface course		Base/Binder Course	
		Mix type	Bitumen type	Mix type	Bitumen type
1	>50 MSA	SMA	Modified bitumen or VG40	DBM	VG40
		GGRB	Crumb rubber modified bitumen		
		BC	With modified bitumen		
2	20-50 MSA	SMA	Modified bitumen or VG40	DBM	VG40
		GGRB	Crumb rubber modified bitumen		
		BC	With modified bitumen or		
3	<20 MSA	BC/DBC/PMC/MSS/Surface Dressing	VG40 or VG30	DBM/BM	VG40 or VG30

6.1.7 Design of Granular (Sub Base and Base) layers

The design of the granular (base and sub base) layers is carried out as per the recommendations of the Guidelines. The granular base and sub-base layers are adopted from the concepts of the minimum thickness and the thickness mentioned in the design catalog of the Guidelines.

The granular Sub-base shall be conformed as Standard Specification for Road and Bridge Works, 2073 (Clause 12001). In the case of the Cement-treated Sub-base shall be constructed as mentioned in Clause 1202. The grading requirement is given in Table 12.1 of the Standard Specifications and physical Requirement in Table 12.2. Grading III and IV shall preferably be used in the lower sub-base. Grading V and VI shall be used as sub-base cum drainage layer.

The minimum thickness of the granular sub-base shall be as:

a. The minimum thickness of drainage as well as filter layer (two layers) shall not be less than 200 mm (100 mm minimum thickness of each layer).

b. The minimum thickness of a single filter-cum-drainage layer shall be 150 mm from functional requirements.

c. The minimum thickness of any compacted granular layer should preferably be at least 2.5 times the nominal maximum size of the aggregate subject to a minimum of 100 mm thickness.

The recommended types for the unbound granular bases are Water Bound Macadam base (Clause 1203), Crusher Run Macadam Base (clause 1204), Telford Base (Clause 1206), Dry Bound base (1207), and Wet Mix macadam (1208) base. These bases are prepared as per the Standard Specifications for Road and Bridge Works. Similarly, the base materials must satisfy the grading and physical requirements for respective types as mentioned in the Standard Specifications. The thickness of the unbound granular layer shall not be less than 150 mm. The Granular Sub Base and Wet Mix Macadam as Granular layers are considered for the design purpose.

6.1.8 Upgraded Highway Cross-sections

The traffic flow pattern and traffic intensity on the main carriageway and service road is different. Therefore, pavement design for the Main carriageway has been carried out using Design MSA and for the service road has been carried out adopting 10 MSA Design Traffic. The typical sections for upgrading of existing carriageway of the KDP section are prepared and shown in **Figure 6.3** and **Figure 6.4.**

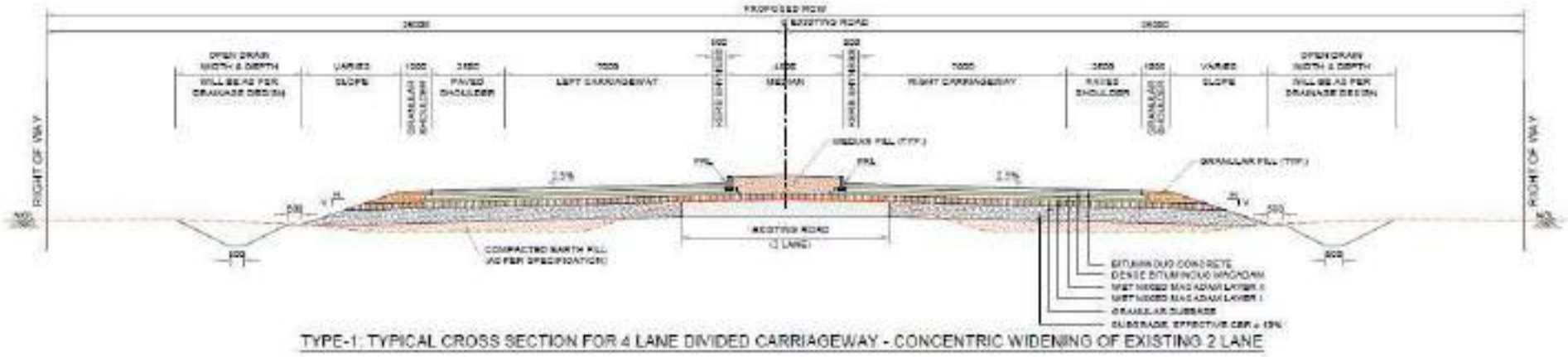


Figure 6.3: Proposed cross-section of the rural areas

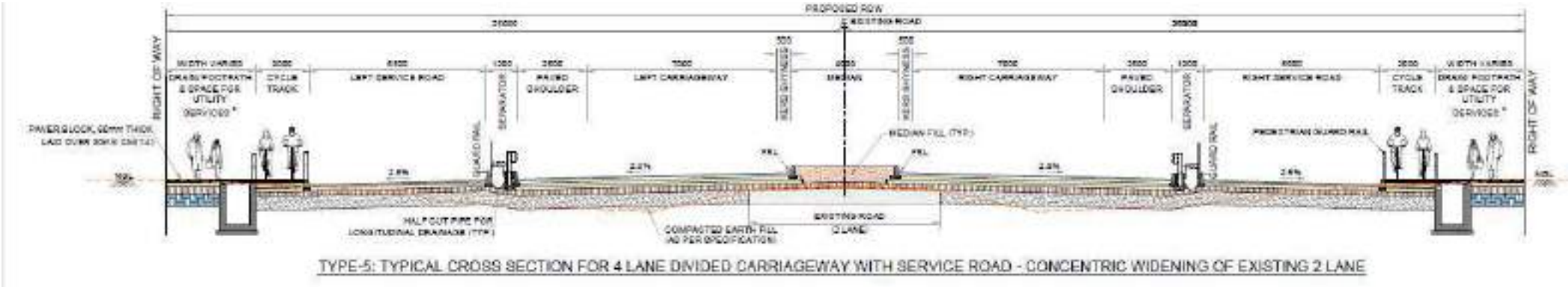


Figure 6.4: Proposed cross-section of the urban areas with service roads

6.1.9 Pavement types

Pavement design for the main and service road has been proposed as the granular sub-base and base and bituminous layers of the binding and wearing course. The design thickness has been adopted from the Pavement Design Guidelines and further the adopted thickness were verified for the failure criteria. The pavement design for the bus-bays (bus stops) and for the truck laybys have been recommended as the rigid type of the pavement. The typical cross sections for Flexible Pavement and Rigid Pavement proposed are shown in **Figure 6.5 and Figure 6.6**.

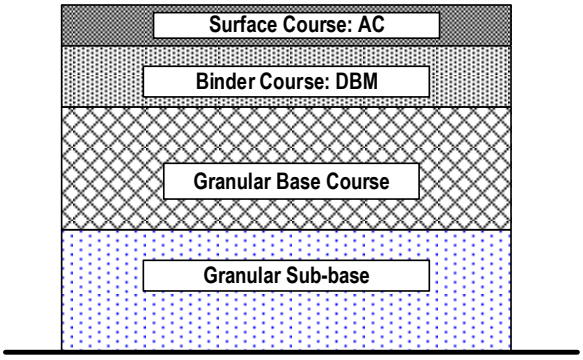


Figure 6.5: Flexible pavement for main carriageway and service Road

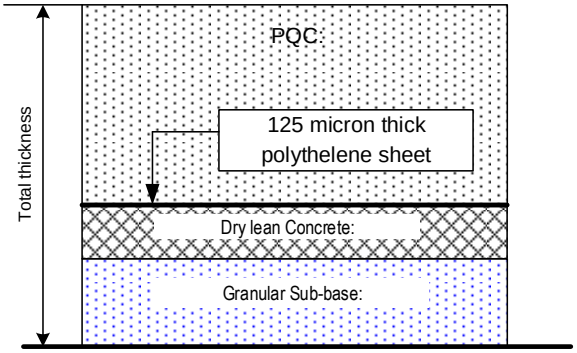


Figure 6.6: Rigid pavement section for Bus bays and truck laybys

6.2 Pavement Design for KDP

The KDP section of Mahendra Highway has been divided into six homogenous considering prevailing/ forecasted traffic pattern and existing road network characteristics.

6.2.1 Design Traffic

The design of pavement mainly depends on the volume of commercial vehicles and respective Axle Load intensity at the base year. Thereafter, the daily axle-load intensity is to be forecasted for the Design Period. The ultimate traffic design traffic adopted in the design is cumulative number of standard axles for the design period.

The different types of commercial vehicles were forecasted for the Design Period of 20 years for each highway sections. The base year commercial traffic for the pavement design has been determined from data collected through Classified Continuous Volume Count survey. The Design Traffic Loading in terms of cumulative number of standard axles for each homogenous section have been worked out by analysis of the axle load survey data. The Average Annual Daily Traffic (AADT) and forecast commercial traffic volume worked out for each homogeneous sections are presented in **Table 6.3 and Table 6.4**.

Table 6.3: Base year traffic volume (AADT, VPD) for the January, 2022 (Consultant's Traffic Survey)

Homogeneous Section	Truck			Bus		
	Multi axle	Heavy	Light	Big	Mini	Micro
Kamala - Dhalkebar	1200	687	125	526	94	620
Dhalkebar- Bardibas	1169	747	137	639	97	529
Bardibas - Nawalpur	800	542	201	673	126	348
Nawalpur - Chapur	814	641	216	623	153	315
Chapur - Nijgadh	813	687	294	621	176	266
Nijgadh - Pathlaiya	748	697	434	744	129	170

Table 6.4: Forecasted commercial traffic volume for 2046 (Consultant's analysis)

Homogeneous Section	Truck			Bus		
	Multi axle	Heavy	Light	Big	Mini	Micro
Kamala - Dhalkebar	2641	1512	276	1043	186	1228
Dhalkebar- Bardibas	2573	1644	302	1268	193	1049
Bardibas - Nawalpur	1522	1031	382	1210	227	627
Nawalpur - Chapur	1549	1221	410	1121	275	567
Chapur - Nijgadh	1549	1309	559	1117	317	479
Nijgadh - Pathlaiya	2660	2294	1213	1878	403	456

The Design Traffic Loading in terms of cumulative number of Million Standards Axle (MSA) has been determined by multiplication of Vehicle Damage Factor worked out from Axle load survey data. The Axle Load Surveys was conducted for commercial vehicles at Pathlaiya and Dhalkebar locations. The data collected at both locations have been taken for representing the loading pattern for the design of pavement. The process of Axle Load data analysis has been explained in the 'Traffic Survey' chapter of this report. The Vehicle Damage Factor (VDF) worked out from the axle load data for each type of commercial vehicle and adopted for working our MSA has been shown in **Table 6.5**.

Table 6.5: Vehicle Damage Factor (VDF) for commercial vehicles (Consultant's study)

MA Truck	Truck	Mini Truck	Large bus	Mini bus	Micro bus
7.12	5.674	1.053	0.660	0.202	0.005

The Design Traffic Loading (repetitions of millions of standard axles) for each homogenous section has been worked out adopting above stated VDF and forecasted no for each category of commercial vehicle for 20 years of Design period. The Design Traffic Loading for all six homogeneous sections is presented in **Table 6.6** below. The details of calculation is presented in **Volume I-B.**

Table 6.6: Design Axle Loads for each Section of KDP

S.N.	Name of Homogeneous Section	Million Standard Axles (MSA) for Design Period
1	Kamala - Dhalkebar	60
2	Dhalkebar- Bardibas	60
3	Bardibas - Nawalpur	38
4	Nawalpur - Chapur	40
5	Chapur – Nijgadh	41
6	Nijgadh - Pathlaiya	72

It can be revealed from above Table that, the Design Traffic Loading in terms of MSA are similar in Kamala – Dhalkebar section and Dhalkebar – Bardibas section. Similarly, Design Traffic Loading are closer in Bardibas – Nawalpur section, Nawalpur – Chapur Section and Chapur – Nijgadh section. Considering closer values of Design Traffic Loading, three sections with different Design Traffic Loading are adopted for Detailed Pavement Design. The detail of adopted Sections with proposed Design Traffic Loading is presented in **Table 6.7**.

Table 6.7: KDP pavement Design Sections and respective design traffic

Section No	Name of Design Section	Design Traffic Loading (MSA)
Section I:	Kamala (CH 237+300) – Bardibas (Bhabsi River, CH 268+300)	60
Section II	Bardibas (Bhabsi River, CH 268+300) - - Nijgadh (Bakaiya River, CH 247+100)	40
Section II:	Nijgadh (Bakaiya River, CH 247+100)) - Pathlaiya Junction (CH 367+000)	75

6.2.2 Design sub-grade strength

The consultant has conducted the CBR test in the laboratory on the subgrade soil above which, the formation for the carriageway has to be built. The CBR test was conducted for the samples taken at 500m interval along the entire highway alignment. The graphical representation of the CBR laboratory of the existing ground soil is shown in **Figure 6.7**.

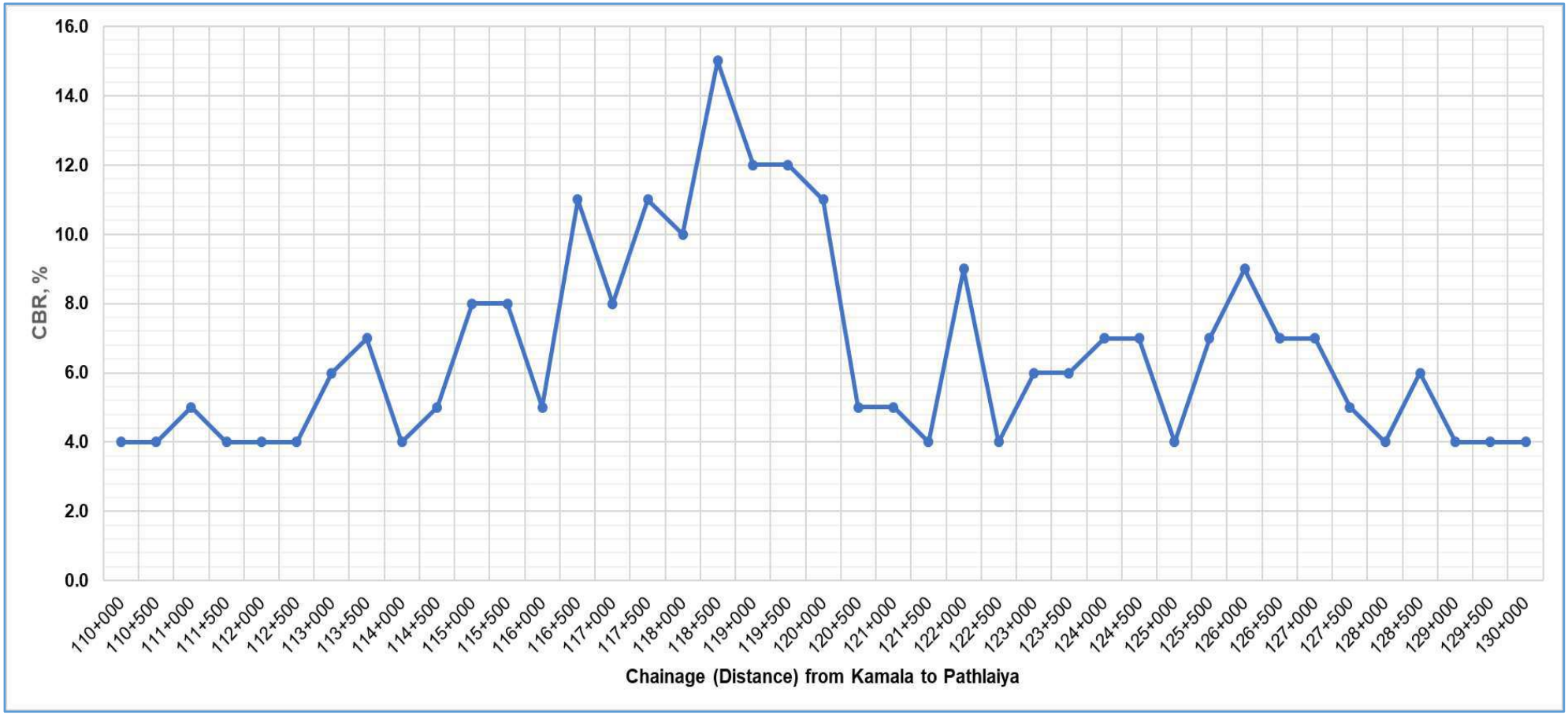


Figure 6.7: CBR values of the existing ground (from Nijgadh to Pathlaiya)

The 90 percentiles of the CBR (laboratory test results) for both sections have been determined as 4 %. Similarly, CBR for the sub-grade of the highway pavement prepared by the borrow material is considered as 15%. The effective CBR has been adopted as 10% for the detailed design of the pavement.

6.2.3 Design of Flexible Pavement

The various alternative of the pavement design has been worked out as per the Pavement Design Guidelines (flexible) second Revision (DoR Publication). The initial trial of the design thickness were checked by the application of IITPave software. The final selection of the pavement thickness (layers) has been adopted separately for the main carriageway and service roads.

a) Pavement for main carriageway

The first trial thickness of pavement layers has been taken as the recommendations from the DoR publication "Guidelines for the Design of Flexible Pavement-2014 (Second revision - 2021) and IRC: 37-2018 Guidelines for the design of Flexible Pavements (Fourth Revision) as shown in **Table 6.8**.

Table 6.8: First trial for the pavement layer thickness for main carriageway for three sections of KDP

Homogeneous Section	Reference	Granular Sub-base (GSB) (mm)	Granular Base (WMM) mm	Binder Course (DBM mm)	Wearing Course (AC, mm)
Kamala – Bardibas (60 MSA)	DoR Guidelines	300	200	60	40
	IRC:37-2018	200	250	110	40
Bardibas – Nijgadh (40 MSA)	DoR Guidelines	250	200	50	40
	IRC:37-2018	200	250	95	40
Nijgadh – Pathlaiya (75 MSA)	DoR Guidelines	300	300	60	40
	IRC:37-2018	200	250	115	40

The pavement layer thickness as shown in **Table 6.8** are taken basis for further analysis on the failure criteria of the respective layers. The analysis of the pavement layer thickness was carried out by the application of IITPave software.

6.2.4 Application of IITPave

The permissible vertical compressive strain at the top of the sub-grade level and the horizontal tensile strain below the bituminous layers have been determined using the pavement design failure criteria (rutting and fatigue models) using Equation1 and Equation 2. The material

properties for the design of flexible pavement are taken as per the Pavement Design Guidelines. These parameters with the analysis parameters are shown in **Table 6.9.** The combined resilient modulus of the sub-grade as well as granular layers have been calculated as per their respective thickness and resilient modulus.

Table 6.9: Design parameters for pavement materials and input parameters in IITPave software

Design Parameters	Details
Subgrade strength (Effective CBR, %)	10
Resilient Modulus of Bituminous Binder Layer (DBM) MPa (VG-30; 25^0c)	3000
Resilient Modulus of Wearing Course (Asphalt Concrete), MPa (VG-30; 25^0c)	3000
Poisson's ration for each layers (three layers)	0.35
Wheel load kN	20,000
Tyre pressure, MPa	0.56
Reliability for the analysis	90 %

The input for the determination of permissible stain in the designated points below the pavement surface have been calculated for each alternative layer thickness using the specified strength of the mix and sub-grade. The strain developed due to the traffic loading at those points have been calculated by using the IITPave software. The analysis was performed with the assumption of three-layer system:

- First layer: combined bituminous layers (Asphalt concrete wearing and Dense Bituminous macadam of Binding layer),
- Second layer: combined granular layers (WMM base and granular sub-base layers),
- Subgrade of 500 mm thickness below the pavement layers.

These results of the IITPave software were compared with the permissible values of the fatigue and rutting criteria. After having the several trial combinations of the layer thickness, the most rationale results achieved for the Project are as shown in **Table 6.10, Table 6.11, and Table 6.12**.

Table 6.10: IITPave input and results for pavement design for Nijgadh – Pathlaiya Section (75 MSA)

Input parameters for IITPave Analysis				
Layers of analysis	**Pavement layers**	**Thickness, mm**	**Elastic Modulus, MPa**	**Remarks**
1- Layer of analysis	AC wearing course	50	3000.00	Combined

Input parameters for IITPave Analysis				
	DBM binder course	100		
2 - Layer of Analysis	WMM base cpourse	250	240.15	Combined
	Granular Sub-base	200		
3 - Layer of analysis	Sub-grade		76.83	
Permissible strains at the critical points				
Maximum Horizontal Tensile Strain at the bottom of bituminous layers (Ɛt) =			0.0001731	
Maximum Vertical Compressive Strain at the top of subgrade (Ɛv) =			0.0003399	
Checking for failure criteria using IITpave				
Fatigue Criteria, Horizontal tensile Strain at the bottom of bituminous layers (Ɛt) =			0.000170	Safe
Rutting criteria, Vertical Compressive Strain at the top of subgrade (Ɛv) =			0.000271	Safe

Table 6.11: IITPave input and results for pavement design for Kamala – Bardibas Section (60 MSA)

Input parameters for IITPave Analysis				
Layers of analysis	**Pavement layers**	**Thickness, mm**	**Elastic Modulus, MPa**	Remarks
1- Layer of analysis	AC wearing course	50	3000.00	Combined
	DBM binder course	90		
2 - Layer of Analysis	WMM base cpourse	250	240.15	Combined
	Granular Sub-base	200		
3 - Layer of analysis	Sub-grade		76.83	
Permissible strains at the critical points				
Maximum Horizontal Tensile Strain at the bottom of bituminous layers (Ɛt) =			0.0001833	
Maximum Vertical Compressive Strain at the top of subgrade (Ɛv) =			0.0003570	
Checking for failure criteria using IITpave				
Fatigue Criteria, Horizontal tensile Strain at the bottom of bituminous layers (Ɛt) =			0.0001809	Safe
Rutting criteria, Vertical Compressive Strain at the top of subgrade (Ɛv) =			0.000287	Safe

Table 6.12: IITPave input and results for pavement design for Bardibas - Nijgadh Section (40 MSA)

Input parameters for IITPave Analysis				
Layers of analysis	**Pavement layers**	**Thickness, mm**	**Elastic Modulus, MPa**	**Remarks**
1- Layer of analysis	AC wearing course	40	3000.00	Combined
	DBM binder course	90		
2 - Layer of Analysis	WMM base course	250	240.15	Combined
	Granular Sub-base	200		

Input parameters for IITPave Analysis				
Layers of analysis	**Pavement layers**	**Thickness, mm**	**Elastic Modulus, MPa**	**Remarks**
3 - Layer of analysis	Sub-grade		76.83	
Permissible strains at the critical points				
Maximum Horizontal Tensile Strain at the bottom of bituminous layers (Ɛt) =			0.0002035	
Maximum Vertical Compressive Strain at the top of subgrade (Ɛv) =			0.0003904	
Checking for failure criteria using IITpave				
Fatigue Criteria, Horizontal tensile Strain at the bottom of bituminous layers (Ɛt) =			0.000187	Safe
Rutting criteria, Vertical Compressive Strain at the top of subgrade (Ɛv) =			0.000293	Safe

The recommended pavement thickness for each homogeneous sections based on above results is as presented in **Table 6.13** below:

Table 6.13: Recommended Pavement Thickness for all Three Sections

Pavement layer	Design Traffic		
	40 MSA	**60 MSA**	**75 MSA**
Wearing Course, AC, mm	40	50	50
Binder Course, DBM, mm	90	90	100
Base course, WMM	250	250	250
Sub-base Course, GSB	200	200	200
Highway Sections	Bardibas, Bhapsi River - Nijgadh, Bakaiya River	Kamal river - Bardibas, Bhapsi River)	Nijgadh, Bakaiya River - Pathlaiya Junction
Highway Chainages	CH 268+300) - CH 347+200)	CH 236+500 – CH 268+300)	CH 347+200 - CH 366+887

Pavement Design for Service Road

The pavement for the service road has been designed for the design traffic 10 MSA for the design years. The initial design thickness of the pavement layers are taken from the IRC: 37-2018 and Guidelines for the Design of Flexible Pavement (second revision 2021). The checking for against the failure criteria was performed by using the IITPave software. The initial design thickness is given in **Table 6.14**.

Table 6.14: Initial Pavement design for Service Road (10 MSA)

Reference guide	Granular Sub-base (mm)	Granular Base (WMM) mm	Binder Course (DBM mm)	Wearing Course (AC, mm)	Total thickness, mm
IRC:37- 2018	200	250	50	30	530
DoR Guidelines	150	150	0	40	340

The initial layer thickness from the design guidelines as shown in **Table 6.13** have been considered for the further analysis using the IITPave software. The most suitable pavement composition for the service road is arrived at as shown in **Table 6.15** below:

Table 6.15: Results of the IITPave & Recommended layer thickness for service road (10 MSA)

Input parameters for IITPave Analysis				
Layers of analysis	**Pavement layers**	**Thickness, mm**	**Elastic Modulus, MPa**	Remarks
1- Layer of analysis	AC wearing course	40	3000.00	Combined
	DBM binder course	50		
2 - Layer of Analysis	WMM base course	150	200.10	Combined
	Granular Sub-base	150		
3 - Layer of analysis	Sub-grade		76.83	
Permissible strains at the critical points				
Maximum Horizontal Tensile Strain at the bottom of bituminous layers (Ɛt) =			0.0003891	
Maximum Vertical Compressive Strain at the top of subgrade (Ɛv) =			0.0006732	
Checking for failure criteria using IITpave				
Fatigue Criteria, Horizontal tensile Strain at the bottom of bituminous layers (Ɛt) =			0.0002913	Safe
Rutting criteria, Vertical Compressive Strain at the top of subgrade (Ɛv) =			0.0005962	Safe

Table 6.16: Final pavement design result (service road)

Pavement layers	Design Thickness, mm	Adopted Thickness, mm	Remarks
AC wearing course	40	40	
DBM binder course	50	50	
WMM base course	150	150	
Granular Sub-base	150	200	same thickness of GSB as of the main carriageway

6.2.5 Design of Rigid Pavement

The pavement type for the bus stops/bays and for the truck laybys are recommended as the rigid pavement. The rigid pavement design has been carried out for Bus stops/ bays and Truck Laybye locations with the following consideration:

- The rigid pavement for those places is taken as Continuously Reinforced Concrete Pavement (CRCP) type with the elastic joint. The design has been followed the '**Pavement Design Guidelines (Rigid Pavement); DoR publications** and the IRC:118-2015, **'Guidelines for the Design and Construction of Continuously Reinforced Concrete Pavement (CRCP)**'

The design of rigid pavement for the Bus stops (bus bays), Truck Laybys are designed as the continuously reinforced concrete pavement (CRCP). The design is concluded as the determination of the required reinforcing steel (longitudinal as well as transverse bars) for the given depth of the concrete slab of the pavement. The design is started as the assumption of the slab depth of 300 mm and other calculations were performed.

6.2.5.1 Pavement composition

The CRCP pavement is recommended to provide with the Dry Lean Concrete (DLC) under the concrete pavement slab. A typical section of the rigid pavement is shown in in **Figure 6.6**.

The support for the CRCP shall be uniform and satisfy the required bearing capacity. As per the pavement design guidelines Subgrade of minimum 500 mm thickness is required to be provided under subbase and compacted to a minimum of 97 percent of Maximum Dry Density (MDD) of heavy compaction and soaked minimum soaked CBR shall not be less than 10 percent at 97 percent of MDD of heavy compaction. Subbase is a lower pavement layer which is provided above the subgrade and below the base layer. This mix is normally produced with crushed stone aggregates. Base layer can be of either Dry Lean Concrete (DLC) layer or a bituminous layer. It is important that the base should not get eroded due to entry of moisture. Use of granular layers and cement treated or modified soil can also be constructed but such layer requires high degree of quality control in respect of uniformity in mixing cement with soil.

6.2.5.2 Longitudinal reinforcement

The primary reinforcement of CRCP consists of deformed bars placed in the longitudinal direction. It helps in controlling and distributing cracks in transverse direction with close spacing and minimal width. The steel bars for longitudinal reinforcement is taken as 20 mm diameter. As per the IRC: 118-2015 steel percentage of 0.7 percent of pavement cross-section is taken for the design. The clear spacing between the two adjacent bars should be at least equal to three times the dimension of the coarsest aggregate used for the concrete mix.

The width of each concrete slab is 3.5 m. The steel required in each lane of 350 cm at the rate of 0.7% is: 73.5 sq.cm. The cross-sectional area of the 20 mm diameter bar is 3.14 sq. cm, then the number of bars for the longitudinal reinforcement is 24 numbers. Providing the cover on the both sides of the slab, the spacing of 143 mm c/c.

6.2.5.3 Transverse reinforcement

The traverse reinforcement is provided for the full width of the pavement and these bars are tied to the longitudinal bars which help supporting them. The transverse bars, therefore, are fixed on chair assembly first and longitudinal bars placed above them. The reinforcement

design is based on equilibrium of base layer restraint (friction) and concrete contraction forces. The area (percentage) of steel for the transverse reinforcement is calculated from the equation suggested as:

$$P_t = \frac{\gamma_c W_s F}{2 f_s} x100$$

Where,

P_t – Transverse steel, %

γ_c - Unit weight of concrete (24 kN/m3)

W_s - Total pavement width (3.5 m)

F - Sub-base friction factor, (1.5)

f_s - Allowable working stress in steel (75% of yield strength), (490330 kN/m^2)

The calculated percentage of transverse steel is 0.0171 % of the cross section of (1 m length) the slab. The reinforcement bar of 12 mm diameter is used for the transverse steel therefore the spacing of the bar calculated as 219 mm however, the recommended spacing of the transverse bars is 60 cm c/c. The cross section of the continuously reinforced concrete pavement is shown in **Figure 6.8.**

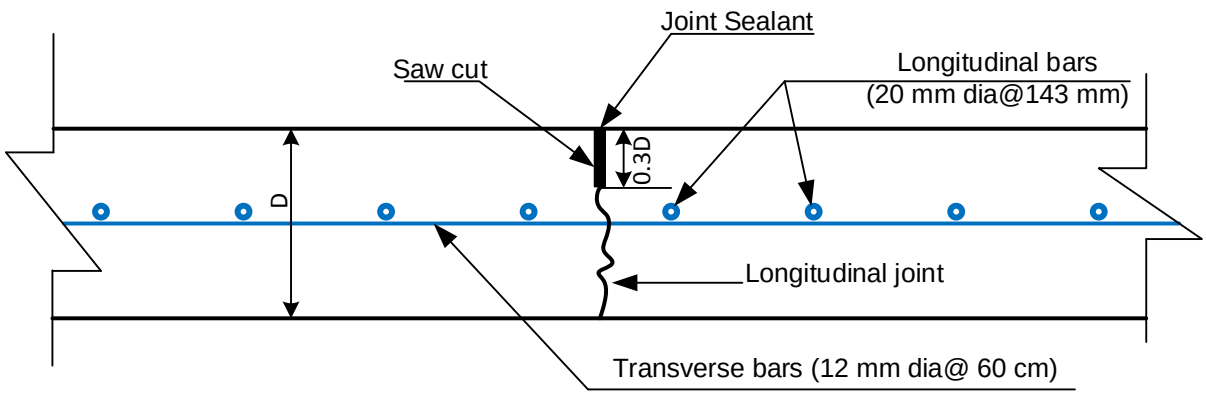


Figure 6.8: Cross-sectional view of the CRCP for bus-bay and truck laybys

6.2.6 Bus – bay and Truck Laybys

Mainly bus stops are located along the service road in the urban area. However, in the case of rural types of road section, the bus-bays are provided with the rigid pavement. Similarly, the truck laybys are provided at the designated locations along the rural type of the road sections.

The total thickness rigid pavement for the bus-bay as well as truck-laybys is 650 mm as shown in **Figure 6.9**.

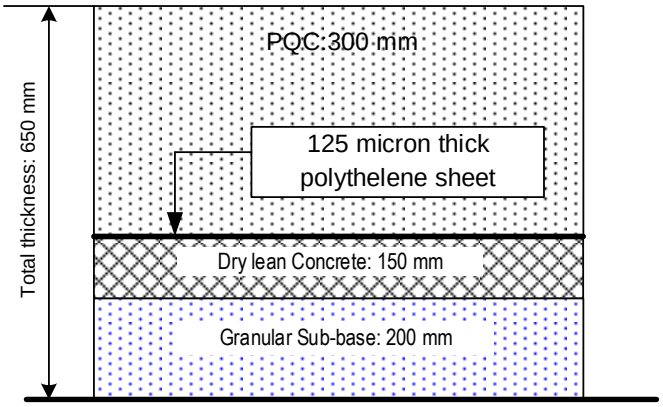


Figure 6.9: Section of the rigid pavement

The pavement for the two-lane wide truck lay-bys is identical with the CRCP pavement designed for bus-bays. The longitudinal joint shall be provided as shown in **Figure 6.8**. The typical layout of the bus-bay and truck-laybys is shown in **Figure 6.10 and Figure 6.11**.

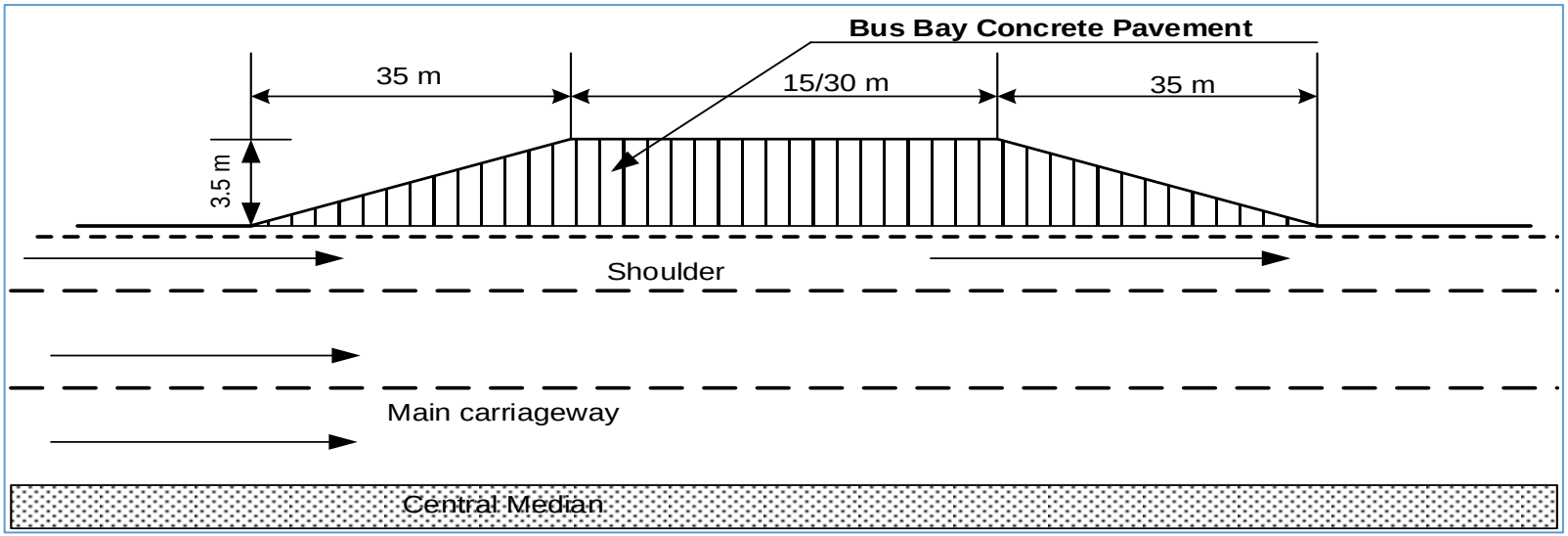


Figure 6.10: Typical layout of the bus-bay

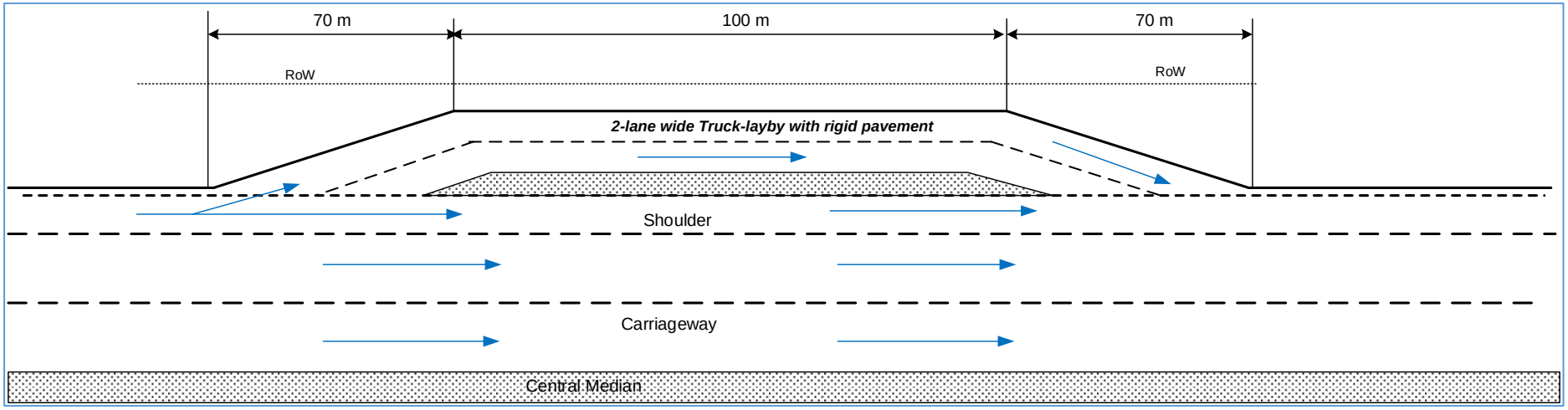


Figure 6.11: Typical layout of the truck-layout

6.2.7 Pavement composition for cycle track

In the urban sections of the highway, the service road have been provided with the cycle track and footpath at the outer edge of the service roads on both sides. The construction of the cycle track paved section was separated by the kerb-stone with the service roads section. The cycle-track and the footpath has been constructed over the sand bedding. The thickness of the sand bedding along the cycle track and footpath is 30mm. The sand layer is supported by the compacted gravel and granular sub base of the service road along the cycle track, whereas the sand bedding was laid over the granular sub base along the footpath. Covered drainage channel has been designed in the space under the footpath. The surface of the footpath as well as cycle-track is made by the 50 mm thick cast-in-situ cement concrete M20. This concrete slab is supported by the 12 mm thick cement mortar of 1:3. The details of this sections has been shown in the typical cross-section of the highway along the urban area. The sectional view of the footpath and the cycle track is shown in the figure below.

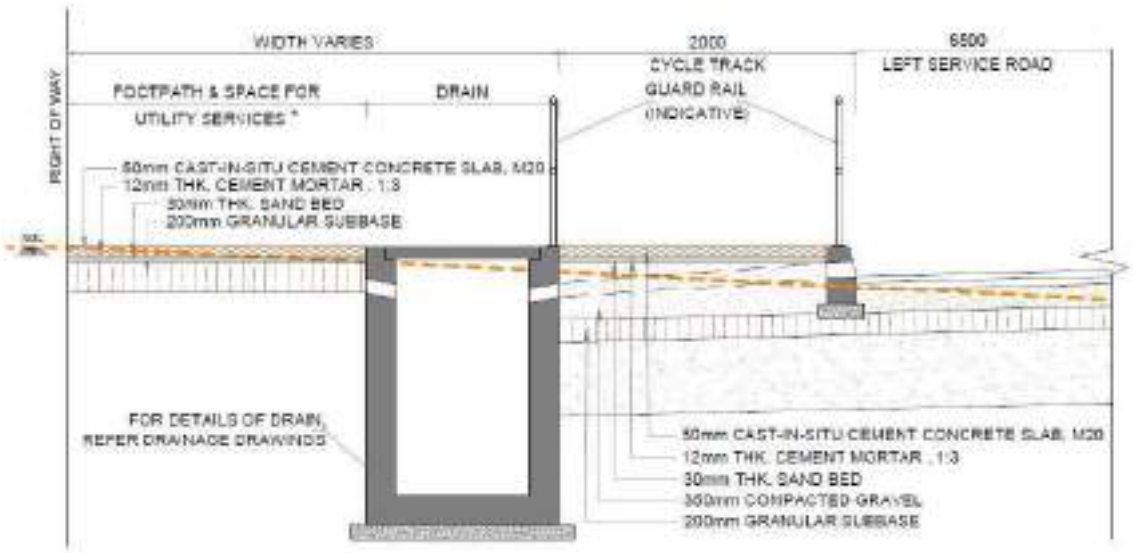


Figure 6.12: Footpath and Cycle track Cross-section

Chapter 7: Geometric Design

7.1 General

The geometric design for the road has been carried out considering the proposal of existing bridge structures and new bridge structures. There are total seventy six (76) nos. of major and minor bridges provided across the streams crossing the road for entire length.

The geometric design of the road is carried out to provide safe and smooth movement of vehicles operating at the designated posted speed with minimum disturbance to local / slow moving traffic. The proposed four laning of Kamala – Dhalkebar - Pathlaiya section of the Mahendra Highway is classified as Class II road as per NRS 2070 and hence, the geometric parameters are considered for this category of road. The Consultant has also reviewed the provisions of Indian Roads Congress applicable for four laning of highway under mixed traffic conditions with partial access controlled facility and made certain modifications in the design standards. These are presented in Chapter 2 of this report.

7.2 Typical Cross Sections

The horizontal alignment of the proposed four lane divided road depends whether the existing bridges (76 nos) are proposed to be retained / widened / dismantled or reconstructed. The Consultant had prepared several options for the bridges and carried out detailed discussion with the Client during the Conceptual Design Stage as well as subsequent meetings/site inspections. The client had directed the consultant to retain existing bridges with repair and rehabilitation wherever possible and provide new bridge on South of existing bridge to cater for bi-directional traffic.

The available Right of Way for entire length of the project road is 50m, i.e., 25m on both sides from the Center line of existing road.

The Consultant had proposed grade separated structures in form of Flyover and Vehicular Underpass at identified Major junctions in congested urban sections at DDPR submission stage in order to separate through and local cross traffic for safe and smooth movement.

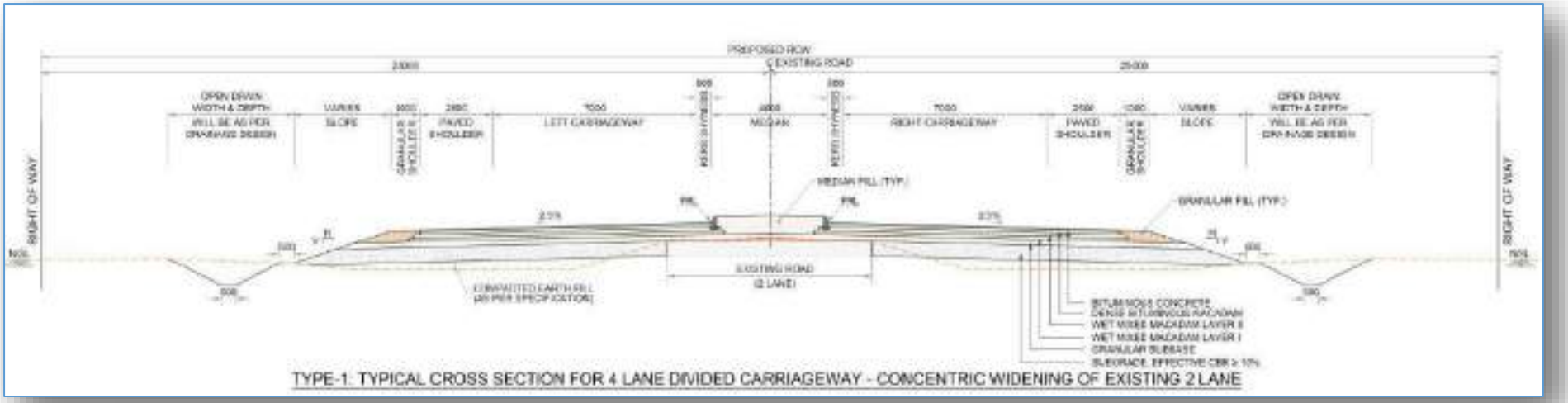
Considering the above all aspects, the horizontal alignment design is carried as follows:

- Concentric widening in normal sections, i.e., rural and urban sections with alignment set out line generally along the existing road center.

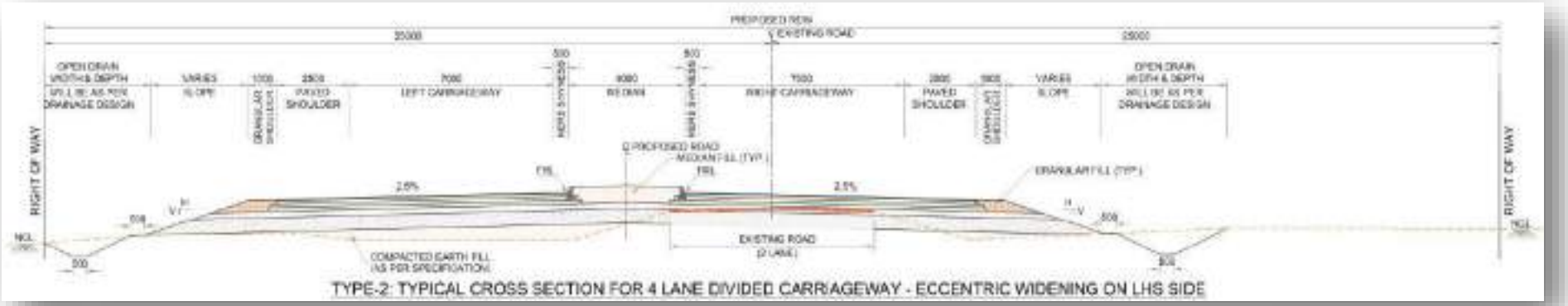
- Alignment set out line designed slightly away from the crash barrier of the existing bridge at sections where existing bridges are proposed to be retained and new bridge proposed on South.
- Concentric widening of existing road at underpass and flyover locations including approaches.
- Concentric widening on sections where few existing bridges are proposed to be “not used / abandoned” and new bridges are proposed on North and South of the abandoned bridges.

7.3 Typical Cross Sections

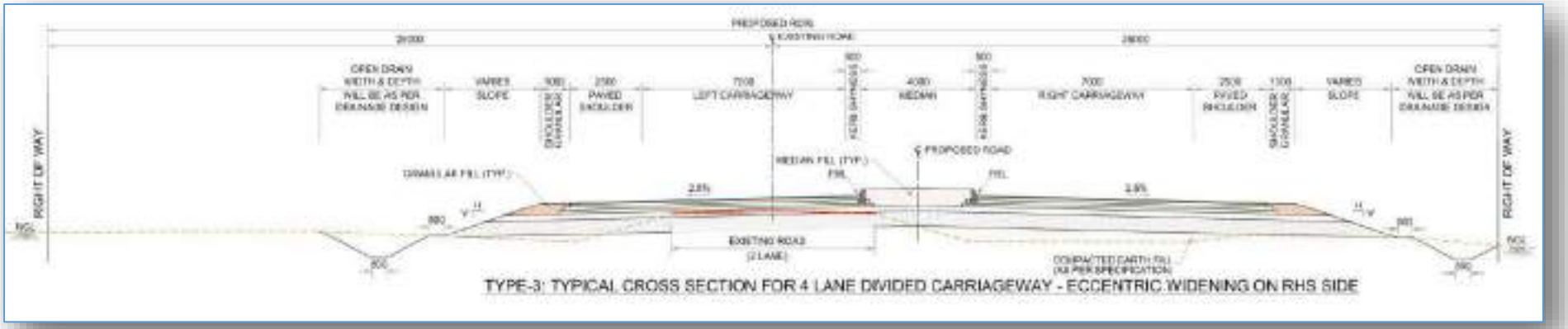
The consultant has developed Typical Cross Sections for road and structures depending on the project features, type of widening proposed, use of existing road etc., The developed Typical Cross Sections are presented as **Type 1 to Type 12** for reference.



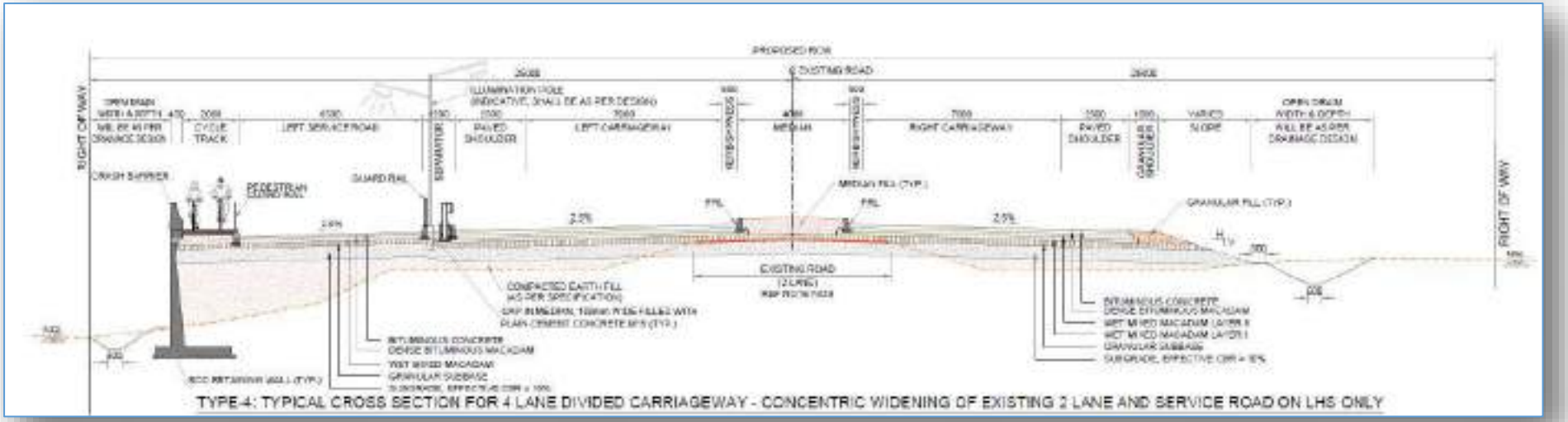
TYPE-1: TYPICAL CROSS SECTION FOR 4 LANE DIVIDED CARRIAGEWAY - CONCENTRIC WIDENING OF EXISTING 2 LANE



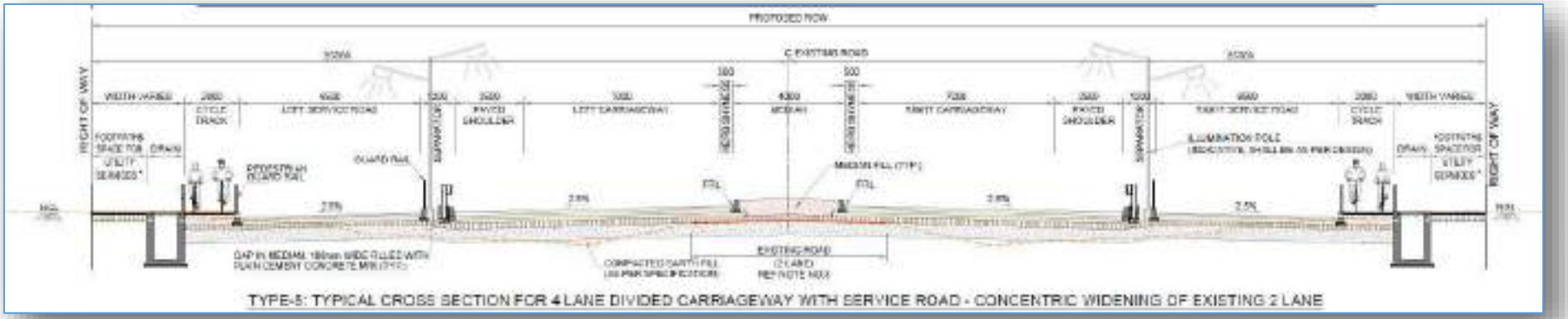
TYPE-2: TYPICAL CROSS SECTION FOR 4 LANE DIVIDED CARRIAGEWAY - ECCENTRIC WIDENING ON LHS SIDE



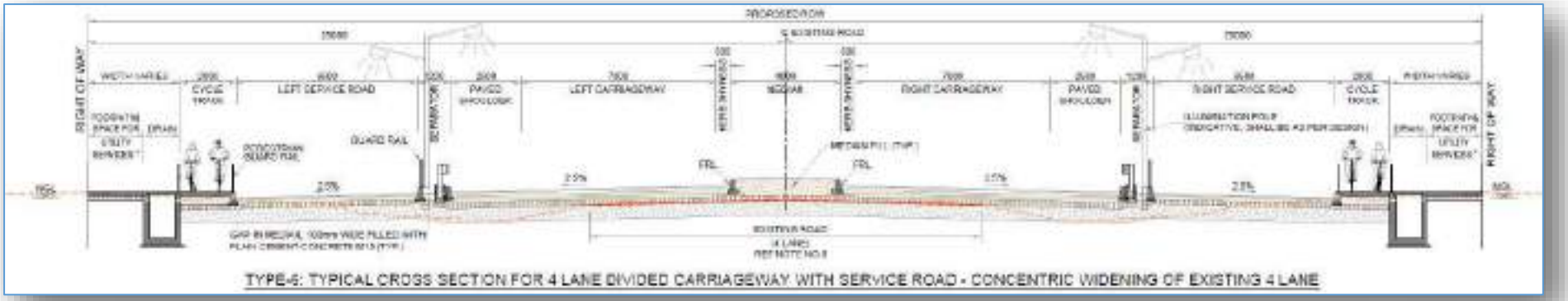
TYPE-3: TYPICAL CROSS SECTION FOR 4 LANE DIVIDED CARRIAGEWAY - ECCENTRIC WIDENING ON RHS SIDE



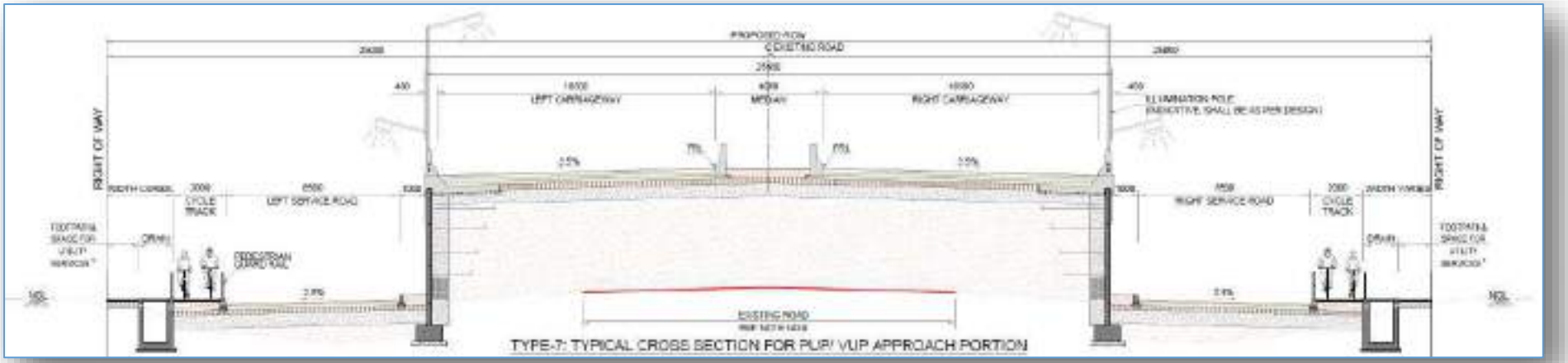
TYPE-4: TYPICAL CROSS SECTION FOR 4 LANE DIVIDED CARRIAGEWAY - CONCENTRIC WIDENING OF EXISTING 2 LANE AND SERVICE ROAD ON LHS ONLY



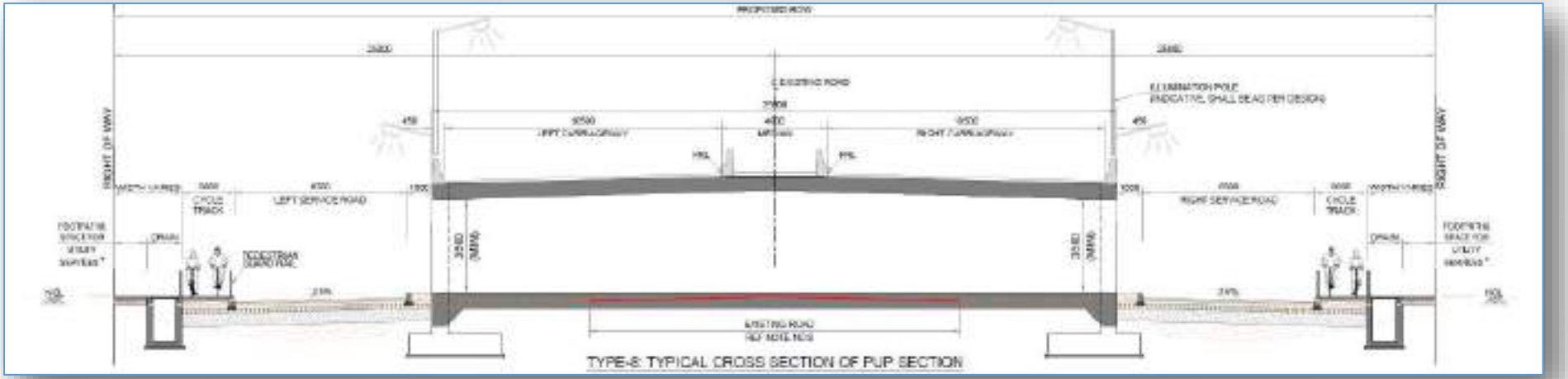
TYPE-5: TYPICAL CROSS SECTION FOR 4 LANE DIVIDED CARRIAGEWAY WITH SERVICE ROAD - CONCENTRIC WIDENING OF EXISTING 2 LANE



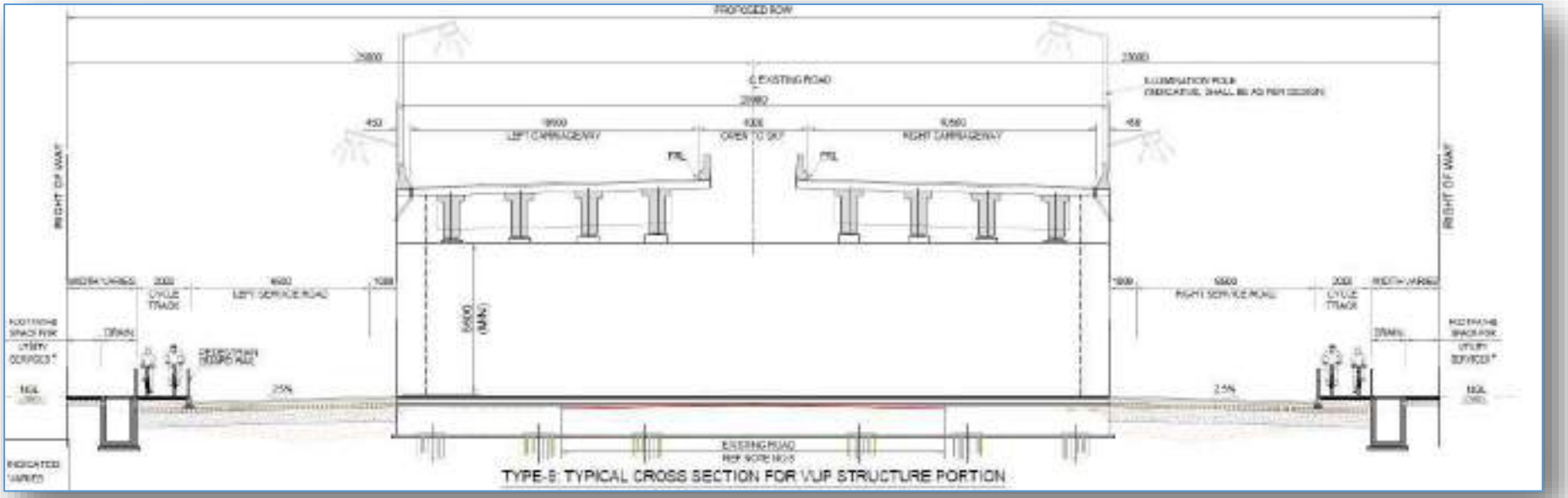
TYPE-6: TYPICAL CROSS SECTION FOR 4 LANE DIVIDED CARRIAGEWAY WITH SERVICE ROAD - CONCENTRIC WIDENING OF EXISTING 4 LANE



TYPE-7: TYPICAL CROSS SECTION FOR PUP/ VUP APPROACH PORTION



TYPE-8: TYPICAL CROSS SECTION OF PUP SECTION


PROPOSED ROW
EXISTING ROAD
LEFT CARRIAGEWAY
OPEN TO SKY
RIGHT CARRIAGEWAY
RIGHT OF WAY
RIGHT OF WAY
LEFT SERVICE ROAD
RIGHT SERVICE ROAD
CYCLE TRACK
CYCLE TRACK
EXISTING ROAD
TYPE-6: TYPICAL CROSS SECTION FOR VUP STRUCTURE PORTION

7.3.1 Schedule of Typical Cross Sections

The schedule of typical cross sections has been worked out based on the widening scheme of the bridges and proposal for alignment design line (horizontal geometry). The Consultant has worked out 12 types of typical cross sections applicable for complete project road. The bridge spans are excluded in the TCS. The transition section between the road section and approaches to bridges / structures are also identified while preparing Cross Section Schedule. The schedule of various types of cross sections proposed to be used for development of the project road is provided **Table 7.1** below.

Table 7.1: Schedule for Typical Cross Section

Sl No	Design Chainage (m)		Length (m)	Cross Section Type / Other Details
	From	To		
1	236+500	236+702	202	Transition Portion
2	236+702	237+342	640	Kamala Bridge
3	237+342	237+500	158	Type-2
4	237+500	237+930	430	Type-2
5	237+930	238+080	150	Transition Portion
6	238+080	238+125	45	Kamala Canal
7	238+125	238+290	165	Transition Portion
8	238+290	239+280	990	Type-1
9	239+280	239+400	120	Transition Portion
10	239+400	239+900	500	Type-5
11	239+900	240+020	120	Transition Portion
12	240+020	241+430	1410	Type-1
13	241+430	241+584	154	Transition Portion
14	241+584	241+905	321	Charnath Bridge
15	241+905	242+060	155	Transition Portion
16	242+060	242+880	820	Type-1
17	242+880	243+000	120	Transition Portion
18	243+000	243+100	100	Type-5
19	243+100	243+396	296	Type-7
20	243+396	243+404	8	Type-8
21	243+404	243+630	226	Type-7
22	243+630	243+650	20	Type-9
23	243+650	243+836	186	Type-7
24	243+836	243+844	8	Type-8
25	243+844	244+100	256	Type-7
26	244+100	244+220	120	Transition Portion
27	244+220	245+020	800	Type-1
28	245+020	245+172	152	Transition Portion
29	245+172	245+284	112	Baluwa Bridge
30	245+284	245+440	156	Transition Portion
31	245+440	247+380	1940	Type-1
32	247+380	247+500	120	Transition Portion
33	247+500	247+800	300	Type-5
34	247+800	247+920	120	Transition Portion
35	247+920	250+600	2680	Type-1

Sl No	Design Chainage (m)		Length (m)	Cross Section Type / Other Details
	From	To		
36	250+600	250+751	151	Transition Portion
37	250+751	250+771	20	Jagdev Branch Bridge
38	250+771	251+068	297	Transition Portion
39	251+068	251+121	53	Jagadev Bridge
40	251+121	251+295	174	Transition Portion
41	251+295	252+195	900	Type-1
42	252+195	252+347	152	Transition Portion
43	252+347	252+613	266	Jalad Bridge
44	252+613	252+770	157	Transition Portion
45	252+770	254+350	1580	Type-1
46	254+350	254+503	153	Transition Portion
47	254+503	254+822	319	Aurahi Bridge
48	254+822	254+980	158	Transition Portion
49	254+980	255+985	1005	Type-1
50	255+985	256+138	153	Transition Portion
51	256+138	256+234	96	Basai Bridge
52	256+234	256+440	206	Transition Portion
53	256+440	258+300	1860	Type-5
54	258+300	258+420	120	Transition Portion
55	258+420	258+565	145	Type-1
56	258+565	258+712	147	Transition Portion
57	258+712	258+756	44	Sukhajor Bridge
58	258+756	258+910	154	Transition Portion
59	258+910	260+740	1830	Type-1
60	260+740	260+887	147	Transition Portion
61	260+887	260+962	75	Barahari Bridge
62	260+962	261+110	148	Transition Portion
63	261+110	265+090	3980	Type-1
64	265+090	265+229	139	Transition Portion
65	265+229	265+455	226	Ratu Bridge
66	265+455	265+595	140	Transition Portion
67	265+595	266+280	685	Type-1
68	266+280	266+400	120	Transition Portion
69	266+400	268+100	1700	Type-5
70	268+100	268+278	178	Transition Portion
71	268+278	268+353	75	Bhapsi Bridge
72	268+353	268+485	132	Transition Portion
73	268+485	269+210	725	Type-1
74	269+210	269+360	150	Transition Portion
75	269+360	269+389	29	Atabbe Bridge
76	269+389	269+540	151	Transition Portion
77	269+540	270+680	1140	Type-1
78	270+680	270+810	130	Transition Portion
79	270+810	270+935	125	Jangapul-1 Bridge
80	270+935	271+060	125	Transition Portion
81	271+060	271+330	270	Type-1
82	271+330	271+477	147	Transition Portion
83	271+477	271+552	75	Gadhanta Bridge
84	271+552	271+690	138	Transition Portion

Sl No	Design Chainage (m)		Length (m)	Cross Section Type / Other Details
	From	To		
85	271+690	274+760	3070	Type-1
86	274+760	274+904	144	Transition Portion
87	274+904	274+944	40	Belgachhi Bridge
88	274+944	275+090	146	Transition Portion
89	275+090	275+470	380	Type-1
90	275+470	275+621	151	Transition Portion
91	275+621	275+641	20	Tuteswor-1 Bridge
92	275+641	275+847	206	Transition Portion
93	275+847	275+867	20	Tuteswor-2 Bridge
94	275+867	276+015	148	Transition Portion
95	276+015	277+050	1035	Type-1
96	277+050	277+201	151	Transition Portion
97	277+201	277+378	177	Maraha Bridge
98	277+378	277+510	132	Transition Portion
99	277+510	278+750	1240	Type-1
100	278+750	278+895	145	Transition Portion
101	278+895	278+933	38	Dholan Bridge
102	278+933	279+085	152	Transition Portion
103	279+085	280+425	1340	Type-1
104	280+425	280+566	141	Transition Portion
105	280+566	280+586	20	Jarlahi Bridge
106	280+586	280+735	149	Transition Portion
107	280+735	281+825	1090	Type-1
108	281+825	281+975	150	Transition Portion
109	281+975	282+004	29	Batuwa Brdige
110	282+004	282+155	151	Transition Portion
111	282+155	282+560	405	Type-1
112	282+560	282+709	149	Transition Portion
113	282+709	282+811	102	Bhankhe Bridge
114	282+811	282+960	149	Transition Portion
115	282+960	285+565	2605	Type-1
116	285+565	285+712	147	Transition Portion
117	285+712	285+737	25	Amuwa Bridge
118	285+737	285+890	153	Transition Portion
119	285+890	290+030	4140	Type-1
120	290+030	290+150	120	Transition Portion
121	290+150	290+275	125	Phuljor Bridge
122	290+275	290+415	140	Transition Portion
123	290+415	291+705	1290	Type-5
124	291+705	291+855	150	Transition Portion
125	291+855	291+884	29	Kalinjor-1 Bridge
126	291+884	292+035	151	Transition Portion
127	292+035	292+520	485	Type-1
128	292+520	292+671	151	Transition Portion
129	292+671	292+737	66	Kalinjor-2 Bridge
130	292+737	292+890	153	Transition Portion
131	292+890	294+030	1140	Type-1
132	294+030	294+150	120	Transition Portion
133	294+150	294+360	210	Type-5

Sl No	Design Chainage (m)		Length (m)	Cross Section Type / Other Details
	From	To		
134	294+360	294+556	196	Type-7
135	294+556	294+564	8	Type-8
136	294+564	294+890	326	Type-7
137	294+890	294+910	20	Type-9
138	294+910	295+066	156	Type-7
139	295+066	295+074	8	Type-8
140	295+074	295+250	176	Type-7
141	295+250	295+350	100	Transition Portion
142	295+350	295+375	25	Dumdume Bridge
143	295+375	295+550	175	Transition Portion
144	295+550	296+300	750	Type-5
145	296+300	296+420	120	Transition Portion
146	296+420	298+980	2560	Type-1
147	298+980	299+100	120	Transition Portion
148	299+100	299+316	216	Type-7
149	299+316	299+324	8	Type-8
150	299+324	299+540	216	Type-7
151	299+540	299+560	20	Type-9
152	299+560	299+816	256	Type-7
153	299+816	299+824	8	Type-8
154	299+824	300+050	226	Type-7
155	300+050	300+170	120	Transition Portion
156	300+170	300+220	50	Type-1
157	300+220	300+365	145	Transition Portion
158	300+365	300+569	204	Lakhandei Bridge
159	300+569	300+720	151	Transition Portion
160	300+720	301+760	1040	Type-1
161	301+760	301+912	152	Transition Portion
162	301+912	302+022	110	Chapani Bridge
163	302+022	302+170	148	Transition Portion
164	302+170	303+480	1310	Type-1
165	303+480	303+600	120	Transition Portion
166	303+600	303+780	180	Type-5
167	303+780	303+986	206	Type-7
168	303+986	303+994	8	Type-8
169	303+994	304+180	186	Type-7
170	304+180	304+200	20	Type-9
171	304+200	304+386	186	Type-7
172	304+386	304+394	8	Type-8
173	304+394	304+600	206	Type-7
174	304+600	304+800	200	Type-5
175	304+800	304+920	120	Transition Portion
176	304+920	306+480	1560	Type-1
177	306+480	306+600	120	Transition Portion
178	306+600	306+876	276	Type-7
179	306+876	306+884	8	Type-8
180	306+884	307+040	156	Type-7
181	307+040	307+060	20	Type-9
182	307+060	307+296	236	Type-7

Sl No	Design Chainage (m)		Length (m)	Cross Section Type / Other Details
	From	To		
183	307+296	307+304	8	Type-8
184	307+304	307+500	196	Type-7
185	307+500	307+732	232	Transition Portion
186	307+732	307+770	38	Rai Bridge
187	307+770	307+920	150	Transition Portion
188	307+920	309+845	1925	Type-1
189	309+845	309+995	150	Transition Portion
190	309+995	310+035	40	Dumajor Bridge
191	310+035	310+185	150	Transition Portion
192	310+185	311+430	1245	Type-1
193	311+430	311+575	145	Transition Portion
194	311+575	311+595	20	Godari Bridge
195	311+595	311+850	255	Transition Portion
196	311+850	312+300	450	Type-5
197	312+300	312+455	155	Transition Portion
198	312+455	312+480	25	Bhagmati East Bridge
199	312+480	312+625	145	Transition Portion
200	312+625	312+785	160	Type-5
201	312+785	312+936	151	Transition Portion
202	312+936	313+299	363	Bhagmati Bridge
203	313+299	313+450	151	Transition Portion
204	313+450	313+650	200	Type-5
205	313+650	313+801	151	Transition Portion
206	313+801	313+826	25	Bhagmati West Bridge
207	313+826	314+138	312	Transition Portion
208	314+138	314+173	35	Gairi Bridge
209	314+173	314+330	157	Transition Portion
210	314+330	317+500	3170	Type-1
211	317+500	317+653	153	Transition Portion
212	317+653	317+719	66	Paurai Bridge
213	317+719	317+870	151	Transition Portion
214	317+870	319+170	1300	Type-1
215	319+170	319+322	152	Transition Portion
216	319+322	319+342	20	Lachkan Bridge
217	319+342	319+500	158	Transition Portion
218	319+500	323+405	3905	Type-1
219	323+405	323+565	160	Transition Portion
220	323+565	323+590	25	Katha ko pul Bridge
221	323+590	323+750	160	Transition Portion
222	323+750	324+820	1070	Type-1
223	324+820	324+970	150	Transition Portion
224	324+970	325+135	165	Chandi Bridge
225	325+135	325+350	215	Transition Portion
226	325+350	327+300	1950	Type-5
227	327+300	327+420	120	Transition Portion
228	327+420	327+845	425	Type-1
229	327+845	327+995	150	Transition Portion
230	327+995	328+015	20	Jungle Tole Bridge
231	328+015	328+165	150	Transition Portion

Sl No	Design Chainage (m)		Length (m)	Cross Section Type / Other Details
	From	To		
232	328+165	329+580	1415	Type-1
233	329+580	329+726	146	Transition Portion
234	329+726	329+751	25	Amu-1 Bridge
235	329+751	329+900	149	Transition Portion
236	329+900	332+630	2730	Type-1
237	332+630	332+782	152	Transition Portion
238	332+782	332+812	30	Kathi Bridge
239	332+812	332+970	158	Transition Portion
240	332+970	333+540	570	Type-1
241	333+540	333+688	148	Transition Portion
242	333+688	333+754	66	Lamaha Bridge
243	333+754	333+900	146	Transition Portion
244	333+900	334+290	390	Type-1
245	334+290	334+443	153	Transition Portion
246	334+443	334+476	33	Kali khola
247	334+476	334+630	154	Transition Portion
248	334+630	339+090	4460	Type-1
249	339+090	339+242	152	Type-3
250	339+242	339+406	164	Dhansar Bridge
251	339+406	339+560	154	Type-3
252	339+560	342+080	2520	Type-1
253	342+080	342+238	158	Transition Portion
254	342+238	342+263	25	Lamopul
255	342+263	342+420	157	Transition Portion
256	342+420	343+400	980	Type-1
257	343+400	343+550	150	Transition Portion
258	343+550	343+583	33	Bhamara Bridge
259	343+583	343+735	152	Transition Portion
260	343+735	343+920	185	Type-1
261	343+920	344+068	148	Transition Portion
262	344+068	344+088	20	Rampul Bridge
263	344+088	344+250	162	Transition Portion
264	344+250	345+700	1450	Type-5
265	345+700	346+800	1100	Type-6
266	346+800	347+012	212	Transition Portion
267	347+012	347+367	355	Bakeya Bridge
268	347+367	347+520	153	Transition Portion
269	347+520	348+750	1230	Type-1
270	348+750	348+870	120	Transition Portion
271	348+870	348+958	88	Type-5
272	348+958	348+993	35	Unasi Bridge
273	348+993	349+060	67	Type-5
274	349+060	349+180	120	Transition Portion
275	349+180	353+430	4250	Type-1
276	353+430	353+590	160	Transition Portion
277	353+590	353+625	35	Terhakilo Bridge
278	353+625	353+780	155	Transition Portion
279	353+780	354+470	690	Type-1
280	354+470	354+620	150	Transition Portion

Sl No	Design Chainage (m)		Length (m)	Cross Section Type / Other Details
	From	To		
281	354+620	354+655	35	Barahakilo Bridge
282	354+655	354+810	155	Transition Portion
283	354+810	356+975	2165	Type-1
284	356+975	357+124	149	Transition Portion
285	357+124	357+289	165	Pasaha Bridge
286	357+289	357+440	151	Transition Portion
287	357+440	358+290	850	Type-1
288	358+290	358+440	150	Transition Portion
289	358+440	358+475	35	Bangandi Bridge
290	358+475	358+625	150	Transition Portion
291	358+625	360+670	2045	Type-1
292	360+670	360+816	146	Transition Portion
293	360+816	360+882	66	Balganga Bridge
294	360+882	361+030	148	Transition Portion
295	361+030	362+690	1660	Type-1
296	362+690	362+839	149	Transition Portion
297	362+839	362+885	46	Baijura Bridge
298	362+885	363+035	150	Transition Portion
299	363+035	365+540	2505	Type-1
300	365+540	365+688	148	Transition Portion
301	365+688	365+723	35	Tin Bridge
302	365+723	365+870	147	Transition Portion
303	365+870	366+180	310	Type-1
304	366+180	366+300	120	Transition Portion
305	366+300	366+750	450	Type-6
306	366+750	366+887	137	Pathlaiya Jn

The Typical Cross Section wise length has been worked out and summary has been provided in **Table 7.2** below for reference.

Table 7.2: Summary Length for Typical Cross Sections

TCS Type	Length (in m)
Type-1	86345
Type-2	588
Type-3	306
Type-4	-
Type-5	11455
Type-6	1550
Type-7	4380
Type-8	80
Type-9	100
Transition Portion	19850
Structure Portion	5733
Total Length	130387

7.4 Alignment Design

The geometric design is carried out using topography survey carried out at Concept Design stage as per Scope of Services. The horizontal geometric parameters used for the detailed design are mentioned in Chapter 2. The general principles adopted in the design are as follows:

- Right of Way of 25m on either side of centerline of existing road
- For Bridge and its approaches sections - New bridges will be provided on Southern side of existing bridge and alignment will be left eccentric. Accordingly, the alignment design line is considered at an approximate distance of 1m south of existing bridge.
- Horizontal design is carried out considering design speed of 100 Kmph except at locations where land is a constraint and the proposed 4 lane cannot be accommodated within 50m right of way. Design speed of 75 Kmph is adopted in such sections.
- Adequate provision of length of circular curve, transition curve and rollover length.
- The central median on the normal section (4m) is flared to merge with the kerb edges of existing and new bridge for those existing bridges, which are not proposed to be used as per observations made, while carrying out structural inventory / condition surveys.

The geometric design has been carried out using MX Roads software. The summary of alignment design with geometric parameters is provided in **Table 7.3** below.

Table 7.3: Details of Horizontal Alignment Design

No.	HIP (Horizontal Intersection Point)		Deflection Angle			Element	Length, m	Chord Length, m	Radius (m)	Hand of Arc	Super Elevation (%)	Design speed (km/hr)	Extra widening, m
	Easting	Northing	Deg	Min	Sec								
1	415347.494	2973971.642				Straight	13.624						
2	415317.754	2973962.832	179	0	12.418	Arc	34.786	34.786	2000	Left	Normal camber	100	--NR--
						Straight	139.329						
3	415153.737	2973911.129	179	7	34.361	Arc	30.501	30.501	2000	Right	Normal camber	100	--NR--
						Straight	673.697						
	414435.994	2973696.852				Transition		90					
4	414145.639	2973637.964	123	55	3.592	Arc	489.411	489.41	500	Right	5	100	--NR--
	413934.697	2973846.099				Transition		90					
						Straight	139.352						
5	413790.575	2974016.481	178	38	14.457	Arc	47.565	47.565	2000	Right	Normal camber	100	--NR--
						Straight	98.652						
6	413687.967	2974143.807	178	25	50.26	Arc	82.172	82.172	3000	Left	Normal camber	100	--NR--
						Straight	379.688						
	413382.568	2974502.22				Transition		75					
7	413315.389	2974566.54	159	9	18.442	Arc	134.61	134.61	370	Left	5	75	--NR--
	413229.652	2974602.782				Transition		75					
						Straight	1783.298						
	411432.829	2975155.808				Transition		70					
8	411330.102	2975183.529	170	30	8.043	Arc	165.767	165.767	1000	Left	4.4	100	--NR--
	411224.201	2975193.921				Transition		70					
						Straight	798.337						

No.	HIP (Horizontal Intersection Point)		Deflection Angle			Element	Length, m	Chord Length, m	Radius (m)	Hand of Arc	Super Elevation (%)	Design speed (km/hr)	Extra widening, m
	Easting	Northing	Deg	Min	Sec								
	410320.898	2975250.733				Transition		90					
9	410194.832	2975269.1	159	54	26.694	Arc	192.875	192.875	550	Right	5	100	--NR--
	410082.692	2975329.681				Transition		90					
						Straight	350.656						
	409688.176	2975586.54				Transition		90					
10	409591.35	2975638.456	162	51	6.36	Arc	158.625	158.625	530	Left	5	100	--NR--
	409483.459	2975659.534				Transition		90					
						Straight	1873.997						
11	407536.168	2975870.713	179	3	25.044	Arc	49.378	49.377	3000	Left	Normal camber	100	--NR--
						Straight	187.344						
12	407307.095	2975891.747	178	58	6.477	Arc	36.007	36.007	2000	Right	Normal camber	100	--NR--
						Straight	134.593						
	407102.291	2975914.277				Transition		80					
13	407012.891	2975933.3	161	35	56.213	Arc	128.464	128.463	400	Right	5	75	--NR--
	406933.993	2975979.605				Transition		80					
						Straight	43.669						
	406817.934	2976064.355				Transition		70					
14	406755.346	2976106.782	174	0	50.331	Arc	104.476	104.476	1000	Left	4.4	100	--NR--
	406688.668	2976142.455				Transition		70					
						Straight	3065.705						
15	403769.373	2977575.217	171	22	18.036	Arc	278.596	278.597	1850	Right	Normal camber	100	--NR--
						Straight	853.102						
16	402919.358	2978165.326	177	35	15.84	Arc	84.204	84.204	2000	Right	Normal camber	100	--NR--

No.	HIP (Horizontal Intersection Point)		Deflection Angle			Element	Length, m	Chord Length, m	Radius (m)	Hand of Arc	Super Elevation (%)	Design speed (km/hr)	Extra widening, m
	Easting	Northing	Deg	Min	Sec								
						Straight	34.068						
	402800.075	2978255.808				Transition		110					
17	402611.272	2978366.579	137	10	39.003	Arc	347.538	347.538	465	Left	5	100	--NR--
	402397.344	2978319.476				Transition		110					
						Straight	399.979						
18	401929.836	2978156.724	178	45	32.286	Arc	43.32	43.32	2000	Right	Normal camber	100	--NR--
						Straight	170.77						
19	401711.311	2978085.917	178	34	34.082	Arc	74.553	74.553	3000	Left	Normal camber	100	--NR--
						Straight	202.74						
	401428.194	2977986.343				Transition		90					
20	401339.71	2977963.926	166	0	50.933	Arc	122.05	122.05	500	Right	5	100	--NR--
	401248.358	2977963.551				Transition		90					
						Straight	67.537						
21	401049.774	2977980.652	178	21	20.099	Arc	143.502	143.502	5000	Left	Normal camber	100	--NR--
						Straight	84.748						
22	400857.11	2977991.685	177	54	37.096	Arc	72.944	72.944	2000	Right	Normal camber	100	--NR--
						Straight	352.913						
23	400440.165	2978030.857	178	18	57.93	Arc	58.779	58.78	2000	Right	Normal camber	100	--NR--
						Straight	95.573						
	400256.502	2978053.574				Transition		90					
24	399973.566	2978114.794	125	8	7.487	Arc	478.784	478.784	500	Right	5	100	--NR--

No.	HIP (Horizontal Intersection Point)		Deflection Angle			Element	Length, m	Chord Length, m	Radius (m)	Hand of Arc	Super Elevation (%)	Design speed (km/hr)	Extra widening, m
	Easting	Northing	Deg	Min	Sec								
	399860.763	2978381.474				Transition		90					
						Straight	196.827						
	399764.025	2978683.301				Transition		90					
25	399662.065	2978924.333	130	15	45.833	Arc	434.04	434.04	500	Left	5	100	--NR--
	399412.172	2979002.333				Transition		90					
						Straight	156.959						
26	399179.012	2979052.652	178	45	56.424	Arc	43.086	43.086	2000	Right	Normal camber	100	--NR--
						Straight	344.477						
27	398802.719	2979142.386	178	48	25.061	Arc	41.645	41.645	2000	Right	Normal camber	100	--NR--
						Straight	167.055						
28	398590.108	2979197.79	178	47	2.825	Arc	63.663	63.663	3000	Left	Normal camber	100	--NR--
						Straight	732.392						
29	397817.065	2979381.81	178	50	17.196	Arc	60.836	60.836	3000	Left	Normal camber	100	--NR--
						Straight	182.389						
30	397590.145	2979430.988	178	53	22.764	Arc	38.758	38.758	2000	Right	Normal camber	100	--NR--
						Straight	125.178						
31	397430.91	2979468.742	178	54	22.066	Arc	38.183	38.184	2000	Right	Normal camber	100	--NR--
						Straight	185.212						
32	397207.819	2979526.156	179	0	17.127	Arc	52.111	52.111	3000	Left	Normal camber	100	--NR--

No.	HIP (Horizontal Intersection Point)		Deflection Angle			Element	Length, m	Chord Length, m	Radius (m)	Hand of Arc	Super Elevation (%)	Design speed (km/hr)	Extra widening, m
	Easting	Northing	Deg	Min	Sec								
33	396719.315	2979642.867				Straight	531.474						
33	396614.778	2979667.842	143	51	39.151	Arc	100.919	100.919	160	Left	4.4	40	0.6
						Straight	29.431						
34	396455.664	2979601.276	82	44	10.266	Arc	135.806	135.806	80	Right	5	40	0.9
						Straight	404.374						
	396307.843	2980136.539				Transition		90					
35	396258.087	2980272.297	156	27	15.232	Arc	226.023	226.023	550	Left	5	100	--NR--
	396158.203	2980376.922				Transition		90					
						Straight	243.542						
36	395912.396	2980595.468	178	32	51.741	Arc	50.695	50.695	2000	Left	Normal Camber	100	--NR--
						Straight	135.567						
37	395770.103	2980715.663	178	32	51.741	Arc	50.695	50.694	2000	Right	Normal Camber	100	--NR--
						Straight	256.979						
	395519.21	2980938.731				Transition		80					
38	395464.398	2980995.114	169	11	55.102	Arc	103.686	103.686	550	Right	5	100	--NR--
	395421.097	2981060.804				Transition		80					
						Straight	265.477						
	395236.095	2981391.495				Transition		90					
39	395146.65	2981522.206	151	11	17.028	Arc	251.432	251.431	500	Left	5	100	--NR--
	395005.223	2981593.668				Transition		90					
						Straight	437.388						
	394496.401	2981795.642				Transition		75					
40	394310.435	2981881.256	151	11	53.181	Arc	351.882	351.882	700	Right	5	100	--NR--
	394188.707	2982045.89				Transition		75					

No.	HIP (Horizontal Intersection Point)		Deflection Angle			Element	Length, m	Chord Length, m	Radius (m)	Hand of Arc	Super Elevation (%)	Design speed (km/hr)	Extra widening, m
	Easting	Northing	Deg	Min	Sec								
						Straight	225.112						
	394004.133	2982325.718				Transition		90					
41	393903.625	2982512.766	139	55	4.236	Arc	349.783	349.783	500	Right	5	100	--NR--
	393947.171	2982720.669				Transition		90					
						Straight	89.079						
	394008.289	2982920.745				Transition		90					
42	394042.832	2983085.699	149	1	1.909	Arc	270.376	270.376	500	Left	5	100	--NR--
	393987.515	2983244.971				Transition		90					
						Straight	901.549						
	393572.45	2984163.826				Transition		70					
43	393524.9	2984279.742	168	21	22.208	Arc	203.223	203.223	1000	Right	4.4	100	--NR--
	393501.721	2984402.879				Transition		70					
						Straight	257.153						
	393448.471	2984752.7				Transition		75					
44	393373.956	2985113.111	128	25	24.384	Arc	639.128	639.128	710	Left	5	100	--NR--
	393045.268	2985278.727				Transition		75					
						Straight	433.894						
45	392550.053	2985496.276	178	41	38.072	Arc	113.978	113.978	5000	Right	Normal Camber	100	--NR--
						Straight	587.53						
46	391922.727	2985789.098	177	15	46.226	Arc	95.545	95.545	2000	Left	Normal Camber	100	--NR--
						Straight	374.689						
47	391467.702	2985975.577	178	24	44.029	Arc	138.559	138.559	5000	Right	Normal Camber	100	--NR--
						Straight	1205.13						

No.	HIP (Horizontal Intersection Point)		Deflection Angle			Element	Length, m	Chord Length, m	Radius (m)	Hand of Arc	Super Elevation (%)	Design speed (km/hr)	Extra widening, m
	Easting	Northing	Deg	Min	Sec								
48	390106.914	2986577.82	173	53	2.963	Arc	426.966	426.967	4000	Left	Normal Camber	100	--NR--
						Straight	306.802						
49	389568.164	2986750.346	177	24	35.887	Arc	90.409	90.409	2000	Left	Normal Camber	100	--NR--
						Straight	33.025						
50	389452.446	2986781.714	177	36	48.815	Arc	83.302	83.302	2000	Right	Normal Camber	100	--NR--
						Straight	259.56						
51	389143.265	2986879.514	178	40	43.272	Arc	46.123	46.123	2000	Right	Normal Camber	100	--NR--
						Straight	212.494						
52	388900.802	2986962.408	178	48	53.594	Arc	41.368	41.368	2000	Left	Normal Camber	100	--NR--
						Straight	207.327						
53	388655.6	2987040.612	178	19	4.744	Arc	58.713	58.713	2000	Left	Normal Camber	100	--NR--
						Straight	111.592						
54	388491.986	2987087.551	178	19	24.545	Arc	58.521	58.521	2000	Right	Normal Camber	100	--NR--
						Straight	245.939						
55	388206.162	2987178.681	178	34	45.334	Arc	49.593	49.594	2000	Right	Normal Camber	100	--NR--
						Straight	150.257						

No.	HIP (Horizontal Intersection Point)		Deflection Angle			Element	Length, m	Chord Length, m	Radius (m)	Hand of Arc	Super Elevation (%)	Design speed (km/hr)	Extra widening, m
	Easting	Northing	Deg	Min	Sec								
56	388017.317	2987244.091	178	34	45.334	Arc	49.593	49.593	2000	Left	Normal Camber	100	--NR--
						Straight	247.135						
57	387749.083	2987329.613	179	46	47.575	Arc	19.209	19.209	5000	Left	Normal Camber	100	--NR--
						Straight	261.627						
58	387466.893	2987418.392	179	26	10.773	Arc	49.19	49.189	5000	Left	Normal Camber	100	--NR--
						Straight	253.801						
59	387185.844	2987503.782	179	7	16.194	Arc	30.677	30.677	2000	Right	Normal Camber	100	--NR--
						Straight	316.538						
60	386826.643	2987618.963	177	24	9.685	Arc	90.663	90.663	2000	Right	Normal Camber	100	--NR--
						Straight	17.52						
61	386725.215	2987656.636	177	24	9.686	Arc	90.663	90.663	2000	Left	Normal Camber	100	--NR--
						Straight	89.411						
62	386565.835	2987707.743	178	7	51.599	Arc	65.24	65.24	2000	Left	Normal Camber	100	--NR--
						Straight	85.091						
63	386421.257	2987748.955	178	7	51.599	Arc	65.24	65.24	2000	Right	Normal Camber	100	--NR--
						Straight	778.785						

No.	HIP (Horizontal Intersection Point)		Deflection Angle			Element	Length, m	Chord Length, m	Radius (m)	Hand of Arc	Super Elevation (%)	Design speed (km/hr)	Extra widening, m
	Easting	Northing	Deg	Min	Sec								
64	385207.652	2988138.11	162	27	2.819	Arc	918.875	918.875	3000	Left	Normal Camber	100	--NR--
						Straight	986.746						
65	383526.75	2988144.852	166	49	1.407	Arc	460.172	460.171	2000	Left	Normal Camber	100	--NR--
						Straight	55.808						
66	383137.689	2988055.365	167	11	4.012	Arc	223.674	223.673	1000	Right	Normal Camber	65	--NR--
						Straight	130.75						
67	382786.569	2988054.521	167	39	51.998	Arc	215.296	215.296	1000	Right	Normal Camber	65	--NR--
						Straight	915.487						
	381727.383	2988283.486				Transition		90					
68	381542.582	2988306.305	145	17	28.326	Arc	302.891	302.891	500	Left	5	100	--NR--
	381377.605	2988219.81				Transition		90					
						Straight	62.462						
	381224.17	2988120.837				Transition		90					
69	381042.63	2988025.665	141	24	54.238	Arc	336.717	336.717	500	Right	5	100	--NR--
	380841.295	2988064.5				Transition		90					
						Straight	239.578						
70	380522.415	2988156.383	178	9	8.472	Arc	64.495	64.495	2000	Right	Normal Camber	100	--NR--
						Straight	116.571						
71	380351.582	2988211.633	178	14	23.161	Arc	61.444	61.444	2000	Left	Normal Camber	100	--NR--
						Straight	870.63						

No.	HIP (Horizontal Intersection Point)		Deflection Angle			Element	Length, m	Chord Length, m	Radius (m)	Hand of Arc	Super Elevation (%)	Design speed (km/hr)	Extra widening, m
	Easting	Northing	Deg	Min	Sec								
72	379463.656	2988468.952	178	47	47.677	Arc	46.208	46.208	2200	Left	Normal Camber	100	--NR--
						Straight	184.759						
73	379242.543	2988528.026	178	47	47.676	Arc	42.007	42.007	2000	Right	Normal Camber	100	--NR--
						Straight	272.979						
74	378706.654	2988683.326	173	57	22.388	Arc	527.419	527.419	5000	Left	Normal Camber	100	--NR--
	378045.052	2988801.386				Straight	1843.551						
75	376396.542	2989095.557	166	21	55.251	Arc	475.939	475.939	2000	Left	Normal Camber	100	--NR--
						Straight	336.725						
	375761.817	2989056.547				Transition		90					
76	375633.837	2989060.217	157	48	11.207	Arc	193.704	193.704	500	Right	5	100	--NR--
	375516.659	2989111.988				Transition		90					
						Straight	306.493						
	375149.383	2989315.516				Transition		80					
77	375071.161	2989365.954	167	21	51.009	Arc	132.322	132.322	600	Right	5	100	--NR--
	375005.841	2989432.305				Transition		80					
						Straight	202.389						
	374799.755	2989671.636				Transition		90					
78	374682.461	2989785.34	150	7	15.079	Arc	260.745	260.745	500	Left	5	100	--NR--
	374524.045	2989825.521				Transition		90					
						Straight	4219.975						
79	369268.473	2990665.077	129	42	12.237	Arc	1948.808	1948.81	2220	Right	Normal Camber	100	--NR--

No.	HIP (Horizontal Intersection Point)		Deflection Angle			Element	Length, m	Chord Length, m	Radius (m)	Hand of Arc	Super Elevation (%)	Design speed (km/hr)	Extra widening, m
	Easting	Northing	Deg	Min	Sec								
						Straight	489.753						
	368471.03	2992012.012				Transition		50					
80	368185.025	2992477.23	141	7	6.021	Arc	1017.919	1017.92	1500	Left	2.9	100	--NR--
	367670.362	2992659.847				Transition		50					
						Straight	1193.503						
81	366483.065	2993058.981	179	0	58.811	Arc	51.505	51.504	3000	Right	Normal Camber	100	--NR--
						Straight	197.732						
82	366246.24	2993143.147	178	56	10.251	Arc	55.701	55.702	3000	Left	Normal Camber	100	--NR--
						Straight	672.17						
83	365579.588	2993366.219	179	53	12.661	Arc	5.925	5.925	3000	Right	Normal Camber	100	--NR--
						Straight	5123.921						
	360676.657	2995017.586				Transition		70					
84	360313.037	2995154.7	139	6	54.399	Arc	699.304	699.304	980	Right	4.5	100	--NR--
	360127.873	2995496.374				Transition		70					
						Straight	319.524						
85	359952.495	2995849.541	178	23	19.956	Arc	56.239	56.239	2000	Left	Normal Camber	100	--NR--
						Straight	112.229						
86	359873.581	2995997.834	178	25	0.497	Arc	55.264	55.264	2000	Right	Normal Camber	100	--NR--
						Straight	260.776						
87	359729.327	2996287.971	177	57	35.713	Arc	71.212	71.212	2000	Right	Normal Camber	100	--NR--

No.	HIP (Horizontal Intersection Point)		Deflection Angle			Element	Length, m	Chord Length, m	Radius (m)	Hand of Arc	Super Elevation (%)	Design speed (km/hr)	Extra widening, m
	Easting	Northing	Deg	Min	Sec								
						Straight	74.976						
88	359669.209	2996420.522	177	59	49.446	Arc	69.916	69.916	2000	Left	Normal Camber	100	--NR--
						Straight	588.44						
	359368.27	2997026.782				Transition		80					
89	359280.154	2997167.08	141	39	34.347	Arc	267.667	267.667	400	Left	5	75	--NR--
	359123.937	2997222.494				Transition		80					
						Straight	289.496						
90	358762.57	2997311.262	178	52	57.629	Arc	58.503	58.503	3000	Right	Normal Camber	100	--NR--
						Straight	195.293						
91	358517.327	2997376.601	178	52	57.629	Arc	58.503	58.503	3000	Left	Normal Camber	100	--NR--
	358412.613	2997402.324				Straight	3655.9						
92	354240.129	2998427.277	148	29	55.705	Arc	1401.989	1401.99	2550	Right	Normal Camber	100	--NR--
						Straight	367.908						
	353452.047	2999223.723				Transition		50					
93	353314.876	2999357.804	166	40	47.129	Arc	348.723	348.723	1500	Left	2.9	100	--NR--
	353150.502	2999456.676				Transition		50					
						Straight	760.846						
94	352207.697	3000002.592	168	45	27.593	Arc	588.647	588.648	3000	Right	Normal Camber	100	--NR--
						Straight	87.843						
95	351894.132	3000278.208	178	1	52.804	Arc	68.719	68.72	2000	Left	Normal Camber	100	--NR--

No.	HIP (Horizontal Intersection Point)		Deflection Angle			Element	Length, m	Chord Length, m	Radius (m)	Hand of Arc	Super Elevation (%)	Design speed (km/hr)	Extra widening, m
	Easting	Northing	Deg	Min	Sec								
						Straight	76.414						
96	351783.584	3000368.839	178	9	24.286	Arc	64.342	64.342	2000	Right	Normal Camber	100	--NR--
						Straight	159.709						
97	351614.661	3000516.664	178	7	58.701	Arc	65.172	65.171	2000	Right	Normal Camber	100	--NR--
						Straight	114.758						
98	351484.785	3000638.013	178	15	30.182	Arc	60.794	60.794	2000	Left	Normal Camber	100	--NR--
						Straight	460.2						
99	350834.609	3001209.501	165	44	54.858	Arc	746.203	746.203	3000	Right	Normal Camber	100	--NR--
						Straight	448.425						
100	350160.035	3002193.441	167	35	41.434	Arc	736.137	736.137	3400	Left	Normal Camber	100	--NR--
						Straight	597.16						
	349411.068	3002895.806				Transition		90					
101	349190.659	3003067.376	126	3	21.827	Arc	461.335	461.335	490	Left	5	100	--NR--
	348922.153	3002990.155				Transition		90					
						Straight	331.266						
102	348047.302	3002648.946	154	17	15.268	Arc	1077.04	1077.04	2400	Left	Normal Camber	100	--NR--
						Straight	377.031						
103	346929.269	3001449.199	154	1	6.903	Arc	1405.73	1405.73	3100	Right	Normal Camber	100	--NR--
						Straight	597.911						

No.	HIP (Horizontal Intersection Point)		Deflection Angle			Element	Length, m	Chord Length, m	Radius (m)	Hand of Arc	Super Elevation (%)	Design speed (km/hr)	Extra widening, m
	Easting	Northing	Deg	Min	Sec								
104	345681.303	3000969.205	178	37	26.039	Arc	48.035	48.035	2000	Right	Normal Camber	100	--NR--
						Straight	34.728						
105	345478.194	3000896.635	178	30	5.2	Arc	313.857	313.857	12000	Left	Normal Camber	100	--NR--
						Straight	406.119						
106	344944.698	3000690.132	179	52	15.312	Arc	18.023	18.023	8000	Right	Normal Camber	100	--NR--
						Straight	1173.356						
107	343756.531	3000233.296	174	48	45.762	Arc	181.071	181.071	2000	Right	Normal Camber	100	--NR--
						Straight	739.39						
108	341772.483	2999670.227	152	18	25.824	Arc	2416.655	2416.65	5000	Right	Normal Camber	100	--NR--
						Straight	200.114						
109	340273.061	2999984.811	174	18	5.506	Arc	198.914	198.915	2000	Right	Normal Camber	100	--NR--
						Straight	120.715						
110	340001.081	3000070.813	176	16	37.579	Arc	129.954	129.953	2000	Right	Normal Camber	100	--NR--
						Straight	224.689						
111	339569.071	3000238.99	175	1	16.347	Arc	347.585	347.586	4000	Right	Normal Camber	100	--NR--
						Straight	279.836						
112	339146.997	3000447.126	179	2	1.5	Arc	33.728	33.729	2000	Left	Normal Camber	100	--NR--

No.	HIP (Horizontal Intersection Point)		Deflection Angle			Element	Length, m	Chord Length, m	Radius (m)	Hand of Arc	Super Elevation (%)	Design speed (km/hr)	Extra widening, m
	Easting	Northing	Deg	Min	Sec								
						Straight	235.142						
113	338902.433	3000562.641	179	3	34.58	Arc	36.929	36.929	2250	Right	Normal Camber	100	--NR--
						Straight	275.144						
114	338611.557	3000705.917	178	26	22.615	Arc	61.276	61.276	2250	Right	Normal Camber	100	--NR--
						Straight	104.969						
115	338456.037	3000787.856	178	27	55.695	Arc	80.348	80.348	3000	Left	Normal Camber	100	--NR--
	338359.32	3000835.55				Straight	431.183						
116	337386.993	3001315.031	156	56	5.691	Arc	1288.197	1288.2	3200	Right	Normal Camber	100	--NR--
						Straight	785.841						
117	335992.367	3002937.248	151	54	28.213	Arc	1372.842	1372.84	2800	Left	Normal Camber	100	--NR--
						Straight	848.561						
118	334545.416	3003499.124	179	57	17.94	Arc	6.286	6.286	8000	Right	Normal Camber	100	--NR--
						Straight	1395.17						
119	333231.641	3004010.474	179	50	8.627	Arc	22.936	22.936	8000	Left	Normal Camber	100	--NR--
						Straight	649.507						
120	332593.856	3004256.611	179	8	4.485	Arc	45.313	45.313	3000	Left	Normal Camber	100	--NR--
						Straight	301.373						

No.	HIP (Horizontal Intersection Point)		Deflection Angle			Element	Length, m	Chord Length, m	Radius (m)	Hand of Arc	Super Elevation (%)	Design speed (km/hr)	Extra widening, m
	Easting	Northing	Deg	Min	Sec								
121	332277.527	3004373.231	179	19	56.324	Arc	26.22	26.22	2250	Right	Normal Camber	100	--NR--
						Straight	260.263						
122	331997.282	3004480.275	178	38	39.553	Arc	53.237	53.237	2250	Right	Normal Camber	100	--NR--
						Straight	225.449						
123	331716.671	3004595.137	178	2	48.47	Arc	102.269	102.269	3000	Left	Normal Camber	100	--NR--
						Straight	256.046						
124	331419.056	3004705.273	179	36	43.757	Arc	20.308	20.307	3000	Right	Normal Camber	100	--NR--
						Straight	959.495						
125	330065.846	3005216.484	153	10	34.657	Arc	936.324	936.324	2000	Left	Normal Camber	100	--NR--
						Straight	2679.057						
	326881.507	3004874.585				Transition		70					
126	326574.131	3004852.429	148	12	4.203	Arc	554.994	554.995	1000	Right	4.4	100	--NR--
	326301.208	3004995.57				Transition		70					
						Straight	117.759						
	326117.799	3005100.105				Transition		70					
127	326075.85	3005126	177	1	28.974	Arc	51.929	51.928	1000	Right	4.4	100	--NR--
	326035.295	3005154.042				Transition		70					
						Straight	275.627						
128	325726.213	3005384.15	172	47	10.405	Arc	125.904	125.904	1000	Right	Normal Camber	75	--NR--
						Straight	33.468						

No.	HIP (Horizontal Intersection Point)		Deflection Angle			Element	Length, m	Chord Length, m	Radius (m)	Hand of Arc	Super Elevation (%)	Design speed (km/hr)	Extra widening, m
	Easting	Northing	Deg	Min	Sec								
129	325607.137	3005498.663	172	8	23.156	Arc	137.187	137.187	1000	Left	Normal Camber	75	--NR--
						Straight	181.885						
130	325139.201	3005838.897	165	37	16.493	Arc	652.487	652.487	2600	Left	Normal Camber	100	--NR--
						Straight	923.635						
131	323956.323	3006308.235	179	11	54.326	Arc	41.97	41.97	3000	Left	Normal Camber	100	--NR--
						Straight	503.332						
132	323411.797	3006515.521	177	19	37.027	Arc	116.634	116.634	2500	Right	Normal Camber	100	--NR--
						Straight	131.902						
133	323031.9	3006680.811	168	52	17.331	Arc	446.727	446.727	2300	Right	Normal Camber	100	--NR--
						Straight	355.19						
134	322533.769	3007024.988	178	59	55.919	Arc	52.419	52.419	3000	Left	Normal Camber	100	--NR--
						Straight	253.388						
135	322278.167	3007195.073	178	57	9.384	Arc	54.841	54.841	3000	Right	Normal Camber	100	--NR--
						Straight	281.522						
136	322004.031	3007384.81	178	43	35.567	Arc	48.897	48.897	2200	Right	Normal Camber	100	--NR--
						Straight	162.225						

No.	HIP (Horizontal Intersection Point)		Deflection Angle			Element	Length, m	Chord Length, m	Radius (m)	Hand of Arc	Super Elevation (%)	Design speed (km/hr)	Extra widening, m
	Easting	Northing	Deg	Min	Sec								
137	321824.968	3007514.724	178	40	49.032	Arc	69.1	69.1	3000	Left	Normal Camber	100	--NR--
						Straight	875.394						
138	320514.314	3008420.303	142	16	59.79	Arc	1316.562	1316.56	2000	Left	Normal Camber	100	--NR--
						Straight	1389.267						
139	318423.394	3008307.988	179	10	38.397	Arc	43.075	43.075	3000	Right	Normal Camber	100	--NR--
						Straight	358.923						
140	318023.669	3008292.268	179	15	8.506	Arc	39.146	39.146	3000	Left	Normal Camber	100	--NR--
						Straight	532.159						
141	317470.336	3008263.272	179	55	56.618	Arc	4.72	4.72	4000	Right	Normal Camber	100	--NR--
						Straight	968.744						
142	316037.872	3008189.902	162	26	39.301	Arc	919.217	919.217	3000	Left	Normal Camber	100	--NR--
						Straight	1326.316						
143	314345.441	3007557.537	179	48	12.219	Arc	34.314	34.315	10000	Left	Normal Camber	100	--NR--
	313519.592	3007245.731				Straight	1271.367						
144	313121.576	3007095.457	178	52	23.493	Arc	39.333	39.333	2000	Left	Normal Camber	100	--NR--
						Straight	69.813						

No.	HIP (Horizontal Intersection Point)		Deflection Angle			Element	Length, m	Chord Length, m	Radius (m)	Hand of Arc	Super Elevation (%)	Design speed (km/hr)	Extra widening, m
	Easting	Northing	Deg	Min	Sec								
145	312880.39	3006998.934	172	12	21.303	Arc	340.081	340.081	2500	Right	Normal Camber	100	--NR--
						Straight	184.885						
146	312459.086	3006893.757	176	22	40.761	Arc	158.04	158.04	2500	Right	Normal Camber	100	--NR--
						Straight	218.185						
147	312060.027	3006820.551	178	26	46.13	Arc	216.959	216.959	8000	Left	Normal Camber	100	--NR--
						Straight	554.821						
148	310634.577	3006518.888	146	2	52.058	Arc	1540.702	1540.7	2600	Right	Normal Camber	100	--NR--
						Straight	272.39						
149	309619.615	3006929.025	178	54	28.464	Arc	57.182	57.182	3000	Left	Normal Camber	100	--NR--
						Straight	216.29						
150	309369.798	3007024.476	178	51	5.711	Arc	45.098	45.098	2250	Right	Normal Camber	100	--NR--
						Straight	295.423						
151	309044.925	3007156.126	176	16	12.585	Arc	65.098	65.098	1000	Right	Normal Camber	75	--NR--
						Straight	6.905						
152	308979.727	3007187.629	176	13	34.199	Arc	65.866	65.866	1000	Left	Normal Camber	75	--NR--
						Straight	3018.324						

No.	HIP (Horizontal Intersection Point)		Deflection Angle			Element	Length, m	Chord Length, m	Radius (m)	Hand of Arc	Super Elevation (%)	Design speed (km/hr)	Extra widening, m
	Easting	Northing	Deg	Min	Sec								
153	306124.47	3008342.127	178	54	32.501	Arc	57.123	57.124	3000	Left	Normal Camber	100	--NR--
						Straight	179.344						
154	305909.6	3008424.284	179	9	16.423	Arc	44.267	44.267	3000	Right	Normal Camber	100	--NR--
						Straight	230.031						
155	305630.994	3008535.549	178	10	22.469	Arc	95.666	95.667	3000	Right	Normal Camber	100	--NR--
						Straight	110.538						
156	305447.646	3008615.64	178	24	25.855	Arc	83.4	83.4	3000	Left	Normal Camber	100	--NR--
						Straight	922.863						
157	304527.198	3008987.605	179	35	45.844	Arc	56.4	56.4	8000	Left	Normal Camber	100	--NR--
						Straight	386.692						
158	304134.564	3009143.063	179	49	49.695	Arc	14.794	14.794	5000	Right	Normal Camber	100	--NR--
						Straight	330.92						
159	303788.022	3009281.458	178	0	15.037	Arc	69.667	69.668	2000	Right	Normal Camber	100	--NR--
						Straight	136.528						
160	303602.661	3009363.079	178	12	51.088	Arc	62.336	62.337	2000	Left	Normal Camber	100	--NR--
						Straight	2142.785						

No.	HIP (Horizontal Intersection Point)		Deflection Angle			Element	Length, m	Chord Length, m	Radius (m)	Hand of Arc	Super Elevation (%)	Design speed (km/hr)	Extra widening, m
	Easting	Northing	Deg	Min	Sec								
161	301554.049	3010189.935	178	39	15.863	Arc	70.455	70.455	3000	Left	Normal Camber	100	--NR--
						Straight	119.984						
162	301373.237	3010258.022	178	32	55.671	Arc	75.985	75.984	3000	Right	Normal Camber	100	--NR--
						Straight	161.265						
163	301161.969	3010343.746	178	54	8.423	Arc	57.473	57.473	3000	Right	Normal Camber	100	--NR--
						Straight	201.296						
164	300924.217	3010445.564	178	54	27.088	Arc	57.202	57.202	3000	Left	Normal Camber	100	--NR--
	300376.44	3010667.889				Straight	562.574						

7.4.1 Summary of Horizontal Alignment Design

The summary of alignment design is given below:

- Length of alignment in straight : 90461.810m (69.36%)
- Length of alignment on curves without superelevation : 29938.043m (22.96%)
- Length of alignment on curve with superelevation : 10017.148m (7.21%)

The maximum superelevation for entire length proposed is limited to 5%.

The minimum radius of curve required for avoiding superelevation is adopted as 2000m.

7.4.2 Summary of Vertical Alignment Design

The vertical alignment for the project is designed considering the following:

- Maintain the existing gradient at all bridge structures.
- Maximum longitudinal gradient of 3.3%, mainly at flyover and underpass approaches.

The tangents of the adjoining grades are smoothened by providing longer vertical curves. The minimum length of summit curve and valley curve is adopted considering the K value as per NRS and IRC: SP-23. As per IRC: SP -23, the minimum longitudinal gradient follows 0.3% considering sufficient surface drainage. However, for the project road, certain sections of the road are designed with the same vertical grade generally to minimize the filling which has resulted in grade less than 0.3%. The longitudinal drains are provided on both sides of the main road to cater for surface drainage. The Median drains are proposed at superelevated sections, where RL of inner edge of both carriageway are different than each other. The Details of vertical alignment design carried out is in Given in **Table 7.4**.

Table 7.4: Details of Vertical Alignment Design

VIP			Element type	Type of curve	Length / curve length	Gradient			K value
No.	Chainage,m	Level,m				In	Out	Difference	
1	236470.00	110.323				--	0.754	--	
			Grade		84.59				
2	236614.59	111.413	Curve	Hog	120	0.754	0	-0.754	159.182
			Grade		672.005				
3	237406.595	111.413	Curve	Sag	120	0	0.056	0.056	2142.89

VIP			Element type	Type of curve	Length / curve length	Gradient			K value
No.	Chainage,m	Level,m				In	Out	Difference	
			Grade		365.467				
4	237882.062	111.679	Curve	Sag	100	0.056	0.48	0.424	236.082
			Grade		499.228				
5	238491.29	114.601	Curve	Hog	120	0.48	0.21	-0.27	444.393
			Grade		534.26				
6	239145.55	115.972	Curve	Sag	120	0.21	0.402	0.192	624.878
			Grade		454.949				
7	239720.499	118.281	Curve	Hog	120	0.402	-0.175	-0.577	208.173
			Grade		144.229				
8	239984.728	117.819	Curve	Sag	120	-0.175	0.453	0.628	191.242
			Grade		693.066				
9	240797.794	121.499	Curve	Sag	120	0.453	0.757	0.304	394.463
			Grade		592.841				
10	241510.635	126.894	Curve	Hog	120	0.757	0	-0.757	158.556
			Grade		344.34				
11	241974.975	126.894	Curve	Hog	120	0	-0.105	-0.105	1138.58
			Grade		274.558				
12	242409.533	126.436	Curve	Sag	200	-0.105	0.671	0.776	257.564
			Grade		478.252				
13	243047.785	130.719	Curve	Sag	120	0.671	2.5	1.829	65.612
			Grade		342.215				
14	243640	145.525	Curve	Hog	380	2.5	-2.459	-4.959	76.629
			Grade		102.199				
15	243992.199	136.865	Curve	Sag	120	-2.459	0.5	2.959	40.555
			Grade		704.051				
16	244806.25	140.935	Curve	Hog	100	0.5	-0.215	-0.715	139.851
			Grade		196.993				
17	245093.242	140.318	Curve	Sag	80	-0.215	0.002	0.217	367.965
			Grade		171.881				

VIP			Element type	Type of curve	Length / curve length	Gradient			K value
No.	Chainage,m	Level,m				In	Out	Difference	
18	245355.123	140.324	Curve	Sag	100	0.002	0.863	0.861	116.184
			Grade		214.307				
19	245679.43	143.123	Curve	Hog	120	0.863	0.294	-0.569	210.779
			Grade		159.144				
20	245958.574	143.943	Curve	Sag	120	0.294	0.885	0.591	202.887
			Grade		691.438				
21	246770.012	151.126	Curve	Hog	120	0.885	0.204	-0.681	176.215
			Grade		384.326				
22	247274.338	152.156	Curve	Sag	120	0.204	0.531	0.327	367.794
			Grade		191.026				
23	247585.364	153.806	Curve	Hog	120	0.531	0.044	-0.487	246.823
			Grade		227.439				
24	247932.803	153.96	Curve	Sag	120	0.044	0.464	0.42	286.274
			Grade		618.723				
25	248671.526	157.384	Curve	Hog	120	0.464	-0.221	-0.685	175.384
			Grade		231.59				
26	249023.116	156.608	Curve	Sag	120	-0.221	0.582	0.803	149.575
			Grade		1445.64				
27	250603.755	165.8	Curve	Hog	150	0.582	-0.218	-0.8	187.489
			Grade		538.771				
28	251277.526	164.328	Curve	Hog	120	-0.218	-0.426	-0.208	577.796
			Grade		294.902				
29	251692.428	162.56	Curve	Sag	120	-0.426	-0.163	0.263	456.129
			Grade		917.118				
30	252719.546	160.885	Curve	Sag	100	-0.163	-0.139	0.024	4125.46
			Grade		327.833				
31	253157.379	160.277	Curve	Sag	120	-0.139	0.908	1.047	114.616
			Grade		794.558				
32	254211.937	169.854	Curve	Hog	400	0.908	-0.003	-0.911	439.157

VIP			Element type	Type of curve	Length / curve length	Gradient			K value
No.	Chainage,m	Level,m				In	Out	Difference	
			Grade		452.65				
33	254914.587	169.835	Curve	Hog	100	-0.003	-0.141	-0.138	723.659
			Grade		406.822				
34	255496.41	169.015	Curve	Sag	250	-0.141	0.282	0.423	590.594
			Grade		243.226				
35	255939.636	170.267	Curve	Hog	150	0.282	0	-0.282	531.138
			Grade		232.775				
36	256297.411	170.267	Curve	Sag	100	0	0.5	0.5	200
			Grade		221.385				
37	256628.796	171.924	Curve	Hog	120	0.5	0.04	-0.46	260.85
			Grade		543.194				
38	257291.99	172.189	Curve	Sag	120	0.04	0.995	0.955	125.662
			Grade		154.04				
39	257566.03	174.915	Curve	Hog	120	0.995	0.491	-0.504	237.951
			Grade		338.64				
40	258024.67	177.166	Curve	Hog	120	0.491	0.084	-0.407	295.181
			Grade		239.908				
41	258384.578	177.468	Curve	Sag	120	0.084	0.391	0.307	390.667
			Grade		362.587				
42	258867.165	179.356	Curve	Sag	120	0.391	0.775	0.384	312.294
			Grade		257.216				
43	259234.381	182.204	Curve	Sag	100	0.775	0.995	0.22	456.205
			Grade		561.377				
44	259905.758	188.882	Curve	Hog	120	0.995	-0.071	-1.066	112.614
			Grade		430.339				
45	260446.097	188.499	Curve	Sag	100	-0.071	0.078	0.149	673.544
			Grade		313.619				
46	260849.716	188.812	Curve	Sag	80	0.078	0.22	0.142	560.77
			Grade		85.526				

VIP			Element type	Type of curve	Length / curve length	Gradient			K value
No.	Chainage,m	Level,m				In	Out	Difference	
47	261025.242	189.199	Curve	Sag	100	0.22	0.899	0.679	147.343
			Grade		220.655				
48	261345.897	192.081	Curve	Hog	100	0.899	0.681	-0.218	459.699
			Grade		602.37				
49	262058.267	196.935	Curve	Sag	120	0.681	1.269	0.588	204.255
			Grade		441.909				
50	262620.176	204.065	Curve	Hog	120	1.269	0.699	-0.57	210.4
			Grade		489.98				
51	263230.156	208.326	Curve	Hog	120	0.699	0.269	-0.43	279.128
			Grade		190.828				
52	263540.984	209.161	Curve	Sag	120	0.269	1.123	0.854	140.413
			Grade		597.11				
53	264258.094	217.216	Curve	Hog	120	1.123	0.66	-0.463	258.841
			Grade		376.17				
54	264754.264	220.489	Curve	Sag	120	0.66	1.45	0.79	151.903
			Grade		270.03				
55	265144.294	226.143	Curve	Hog	120	1.45	0	-1.45	82.78
			Grade		489.194				
56	265753.488	226.143	Curve	Sag	120	0	0.585	0.585	205.058
			Grade		149.377				
57	266022.866	227.719	Curve	Hog	120	0.585	-0.527	-1.112	107.924
			Grade		173.208				
58	266306.073	226.228	Curve	Hog	100	-0.527	-1.275	-0.748	133.619
			Grade		401.597				
59	266817.671	219.704	Curve	Sag	120	-1.275	0.104	1.379	87.025
			Grade		322.117				
60	267274.788	220.179	Curve	Hog	150	0.104	-0.975	-1.079	139.097
			Grade		484.752				
61	267959.54	213.506	Curve	Sag	250	-0.975	-0.179	0.796	314.183

VIP			Element type	Type of curve	Length / curve length	Gradient			K value
No.	Chainage,m	Level,m				In	Out	Difference	
			Grade		394.537				
61	268529.077	212.487	Curve	Sag	100	-0.179	0.058	0.237	421.506
			Grade		235.661				
62	268864.738	212.683	Curve	Hog	100	0.058	-0.455	-0.513	194.874
			Grade		300.985				
63	269275.723	210.814	Curve	Sag	120	-0.455	0	0.455	263.875
			Grade		182.396				
64	269578.119	210.814	Curve	Hog	120	0	-0.055	-0.055	2172.67
			Grade		200.469				
65	269898.588	210.637	Curve	Sag	120	-0.055	0.449	0.504	237.864
			Grade		398.854				
66	270417.442	212.968	Curve	Hog	120	0.449	0.012	-0.437	274.549
			Grade		570.797				
67	271148.239	213.057	Curve	Sag	200	0.012	0.453	0.441	453.94
			Grade		298.17				
68	271631.409	215.245	Curve	Hog	170	0.453	-1.384	-1.837	92.56
			Grade		197.682				
69	271974.091	210.502	Curve	Sag	120	-1.384	-0.062	1.322	90.787
			Grade		246.084				
70	272340.175	210.275	Curve	Hog	120	-0.062	-0.331	-0.269	446.158
			Grade		433.063				
71	272893.238	208.444	Curve	Sag	120	-0.331	0.555	0.886	135.431
			Grade		189.869				
72	273218.107	210.247	Curve	Hog	150	0.555	-0.753	-1.308	114.65
			Grade		244.155				
73	273587.262	207.466	Curve	Sag	100	-0.753	-0.128	0.625	159.982
			Grade		257.972				
74	273955.234	206.994	Curve	Hog	120	-0.128	-1.01	-0.882	136.11
			Grade		390.347				

VIP			Element type	Type of curve	Length / curve length	Gradient			K value
No.	Chainage,m	Level,m				In	Out	Difference	
75	274465.581	201.84	Curve	Sag	120	-1.01	-0.138	0.872	137.646
			Grade		200.953				
76	274786.534	201.397	Curve	Hog	120	-0.138	-0.667	-0.529	226.713
			Grade		159.724				
78	275066.258	199.53	Curve	Hog	120	-0.667	-1.646	-0.979	122.675
			Grade		253.4				
79	275439.658	193.385	Curve	Sag	120	-1.646	-0.012	1.634	73.457
			Grade		379.489				
80	275929.147	193.326	Curve	Sag	100	-0.012	0.109	0.121	827.206
			Grade		170.669				
81	276209.816	193.632	Curve	Sag	120	0.109	0.737	0.628	191.026
			Grade		178.242				
82	276518.058	195.904	Curve	Hog	140	0.737	-0.735	-1.472	95.073
			Grade		225.012				
83	276873.07	193.293	Curve	Sag	120	-0.735	0.476	1.211	99.08
			Grade		147.197				
84	277140.267	194.564	Curve	Hog	120	0.476	0	-0.476	252.271
			Grade		154.443				
85	277414.71	194.564	Curve	Hog	120	0	-0.543	-0.543	220.93
			Grade		213.771				
86	277748.481	192.751	Curve	Sag	120	-0.543	-0.158	0.385	311.216
			Grade		325.411				
87	278183.892	192.065	Curve	Sag	100	-0.158	0	0.158	634.621
			Grade		200.279				
88	278484.171	192.065	Curve	Sag	100	0	0.387	0.387	258.285
			Grade		184.186				
89	278778.357	193.204	Curve	Hog	120	0.387	0	-0.387	309.942
			Grade		127.298				
90	279025.655	193.204	Curve	Hog	120	0	-0.717	-0.717	167.436

VIP			Element type	Type of curve	Length / curve length	Gradient			K value
No.	Chainage,m	Level,m				In	Out	Difference	
			Grade		202.955				
91	279348.61	190.889	Curve	Sag	120	-0.717	0.192	0.909	132.024
			Grade		245.891				
92	279724.501	191.612	Curve	Hog	140	0.192	-0.441	-0.633	221.166
			Grade		348.895				
93	280193.396	189.545	Curve	Sag	100	-0.441	0.045	0.486	206.005
			Grade		187.226				
94	280460.622	189.664	Curve	Hog	60	0.045	0	-0.045	1347.36
			Grade		160				
95	280710.622	189.664	Curve	Hog	120	0	-0.532	-0.532	225.678
			Grade		1059.95				
96	281880.575	183.443	Curve	Sag	100	-0.532	-0.329	0.203	494.364
			Grade		263.349				
97	282253.924	182.213	Curve	Sag	120	-0.329	0.567	0.896	133.867
			Grade		230.588				
98	282594.512	184.144	Curve	Hog	100	0.567	0	-0.567	176.379
			Grade		507.673				
99	283202.185	184.144	Curve	Hog	100	0	-0.361	-0.361	277.175
			Grade		323.523				
100	283625.708	182.616	Curve	Hog	100	-0.361	-0.67	-0.309	323.909
			Grade		1752.85				
101	285488.556	170.144	Curve	Sag	120	-0.67	0	0.67	179.235
			Grade		304.202				
102	285902.758	170.144	Curve	Hog	100	0	-0.202	-0.202	493.853
			Grade		344.962				
103	286347.72	169.243	Curve	Hog	100	-0.202	-0.478	-0.276	362.721
			Grade		270.778				
104	286718.498	167.47	Curve	Sag	100	-0.478	-0.022	0.456	219.359
			Grade		424.414				

VIP			Element type	Type of curve	Length / curve length	Gradient			K value
No.	Chainage,m	Level,m				In	Out	Difference	
105	287242.912	167.353	Curve	Sag	100	-0.022	0.18	0.202	494.949
			Grade		431.427				
106	287824.339	168.398	Curve	Hog	200	0.18	-0.602	-0.782	255.693
			Grade		578.184				
107	288552.523	164.011	Curve	Sag	100	-0.602	0.257	0.859	116.414
			Grade		181.712				
108	288884.235	164.862	Curve	Hog	200	0.257	-0.338	-0.595	336.413
			Grade		684.716				
109	289718.951	162.041	Curve	Sag	100	-0.338	0.222	0.56	178.473
			Grade		247.652				
110	290066.603	162.814	Curve	Hog	100	0.222	0	-0.222	449.744
			Grade		200				
111	290356.603	162.814	Curve	Sag	80	0	0.035	0.035	2311.42
			Grade		404.066				
112	290850.669	162.985	Curve	Hog	100	0.035	-0.307	-0.342	292.59
			Grade		467.866				
113	291428.535	161.21	Curve	Sag	120	-0.307	0.946	1.253	95.733
			Grade		158.907				
114	291717.442	163.944	Curve	Hog	140	0.946	0	-0.946	147.941
			Grade		155.016				
115	292017.458	163.944	Curve	Hog	150	0	-1.984	-1.984	75.601
			Grade		109.611				
116	292302.069	158.297	Curve	Sag	200	-1.984	0	1.984	100.801
			Grade		360.314				
117	292822.383	158.297	Curve	Hog	120	0	-0.984	-0.984	121.971
			Grade		173.583				
118	293105.966	155.507	Curve	Sag	100	-0.984	-0.642	0.342	292.628
			Grade		672.455				
119	293878.421	150.547	Curve	Sag	100	-0.642	-0.129	0.513	194.947

VIP			Element type	Type of curve	Length / curve length	Gradient			K value
No.	Chainage,m	Level,m				In	Out	Difference	
			Grade		397.658				
120	294401.079	149.872	Curve	Sag	150	-0.129	2.503	2.632	56.997
			Grade		144.067				
121	294835.146	160.735	Curve	Hog	430	2.503	-3.3	-5.803	74.105
			Grade		181.332				
122	295296.478	145.511	Curve	Sag	130	-3.3	0	3.3	39.394
			Grade		439.162				
123	295860.64	145.511	Curve	Hog	120	0	-0.501	-0.501	239.752
			Grade		383.889				
124	296354.529	143.039	Curve	Sag	100	-0.501	0.051	0.552	181.34
			Grade		484.887				
125	296949.416	143.342	Curve	Hog	120	0.051	-0.236	-0.287	417.601
			Grade		263.908				
126	297323.324	142.458	Curve	Sag	100	-0.236	0.616	0.852	117.341
			Grade		210.997				
127	297684.321	144.681	Curve	Hog	200	0.616	-0.463	-1.079	185.312
			Grade		368.624				
128	298212.945	142.231	Curve	Sag	120	-0.463	0.368	0.831	144.377
			Grade		323.014				
129	298695.959	144.007	Curve	Hog	200	0.368	-0.374	-0.742	269.54
			Grade		321.681				
130	299177.64	142.204	Curve	Sag	120	-0.374	2.5	2.874	41.753
			Grade		117.36				
131	299545	151.387	Curve	Hog	380	2.5	-2.505	-5.005	75.928
			Grade		147.443				
132	299982.443	140.429	Curve	Sag	200	-2.505	0.929	3.434	58.236
			Grade		160.456				
133	300292.899	143.314	Curve	Hog	100	0.929	0	-0.929	107.61
			Grade		538.638				

VIP			Element type	Type of curve	Length / curve length	Gradient			K value
No.	Chainage,m	Level,m				In	Out	Difference	
134	300931.537	143.314	Curve	Sag	100	0	0.138	0.138	725.278
			Grade		359.255				
135	301400.792	143.961	Curve	Hog	120	0.138	-0.189	-0.327	367.668
			Grade		296.89				
136	301807.682	143.194	Curve	Sag	100	-0.189	0	0.189	530.495
			Grade		172.8				
137	302080.482	143.194	Curve	Sag	100	0	0.016	0.016	6234.98
			Grade		161.869				
138	302342.351	143.236	Curve	Sag	100	0.016	0.528	0.512	195.272
			Grade		172.428				
139	302614.779	144.675	Curve	Hog	100	0.528	0.157	-0.371	269.623
			Grade		270.999				
140	302985.778	145.259	Curve	Hog	100	0.157	0.101	-0.056	1762.41
			Grade		401.627				
141	303487.405	145.764	Curve	Hog	100	0.101	-0.22	-0.321	312.331
			Grade		211.195				
142	303813.6	145.048	Curve	Sag	130	-0.22	2.51	2.73	47.621
			Grade		121.4				
143	304190	154.497	Curve	Hog	380	2.51	-2.51	-5.02	75.686
			Grade		108.813				
144	304553.813	145.364	Curve	Sag	130	-2.51	-0.553	1.957	66.429
			Grade		202.512				
145	304871.325	143.607	Curve	Hog	100	-0.553	-0.918	-0.365	273.936
			Grade		178.088				
146	305149.413	141.053	Curve	Sag	100	-0.918	-0.197	0.721	138.576
			Grade		270.954				
147	305520.367	140.323	Curve	Sag	100	-0.197	0	0.197	508.156
			Grade		227.405				
148	305847.772	140.323	Curve	Hog	100	0	-0.056	-0.056	1780.67

VIP			Element type	Type of curve	Length / curve length	Gradient			K value
No.	Chainage,m	Level,m				In	Out	Difference	
			Grade		816.289				
149	306779.061	139.8	Curve	Sag	130	-0.056	2.51	2.566	50.656
			Grade		15.939				
150	307050	146.601	Curve	Hog	380	2.51	-2.51	-5.02	75.689
			Grade		38.42				
151	307343.42	139.235	Curve	Sag	130	-2.51	-0.072	2.438	53.312
			Grade		161.668				
152	307620.088	139.036	Curve	Sag	100	-0.072	0.091	0.163	614.303
			Grade		168.549				
153	307888.637	139.28	Curve	Hog	100	0.091	-0.606	-0.697	143.557
			Grade		324.372				
154	308323.009	136.649	Curve	Sag	120	-0.606	0.616	1.222	98.237
			Grade		162.202				
155	308645.211	138.633	Curve	Hog	200	0.616	-0.647	-1.263	158.436
			Grade		770.811				
156	309591.022	132.518	Curve	Sag	150	-0.647	0.485	1.132	132.521
			Grade		168.804				
157	309884.826	133.944	Curve	Hog	100	0.485	0	-0.485	206.034
			Grade		160				
158	310144.826	133.944	Curve	Hog	100	0	-1.035	-1.035	96.623
			Grade		227.166				
159	310471.992	130.558	Curve	Sag	100	-1.035	-0.062	0.973	102.759
			Grade		559.96				
160	311141.952	130.144	Curve	Sag	120	-0.062	0.853	0.915	131.127
			Grade		409.243				
161	311661.195	134.575	Curve	Hog	100	0.853	-0.66	-1.513	66.076
			Grade		225.715				
162	311986.91	132.425	Curve	Sag	100	-0.66	0.648	1.308	76.446
			Grade		169.12				

VIP			Element type	Type of curve	Length / curve length	Gradient			K value
No.	Chainage,m	Level,m				In	Out	Difference	
163	312256.03	134.169	Curve	Hog	100	0.648	-0.126	-0.774	129.145
			Grade		230.207				
164	312586.237	133.752	Curve	Sag	100	-0.126	0.846	0.972	102.844
			Grade		194.776				
165	312881.013	136.246	Curve	Hog	100	0.846	-0.001	-0.847	118.1
			Grade		406.324				
167	313387.337	136.243	Curve	Hog	100	-0.001	-1.102	-1.101	90.809
			Grade		180.166				
168	313692.503	132.88	Curve	Sag	150	-1.102	0	1.102	136.13
			Grade		182.347				
169	313999.85	132.88	Curve	Sag	100	0	0.218	0.218	458.6
			Grade		149.109				
170	314258.959	133.445	Curve	Sag	120	0.218	0.815	0.597	201.017
			Grade		312.076				
171	314681.035	136.885	Curve	Sag	100	0.815	0.992	0.177	563.826
			Grade		165.303				
172	314996.338	140.014	Curve	Hog	200	0.992	-0.619	-1.611	124.123
			Grade		301.426				
173	315447.764	137.22	Curve	Sag	100	-0.619	-0.424	0.195	513.695
			Grade		428.821				
174	315986.585	134.934	Curve	Hog	120	-0.424	-1.105	-0.681	176.406
			Grade		250.934				
175	316357.519	130.837	Curve	Sag	120	-1.105	-0.343	0.762	157.672
			Grade		463.805				
176	316941.324	128.832	Curve	Hog	120	-0.343	-0.716	-0.373	322.047
			Grade		76.718				
178	317128.042	127.495	Curve	Sag	100	-0.716	-0.124	0.592	168.979
			Grade		217.068				
179	317445.11	127.101	Curve	Sag	100	-0.124	0.665	0.789	126.766

VIP			Element type	Type of curve	Length / curve length	Gradient			K value
No.	Chainage,m	Level,m				In	Out	Difference	
			Grade		453.122				
180	317998.232	130.777	Curve	Hog	100	0.665	-0.071	-0.736	135.965
			Grade		832.42				
181	318930.652	130.116	Curve	Sag	100	-0.071	0.107	0.178	560.702
			Grade		178.014				
182	319198.666	130.404	Curve	Hog	80	0.107	0	-0.107	744.483
			Grade		170				
183	319468.666	130.404	Curve	Hog	120	0	-1.003	-1.003	119.667
			Grade		157.954				
184	319736.62	127.717	Curve	Sag	100	-1.003	-0.827	0.176	567.803
			Grade		156.25				
185	320092.87	124.772	Curve	Sag	300	-0.827	0.662	1.489	201.537
			Grade		166.905				
186	320484.775	127.366	Curve	Hog	150	0.662	-0.665	-1.327	113.032
			Grade		183.871				
187	320803.646	125.245	Curve	Sag	120	-0.665	0.187	0.852	140.88
			Grade		470.291				
188	321383.937	126.328	Curve	Hog	100	0.187	-0.287	-0.474	211.156
			Grade		759.23				
189	322243.167	123.862	Curve	Sag	100	-0.287	0.833	1.12	89.298
			Grade		166.943				
190	322535.11	126.294	Curve	Hog	150	0.833	-0.583	-1.416	105.94
			Grade		186.955				
191	322857.065	124.417	Curve	Sag	120	-0.583	0.317	0.9	133.343
			Grade		475.931				
192	323442.996	126.274	Curve	Hog	100	0.317	0	-0.317	315.526
			Grade		169.86				
193	323712.856	126.274	Curve	Hog	100	0	-0.356	-0.356	281.147
			Grade		220.789				

VIP			Element type	Type of curve	Length / curve length	Gradient			K value
No.	Chainage,m	Level,m				In	Out	Difference	
194	324033.645	125.133	Curve	Sag	100	-0.356	0.046	0.402	249.108
			Grade		411.517				
195	324545.162	125.367	Curve	Sag	100	0.046	0.902	0.856	116.742
			Grade		261.284				
196	324906.446	128.627	Curve	Hog	100	0.902	0	-0.902	110.823
			Grade		235.002				
197	325241.448	128.627	Curve	Sag	100	0	0.121	0.121	826.629
			Grade		73.592				
198	325415.04	128.837	Curve	Hog	100	0.121	-0.301	-0.422	236.985
			Grade		59.106				
199	325574.146	128.358	Curve	Sag	100	-0.301	0.279	0.58	172.242
			Grade		537.277				
200	326211.423	130.139	Curve	Sag	100	0.279	0.505	0.226	444.308
			Grade		685.271				
201	326996.694	134.101	Curve	Hog	100	0.505	0.293	-0.212	472.684
			Grade		395.253				
202	327491.947	135.552	Curve	Sag	100	0.293	0.823	0.53	188.712
			Grade		202.228				
203	327794.175	138.039	Curve	Hog	100	0.823	0.385	-0.438	228.6
			Grade		319.777				
204	328213.952	139.657	Curve	Hog	100	0.385	0.233	-0.152	656.796
			Grade		177.029				
205	328490.981	140.303	Curve	Sag	100	0.233	0.512	0.279	358.28
			Grade		551.962				
206	329142.943	143.643	Curve	Sag	100	0.512	1.105	0.593	168.677
			Grade		316.66				
207	329584.603	148.524	Curve	Hog	150	1.105	0	-1.105	135.728
			Grade		150				
208	329884.603	148.524	Curve	Hog	150	0	-0.793	-0.793	189.122

VIP			Element type	Type of curve	Length / curve length	Gradient			K value
No.	Chainage,m	Level,m				In	Out	Difference	
			Grade		353.987				
209	330413.59	144.328	Curve	Sag	200	-0.793	1.034	1.827	109.464
			Grade		230.784				
210	330819.374	148.524	Curve	Hog	150	1.034	0	-1.034	145.075
			Grade		148.067				
211	331117.441	148.524	Curve	Hog	150	0	-0.49	-0.49	306.039
			Grade		237.684				
212	331480.125	146.746	Curve	Sag	100	-0.49	0.119	0.609	164.09
			Grade		325.559				
213	331905.684	147.254	Curve	Hog	100	0.119	0.016	-0.103	972.697
			Grade		318.665				
214	332324.349	147.323	Curve	Sag	100	0.016	0.352	0.336	297.932
			Grade		243.909				
215	332668.258	148.534	Curve	Hog	100	0.352	0	-0.352	283.988
			Grade		150				
216	332918.258	148.534	Curve	Hog	100	0	-0.327	-0.327	306.118
			Grade		464.176				
217	333482.434	146.691	Curve	Hog	100	-0.327	-0.844	-0.517	193.319
			Grade		270.875				
218	333853.309	143.561	Curve	Hog	100	-0.844	-1.131	-0.287	348.937
			Grade		136.083				
219	334089.392	140.892	Curve	Sag	100	-1.131	-0.006	1.125	88.901
			Grade		339.409				
220	334528.801	140.867	Curve	Sag	100	-0.006	0.954	0.96	104.192
			Grade		803.801				
221	335432.602	149.49	Curve	Hog	100	0.954	-0.035	-0.989	101.152
			Grade		241.743				
222	335774.345	149.372	Curve	Sag	100	-0.035	0.684	0.719	139.096
			Grade		278.114				

VIP			Element type	Type of curve	Length / curve length	Gradient			K value
No.	Chainage,m	Level,m				In	Out	Difference	
223	336202.459	152.302	Curve	Hog	200	0.684	-0.677	-1.361	146.941
			Grade		315.796				
224	336668.255	149.15	Curve	Sag	100	-0.677	-0.091	0.586	170.879
			Grade		418.138				
225	337186.393	148.676	Curve	Hog	100	-0.091	-0.272	-0.181	553.548
			Grade		438.337				
226	337724.73	147.211	Curve	Sag	100	-0.272	0.779	1.051	95.128
			Grade		177.645				
227	338012.375	149.452	Curve	Hog	120	0.779	-0.771	-1.55	77.4
			Grade		178.585				
228	338310.96	147.149	Curve	Sag	120	-0.771	0.069	0.84	142.806
			Grade		220.59				
229	338651.55	147.384	Curve	Sag	120	0.069	1.585	1.516	79.162
			Grade		351.332				
230	339122.882	154.854	Curve	Hog	120	1.585	0	-1.585	75.716
			Grade		276.475				
231	339519.357	154.854	Curve	Hog	120	0	-1.163	-1.163	103.17
			Grade		333.889				
232	339963.246	149.691	Curve	Sag	100	-1.163	0.028	1.191	83.989
			Grade		249.041				
233	340312.287	149.787	Curve	Sag	100	0.028	0.926	0.898	111.299
			Grade		217.501				
234	340629.788	152.727	Curve	Hog	100	0.926	-0.006	-0.932	107.303
			Grade		1091.9				
235	341821.687	152.656	Curve	Hog	100	-0.006	-0.232	-0.226	442.494
			Grade		181.097				
236	342102.784	152.004	Curve	Sag	100	-0.232	0	0.232	431.13
			Grade		200				
237	342402.784	152.004	Curve	Sag	100	0	0.208	0.208	481.82

VIP			Element type	Type of curve	Length / curve length	Gradient			K value
No.	Chainage,m	Level,m				In	Out	Difference	
			Grade		189.574				
238	342692.358	152.605	Curve	Sag	100	0.208	0.579	0.371	269.181
			Grade		597.703				
239	343390.061	156.645	Curve	Hog	100	0.579	0	-0.579	172.699
			Grade		249.747				
240	343739.808	156.645	Curve	Hog	100	0	-0.545	-0.545	183.586
			Grade		405.964				
241	344245.772	153.889	Curve	Sag	100	-0.545	0.747	1.292	77.391
			Grade		277.456				
242	344633.228	156.785	Curve	Hog	120	0.747	-0.696	-1.443	83.123
			Grade		201.174				
243	344954.402	154.549	Curve	Sag	120	-0.696	0.306	1.002	119.75
			Grade		150.033				
244	345224.435	155.375	Curve	Hog	120	0.306	0.16	-0.146	819.991
			Grade		308.091				
245	345652.526	156.058	Curve	Sag	120	0.16	0.34	0.18	666.512
			Grade		346.16				
246	346123.686	157.658	Curve	Hog	130	0.34	-0.853	-1.193	108.996
			Grade		205.829				
247	346459.515	154.793	Curve	Sag	130	-0.853	0.601	1.454	89.38
			Grade		383.378				
248	346957.893	157.79	Curve	Hog	100	0.601	0	-0.601	166.292
			Grade		384.288				
249	347442.181	157.79	Curve	Hog	100	0	-0.463	-0.463	216.117
			Grade		351.684				
250	347893.865	155.7	Curve	Sag	100	-0.463	0.106	0.569	175.922
			Grade		851.561				
251	348845.426	156.706	Curve	Hog	100	0.106	0	-0.106	945.886
			Grade		160				

VIP			Element type	Type of curve	Length / curve length	Gradient			K value
No.	Chainage,m	Level,m				In	Out	Difference	
252	349105.426	156.706	Curve	Hog	100	0	-0.111	-0.111	900.011
			Grade		309.505				
253	349514.931	156.251	Curve	Hog	100	-0.111	-0.452	-0.341	293.546
			Grade		195.282				
254	349810.213	154.917	Curve	Sag	100	-0.452	0.532	0.984	101.639
			Grade		236.775				
255	350171.988	156.842	Curve	Hog	150	0.532	-0.559	-1.091	137.443
			Grade		252.461				
256	350549.449	154.731	Curve	Sag	100	-0.559	-0.155	0.404	247.545
			Grade		1258.7				
257	351908.147	152.621	Curve	Sag	100	-0.155	0.718	0.873	114.55
			Grade		175.969				
258	352209.116	154.781	Curve	Hog	150	0.718	-0.923	-1.641	91.452
			Grade		202.361				
259	352536.477	151.761	Curve	Sag	100	-0.923	-0.432	0.491	203.902
			Grade		104.284				
260	352720.761	150.965	Curve	Sag	60	-0.431	-0.094	0.337	177.675
			Grade		407.623				
261	353223.384	150.494	Curve	Sag	130	-0.094	2.026	2.12	61.316
			Grade		131.047				
262	353484.431	155.784	Curve	Hog	130	2.026	0	-2.026	64.151
			Grade		104.071				
263	353718.502	155.784	Curve	Hog	130	0	-2.14	-2.14	60.736
			Grade		213.392				
264	354061.894	148.434	Curve	Sag	130	-2.14	-0.791	1.349	96.337
			Grade		263.125				
265	354450.019	145.364	Curve	Sag	120	-0.791	0	0.791	151.71
			Grade		402.059				
266	354962.078	145.364	Curve	Hog	100	0	-0.197	-0.197	508.67

VIP			Element type	Type of curve	Length / curve length	Gradient			K value
No.	Chainage,m	Level,m				In	Out	Difference	
			Grade		405.109				
267	355467.187	144.371	Curve	Sag	100	-0.197	0.009	0.206	486.791
			Grade		975.158				
268	356542.345	144.466	Curve	Sag	100	0.009	0.726	0.717	139.378
			Grade		411.541				
269	357063.886	148.254	Curve	Hog	120	0.726	0	-0.726	165.219
			Grade		164.637				
270	357348.523	148.254	Curve	Hog	120	0	-0.329	-0.329	364.777
			Grade		379.745				
271	357848.268	146.61	Curve	Sag	120	-0.329	0.316	0.645	185.942
			Grade		326.912				
272	358295.18	148.024	Curve	Hog	120	0.316	0.003	-0.313	382.409
			Grade		458.452				
273	358873.632	148.039	Curve	Sag	120	0.003	0.718	0.715	167.773
			Grade		270.614				
274	359264.246	150.843	Curve	Hog	120	0.718	0.201	-0.517	232.062
			Grade		726.896				
275	360101.142	152.523	Curve	Sag	100	0.201	0.251	0.05	2009.52
			Grade		211.75				
276	360422.892	153.329	Curve	Sag	120	0.251	0.935	0.684	175.402
			Grade		176.903				
277	360719.795	156.104	Curve	Hog	120	0.935	0	-0.935	128.39
			Grade		161.283				
278	361001.078	156.104	Curve	Hog	120	0	-0.193	-0.193	621.739
			Grade		131.442				
279	361242.52	155.638	Curve	Sag	100	-0.193	0.161	0.354	282.669
			Grade		963.051				
280	362305.571	157.347	Curve	Sag	100	0.161	0.265	0.104	956.602
			Grade		299.924				

VIP			Element type	Type of curve	Length / curve length	Gradient			K value
No.	Chainage,m	Level,m				In	Out	Difference	
281	362705.495	158.408	Curve	Hog	100	0.265	0	-0.265	376.931
			Grade		159.802				
282	362965.297	158.408	Curve	Sag	100	0	0.507	0.507	197.371
			Grade		306.584				
283	363371.881	160.468	Curve	Hog	100	0.507	0.147	-0.36	278.275
			Grade		533.386				
284	364005.267	161.401	Curve	Sag	100	0.147	0.755	0.608	164.536
			Grade		159.578				
285	364264.845	163.361	Curve	Hog	100	0.755	-0.042	-0.797	125.45
			Grade		734.6				
286	365099.445	163.01	Curve	Sag	100	-0.042	0.47	0.512	195.418
			Grade		412.703				
287	365612.148	165.418	Curve	Hog	100	0.47	-0.15	-0.62	161.369
			Grade		275.923				
288	365988.071	164.854	Curve	Sag	100	-0.15	0.284	0.434	230.312
			Grade		163.581				
289	366251.652	165.603	Curve	Hog	100	0.284	0.026	-0.258	386.952
			Grade		279.176				
290	366620.828	165.698	Curve	Sag	80	0.026	0.215	0.189	422.422
			Grade		19.353				
291	366680.181	165.826				0.215	--	--	

7.5 Review of Realignment Sections

The Consultant have carried our detailed alignment for the proposed four lane divided road. There are five (5) locations on the project road where, the horizontal alignment has been designed with Design speed less than 100 Kmph to fit the proposed cross section within 50m right of way. The five locations are;

- Dhalkebar,
- Badhari Bazar,
- Banke Bridge approach,

- Hariyon and
- Baghmati river main bridge approach.

The realignment options for above identified locations were presented during the review meeting at Client's office on 22/12/2021. After detailed deliberations, it was agreed that; the alignment accommodated within right of way of 50m as much as possible except at Dhalkebar where realignment would be required. During the Design review meeting held on 07/02/2022, the Consultant suggested that; if the Design Speed is reduced to 75% of desirable speed (as per NRS), then the alignment at 4 locations except Dhalkebar can be accommodated within existing 50m RoW. The client had reviewed the proposal and suggested the Consultant vide letter ref no DCID:6/2078-79/362 dated 13/02/2022 to adopt guiding principles given in clause 7(b) of NRS 2070 in case of unavoidable circumstance to avoid / minimize land and structure acquisition. The Consultant had revised the alignment to accommodate the alignment within the right of way at four locations. The alignment design with compromised Design Speed has been carried out at Dhalkebar junction. The figure showing location of Dhalkebar with the proposal is provided as **Figure 7.1** below.

Figure 7.1: Existing Alignment and Proposed realignment at Dhalkebar Junction

The Consultant along with World Bank and DoR officials carried out site inspection on 04th and 05th April 2022 to review the feasibility of realignment at Dhalkebar. After detailed joint site inspection, DoR advised the consultant to prepare the options of (i) flyover at Dhalkebar following existing road alignment with reduced design speed (ii) realignment with flyover with design speed of 75 Kmph and (iii) surface level rotary improvements. The Consultant prepared three options and submitted to Client on 07/05/2022 vide letter no. KDP-DPR-2078/79-71.

The Consultant was advised to modify the geometry of flyover on existing road with an intent to increase the design speed. The Consultant modified the horizontal geometry of the flyover. However, the revised horizontal geometry resulted in land/ structure acquisition of appr. 1852 Sqm near Dhalkebar junction. Considering the requirement of DoR, the flyover proposal on existing road without land acquisition has been adopted as part of detailed horizontal alignment design.

The Consultant had proposed flyovers at 4 locations as part of DDPR submission. These locations are Dhalkebar, Baribas, Chandranighapur and Pathlaiya junctions. After several rounds of discussions with Client, DoR has suggested not to include any flyovers as part of Final DPR (ref minutes of meeting Dt 01-04-2023). Hence, the consultant has not considered any flyovers as part of Final DPR submissions.

7.6 Engineering Drawings

The Consultant has prepared plan and profile drawings covering details of central median, main road, paved shoulder / separator, service road (Travel Lane) and footpath. Embankment / Cut slope lines are also generated based on the typical cross sections. The plan information consists of taper / transition sections at approaches to be bridges and main road / service roads. The profile and the table consist of horizontal curve parameters (circular and transition curve), superelevation schematic, vertical curves parameters (length and K values). Tentative locations of provision of earth retaining structures to contain the embankment soil within 50m RoW are also shown in the drawing.

Chapter 8: Hydraulic Analysis & Drainage Design

8.1 General

Under the scope of upgradation of 130 km KDP stretch of east-west highway several new additional bridges, culverts are designed. There are altogether 76 bridges, 102 culverts and 25 causeways along KDP stretch to cross the natural water ways. Those water ways comprise of large river system originating from Mahabharat range, medium to small river systems originating from Churia/Siwalik hills, local drains and flow paths to release water impounded by the construction of high road embankment obstructing natural drainage of local runoffs. Those existing structures are either augmented with additional new structures or upgraded to new geometry and types. Rivers originating from Mahabharat range are perennial in nature, while those originating from Churia/Siwalik ranges are ephemeral. The streams that highway crosses or encroach upon are alluvial. In alluvial stream systems, it is the rule rather than the exception that banks will erode; sediments will be deposited; and floodplains, islands and side channels will undergo modification with time. Alluvial channels continually change position and shape as a consequence of hydraulic forces exerted on the bed and banks. These changes may be gradual or rapid and may be the result of natural causes or man's activities.

Design of the components of Bridges and culverts requires information on design peak flows, depth and velocity of flow and discharge intensities in the vicinity of structures. Peak flows are estimated using rainfall runoff relationship if the river basin are ungauged and statistically if they are gauged. The peak discharge thus calculated when routed through the river channel results in spatially varying flow depth and velocities along the river reach due to variation in channel geometry and topography. Such analysis is required to know the High flood level and velocity of flow at the crossing structures and it's vicinity. The hydrological surveys are thus carried out to acquire the information pertaining to such analysis and morphological characteristics of the river reaches in the vicinity of the crossing.

The detailed hydrological, hydraulic and river training studies together with required field investigations of bridges and culverts have been carried out for KDP project. The following paras provide the design parameters like design flood, high flood levels, and scour depths for the design of bridges in rivers. Similarly, parameters for design of culverts at small drainage locations and road drainage system are also provided. River training works are also performed wherever necessary.

8.2 Project Area Description

The KDP road alignment passes through the area of the fluvial sediments of the Indo-Gangetic Plain, just south of the Siwalik Ridge. The elevation of the Gangetic Plain ranges from 100 to 300 m above mean sea level (amsl). Overall topography of road alignment from Kamala to Pathlaiya is nearly with flat to very gentle gradient. The alignment crosses major rivers like the Kamala, Bagmati, Bakaiya, Pashaha Khola, Dudhaura Khola etc. These rivers are originated from the Mahabharat Range and Lesser Himalaya and perennial in nature. But small rivers along the road alignment are originated from the Siwalik Range and are ephemeral. Those ephemeral rivers carry heavy sediment loads and debris during the heavy rainfall event. **Table 8.1** below shows the distribution of numbers of rivers and corresponding catchment area class at crossing.

Table 8.1: Distribution of numbers of rivers crossing the road alignment

Catchment area at crossing (km^2)	Numbers of rivers
>1000	2
1000 to 100	3
100 - 25	17
< 25	51

Most of the rivers included in the project, originates from Siwalik and flows toward south in the Terai plain with very low gradient. Geologically, the upper reach comprises the Siwalik Hills, while the lower reach is in the Terai, the northern extension of the Indo-Gangetic Plain. The upper reach has all the three subgroups of the Siwaliks, namely, the Lower Siwaliks, the Middle Siwaliks, and the Upper Siwaliks.

The Lower Siwaliks are composed of brown sandstone and clays. The Middle Siwaliks are characterized by thick beds of sandstone. The Upper Siwaliks form the major part of the watershed and are composed of conglomerates with pebbles and boulders. The topography of the Upper Siwaliks is highly dissected, coarsely textured, and subdued. To the south lies a depositional zone of very low relief and gentle slopes. The slope of the river bed at crossings ranges from 0.041 to 0.0012.

Most of the rivers are split meandering and braided, having unconfined valley in flood plain to less confined valley. Most of these rivers consist of sand, gravel and boulders as their bed material. Most dominant type of bed material observed during the field investigation was sand and gravel. The weighted mean size of bed material of river at crossings ranges from 12mm

to 0.02mm. The channel pattern in these rivers are braided with several active channels. Typical characteristic of these type of rivers includes

i. Channels are split by island and bars;
ii. Meandering pattern indicates erosion at outside of bends;
iii. Bar material generally composed of sand and gravel; and
iv. Most of the rivers are aggrading in nature

The Land Use of the alignment is dominated by the forest cover, settlement area, cultivated area and Barren land. Residual soil deposits are dominantly found throughout the road alignment over the loose fluvial sediments of the Bhabar zone. The main reason for occurrences of the residual soil is weathering of alluvial deposits of the Bhabhar zone. Alluvial deposits are mainly found on banks of the Kamala River, Bagmati River, Bakaiya Khola and other small rivers.

The entire KDP reach of highway lies in the lower tropical area with elevation from mean sea level below 300m. Temperature and annual precipitation at different location in the vicinity of KDP reach of highway are presented in **Table 8.2** below**.**

Table 8.2: Temperature and annual precipitation in the vicinity of KDP

Location	Maximum Temperature (°C)	Minimum Temperature (°C)	Annual Precipitation (mm)
Gaur (Rautahat)	32.1	20.13	1611
Jaleshwar (Mahottari)	31.6	19.9	1435
Malangwa (Sarlahi)	29.6	18.4	1675
Janakpur (Dhanusa)	29.7	16.1	1555
Simara (Bara)	30	18.9	1853

8.3 Scope and Methodology

8.3.1 Scope of works

Hydraulic analysis includes the works of field investigation, field measurement (Cross Sectional and L-Sectional surveys) , secondary data collection (Data of Hydro-Metrological Stations), Rainfall Runoff Analysis, Frequency Analysis, Design Discharge Calculations, Water Surface profile Calculation (HFL, LWL) Scour Calculation and recommendation on the

basis of study for the design of bridge, culverts, river training works and drainage networks. These scope of works have been listed in ToR as

For determination of all design data the consultant shall carry out a detailed hydrological survey and study of the river and bridge sites, which shall include the following:

a) Catchment area of the river up to bridge site;
b) Nature, size and quantities of debris carried by the river;
c) Intensity, duration and distribution of rain in the catchment;
d) Existing bridge or other hydraulic structures across the river in the vicinity of the proposed bridge site with their details as much as possible;
e) General slope of the river from the critical point (origin) of the river up to bridge site and general slope of the catchment in both sides of the river;
f) Cross sections covering 100m on either side. Beyond flood lines of the river at proposed bridge site, at about 500m. uls and about 200m dis. wherein HFL, LWL, LBL, area of the cross section, wetted perimeter and geological profile with silt factor of each strata (at proposed bridge site only) indicated. (Horizontal and vertical scale of the cross section shall be the same.);
g) Bed slope of the river which must start from 100m up of the U/S cross section and end at 100 m. down of the dis. cross section;
h) Maximum discharge calculated by established formulas with different return periods and the peak discharge observed over a period of 100 years;
i) Velocity and depth of flow at the time of survey;
j) Shifting of the river in the past at proposed bridge site and in its vicinity;
k) River-bed degradation or aggradation (covering 500m upstream and 500m downstream);
l) Use of river as migration corridor of wildlife and fisheries;
m) Other information required for river control, design, construction and maintenance of the bridge;

The hydrological survey shall collect secondary data, preferably from the governmental sources, to determine the following:

a) Unit hydrograph for the catchment of River for bridge construction
b) Size of the opening and location of cross drainage structure
c) Minimize modification to the natural drainage pattern

After the selection of the proposed bridge site with alternatives and preparation of topographic maps, the Consultant shall discuss the collected hydrological and other data and decide the following points with the client for final decision of the bridge site:

a) Design discharge
b) Scour depth, Maximum Scour depth
c) Linear waterway needed to be provided
d) Anticipated soil condition for foundation
e) The most feasible proposed bridge site
f) River- training & approach roads
g) Type of proposed foundation, substructure and superstructure

The Consultant shall also carry out a detailed hydrological survey and study along the road alignments and identify catchment, discharge in drain, cross drainage, seepage area etc.

8.3.2 Methodology

Following methodologies were adopted to complete the objectives of hydraulic analysis and drainage design:

- Collection of rainfall data for representative stations around the vicinity of catchments from Department of Hydrology and Meteorology (DHM).
- Delineation of catchment areas at drainage crossing sites by using digital topographical maps and verifying by Google Earth Pro and GIS using SRTM data.
- Rainfall analysis (estimating rainfall of design frequency) at stations having more than 25 years of data by applying Cumfreq software.
- Determination of floods of design frequency by using rainfall-runoff models and statistical approach if the river is gauged.
- Comparison of floods by different methods and determination of the design flood for each river/stream/drain.
- Determination of HFL, water surface profile, average and maximum velocities using hydraulic modeling.
- Determination of general scour at crossing using regime equations and Blench zero bed approach
- Comparison of general scour by different methods and determination of the design scour.
- Determination of maximum scours at structural components of crossings.

- Preparation of networks of side and cross drains and determination of design discharge, depth and velocity at different strategic location to ascertain the required dimension of related structures.
- Design of required river training works at the vicinity of the proposed bridge based on survey data and field verification.

8.4 Primary Data Collection

As a part of hydrological Investigation, the consultant team has performed the field assessment of existing bridge sites. During the investigation the team has collected some information pertaining to hydrological and hydraulic parameters of each bridge site. **Table 8.3** below presents the details of information collected during field assessment. Those information in conjunction with L and X-sectional survey data along the river reach were used for assessing the status of the existing bridges and culverts.

Table 8.3: Field data of Existing Bridges of KDP Road

Name of Bridge	Chainage (Km.m)	Length of Bridge (m)	Bed level below deck (m)	HFL below deck (m)	Bed Material Composition	Type of River	Nature (Siltation)
Kamala	237.323	640	9	4	Sand and Gravel	Perennial	Aggrading
Kamala Canal	238.398	70.4					
Charnath	241.645	322	4.5	2	Sand and Gravel	Ephemeral	Aggrading
Baluwa	245.39	111	4.7	2	Sand and Gravel	Ephemeral	Aggrading
Jagadav Branch	251.1	26.6					
Jagadav	251.39	96	6	4	Sand and Gravel	Ephemeral	Aggrading
Jalad	252.96	266	6.2	2	Sand and Gravel	Ephemeral	Aggrading
Aurahi	255.061	319	6.4	4	Sand and Gravel	Ephemeral	Aggrading
Basai	256.715	96	5.8	2	Sand and Gravel	Ephemeral	Aggrading
Sukhajor	259.23	44.2	6	4	Sand and Gravel	Ephemeral	Aggrading
Barahari	261.54	75	6	3	Sand and Gravel	Ephemeral	Aggrading
Ratu (New)	265.82	225.3	7	3.5	Sand and Gravel	Ephemeral	Aggrading
Ratu Chahara	266.72	18.8			Sand and Gravel	Ephemeral	Aggrading

Name of Bridge	Chainage (Km.m)	Length of Bridge (m)	Bed level below deck (m)	HFL below deck (m)	Bed Material Composition	Type of River	Nature (Siltation)
Bhapsi (new)	268.73	50.46	Under Construction		Sand and Gravel	Ephemeral	Aggrading
Atabbe	269.97	28.6	7.8	2	Sand and Gravel	Ephemeral	Aggrading
Janga Pul-1	271.3	75		1	Sand and Gravel	Perennial	Stable
Gaushala	271.595	37.5	4.4	2.2	Gravel	Ephemeral	Aggrading
Gadhanta	271.95	62.5	3.5	1.5	Sand and Gravel	Ephemeral	Aggrading
Belgachhi (DhungreKhola)	275.4	38.1	2.3	0.5	Sand and Gravel	Ephemeral	Aggrading
Tuteshwor -1	276.105	19	3.8	2	Sand and Gravel	Ephemeral	Degrading
Tuteshwor - 2	280.5	19	5.3	2.5	Gravel	Ephemeral	Aggrading
Maraha Bridge	277.559	132	4.5	2	Sand and Gravel	Ephemeral	Aggrading
MarahaKholsiPul/ BatuwaKhola	278.83	19	3.7	2	Gravel	Ephemeral	Aggrading
Dholan	279.385	38	2.6	1.5	Sand and Gravel	Ephemeral	Aggrading
Jarlahi (KholsiPul)	281.064	19	4	2.5	Sand and Gravel	Ephemeral	Aggrading
Batuwa/ Budakhola	282.49	28.5	4	2	Sand and Gravel	Ephemeral	Aggrading
Bankhe	283.3	102.5	4.8	2	Sand and Gravel	Ephemeral	Aggrading
Amuwa	286.26	18.65	4.5	2	Sand and Gravel	Ephemeral	Aggrading
Phuljor	290.8	87.4	4.8	2.5	Sand and Gravel	Ephemeral	Aggrading
Kalinjor - 1	292.5	28.5	4.4	3	Sand and Gravel	Ephemeral	Aggrading
Kalinjor - 2	293.35	63.4	6.4	3	Silt	Perennial	Stable
Betini	294.77	12	2.5	2	Silt	Ephemeral	Degrading
Dumdume	296	18.7	3.4	1.5	Silt	Perennial	Stable
Bastipur	296.94	18.8			Sand and Gravel	Ephemeral	Aggrading
Lakhandei	301.19	204.55	6.2	2	Sand and Gravel	Ephemeral	Aggrading
Chapani	302.3	66.4	5.8	2	Sand and Gravel	Perennial	Aggrading
Bastol	303.164	20.8			No Flow Characteristics Observed		

Name of Bridge	Chainage (Km.m)	Length of Bridge (m)	Bed level below deck (m)	HFL below deck (m)	Bed Material Composition	Type of River	Nature (Siltation)
Sukhapokhari	306.235	20			No Flow Characteristics Observed		
Rai Bridge/ HarionKhola	308.265	38	6	2.5	Sand and Gravel	Perennial	Degrading
Dumajor	310.516	37.5	4	1.8	Sand and Gravel	Ephemeral	Aggrading
Godari	312.055	19.4	2	1.5	Sand and Gravel	Ephemeral	Aggrading
Bagmati	313.53	363.5	10.8		Sand and Gravel	Perennial	Aggrading
Bagmati East	313.93	11.3			Canal Crossing		
Bagmati West	314.23	11.57			Canal Crossing		
Gairi	314.594	34.25	5	2.5	Sand and Gravel	Ephemeral	Aggrading
GairiKhola	315.445	11.5			No Flow Characteristics Observed		
Paurai	318.38	66.4	5.4	2.5	Sand and Gravel	Ephemeral	Aggrading
Lachkan	319.74	22.67	2.6		No Flow Characteristics Observed		
Katha KoPul/	324.165	46	2.4		No Flow Characteristics Observed		
Chandi	325.8	165	7.7	3.5	Sand and Gravel	Perennial	Aggrading
Dhou	327.94	22.5	1		No Flow Characteristics Observed		
Jungle Tole	328.74	34.08	1.8		No Flow Characteristics Observed		
Amu -1	330.27	34.08	2.5		No Flow Characteristics Observed		
Amu – 2	331.505	22.73	3		No Flow Characteristics Observed		
Kathi	333.31	56.8	2.3		No Flow Characteristics Observed		
Lamaha	334.43	65.9	9.4	6	Gravel	Perennial	Stable
Kali Khola	335	34	6.45	3.5	Sand and Gravel	Perennial	Degrading

Name of Bridge	Chainage (Km.m)	Length of Bridge (m)	Bed level below deck (m)	HFL below deck (m)	Bed Material Composition	Type of River	Nature (Siltation)
Dhansasr	339.92	164.6	5.4	2	Sand and Gravel	Ephemeral	Aggrading
Lamopul	342.77	45.4	3		No Flow Characteristics Observed		
Bhamara	344	32.89	9.2	5	Sand and Gravel	Ephemeral	Aggrading
Rampul	344.6	22.5	3.5		No Flow Characteristics Observed		
Bakeya	347.715	355.59	8.6	4	Sand and Gravel	Perennial	Aggrading
Unasi	349.51	89.6	2.8		No Flow Characteristics Observed		
Terhakilo	354.21	45.6	2	0	Sand and Gravel	Ephemeral	Aggrading
Barahakilo	355.26	34	4.8	2.5	Gravel	Ephemeral	Stable
Pasaha	357.875	165	7.5	3.2	Sand and Gravel	Perennial	Aggrading
Pasaha Branch	358.07	22.2			Sand and Gravel		
Bangandi	359.145	113.6	4.2		No Flow Characteristics Observed		
Balganga	361.59	67.1	8	4.5	Sand and Gravel	Ephemeral	Aggrading
Baijura	363.55	46.1	5.5	3	Sand and Gravel	Ephemeral	Aggrading
Dudhaura	364.263	89.3	Under Construction		Sand and Gravel	Ephemeral	Aggrading
Dhungre– 1	365.163	22.8	3		No Flow Charecteristics Observed		
Dhungre – 2	365.385	23.3	5.5		No Flow Charecteristics Observed		
Tin Number	366.47	23.16	4.6	3	Sand and Gravel	Ephemeral	Stable
Dui Number	367	34.74	4	2.5	Sand	Ephemeral	Stable
Ek Number	367.225	11.45	2.6		No Flow Charecteristics Observed		

The survey is a critical component of any hydraulic investigations. The recommended survey requirements for a simple water course include cross sections for the reach both downstream and upstream of the crossing.

Downstream of the crossing, the general requirement is to have at least 10 cross sections spaced approximately 50 m apart. These cross sections at right angles to the flow and should extend to higher than the highest expected flood level, so that the model can represent all of the flow. The maximum surveyed level is usually higher than the bank level of the stream, since over-bank or floodplain flow is common. The cross sections should represent the downstream reach sufficiently to allow the backwater model to calculate the flood level immediately downstream of the bridge accurately.

Upstream of the crossing, at least 10 cross sections are also suggested, also spaced about 50 m apart. These upstream cross sections ensure that the afflux or the impact of the crossing on flood levels can be calculated accurately. As well as the cross sections, the stream bed profile over the reach of the river upstream and downstream of the bridge site (included with the cross sections above) should also be surveyed. This provides assistance with the estimation of the flood profile and also helps to identify locations where there are changes in bed slope, which is useful in the hydraulic modelling. It is important that the cross sections should extend up to above the level of the highest expected flood. If the cross sections do not extend sufficiently high, the calculated flood levels and velocities will be too high because the cross sections are extended vertically in the hydraulic modelling. In some cases, survey of the floor levels of potentially affected buildings or other infrastructure should be taken to assist in assessing afflux at these buildings.

For this purpose, cross-sectional information (covering main channel and over banks) of the rivers, streams and water-courses at 20 m interval from 500 m downstream to 500 m upstream of the crossing sites along with the geometry of bridges were collected by the survey team.

In addition, the pertinent primary information required for hydraulic analysis are weighted mean size of river bed materials at the crossings. Primary data pertaining to bed materials are collected by geo-technical team.

8.5 Rainfall analysis

Most of the stream crossing the road alignment are ungauged. The design flood discharge at the crossing is thus estimated using rainfall runoff relationship for most of the locations. For this purpose, estimation of 24 hours maximum rainfall amount of design return period for the

basin is needed. Such hydrological characteristics of the basin estimated using the observed time series of the rain-gauge stations in the vicinity of the basins.

The relevant rainfall and river gauging stations for the project area have been identified. The digital data were collected from the Department of Hydrology and Meteorology (DHM). These data are presented in Appendix HY-1 whose summary are presented in **Table 8.4** below.

Table 8.4: Summary of Rainfall Stations for Project Area

S.N	Station Name	St. Index	District	Lat. (Deg, Min)	Long. (Deg, min)	Elev. (m)	Data Available From	
1	Simra Airport	909	Bara	2710	8459	130	Sept	1966
2	Nijgadh	910	Bara	2711	8510	244	June	1955
3	Parwanipur	911	Bara	2704	8458	115	Jan	1967
4	Ramoli Bairiya	912	Routahat	2701	8523	152	Feb.	1956
5	Pattharkot(East)	1109	Sarlahi	2705	8540	275	Jan	1972
6	Tulsi	1110	Dhanusa	2702	8555	457	March	1973
7	Chisapani Bazar	1112	Dhanusa	2655	8610	165	Jan	1972
8	Gausala	1119	Mahottari	2653	8547	200	Feb	1979
9	Karmaiya	1121	Sarlahi	2707	8528	131	Aug	1983
10	Amlekhgunj	907	Bara	2728	8500	396	June	1955

Figure 8.1 below shows the location of those relevant hydro met stations in the vicinity of the road alignment.

Figure 8.1: Hydro-Met stations in the vicinity of the Project Road

8.5.1 Design Frequency

Hydrologic systems are sometimes impacted by extreme events, such as severe storms and floods. The magnitude of an extreme event is inversely related to its frequency of occurrence, very severe events occurring less frequently than more moderate events.

The definition of the return period T is that a given rainfall depth x with a return period T is exceeded, on the average, once in T years. The risk of 100 years return period to occur at least once in 100 years of project life is 64%. The frequency or return period was used as 100 years for estimating the design flood for the project.

24 hours maximum rainfall amount of 100 years return period (R100yr) for the basin was estimated with following steps and presented in **Table 8.5** below**.**

- The annual maximum daily rainfall point values of the relevant stations in the vicinity of the catchment area are collected.
- The gaps in the records were filled by fitting a multiple regression model (the records with gap as dependent variables and those without gaps as independent variables) which predict the value of gap in a particular year based on the values of the corresponding year in other nearby stations.
- Spatial averaging of the maximum 24 hours rainfall over the basin was estimated using Thiessen's Polygon method

- In order to estimate 100 years, return period 24 hours annual maximum rainfall (R100yr) over the catchment, probability distribution was fitted to spatially averaged series using Cumfreq software.
- Using the best fit distribution 24 hours maximum rainfall for 100 years return periods was estimated

Table 8.5: Estimation of point rainfall, R100yr for each station

Rainfall St. no.	No. of years	Maximum value, mm	Best fit distribution	Point R_{100yr}, mm
907	36	399	Laplace distribution	444.95
909	36	300.3	Frechet type (Fisher-Tippett 2)	345.84
910	36	444.6	Laplace distribution	502.5
1109	36	437	Laplace distribution	448.59
1110	36	436.1	Laplace distribution	519.38
1112	36	315	log-logistic Distribution	386
1117	36	482.2	Laplace distribution	565.41
1121	36	432	Laplace distribution	465.58
1213	34	231.4	generalized extreme value (GEV)	396.99
1075	26	280	Burr frequency function	374.27
1001	32	191.2	Gumbel	221.17

The time series of annual maximum daily rainfall amounts of the relevant stations, their Thiessen's weightages over the catchment area of river at crossing points, time series of spatially averaged annual maximum daily rainfall amounts for corresponding catchment areas and their best fit probability distribution and R100yr are presented in **Volume I-B** for reference.

8.5.2 Design Standard for Bridges

The design standard adopted for the bridge hydraulic analysis is as per the Nepal Bridge Standard 2067. Free Board consideration for bridges has been kept as per the Nepal Bridge Standard 2067.

8.5.3 Rainfall Intensity and IDF Curves

An Intensity-Duration-Frequency curve (IDF Curve) is a graphical representation of the probability that a given average rainfall intensity will occur for a particular duration of rainfall (equal to exceeding time of concentration) and particular frequency (return period). Values obtained by frequency analysis are adopted for preparation of IDF Curves and determination of design intensities for the design of cross, side drains and estimation of peak discharge for streams of small catchment areas (time of concentration < duration of rainfall). IDF curve were developed based on following two methods:

(a) Mononobe Equation

Based on the maximum daily rainfall R24, the Rainfall Intensity for any duration can be obtained from Mononobe equation which is generally applied in mountainous catchment

$$I_{D,T} = \frac{R_{24,T}}{24}\left(\frac{24}{D}\right)^{\frac{2}{3}}$$

Where T is the return period in years and D the duration which is taken as time of concentration tc in hr. Here ID,T is in mm/hr and R24,T is the maximum daily rainfall of return period T.

(b) Based on local observations

For three stations in hills of Nepal (Kathmandu, Okhaldhunga and Pokhara), maximum rainfall observations of 5 min, 10 min, 30 min, 1hr, 2hr, 6 hr, 12 hr, 1 day are plotted in terms of logarithmic of duration in hours versus logarithmic of intensity in mm/hr. They plot in a parallel set of lines. Make a parallel line on the graph with a point [Log (24), Log (R24,T/24)] until desired time of concentration is reached to get the Log (ID,T). The graphical presentation of the same is provided vide **Figure 8.2** below.

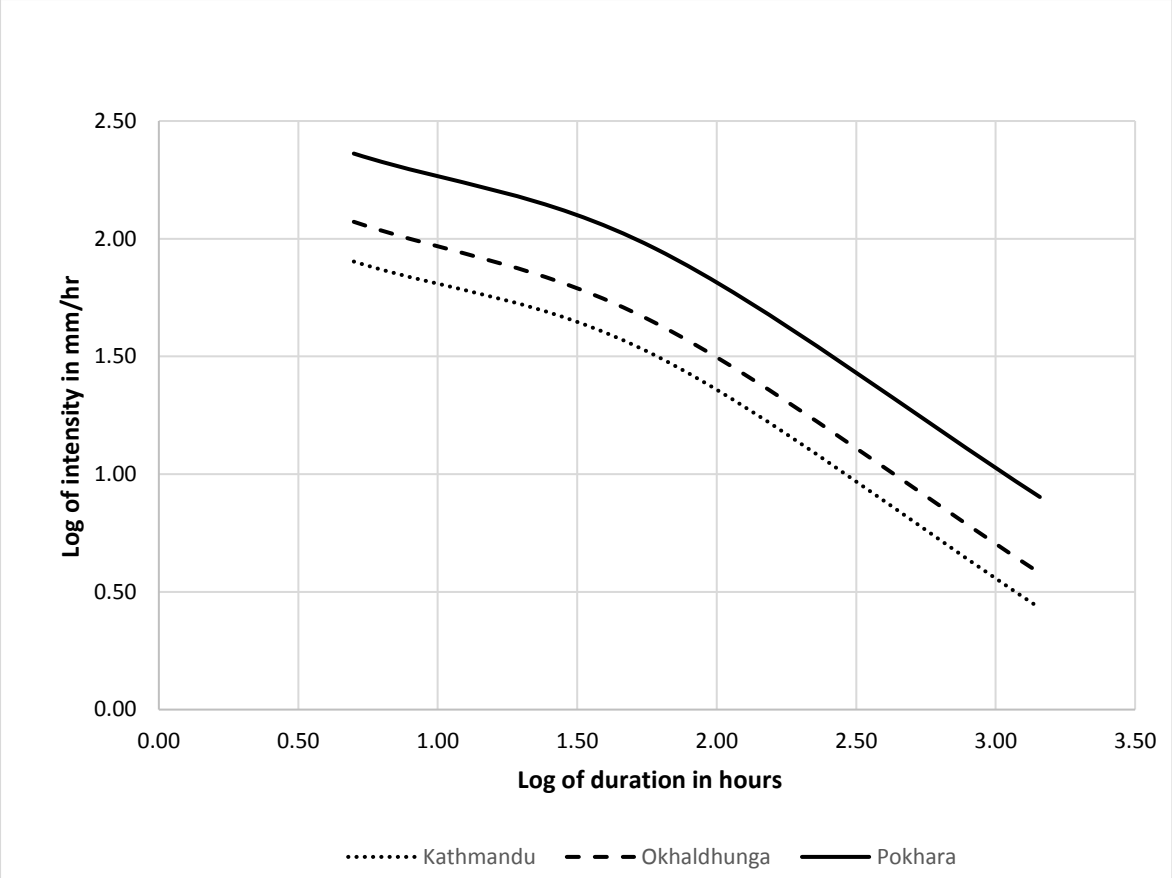


Figure 8.2: Logarithmic plot of intensity and duration curves

The estimated relevant intensity of rainfall (I_(D,T)) using IDF curve are presented in **Volume I-B** for reference**.**

8.6 Climate Change Consideration

To study the impact of climate change on extreme rainfall and flow, GOVERNMENT OF NEPAL Ministry of Energy, Water Resources and Irrigation in 2019 for Preparation of Priority River Basins Flood Risk Management Project conducted analysis using General Circulation Model (GCM) outputs based on the Intergovernmental Panel for Climate Change (IPCC)'s fifth assessment report (AR5 - 2014). The outputs of the AR5 GCM models are named as RCP (Representative Concentration Pathways) scenarios. Projected daily rainfall due to climate change was downloaded for Nepal from the HADGEM2 GCM model (Hadley Centre model of UK Met office) for the 2006 - 2100 duration for AR5 scenarios. The grid size of the HADGEM2 model is 1.875-degree longitude by 1.25-degree latitude. A total of 13 grids covers whole Nepal.

The linear trend analysis of both rainfall series historical and RCP4.5-upscaled has been undertaken. Both series show a positive trend. The trend for the RCP4.5 rainfall is an increase

of 0.651 mm/year, and the trend in the historical data is 0.380 mm/year for Lakhandehi basin (KDP alignment crosses Lakhandehi River, Sarlahi district). For Bakraha river basin (catchment area = 450 km2, originating from Churia hill, Morang district). The trend for the RCP4.5 rainfall is an increase of 0.023 mm/year, and the trend in the historical data is 0.352 mm/year. The result shows that the percentage change in projected rainfall due to climate change at Pattharkot Rain fall station (Lakhandehi river basin) varies between 1.4%-21.5% for different return periods and that at Damak rainfall station (Bakraha river basin) varies between 8%-13.3% for different return periods.

Guidelines on hydrologic and Hydraulic Analysis and River Training Works for Bridge design (DoR, 2020) therefore adopted 10% increase in design discharge to consider the impact of climate change in flood. This consideration was incorporated in the hydraulic analysis for the project

8.7 Catchment Characteristics

8.7.1 Drainage Area

The response of the basin to extreme rainfall is characterized mainly by its geometry like size, shape and slope. The catchment area (A) denotes the size. Shape of the basin is represented by Length of the main stream in kilometres from the outlet to the upstream divide (L) and distance in kilometres from the outlet to a point on the stream nearest the centroid of the watershed area (Lc). The maximum elevation of the catchment (Hmax) and minimum elevation at the outlet of the catchment (Hmin) depict the slope of the basin. These characteristics of the drainage areas contributing flows at the highway crossing are presented in **Volume I-B** for reference**.**

Catchment geometry, major hydrologic characteristics of the basins along the project area are generated by the use of GIS tools. Digital elevation model (DEM) of the project area has been used to delineate the catchment area for the major crossing along the KDP alignment. The catchments of the rivers are predominantly elongated type. The Catchment area of Kamala River and Bagmati River are not elongated and can be classified as irregular geometry. The map of catchment areas for major rivers crossing KDP alignment are presented in **Figure 8.3 Table 8.6** below shows the respective chainages of the stream crossing and their catchment area in Km2.

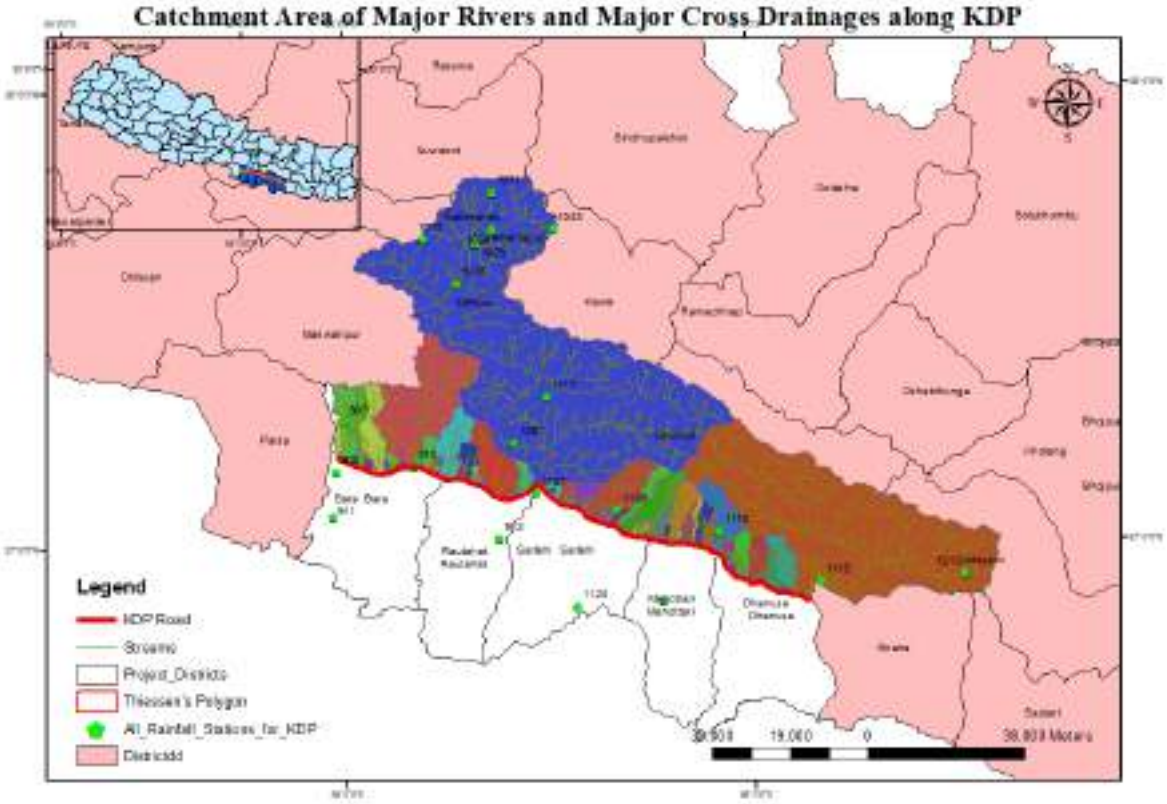


Figure 8.3: Catchment areas for major rivers and cross drainages along KDP alignment

Table 8.6: Chainages of Stream Crossing and their Catchment Areas

Sr. No.	Name of River Bridge	Chainage (Km.m)	Catchment Area
1	Kamala	237.323	1602.37
2	Kamala Canal	238.398	
3	Charnath	241.645	55.5
4	Baluwa	245.39	20.8
5	Jagadav Branch	251.1	0.7
6	Jagadav	251.39	1.48
7	Jalad	252.96	41.6
8	Aurahi	255.061	41.78
9	Basai	256.715	9.34
10	Sukhajor	259.23	3.12
11	Barahari	261.54	14
12	Ratu (New)	265.82	88.84
13	RatuChahara	266.72	0.4
14	Bhapsi (new)	268.73	14.9
15	Atabbe	269.97	2.16
16	Janga Pul-1	271.3	25.9
17	Gaushala /Junga Pul 2	271.595	0.27
18	Gadhanta	271.95	13
19	Belgachhi (DhungreKhola)	275.4	15.06
20	Tuteshwor -1	276.105	4.14

Sr. No.	Name of River Bridge	Chainage (Km.m)	Catchment Area
21	Tuteshwor - 2	280.5	0.86
22	Maraha Bridge	277.559	55.1
23	Maraha Kholsi Pul/ BatuwaKhola	278.83	0.5
24	Dholan	279.385	3.91
25	Jarlahi (KholsiPul)	281.064	1.39
26	Batuwa/ Budakhola	282.49	11.2
27	Bankhe	283.3	40.8
28	Amuwa	286.26	9.24
29	Phuljor	290.8	51.61
30	Kalinjor - 1	292.5	1.84
31	Kalinjor - 2	293.35	44.5
32	Betini	294.77	1.91
33	Dumdume	296	7.3
34	Bastipur	296.94	1.5
35	Lakhandei	301.19	114.84
36	Chapani	302.3	31.3
37	Bastol	303.164	0.13
38	Sukhapokhari	306.235	1.17
39	Rai Bridge/ HarionKhola	308.265	19.9
40	Dumajor	310.516	8.97
41	Godari	312.055	2.8
42	Bagmati	313.53	2810.24
43	Bagmati East	313.93	
44	Bagmati West	314.23	
45	Gairi	314.594	2.27
46	GairiKhola	315.445	0.23
47	Paurai	318.38	28.62
48	Lachkan	319.74	2.64
49	Katha KoPul/	324.165	2.86
50	Chandi	325.8	103.94
51	Dhou	327.94	0.14
52	Jungle Tole	328.74	1.5
53	Amu -1	330.27	1.7
54	Amu – 2	331.505	2.1
55	Kathi	333.31	5.27
56	Lamaha	334.43	35.58
57	Kali Khola	335	4.01
58	Dhansasr	339.92	66.37
59	Lamopul	342.77	1.1
60	Bhamara	344	34.5
61	Rampul	344.6	3.1
62	Bakeya	347.715	350.63
63	Unasi	349.51	2.6
64	Terhakilo	354.21	6.5
65	Barahakilo	355.26	4.4
66	Pasaha	357.875	86.51
67	Pasaha Branch	358.07	0.5
68	Bangandi	359.145	6.5
69	Balganga	361.59	31.4
70	Baijura	363.55	5.63

Sr. No.	Name of River Bridge	Chainage (Km.m)	Catchment Area
71	Dudhaura	364.263	52.99
72	Dhungre– 1	365.163	0.95
73	Dhungre – 2	365.385	0.97
74	Tin Number	366.47	8.42
75	Dui Number	367	1
76	Ek Number	367.225	1

8.7.2 Runoff Coefficient

The estimation of peak discharge from small streams is very sensitive to the runoff coefficient (C) of the watershed. C is estimated by identifying land use/land covers and soil type of each watershed. This is done by overlaying land use/ land cover and soil map onto the watershed maps. The value of C corresponding to different land use type of the watershed are presented in **Table 8.7** below.

Table 8.7: Run off Coefficient for different Geology

Catchment Characteristics	C
Steep, bare rock	0.9
Rock, steep but wooded	0.8
Plateaus lightly covered, ordinary ground, bare	0.7
Clayey soils, stiff and bare	0.6
Clayey soils, lightly covered	0.5
Loam, lightly cultivated or covered	0.4
Loam, largely cultivated	0.3
Sandy soil, light growth	0.2
Sandy soil, covered, heavy bush	0.1
Jungle areas	0.10-0.20

The watersheds of the drains crossing KDP are mostly comprised of either cultivated or jungle areas or mixture of both. The adopted C value of the watershed based on land use type for each drain that crosses KDP alignment are presented in **Volume I-B** for reference.

8.8 Design Flood Estimation

The hydrological study for the bridges and cross drainages are carried out to determine the anticipated flood discharge of various return periods and there by suggesting appropriate structures that can safely pass the design discharge without any impact to road structures. The selection of design return periods for peak discharge is based on the type of structure and design life and presented in **Table 8.8** below.

Table 8.8: Design Return Period Proposed for Peak Discharge

Structures	Design Return period for peak discharge (yrs)
Bridges	100
Culverts and cross drains	50
Side Drains	5

The general procedure (flow chart) for the determination of the Design discharge of various return period for the bridges and cross drainages is presented in **Figure 8.4** below.

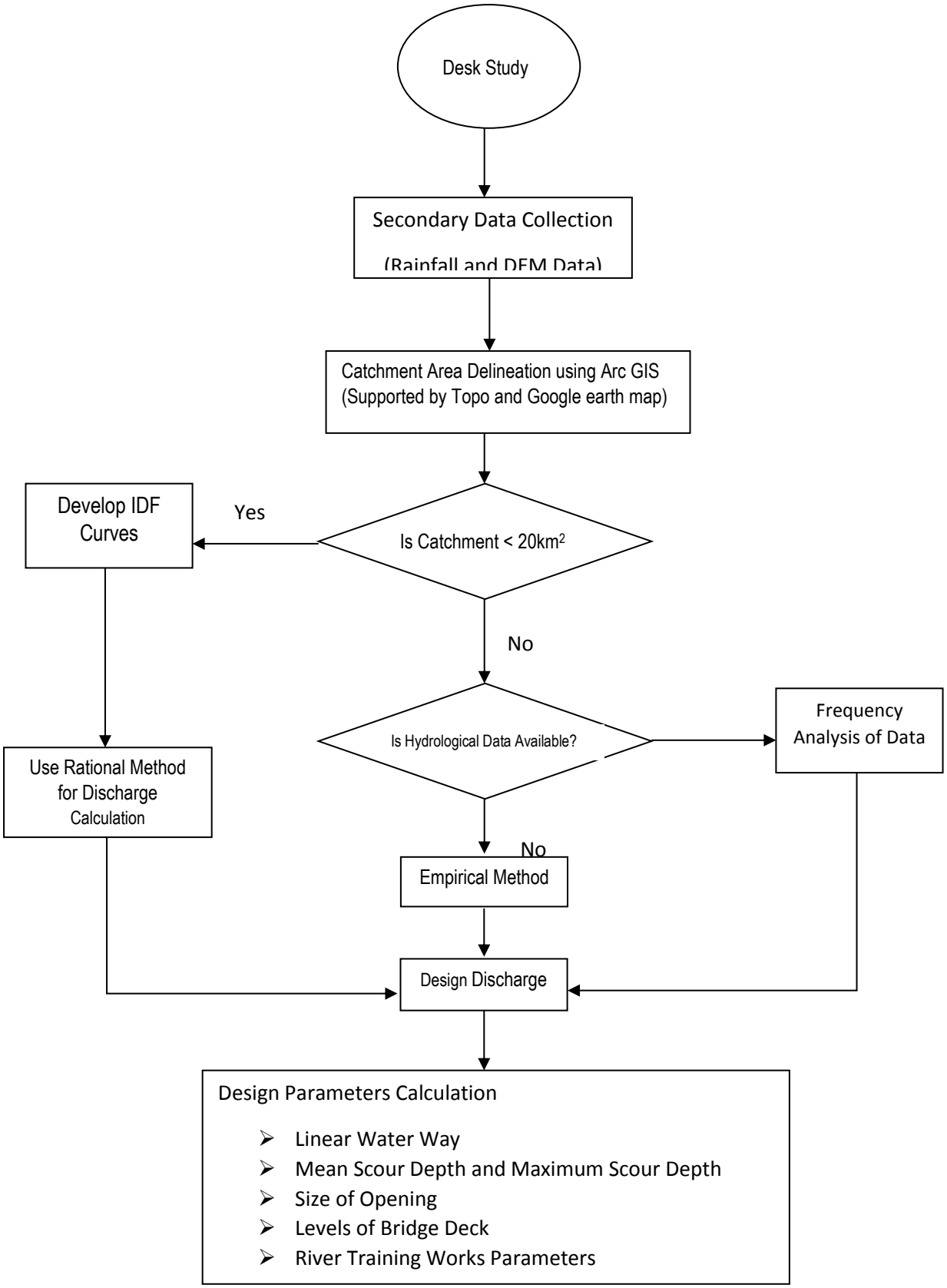


Figure 8.4: Procedure for Peak Discharge Estimation

Estimation of Peak Design Discharge for Ungauged Sites

In the absence of maximum instantaneous flow data at the site, empirical formula, widely used in Nepal were used to estimate design flood discharge. Such methods include the WECS/DHM method, described as follows

a) WECS/DHM method

Water and Energy Commission Secretariat (WECS) in 1990 has published a method for regional hydrological analysis. According to the method, the flood flows for the in any River are given by following equations.

$Q_2 = 1.8767\ (A+1)^{0.8783}$

$Q_{100} = 14.63\ (A+1)^{0.7342}$

$Q_T = \exp\ (\ln Q_2 + s*\sigma)$

Where the subscripts 2 and 100 stand for the return periods in number of years; A is the catchment area in Sq.km below 3000m elevation; T is the return period others than 2 and 100; σ is the standard deviation of the natural logarithms of annual floods ($\sigma = \ln\ (Q_{100}\ /Q_2)/2.326$); and s is standardized normal variate for a particular return period T.

The values of s for return periods of 2yr, 5yr, 10yr, 20yr, 50yr, 100yr, and 200 years are 0, 0.842, 1.282, 1.645, 2.054, 2.326, and 2.576, respectively.

b) Modified Dicken's method

Dicken's method is an empirical one where the peak discharge is given by:

$$Q_T = C_T\ A^{3/4}$$

Where A is the total basin area in sq. km and CT is the modified Dicken's constant proposed by the Irrigation Research Institute, Roorkee, India, based on frequency studies on Himalayan Rivers. CT for the return period T is given by

$$C_T = 2.342\ \log(0.6*T)\log(1185/p)+4$$

Where $p = 100(A_S + 6)/A$

AS is the snow-covered area out of total catchment area A.

c) B.D. Richard's method

B.D. Richard's method of flood estimation using rainfall and catchment characteristics has been comprehensively used in Mahakali Irrigation Project .This method uses parameters such as Tc (time of concentration, hrs), A (catchment area, sq. km.), L (catchment length, km), S (catchment slope), F (area reduction factor), RT (24 hrs rainfall for the return period T, mm), I (rainfall intensity corresponding to Tc), Tc2 (second estimate of time of concentration, hrs), Tc3 (third estimate of time of concentration, hrs), and various other parameters. This method involves following procedure.

Initially certain value is assumed for Tc, then

$F = 1.09352-0.06628 \ln (A)$

$D = 1.102\ L2/ (S*F)$

$R_{TC} = R_T \times 22.127\ T_c^{0.476577}/100$

$I = R_{TC} / T_C$

$K_R = 0.651\ (T_C + 1)$

$C_{KR} = 0.95632/ K_R^{1.4806}$

$T_{C3} = D * C_{KR}$

$T_{C2} = (T_{C3} /0.585378)^{1/2.17608}$

If the difference between the first estimate Tc and the resulting second estimate Tc2 is greater than 5%, the whole process is repeated with Tc = Tc2. Finally, flood discharge (m3/s) is estimated as;

$Q= 0.222*(A*I*F).$

d) Snyder's method

Another well-established method widely used in Nepal is the Snyder's method. For an ungauged river, the flood flow estimation by deriving a synthetic unit hydrograph based on known physical characteristics of the basin is resorted to. The method is based on the analysis on large number of hydrographs from drainage basins ranging in area from 25 sq. km to 25000 sq. km. The method which is used in Nepal to estimate the flood discharge hydrographs in Nepalese rivers is based on the following relationships.

$t_{pr} = 0.75\ C_t(L\ L_c)^{0.3}$

$t_{pr} = t_{pr} /5.5$

$t_{pR} = t_{pr} + 0.25\ (t_R - t_r\ )$

$q_{pR} = 2.78\ C_p / t_{pR}$

$Q_{pR} = q_{pR} * (CA * A) * R$

where,

t_{pr} = lag time from mid-point of effective rainfall of duration t_r to peak of unit hydrograph in hours.

t_r = Standard duration of effective rainfall in hours.

L = Length of the main drain, km

L_c = Length to the center of catchment from site, km

A = Catchment Area, km2

C_t and C_p are regional coefficients adapted from "Hydrologic manual for infrastructures" (WECS, 2018)

e) Rational method

The simplest method to estimate the maximum of run-off is the Rational-Formula which is

$$Q = \frac{CIA}{360}$$

Where,Q is the rate of run-off in cubic meters per second, I is intensity in mm per hour, A is the catchment in hectares, and C is a dimensionless constant, the run-off coefficient. This method is applicable only in case when time of concentration is less than duration of rainfall whose intensity can be considered constant and uniformly distributed over the catchment. Therefore, this method may be applicable only for small watershed having time of concentration less than one hour.

Here I is obtained from intensity-duration-frequency curve corresponding to tc, the time of concentration, which is given by

$t_c = \{0.87L^3/H\}^{0.385}$

where, tc is in hr, L, the longest dimension of stream or watershed is in km, H, the stream fall of vertical drop of the flow form farthest point to the outlet point is in m. If the time of concentration calculated from above equation is less than 15 minutes then it is assumed to be 15 minutes as recommended by ASCE.

The values obtained from above mentioned methods compared. The highest of these values adopted as the design discharge Q, provided it does not exceed the next highest discharge

by more than 50 per cent. If it does, it will be restricted to that limit. The summary of calculation for each point at the crossing (bridge and culverts) are presented **in Volume I-B** for reference.

8.9 Cross-drainages

KDP alignment crosses rivers/streams at 76 locations invoking the design of bridges over them. Furthermore, to maintain the existing slope drainage pattern as much as possible all water courses are culverted through cross drains. These locations are also used as safe discharge point for side drain water at appropriate interval and valley curves. There are 99 numbers of such culverts to fulfill the requirements. Following paras describe the hydraulics of those structures.

8.9.1 Computation of hydraulic parameters for Bridges

In order to obtain hydraulic parameters for the design of the components of bridge, investigations are carried out using hydro-dynamic HEC-RAS model. The model has been set with following conditions.

1. One dimensional steady flow modelling has been used storage does not play big role in defining peak flood levels
2. The cross-sectional survey information of 25m spacing extending 500m upstream and 250m downstream of bridge has been used as Geometry data for the model.
3. The new bridge are set downstream / upstream of existing bridge.
4. The model was set up in mixed flow mode for which upstream and downstream boundary condition are set as normal depth by assigning friction slopes.
5. Design peak flow has been assigned at upstream most section
6. In carrying out the water surface profile computation Manning's n values of 0.03 and 0.035 have been adopted for main channel and overbanks respectively. These values are most appropriate since the bed of the main channel in the Terai plain consists of fine sand and flood plains consists of short grass and scattered brushes.

The hydraulic information of the cross sections like (a) Design Discharge (b) High Flood Level (HFL), (c) Maximum Velocity (Vmax), (d) Maximum depth (hmax), (e) Hydraulic depth (h), (f) Average Velocity (v), (g) Maximum discharge intensity (qmax), (h) Average discharge intensity (q), and (i) Minimum River Bed Level at new and old bridge sites are presented in **Volume I-B**. Cross sections and HFL at bridge sites for Qdesign discharge and the longitudinal water surface along u/s and d/s reach of the bridge site are presented in **Volume I-B** for reference**.**

<u>Estimation of Total Scours for Bridges</u>

The stable hydraulic geometry of a river channel depends upon a number of factors, which include discharge, characteristics of bed and bank materials, and the amount of sediment transported by the channel.

The mean scour depth (D) below highest flood level (HFL) for natural channels flowing over scourable bed is calculated as highest of the following

(i) When the linear regime water way (W) of the river is less than the length of the bridge (L), D is adopted highest of following

(a) $$D = \frac{0.473\, Q^{1/3}}{k_{sf}^{1/3}}$$

(b) $$D = 1.34\, (\frac{q^2}{k_{sf}})^{1/3}$$

Where q = the design discharge for foundation per meter with respect to predominant concentration of flow in any part of waterway by dividing the waterway into compartments as per the concentration of flow.

K_{sf} = Silt factor for a representative sample of bed material obtained up to the level of anticipated deepest scour

'K_{sf} 'is given by the expression $1.76\sqrt{d_m}$, d_m being the weighted mean diameter in millimeter.

(i) When the linear regime water way (W) of the river is greater than the length of the bridge (L)

$$D = 1.34\, (\frac{q^2}{k_{sf}})^{1/3}$$

(ii) Blench Zero bed factor approach

$D = (q_m{}^2/F_b)^{0.33}$

Where,

D = Mean depth of scour measured from the water surface, m

q_m is discharge per unit width in $m^3/s/m$

F_b = **Blench's** "Zero Bed Factor"

The maximum depth of scour below the Highest Flood Level (HFL) for the design of piers and abutments having individual foundations without any floor protection is considered as follows.

Flood without seismic combination:

(i) For piers - 2.0 D (ii) For abutments - 1.27 D with approach retained or lowest bed level

Calculation details for (i) Maximum scour depth measured from HFL at the nose of pier and abutment, ymax, and (ii) Minimum Required Soffit Level are presented in **Volume I-B** for reference.

8.9.2 Culvert Design

There are existing 124 additional crossings along the KDP road besides the bridges. Among them there are 82 culverts, 17 pipe culverts and 25 numbers of causeways. The existing slab culverts are varying in sizes and ranging from 1m×1m to 5m×2.5m, similarly there are single and double cell pipe culverts with 0.90m diameter and causeways with length varying from 75m to 220m. All these cross drainages including causeways has been proposed to be replaced by box culverts of appropriate sizes based on the discharge, topography and road design requirement.

For the cross-drainages, as the catchment areas are small (duration of Rainfall is greater than Travel time), the 50 yr flood discharge has been estimated using the simplified Rational Formula, which can be expressed as `

Q = 0.278 CIA

where,

Q : Design discharge in cu.m/s

C :.,Runoff coefficient,

I : Rainfall intensity in mm/hr

A: Catchment Area in sq. km

Here I is obtained from intensity-duration-frequency curve corresponding to tc, the time of concentration, which is given by

$t_c = \{0.87L^3/H\}^{0.385}$

where, tc is in hr, L, the longest dimension of stream or watershed is in km, H, the stream fall of vertical drop of the flow form farthest point to the outlet point is in m. If the time of concentration calculated from above equation is less than 15 minutes then it is assumed to be 15 minutes as recommended by ASCE.

Based on the maximum daily rainfall R24 as tabulated earlier, the Rainfall Intensity for any duration can be obtained from Mononobe equation which is generally applied in mountainous catchment

$$I_{D,T} = \frac{R_{24,T}}{24}\left(\frac{24}{D}\right)^{\frac{2}{3}}$$

Where T is the return period in years and D the duration which is taken as time of concentration tc in hr. Here ID,T is in mm/hr and R24,T is the maximum daily rainfall of return period T (here taken as 25 yrs). Runoff Coefficient (C) is estimated by identifying land use/land covers and soil type of each watersheds. This is done by overlaying land use/ land cover and soil map onto the watershed maps.

The discharge for the culvert has been computed taking in consideration of discharge from side drains and natural drainage where available. For computing discharge for the side drains, the discharge from the adjacent 50m adjacent land and discharge from the pavement has also been taken into consideration. The computed discharge for proposed culverts has been presented in **Volume I-B** for reference.

Design Consideration of Culverts:

In order to prevent sediment deposition in the culvert, the velocity in culvert should be 2 ~ 3m/s as standard and the minimum velocity should be greater than 1m/s.

Also, in order to prevent the inner wear of the waterway and the scouring of the outlet side, the water slope should be adjusted so that the maximum average flow velocity is within 3.0m/s.

Therefore, the velocity in culvert was adopted 2.5m/s and the slope of culvert was adjusted so that the velocity was 2.5m/s.

For computing the adjusted slope, the Manning's Equation has been used.

The Manning's formula is as follows:

$$V = 1/n*R^{2/3} *S^{1/2}$$

Where,

V = velocity in m/sec

n = coefficient of surface roughness which depends in the roughness of the surfaces.

R = Hydraulic Radius in meters = Aw/Pw

Aw = Area of flow cross section in m2

Pw = Wetted Perimeter in m

S = Slope of energy slope of channel, which is roughly taken as slope of culvert bed

Based on the above equation, the adjusted slope equation is as follows

$$S_{adj} = ((V_{adopted}*n)/ R^{2/3})^2$$

Finally, the allowable discharge is calculated using the formula,

$$Q = 1/n*R^{2/3} * S_{adj}{}^{1/2}*Aw$$

Using the above formula, allowable discharge capacity of the standard box culverts has been determined and checked with the discharge of respective cross drainage, the details of calculation has been given in **Volume I-B** for reference. Generally, a free board of 0.6m is provided for the box culverts while determining the discharge capacity. The size of the box culverts and its free board depends in the topography of the stream, design profile of road, expected sedimentation load, debris flow and location of the culverts such as culverts in valleys, mid-hills and the ridges.vo

8.10 Overtopping Sections

Overtopping Sections of road reaches were identified at distinct valley profile along the road alignment. The estimation of HFL were carried out separately for each valley profile. The analyses are based on assumption that the overland flow during three day maximum rainfall will be impeded by road embankment at valley profiles. Since the flow from three ends accumulates at lowest level of valley along the road alignment the gross accumulation of water will be six times the three day maximum rainfall amount. The net accumulation of water depth at each valley profile is thus estimated by multiplying gross value by appropriate runoff coefficient. HFLs for each valley profiles were then calculated.

During the site visit, the consultant team conducted the Local Interview at different locations along the KDP road for identifying the overtopping sections along the road. Senior citizens were interviewed for identifying the sections that has been overtopped during the heavy rainfall events. As per the information received from the locals, the roads get overtopped only at the causeway locations and no other sections of road was reported to have been overtopped.

8.11 Overall Drainage Plan

8.11.1 Road Side Drainages

Conservation of the natural drainage system around the road alignment is one of the most important concerns during design and construction of roads. For this purposes network of side drains and cross drains along with other related structures were proposed for the project. Design of the components of drainage structures requires information on design peak flows, depth and velocity of flow. Adequacy of capacity of existing and proposed new side drains and cross drains were assessed using standard underlying hydraulic principles.

Side drains were designed to collect and remove surface water from the immediate vicinity of the road and to prevent any sub-surface water from adversely affecting the road pavement structure. The choice of side drain cross-sections were done considering hydraulic capacity, ease of maintenance, space restriction and traffic safety. Design volumes of runoff were adopted to comply with the estimation proposed in previous chapters. Detail design calculation are provided in Annexure 8.7.

The hydraulic design of drain sections were carried out with the help of Manning's equation and checked for non-eroding velocity. The longitudinal slope(S) of the side drain conform the longitudinal slope of the road profile. Wherever the road longitudinal slope exceeds 7%, the side drain longitudinal slopes (S) were cascaded to maintain the slope not beyond 5%.

8.11.2 Median Drainage

Except for narrow medians (less than 5 m wide), it is not desirable to drain the median area towards the pavement surface. Narrow medians are only drained towards the pavement. Medians with a width of up to 1.8 m is provided with kerbs and paved; those with width ranging from 1.8 to 5 m are turfed and crowned for the surface water to run towards the pavement (which are with or without kerbs). For medians that are more than 5 m wide, there are no kerbs at the edge.

In the carriageway draining towards the median, central drain is made to carry the run off. At intervals, rain water is removed from the median by inlets and carried through a drain to an outlet

8.11.3 Catch Drains

The catch water drain intercepts the large quantity of the surface water flow and also breaks the continuity of flow and thereby reduces the velocity of water and prevents the erosion and thereby protect the road pavement. Catch water also help in reducing the size of side drains.

Catch water drain is provided under following conditions:

- When the adjoining ground is steep towards roadside.
- When the quantity of water flow on sloping ground is more.

8.11.4 Drainage Outfall

The preferred method for the disposal of drained water is via outfalls to existing ditches and watercourses. Discharge is kept in the direction of flow of the river or stream. Protection of the bed and edges of the watercourse at the point of entry (by means of rock armour, gabions, headwalls etc.) is provided to prevent erosion by water discharging from the side drain during heavy storms.

In high embankments (over 8 m in height), with steep longitudinal gradients, like on approaches to bridges, serious damage can occur if the rain water is allowed to leave the carriageway in an uncontrolled manner, causing erosion of slopes and shoulders, which may even undermine the road pavement. Longitudinal drains are therefore provided from where the water is led down the slopes by means of stepped outfalls at about 10 to 15 m intervals, finally discharging into the open drain at the bottom.

8.11.5 Riverbank Protection Works

Design Consideration

When embankments encroach on wide floodplains, the flows from these areas must flow parallel to the approach embankment to the bridge opening. These flows can erode the approach embankment. A severe flow contraction at the abutment can reduce the effective bridge opening, which could possibly increase the severity of abutment and pier scour. Guide banks (also referred to as spur dikes) can be used in these cases to prevent erosion of the approach embankments by cutting off the flow adjacent to the embankment, guiding stream flow through a bridge opening, and transferring scour away from abutments to prevent damage caused by abutment scour. The three major enhancements guide banks bring to bridge design are:

- Reduce the separation of flow at the upstream abutment face and thereby maximize the use of the total bridge waterway area
- Reduce the abutment scour due to lessening turbulence at the abutment face.
- Reduce the risk of outflanking of flood to protect the embankment.

Principal factors to be considered when designing guide banks are their orientation to the bridge opening, plan shape, upstream and downstream length, cross-sectional shape, and the crest elevation.

Orientation

Guide banks were set parallel to the abutment and extend upstream from the bridge opening where it is required. The distance between the guide banks at the bridge opening were set equal to the distance between bridge abutments. guide banks with a plan form shape in the form of a quarter of an ellipse, with the ratio of the major axis (length Ls) to the minor axis (offset) of 2:1 were designed. This allows for a gradual constriction of the flow. Thus, if the length of the guide bank measured perpendicularly from the approach embankment to the upstream nose of the guide bank is denoted as Ls, the amount of expansion of each guide bank (offset), measured from the abutment parallel to the approach roadway, should be 0.4 Ls.

Length of the Guide Banks

The length of the guide bank were set as the distance necessary to secure a straight run for the river, and the distance necessary to prevent the formation of a bend in the river so as to avoid the angle of attack of the anticipated flash flood. Length of guide bank were fixed at the bridge sites (without existing training works) considering the meandering nature of rivers, current situation of bank erosion and outflanking possibility of the design flood. The length of guide bank is more sites specific and verified by experts during site visit to make friendlier to natural condition of river flow. In most cases the length were adopted as per Guidelines on hydrologic and Hydraulic Analysis and River Training Works for Bridge design (DoR, 2020).

Protection of slopes

Guide banks are constructed by forming an embankment of soil or sand extending upstream from the abutment of the bridge. To inhibit erosion of the embankment materials, guide banks must be adequately protected with riprap or stone facing or gabion mattresses up to high flood level. Rock riprap should be placed on the stream side face as well as around the end of the

guide bank. Since the river reach will be constricted by guide bunds with varying ratios along both banks, flow velocity will be much higher and varied at different reaches. The analysis were thus carried to arrive design thickness and length of protection works.

The slope of the guide bank may be damaged due to undermining caused by scour. The scour may occur due to high velocity flow on water side of the guide bank. To protect the slope from scour, a launching apron is provided at the toe in the horizontal position. When the scour occurs, it first undermines the farthest end of the launching apron and then gradually extends towards the guide bank. The apron then launches on a slope to cover the face of the scour hole and it forms a continuous inclined carpet in continuation of the slope of the guide bank.

8.11.6 Slope protection works for road side embankment

The faces of the slopes of the road embankment not protected by riprap (Gabion) shall be completely covered by grasses. For those slopes horizontal lines of grasses of Kans species shall be planted with row spacing of 0.5m and 10 cm plant to plant spacing or grass turfing.

Chapter 9: Detailed Structure Designs

9.1 Introduction

Bridges and other structures are the vital components of Highway Network. Their stability, load carrying capacity, structural soundness, functional efficiency, maintaining their serviceability and consequently retaining their level of reliability during their life time deserves high priority from techno-economic considerations. There are many well defined rivers, streams, water ponds carrying perennial as well as seasonal flow. A numbers of culverts and causeways are present in the project corridor which need to be taken care of.

The existing bridges at Kamala- Dhalkebar section are of two-lane (7.0m width) standard while the bridges at Dhalkebar -Pathlaiya section are of intermediate lane (5.5 m width) standard except newly constructed three bridges. This is considered too narrow for vehicles crossing in both directions. As a result, the bridges are now bottlenecks to the traffic. Based on the traffic requirement and the condition of bridges the Consultant had prepared several options for the bridges and discussed with the Client during the concept design stage and subsequent meetings / site inspections. The client had directed the consultant to retain certain existing bridges with repair and rehabilitation wherever possible and provide new bridge on South or north of existing bridge to cater for bi-directional traffic.

Also, as per the agreed to the proposal of the consultants to abandon the existing bridges where new bridges will be constructed on North and South of the abandoned bridges and the existing bridge will be extension of the median of the proposed carriageway, draft design was submitted. To have a detail discussion on submitted draft design, jointly site visited again and most of the issues finalized at site and remaining at office. Major changes in draft design were recommended, that are:

i) Demolish all bridges having length up to 25m.
ii) Use retained bridges as one way traffic and design brides for other way traffic.
iii) Urban road length as well as bridges lies on those road sections converted to rural road and bridges.
iv) Due to poor physical condition, some bridges recommended to demolish
v) Length of some bridges extended while some of bridge length decreased as per site condition and hydrological study report.
vi) Ten numbers of bridges previously recommended replacing by culvert that increased to 15 numbers.

This Chapter has been prepared for the above-mentioned project stretch defining the final upgradation proposal of the consultant after discussion on draft design, site inspection with client and client's ESIA consultant. This chapter will give a comprehensive view of the total stretch with respect to the upgradation of the bridge structures, additional flyovers, VUP/PUP and different types of Animal crossing. Apart from that the design parameters, loadings, load combinations and, durability aspect, and other requirements for the structural design elaborated. As the Kamala – Dhalkebar – Pathalaya is a section of Mahendra Rajmarg whose enhancement of trade among the member countries and increasing traffic volume requires an upgrade of this road section to Asian Highway Standards (Class-I). Considering the above facts, the design parameters have been defined based the National and International standards.

9.2 Codes & References

The codes and specifications with latest revision (As per TOR requirement) which referred for performing the design of structures is given in section 2.4 of this report.

However, the order of precedence in case of conflicts as follows;

1. Nepal Bridge Standard (NBS)2067
2. Nepal Road Standard (NRS) 2070
3. MORT&H / IRC
4. IS Codes
5. AASHTO LRFD, ACI, ASBI, PTI recommendations

9.3 Proposed Bridges and Structures

The detailed proposal of the bridges and the structures have been finalized after detailed discussion with Client and its ESIA consultant. It has been identified that the following structures to be included in the upgraded road for proper functionality.

9.3.1 Bridges

Bridges are defined as structures carrying the main road over the waterways, rivers and flood plains. These bridges constitute the majority of structures on this project. There are 76 nos. of Major and Minor bridges along the stretch and as per TOR the major bridges with length more than 300m to be treated as Special bridge. In his project (section of road) the numbers of bridges more than 300m is 5, however after discussion with Department they have mentioned that the following 3 bridges to be treated as Special Bridge.

- Kamala Bridge
- Bagamati Bridge
- Bakeya Bridge

As mentioned above the upgradation proposal of the consultant for the above-mentioned bridges have been finalized after discussion /site inspection with client and client's ESIA consultant. The final proposal for each and every bridge is mentioned in **Table 9.1**. In the table it has been found that in general there are four types of widening proposal has been mentioned which has been elaborated in the section 9.5.2.

Table 9.1: List of Bridges with Proposed Span Arrangement

S.N.	Topo Chainage (Bridge Center)	Existing Bridge Structure				Proposed Bridge Structure						
		Bridge Name	No. of Span	Span Arrangement	Bridge Length	No of Span	Span Arrangement	Total Length of Bridge	Up Stream Bridge Width	Down Stream Bridge Width	Existing Bridge Retained/ Demolish	Remarks
			No	(in m)	(in m)	No	(in m)	(in m)	(in m)	(in m)		
1	237+022	Kamala Bridge	24	26.65	639.6	4	114+206+206+114	640		11.85	Retain	Special Bridge
2	238+095	Kamala Canal	5	14.1	70.5	1	45	45		11.85	Retain	Span & Length reduced
3	241+744	Charnath	15	21.4	321	15	21.4	321		11.85	Retain	
4	245+228	Baluwa	7	16	112	4	32+32+32+16	112		11.85	Retain	
5	250+760	Jagadav Branch	1	26.6	26.6	1	20	20		11.85	Retain	Length reduced
6	251+090	Jagadav	4	21.5+2*26.5+21.5	96	2	2*26.6	53.2		11.85	Retain	Length reduced
7	252+478	Jalad	10	26.6	266	10	26.6	266		11.85	Retain	
8	254+663	Aurahi	12	26.6	319.2	12	26.6	319.2		11.85	Retain	
9	256+186	Basai	4	21.5+2*26.5+21.5	96	4	21.4+2*26.6+21.4	96		11.85	Retain	
10	258+735	Sukhajor	2	22	44	2	22	44		11.85	T. Retain	
11	260+921	Barahari	3	23.5+28+23.5	75	3	23.5+28+23.5	75	11.85		Retain	
12	265+345	Ratu	6	41+4*36+41	226	6	41+4*36+41	226		11.85	Retain	
13	266+136	Ratu Chahara	2	9.5	19	2	6	12	26.90		Demolish	Replaced by Culvert
14	268+310	Bhapsi	4	12.5	50	3	25	75		11.85	Retain	Span added
15	269+373	Atabbe	3	9.5	28.5	1	28.5	28.5		11.85	T. Retain	
16	270+871	Janga Pul-1	6	12.5	75	5	25	125		11.85	T. Retain	Span added both side
17	271+145	Janga Pul-2	3	12.5	37.5	3	6	18	26.90		Demolish	Replaced by Culvert
18	271+514	Gadhanta	5	12.5	62.5	3	25	75		11.85	T. Retain	Length increased

S.N.	Topo Chainage (Bridge Center)	Existing Bridge Structure				Proposed Bridge Structure						
		Bridge Name	No. of Span	Span Arrangement	Bridge Length	No of Span	Span Arrangement	Total Length of Bridge	Up Stream Bridge Width	Down Stream Bridge Width	Existing Bridge Retained/ Demolish	Remarks
			No	(in m)	(in m)	No	(in m)	(in m)	(in m)	(in m)		
19	274+925	Belgachhi (DhungreKhola)	4	9.5	38	2	20	40	11.85	11.85	Demolish	
20	275+630	Tuteshwor-1	2	9.5	19	1	20	20	11.85	11.85	Demolish	
21	275+856	Tuteshwor - 2	2	9.5	19	1	20	20	11.85	11.85	Demolish	
22	277+266	Maraha	8	15+2*18+2*15+2*18+15	132	5	33	165		11.85	Retain	Length increased
23	278+358	Maraha Kholsi Pul	2	9.45	18.9	3	6	18	26.90		Demolish	Replaced by Culvert
24	278+913	Dholan	4	9.5	38	1	38	38		11.85	T. Retain	
25	280+574	Jarlahi (KholsiPul)	2	9.5	19	1	20	20	11.85	11.85	Demolish	
26	281+990	Batuwa	3	9.5	28.5	1	28.5	28.5		11.85	T. Retain	
27	282+758	Bankhe	6	15+4*18+15	102	3	33+36+33	102		11.85	Retain	
28	285+721	Amuwa	2	9.5	19	1	25	25	11.85	11.85	Demolish	Span increased
29	290+215	Phuljor	7	12.5	87.5	5	25	125	11.85	11.85	T. Retain	Span increased
30	291+868	Kalinjor - 1	3	9.5	28.5	1	28.5	28.5		11.85	T. Retain	
31	292+703	Kalinjor - 2	3	22	66	3	22	66		11.85	T. Retain	
32	294+014	Betini	2	6	12	2	6	12	26.90		Demolish	Replaced by Culvert
33	295+383	Dumdume	2	9.5	19	1	25	25	17.55	17.55	Demolish	Span increased
34	296+287	Bastipur	2	9.5	19	3	6	18	50.00		Demolish	Replaced by Culvert
35	300+466	Lakhandei	12	15+4*18+2*15+4*18+15	204	6	33+36+2*33+36+33	204		11.85	Retain	
36	301+948	Chapani	3	22	66	3	22	66		11.85	T. Retain	
37	302+777	Basatol	2	10.35	20.7	1	6	6	26.90		Demolish	Replaced by Culvert

S.N.	Topo Chainage (Bridge Center)	Existing Bridge Structure				Proposed Bridge Structure						
		Bridge Name	No. of Span	Span Arrangement	Bridge Length	No of Span	Span Arrangement	Total Length of Bridge	Up Stream Bridge Width	Down Stream Bridge Width	Existing Bridge Retained/ Demolish	Remarks
			No	(in m)	(in m)	No	(in m)	(in m)	(in m)	(in m)		
38	305+770	Sukhapokhari	2	9.5	19	3	6	18	26.90		Demolish	Replaced by Culvert
39	307+753	Rai Bridge	4	9.5	38	1	38	38		11.85	T. Retain	
40	310+019	Dumajor	4	9.45	37.8	2	20	40		11.85	T. Retain	
41	311+587	Godari	2	9.45	18.9	1	20	20	11.85	11.85	Demolish	
42	312+474	Bagmati East	1	11.3	11.3	1	25	25		17.55	Retain	Span increased
43	313+121	Bagmati	11	33	363	3	16.5 + 82.5+165+ 82.5 +16.5	363		17.55	T. Retain	Special Bridge
44	313+825	Bagmati West	1	11.57	11.57	1	25	25		17.55	Retain	Span increased
45	314+170	Gairi	3	11.4	34.2	1	35	35		11.85	T. Retain	
46	314+985	Gairi Khola	1	11.5	11.5	1	3	3	26.90		Demolish	Replaced by Culvert
47	317+698	Paurahi	3	22	66	3	22	66		11.85	T. Retain	
48	319+345	Lachkan	2	11.25	22.5	1	20	20	11.85	11.85	Demolish	Length reduced
49	323+590	Katha Ko Pul	4	11.4	45.6	1	25	25		11.85	T. Retain	Length reduced
50	325+067	Chandi	5	33	165	5	33	165		11.85	T. Retain	
51	327+240	Dhou	2	11.25	22.5	1	3	3	50.00		Demolish	Replaced by Culvert
52	328+021	Jungle Tole	3	11.39	34.17	1	20	20		11.85	T. Retain	Length reduced
53	329+752	Amu - 1	3	11.34	34.02	1	25	25	11.85	11.85	Demolish	Length reduced, ELC
54	330+972	Amu - 2	2	11.35	22.7	3	6	18	26.90		Demolish	Replaced by Culvert
55	332+811	Kathi	5	11.35	56.75	1	30	30		11.85	T. Retain	Length reduced
56	333+733	Lamaha	2	33	66	2	33	66		11.85	T. Retain	
57	334+473	Kali Khola	3	11.3	33.9	1	33	33		11.85	T. Retain	

S.N.	Topo Chainage (Bridge Center)	Existing Bridge Structure				Proposed Bridge Structure						
		Bridge Name	No. of Span	Span Arrangement	Bridge Length	No of Span	Span Arrangement	Total Length of Bridge	Up Stream Bridge Width	Down Stream Bridge Width	Existing Bridge Retained/ Demolish	Remarks
			No	(in m)	(in m)	No	(in m)	(in m)	(in m)	(in m)		
58	339+342	Dhansar	8	20.5	164	4	41	164	11.85		Retain	
59	342+268	Lamopul	4	11.3	45.2	1	25	25		11.85	T. Retain	Length reduced
60	343+584	Bhamara	1	33	33	1	33	33		11.85	T. Retain	
61	344+094	Rampul	2	11.3	22.6	1	20	20	11.85	11.85	Demolish	Length reduced
62	347+209	Bakeya	16	22.22	355.52	4	12.6+82.5+165+ 82.5 +12.6	330		11.85	T. Retain	Special Bridge
63	348+947	Unasi	8	11.2	89.6	1	35	35	17.55	17.55	Demolish	
64	353+598	Terhakilo	4	11.4	45.6	1	41	41	11.85	11.85	Demolish	
65	354+646	Barahakilo	3	11.25	33.75	1	35	35		11.85	Retain	
66	357+227	Pasaha	5	33	165	5	33	165		11.85	T. Retain	
67	357+428	Pasaha Branch	2	11.1	22.2	3	6	18	26.90		Demolish	Replaced by Culvert
68	358+470	Bangandi	10	11.36	113.6	1	35	35	11.85	11.85	Demolish	
69	360+869	Balganga	3	22	66	3	22	66		11.85	T. Retain	
70	362+882	Baijura	4	11.5	46	2	23	46		11.85	Retain	
71	363+585	Dudhaura	2	45.25	90.5							Bridge Under Construction
72	364+437	Dhungre - 1	2	11.5	23	3	6	18	26.90		Demolish	Replaced by Culvert
73	364+693	Dhungre - 2	2	11.5	23	3	6	18	26.90		Demolish	Replaced by Culvert
74	365+725	Tin Number	3	11.5	34.5	1	35	35		11.85	Retain	
75	366+321	Dui Number	2	11.5	23	3	6	18	50.00		Demolish	Replaced by Culvert
76	366+510	Ek Number	1	11.5	11.5	2	6	12	50.00		Demolish	Replaced by Culvert

Note: T. Retain – Temporarily Retained

9.3.2 Flyovers

In order to maintain the free flow traffic movement on the highways, flyovers are proposed at the major crossings of the Project Road. These are basically raised structures where the main highway's carriageway is raised in-line with the existing highway in urban and settlement areas. The purpose of the flyovers is to provide connectivity between communities on each side of the highway once the road is upgraded and the minimum clearance below the obligatory span to be kept as 5.5m All design principles explained for the Normal Bridges is applicable to the flyovers. In order to reduce noise pollution, it is proposed that the flyover bridges incorporate transparent noise barriers. These will need to be designed as an integral part of the appearance of the bridges to provide harmony with the environment.

The approach roads supported on Reinforced Earth Wall (RE Wall) up to 5m height, beyond which the bridge spans will commence. This arrangement is considered aesthetically pleasing and economically efficient. The proposed flyovers of the project road are tabulated in the **Table 9.2** below.

Table 9.2: List of Proposed Flyovers

S.N.	Chainage (Center of Structure)	Location	Span Configuration	Total Length (m)	Width of structure (m)
1	267+280	Bardibas Junction	29 x30	670	23.4
2	326+560	Chapur Junction	18x30	540	23.4

9.3.3 Vehicular Underpass (VUP)/Pedestrian Underpass (PUP)

Similar to flyovers, VUP/PUP are constructed in urban and settlement areas to provide safe and smooth access to people and their domestic animals to cross the future dual carriageway. The vehicular underpass has been proposed with opening of 20m and 5.5m height. The opening created by providing 20m span RCC precast girder supported on abutment. The Pedestrian/ Underpasses consist of rectangular box with clear openings of 8m Horizontal X 2.5m Vertical. The proposed VUPs/PUPs of the project road are tabulated on **Table 9.3** below.

Table 9.3: List of Proposed VUP/PUP

Sl. No.	Chainage (Center of Structure) m	Location	Proposed Opening Size for VUP (m)	Proposed Arrangement for PUP (m)	Width of structure (m)
1	243+640	Birendra Bazar	20m (W) x 5.5m (H)	8m (W)x 2.5m (H)	25.9
2	294+900	Lalbandi Bazar	20m (W) x 5.5m (H)	8m (W)x 2.5m (H)	25.9
3	299+545	Nawalpur Junction	20m (W) x 5.5m (H)	8m (W)x 2.5m (H)	25.9
4	304+190	Hariwan Bazar	20m (W) x 5.5m (H)	8m (W)x 2.5m (H)	25.9

Sl. No.	Chainage (Center of Structure) m	Location	Proposed Opening Size for VUP (m)	Proposed Arrangement for PUP (m)	Width of structure (m)
5	307+050	Naya Road Junction	20m (W) x 5.5m (H)	8m (W)x 2.5m (H)	25.9

9.3.4 Reinforced Earth (RE) Walls

Reinforced Earth Wall (RE Wall) is used for sustaining soil laterally so that it can be retained at different levels. RE wall is a combination of earth and linear reinforcement in the form of strips, grids, rod, mesh etc. that are capable of bearing sizable tensile stress.

Elements of Reinforced Soil Wall

Following are the major elements of RE Wall construction.

- Facia Panel/RE panel
- Reinforced Fill
- Drainage Media/Filter Media
- Reinforcement
- Crash Barrier

Precast RE Panel

- The minimum grade of concrete for the precast facia panel should be M35.
- The minimum thickness of the RE Wall facia panel is 180mm.
- Ethylene Propylene Diene Monomer (EPDM) Pads are used to maintain spacing between RE panels.
- The joints between the pads shall be covered from inside with a geotextile Strip of a minimum of 100mm thick

Reinforced Earth Fill

The reinforced earth fill material is essentially borrowed. Geotechnical Properties of this fill material play a significant role in the performance of the RE wall structure. The soil is borrowed from quarries, river beds etc. and the material borrowed would be compatible concerning the quantity required. We should maintain the following properties of reinforced soil during construction.

- Reinforced Material should be free of Organic Material.
- Grain size (Finer Than 75 micron less than 15%)
- Plasticity Index, PI < 6 and Cu >2
- Bulk Density as per design requirement
- OMC as specified in the design

Drainage Media/Filter Media

Filter media should be provided to avoid the development of hydrostatic pressures during RE Wall construction. A Drainage Media of a minimum 600 mm width at the back of the RE panel facing is usually used. Sometimes profiled blocks are also used for the facia which has provision for placing granular drainage.

Reinforcement Material:

Different type of reinforcements is used for the construction of reinforced earth wall. It is either metallic elements like bars, strips, plates etc. or Polymeric elements like strips, grids, rods, mesh etc. All types of reinforcements are taken beyond the Rankine zone into the resistant zone to ensure satisfactory bond and anchorage. The reinforcement can provide resistance to tensile strain. Following are the tests for reinforcement material quality control for RE wall construction.

- Tensile Strength
- Installation damage
- Creep
- Pullout Tests
- Raw material
- Carboxyl End Group(<= 30mmol/Kg)
- Molecular Weight(Polyester >25000g/mol)

RE Wall/RS Wall Friction Slab:

RS Wall friction slab is used to transfer the lateral loads due to the impact of vehicles on the crash barriers. Typically, a friction slab width varies from 1.50-2.50m and thickness of the slab, which is 250mm depends on the crash barrier type provided. Bottom of friction slab should match with the bottom of GSB.

A sample design calculation for Construction of Reinforced Earth Wall along with general arrangement diagram as prepared by a private agency known as REINFORCED EARTH INDIA PVT. LTD. based on the project parameters is presented in **Annexure 9.1**. However, during the execution at site, a detailed design of the same based on the actual site parameters to be done by the implanting agency, selected through proper tendering process by the Client.

9.3.5 Wildlife Crossings

Wildlife crossings has been designed to match the environment and to provide safe uninterrupted access to wild animals where required. As per TOR The Consultant shall conduct the necessary environmental and social assessment with due consultations with relevant stakeholders and with separate ESIA consultants appointed by DOR. In this respect detail discussion was done with DOR and ESIA consultants appointed by DOR. After the joint

site visit it was decided that all the wildlife crossings to be accommodated in the existing bridge and proposed culvert structures. The following type of animal crossing has been recommended by ESIA Consultant.

- Elephant crossing (ELC)
- Medium Size wild animal crossing (MAC)
- Tractor and cattle crossing (TCC)

All the Elephant crossings are under the existing bridges so no new structures to be constructed for this purpose however at two locations i.e., at Amu-1 and Terakilo bridge location the existing bridge need to be raised by more than 5 m. So, it was decided to demolish the existing bridge and rebuilt the new bridges with raised Formation level.

Even all the MAC are under the existing bridges so no new structures to be constructed for this purpose however at one location i.e., at Belgachi bridge location the existing bridge need to be raised by more than 3 m. Considering minimum requirement for elephant crossing, it is proposed to demolish the existing bridge and rebuild the new bridges with raised Formation level.

At all TCC location necessary clearance are available hence, no need to take any special treatment for all those bridges which are accommodating TCC.

The list of all the ELC, MAC and TCC are given in T**able 9.4, 9.5 and 9.6** below.

Table 9.4: List of Elephant Crossing

S. N.	Topo Chainage (Bridge Center)	Exiting Structure			Proposed Structure				Remarks
		Bridge Name/ Structure	Nos of Span (in no)	Span Arrangement/Length (in m)	Total Length (in m)	No of Span (in no)	Span Arrangement (in m)	Total Length (in m)	
1	329+752	Amu - 1	3	11.34	34.02	1	25	25	Existing Road Level to be raised by 5.433 m
2	333+733	Lamaha	2	33	66	2	33	66	Existing Road Level to be raised by 0.249 m
3	339+342	Dhansar	8	20.5	164	4	41	164	Existing Road Level to be raised by 3.51 m
4	347+209	Bakeya	16	22.2	355.2	4	12.6+82.5+165+ 82.5+ 12.6	352	Existing Road Level to be raised by 0.249 m
5	353+628	Terhakilo	4	11.4	45.6	1	35	35	Existing Road Level to be raised by 7.23 m
6	357+227	Pasaha	5	33	165	5	33	165	Existing Road Level to be raised by 1.574 m
7	360+869	Balganga	3	22	66	3	22	66	Existing Road Level to be raised by 0.594 m
8	363+585	Dudhaura	2	45.25	90.5				Bridge Under Construction with sufficient clearance

Table 9.5: List of Medium size Wild Animal Crossing

S. No	Topo Chainage (Bridge Center)	Existing Bridge/ Causeway				Proposed Structure for MAC			
		Name of Bridge/ Structure Type	Nos of Span	Span Arrangement/ Length (in m)	Total Length (in m)	No of Span	Span Arrangement (in m)	Total Length (in m)	Remarks
1	271+514	Gadhanta	5	12.5	62.5	3	25	75	
2	274+925	Belgachhi (DhungreKhola)	4	9.5	38	2	20	40	
3	275+630	Tuteshwor-1	2	9.5	19	1	20	20	
4	277+266	Maraha	8	15+2*18+2*15+2*18+15	132	5	33	165	
5	278+913	Dholan	4	9.5	38	1	38	38	
6	282+758	Bankhe	6	15+4*18+15	102	3	33+36+33	102	
7	285+721	Amuwa	2	9.5	19	1	25	25	
8	292+703	Kalinjor - 2	3	22	66	3	22	66	
9	317+698	Paurahi	3	22	66	3	22	66	
10	322+553	Causeway	1	160	160	1	8	8	Box Culvert

Table 9.6: List of Tractor and Cart Crossing

S. N	Topo Chainage (Bridge Center)	Name of Bridge/ Structure	Existing Structure			Proposed Structure			Remarks
			No of Span	Span Arrangement/ Length	Total Length	No of Span	Span Arrangement/ Length	Total Length	Vertical Clearance above LBL
1	237+022	Kamala	24	26.65	639.6	4	114+206+206+114	640	8.349 m
2	241+744	Charnath	15	21.4	321	15	21.4	321	2.94 m
3	245+228	Baluwa	7	16	112	4	32+32+32+16	112	3.83 m
4	252+478	Jalad	10	26.6	266	10	26.6	266	5.107 m
5	254+663	Aurahi	12	26.6	319.2	12	26.6	319.2	3.70 m
6	256+186	Basai	4	21.5+2*26.5+21.5	96	4	21.5+2*26.5+21.5	96	3.833 m
7	258+735	Sukhajor	2	22	44	2	22	44	4.83 m
8	260+921	Barahari	3	23.5+28+23.5	75	3	23.5+28+23.5	75	3.845 m

S. N	Topo Chainage (Bridge Center)	Name of Bridge/ Structure	Existing Structure			Proposed Structure			Remarks
			No of Span	Span Arrangement/ Length	Total Length	No of Span	Span Arrangement/ Length	Total Length	Vertical Clearance above LBL
9	265+345	Ratu	6	38.5+4*33+38.5	209	6	38.5+4*33+38.5	209	6.679 m
10	268+310	Bhapsi	4	12.5	50	2	25	50	4.37 m
11	290+215	Phuljor	7	12.5	87.5	3	30	90	4.00 m
12	291+868	Kalinjor - 1	3	9.5	28.5	1	28.5	28.5	6.50 m
13	300+466	Lakhandei	12	15+4*18+2*15+4*18+15	204	6	33+36+2*33+36+33	204	3.92 m
14	307+753	Rai Bridge	4	9.5	38	1	38	38	5.45 m
15	313+121	Bagmati	11	33	363	4	99+165+99	363	10.675 m
16	314+170	Gairi	3	11.4	34.2	1	22	22	3.44 m
17	325+067	Chandi	5	33	165	5	33	165	6.263 m
18	343+584	Bhamara	1	33	33	1	33	33	8.121 m

9.3.6 Drainage Box Culverts

All the existing cross drainage structure for drainage purpose have been evaluated and it was found that there exist 127 nos. of cross drainage structure either in the form of slab culvert, box culvert, pipe culvert or causeway. After proper hydraulic calculation box culverts with single or multi cell has been recommended where require to cater for cross drainage. Apart from that existing culvert need to be widened considering the proposed road width at that location. A detailed hydraulic analysis is further done for all the 21 causeways locations present in the current alignment. Necessary modifications have been recommended by providing multicellular box culvert of required size with raised formation level.

These causeways are converted to box culverts. Total 142 numbers of drainage box culverts covering 21 numbers of existing causeways and other cross drainage locations are proposed on the project highway. The detail list of the proposed culverts has been presented in **Table 9.7** below.

Table 9.7: List of Box Culverts Proposed at Causeways

S.N.	Chainage (km+m)	Existing Structure Types	Existing Dimension (Cell No X W X H)	Proposed Structure Types	Proposed Dimension (Cell No X W X H X Cushion Ht.)	Remarks
1	238+960	Slab	2*1*2	Box Culvert	1x3x2	
2	239+198	Slab	1*1.5*0.86	Box Culvert	1x3x2	
3	240+140	Slab	1*0.98*1	Box Culvert	1x3x2.5	
4	240+329	Slab	1*2*1	Box Culvert	1x3x2	
5	240+500	Slab	1*1*1	Box Culvert	1x3x2	
6	240+650	Slab	1*1*0.96	Box Culvert	1x3x2	
7	240+727	Slab	1*0.98*1	Box Culvert	1x3x2	
8	241+008	Slab	1*3*1.45	Box Culvert	1x3x2	
9	242+266	Slab	1*3*1.53	Box Culvert	1x3x3+0.24	
10	242+436	Slab	1*3*1.25	Box Culvert	1x3x2	
11	242+558	Slab	1*2*1.5	Box Culvert	1x3x2	
12	242+764	Slab	1*3*1.7	Box Culvert	1x3x3+0.055	
13	242+860	Slab	1*3*1.53	Box Culvert	1x3x3+0.25	
14	242+965	Slab	1*3*1.35	Box Culvert	1x3x3+0.25	
15	244+162	Slab	1*1.5*1	Box Culvert	1x3x2	
16	245+526	Slab	1*1.5*1	Box Culvert	1x3x2	
17	245+711	Slab	1*2*0.65	Box Culvert	1x3x2	
18	246+041	Slab	1*2*0.8	Box Culvert	1x3x2	
19	246+498	Slab	1*2*1	Box Culvert	1x3x2.5	
20	247+074	Slab	1*3*1	Box Culvert	1x3x2.5	
21	247+472	Slab	1*2.5*1	Box Culvert	1x3x2	
22	248+155	Slab	1*1.5*0.8	Box Culvert	1x3x2	
23	248+476	Slab	1*1.5*0.74	Box Culvert	1x3x2.5	
24	248+869	Slab	1*1.5*0.7	Box Culvert	1x3x2	

S.N.	Chainage (km+m)	Existing Structure Types	Existing Dimension (Cell No X W X H)	Proposed Structure Types	Proposed Dimension (Cell No X W X H X Cushion Ht.)	Remarks
25	249+099	Slab	1*1.5*0.7	Box Culvert	1x3x2	
26	249+359	Slab	1*3*1.5	Box Culvert	1x3x3	
27	249+720	Slab	1*1.15*1.5	Box Culvert	1x3x2	
28	249+910	Slab	1*1.5*1.43	Box Culvert	1x3x3	
29	250+528	Slab	1*1.5*1.3	Box Culvert	1x3x3+0.22	
30	250+559	Slab	1*2*1.54	Box Culvert	1x3x3+0.52	
31	250+652	Slab	1*3*1.7	Box Culvert	1x3x3+0.34	
32	250+898	Slab	1*3*2.55	Box Culvert	1x3x3	
33	251+532	Slab	1*2*1.2	Box Culvert	1x3x2	
34	253+120	Slab	1*3*1.64	Box Culvert	1x3x3	
35	254+048	Slab	Data N.A.	Box Culvert	1x3x2	
36	255+119	Slab	1*3*1.2	Box Culvert	1x3x3	
37	255+314	Slab	1*2*0.75	Box Culvert	1x3x2	
38	255+626	Slab	1*3*1.1	Box Culvert	1x3x2.5	
39	255+686	Slab	1*2*1.28	Box Culvert	1x3x3+0.22	
40	256+568	Slab	1*2*1.28	Box Culvert	1x3x2	
41	256+828	Slab	Data N.A.	Box Culvert	1x3x2	
42	256+980	Slab	Data N.A.	Box Culvert	1x3x2	
43	266+015	Slab	5.24*1.43	Box Culvert	2x3x2	
44	266+335	Pipe	1*0.9(pipe)	Box Culvert	1x3x2	
45	266+459	Slab	5.33*2	Box Culvert	2x3x2.5	
46	266+873	Slab	5.3*1.35	Box Culvert	2x3x2	
47	267+963	Slab	5.3*1.22	Box Culvert	2x3x2	
48	269+074	Pipe	1*0.6(pipe)	Box Culvert	1x3x3+0.08	
49	269+581	Slab	1*5.5*2.5	Box Culvert	1x6x3	
50	270+020	Slab	1*5.5*2.5	Box Culvert	2x3x3	
51	270+216	Slab	1*2.5*1	Box Culvert	2x3x3	
52	272+469	Slab	1*1.62*1.1	Box Culvert	1x3x3	
53	273+223	Causeway	140m	Box Culvert	3x6x3.5	
54	273+890	Causeway	173m	Box Culvert	2x6x3.5	
55	274+011			Box Culvert	2x6x3.5	
56	275+477			Box Culvert	1x6x3+0.04	
57	276+527	Causeway	80m	Box Culvert	2x6x3	
58	279+041	Slab	1*1.5*1	Box Culvert	1x3x3+0.84	
59	279+730	Causeway	90m	Box Culvert	3x6x3.5	
60	280+231			Box Culvert	2x3x2.5	
61	281+416	Slab	5.55*2.3(slab)	Box Culvert	2x3x3	
62	283+845	Slab	2.4*1	Box Culvert	2x3x2+2.152	
63	284+289	Slab	1.5x1	Box Culvert	1x3x2	
64	284+769	Slab	1.6*1(Slab)	Box Culvert	1x3x3	
65	285+188	Slab	1.5*1(Slab)	Box Culvert	1x3x2	
66	286+113	Causeway	185m	Box Culvert	3x6x4	
67	286+600			Box Culvert	1x6x3	
68	287+167	Pipe	2*0.9(Pipe)	Box Culvert	2x3x2	

S.N.	Chainage (km+m)	Existing Structure Types	Existing Dimension (Cell No X W X H)	Proposed Structure Types	Proposed Dimension (Cell No X W X H X Cushion Ht.)	Remarks
69	287+830	Causeway	115m	Box Culvert	3x6x4+0.31	
70	288+884	Causeway	80m	Box Culvert	3x6x4.5+0.09	
71	290+703	Slab	1.56*0.8	Box Culvert	1x3x2	
72	290+826	Slab	Data N.A.	Box Culvert	1x3x2.5	
73	297+020			Box Culvert	1x3x2	
74	297+671	Causeway	80m	Box Culvert	3x6x4+0.39	
75	298+696	Causeway	80m	Box Culvert	3x6x4+0.41	
76	299+405	Slab	4*1.5(Slab)	Box Culvert	1x3x3+3.807	
77	299+833	Slab	N.A.(Slab)	Box Culvert	1x3x3+1.101	
78	301+052	Slab	2*2.5*1(Slab)	Box Culvert	2x3x3+2.157	
79	301+197	Causeway	135m	Box Culvert	2x6x4.5+0.746	
80	301+336	Slab	5*1.75(Slab)	Box Culvert	2x3x3+2.621	
81	303+385	Pipe	1*0.9(Pipe)	Box Culvert	1x6x3	
82	304+010	Causeway	75m	Box Culvert	1x3x3+3.083	
83	304+710	Causeway	90	Box Culvert	1x3x3+0.78	
84	305+069	Pipe	1*0.9(Pipe)	Box Culvert	1x3x3+0.07	
85	305+191	Pipe	N.A(Pipe)	Box Culvert	1x3x2.5	
86	305+227	Pipe	1*0.9(Pipe)	Box Culvert	1x3x3	
87	305+636	Pipe	1*0.9(Pipe)	Box Culvert	1x3x3	
88	306+500			Box Culvert	1x3x2	
89	307+370	Causeway	170m	Box Culvert	2x3x3+0.822	
90	308+645	Causeway	170m	Box Culvert	1x6x3.5	
91	309+033	Slab	5x1	Box Culvert	1x6x3	
92	310+698	Slab	5*1(Slab)	Box Culvert	2x3x2	
93	311+289	Slab	5x1	Box Culvert	1x6x3	
94	313+430	pipe	1x0.9	Box Culvert	1x3x2	
95	313+668	Pipe	1*0.6(Pipe)	Box Culvert	1x3x2	
96	315+896	Slab	5x1.5	Box Culvert	2x3x3	
97	316+558	Slab	5x1.5	Box Culvert	2x3x2.5	
98	316+888	Slab	5*1.5(Slab)	Box Culvert	1x6x3	
99	317+305	Slab	5x1.5	Box Culvert	1x6x3.5	
100	318+520			Box Culvert	2x3x2	
101	320+498	Slab	80m	Box Culvert	3x6x4+0.1	
102	321+770			Box Culvert	2x6x3	
103	322+528	Slab	160m	Box Culvert	2x6x3.5	
104	324+340			Box Culvert	2x3x2	
105	325+520			Box Culvert	1x6x3	
106	326+164	Pipe	1*0.9(Pipe)	Box Culvert	1x3x2	
107	328+483	Pipe	2*0.9(Pipe)	Box Culvert	1x3x2.5	
108	329+360	Causeway	160m	Box Culvert	1x6x4.5+0.04	
109	330+347	Causeway	100m	Box Culvert	1x6x3	
110	331+896	Slab	5*1.8(SLAB)	Box Culvert	1x6x3	
111	334+595	Pipe	1*0.9(Pipe)	Box Culvert	1x3x3+0.02	
112	334+937	Pipe	1*0.9(Pipe)	Box Culvert	1x3x3+0.43	

S.N.	Chainage (km+m)	Existing Structure Types	Existing Dimension (Cell No X W X H)	Proposed Structure Types	Proposed Dimension (Cell No X W X H X Cushion Ht.)	Remarks
113	335+166	Slab	N.A (Slab)	Box Culvert	1x6x4.5	
114	336+205	Causeway	100m	Box Culvert	3x6x4+0.47	
115	337+073	Slab	5*1.67(Slab)	Box Culvert	1x6x3	
116	338+015	Causeway	120m	Box Culvert	2x3x3+0.98	
117	340+907	Slab	5*1.6(Slab)	Box Culvert	1x6x3	
118	341+808	Slab	5*1.6(Slab)	Box Culvert	1x6x3	
119	344+662	Causeway	150m	Box Culvert	2x3x3+1.193	
120	345+350	pipe	1x0.9	Box Culvert	1x3x3+4.214	
121	346+136	Pipe	2*0.9(Pipe)	Box Culvert	2x3x3+1.863	
122	346+525	Slab	5*1.5(Slab)	Box Culvert	2x3x2.5	
123	347+665	Slab	5*1.7(Slab)	Box Culvert	1x6x3	
124	348+056	Slab	5*1.7(Slab)	Box Culvert	2x3x2.5	
125	350+172	Causeway	220m	Box Culvert	2x3x3+1.05	
126	350+273			Box Culvert	1x6x3.5	
127	350+800			Box Culvert	2x3x2.5	
128	351+249	Slab	2.8*1.7(Slab)	Box Culvert	1x3x2	
129	352+107	Causeway	200m	Box Culvert	1x3x3+0.75	
130	352+206			Box Culvert	1x3x3+0.78	
131	352+706	Slab	5*1.7(Slab)	Box Culvert	2x3x2.5	
132	355+300			Box Culvert	2x3x2.5	
133	356+080			Box Culvert	2x6x3.5+0.066	
134	359+478	Slab	5*1.7(Slab)	Box Culvert	2x3x2.5	
135	360+100			Box Culvert	2x3x2.5	
136	361+106			Box Culvert	1x6x3.5	
137	361+703	Slab	5.5*1.8(Slab)	Box Culvert	2x3x3	
138	362+054	Slab	5*1.8(SLAB)	Box Culvert	1x6x3	
139	362+304	Slab	5*1.7(SLAB)	Box Culvert	2x3x2.5	
140	363+184	Slab	1*0.9(SLAB)	Box Culvert	1x3x2.5	
141	363+969	Slab	5*1.7(Slab)	Box Culvert	2x3x2.5	
142	365+002	Slab	5*1.7(Slab)	Box Culvert	2x3x2.5	

9.4 Typical Cross Sections

9.4.1 General

The consultant has developed typical cross sections of structures depending on whether the existing bridges (75 nos) are proposed to be retained / widened / dismantled and reconstructed. The right of way for the project road is proposed at 50m, i.e., 25m measured from existing road center on either side that is also taken into consideration for few bridges for finalizations of the cross sections. The project road has also provisions for underpasses and flyovers. The cross sections of which are developed considering both the structural as well as highway geometry requirements.

The typical cross sections are shown in **Table 9.8, 9.9, 9.10, 9.11 and 9.12,** as follows.

Table 9.8: Cross Section Details of Bridge in Rural Area

Description	Dimensions
Carriageway	8.0 M (Including kerb shyness)
Footpath	2.5m
Crash Barrier	2x0.0.45 =0.9 m
Railing (At the edge of footpath)	0.45 m
Sub Total	11.85 M (Extra Widening if required)

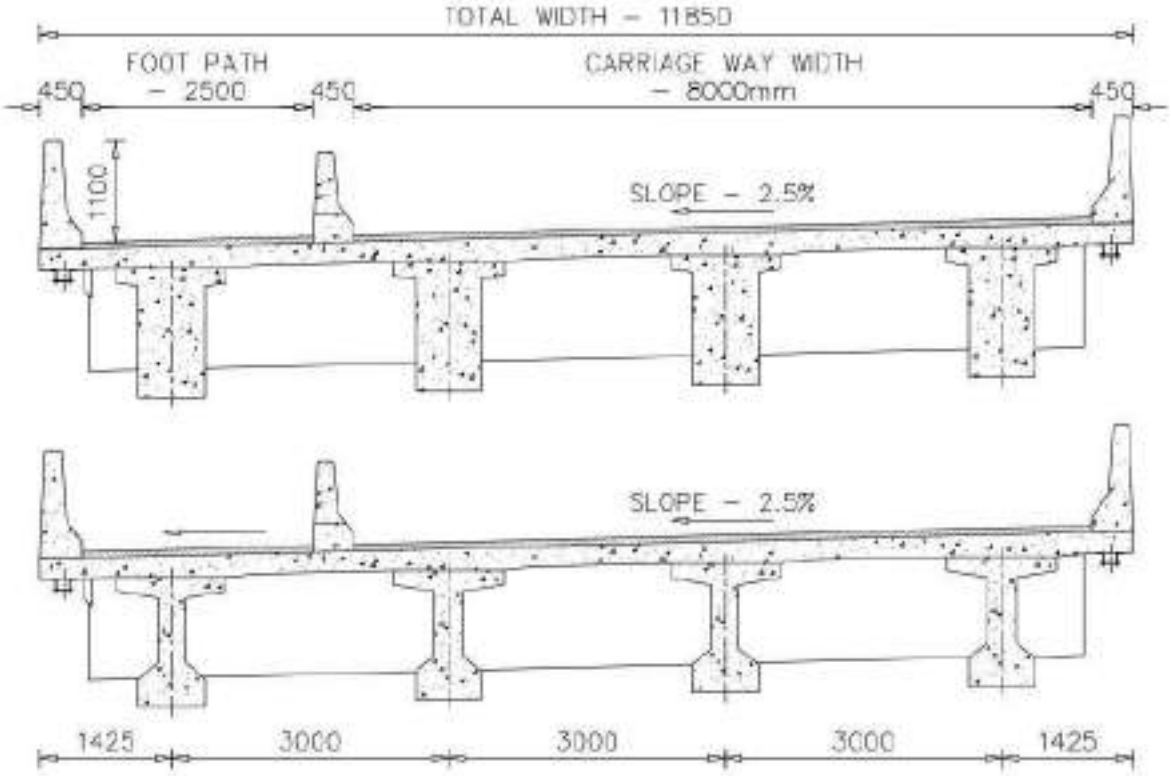


Figure 9.1: Cross Section Details of Bridge in Rural Area

Table 9.9: Cross Section Details of Bridge in Urban Area

Description	Dimensions
Carriageway	8.0 M (Including kerb shyness)
Service Road	6.5 M
Footpath	1.5m
Crash Barrier	2x0.0.45 =0.9 m
Median	0.45 m
Railing (At the edge of footpath)	0.2 m
Sub Total	17.55 M (Extra Widening if required)

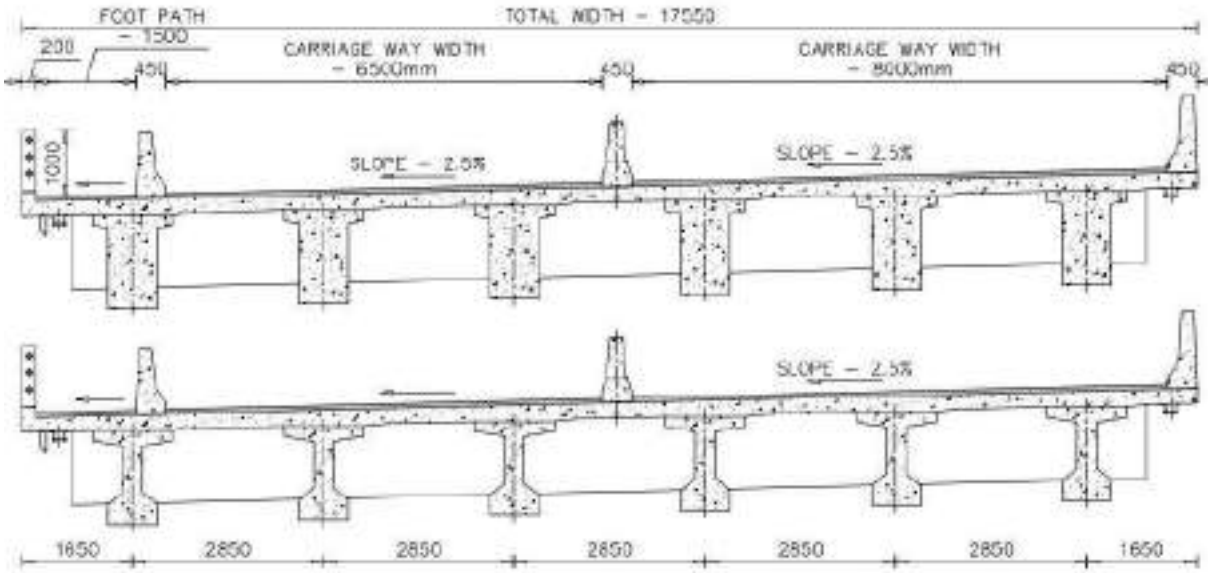


Figure 9.2: Cross Section Details of Bridge in Urban Area

Table 9.10: Overall Cross Section Details of Special Bridge

Description	Dimensions
Carriageway	1x 8.0 M (Including kerb shyness)
Service Road	6.5 M
Footpath	1.3m
Crash Barrier	4x0.0.45 = 1.80 m
Central Pylon	2.0 m
Railing (At the edge of footpath)	0.2 m
Sub Total	19.8 M

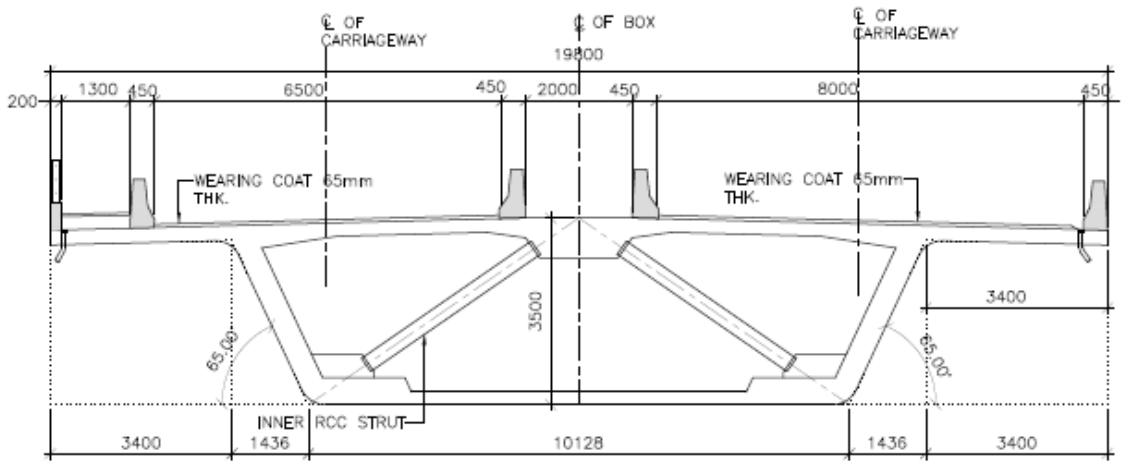


Figure 9.3: Typical Cross Section Details of Special

Table 9.11: Overall Cross Section Details of Flyover

Description	Dimensions
Carriageway	2x 10.5.0 M (Including kerb shyness)
Crash Barrier	2x0.0.45 = 0.90 m
Median	1.5 m
Sub Total	23.40 M (Extra Widening if required)

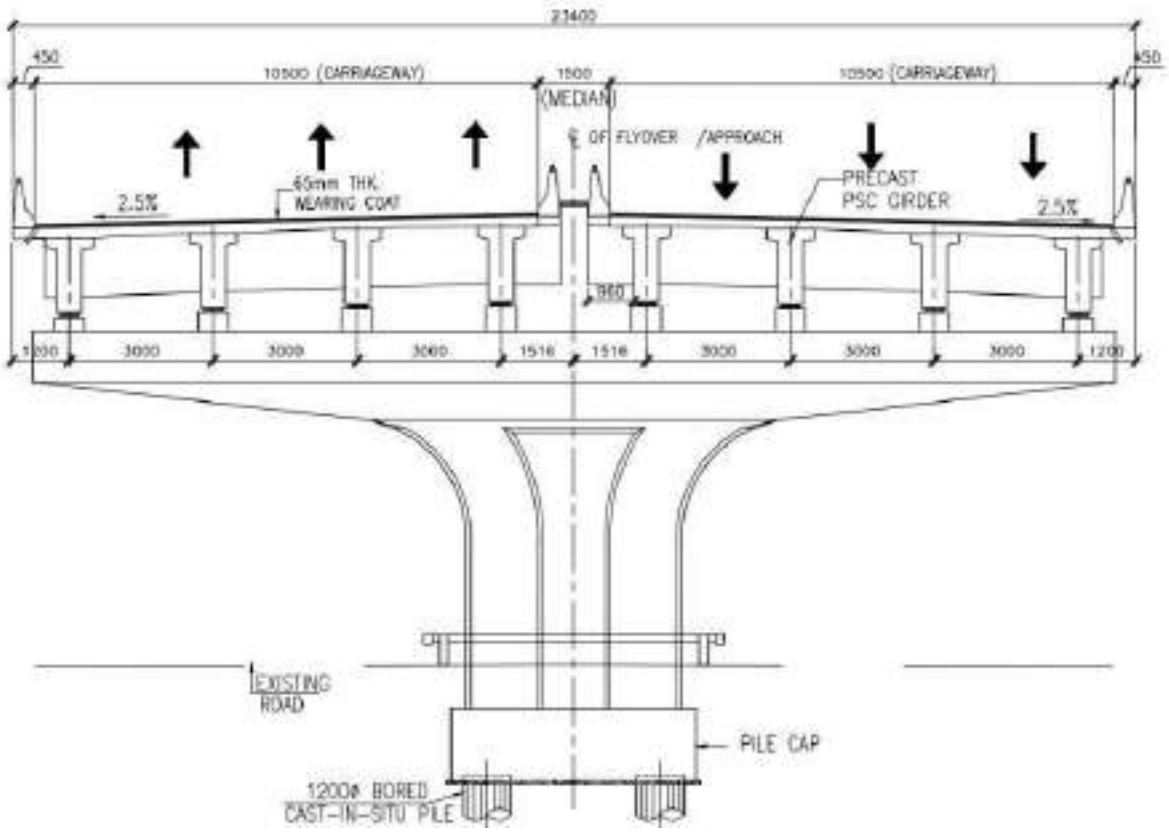
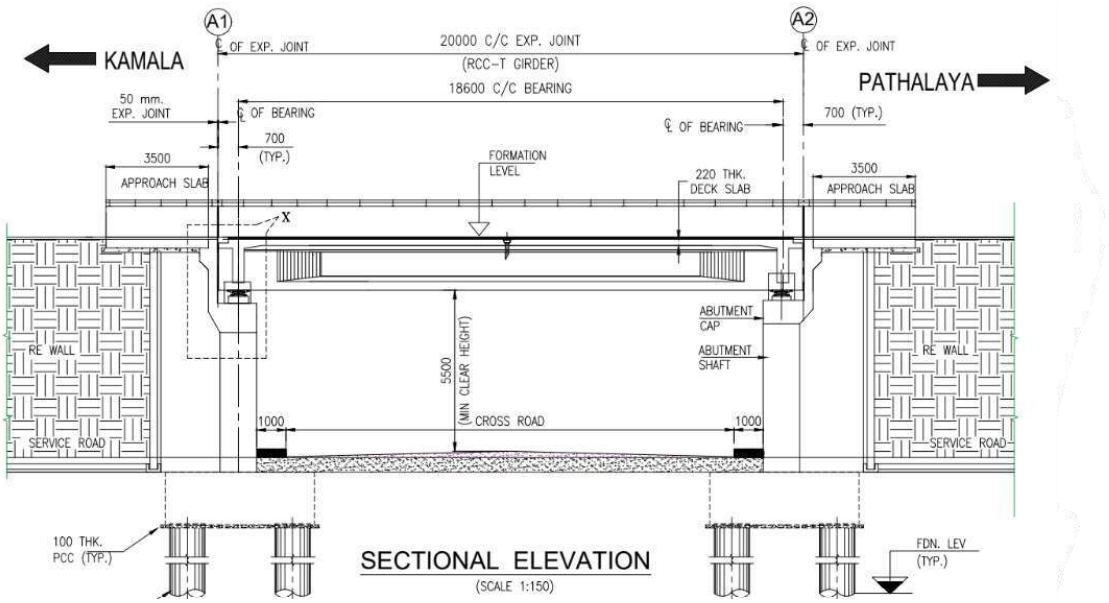


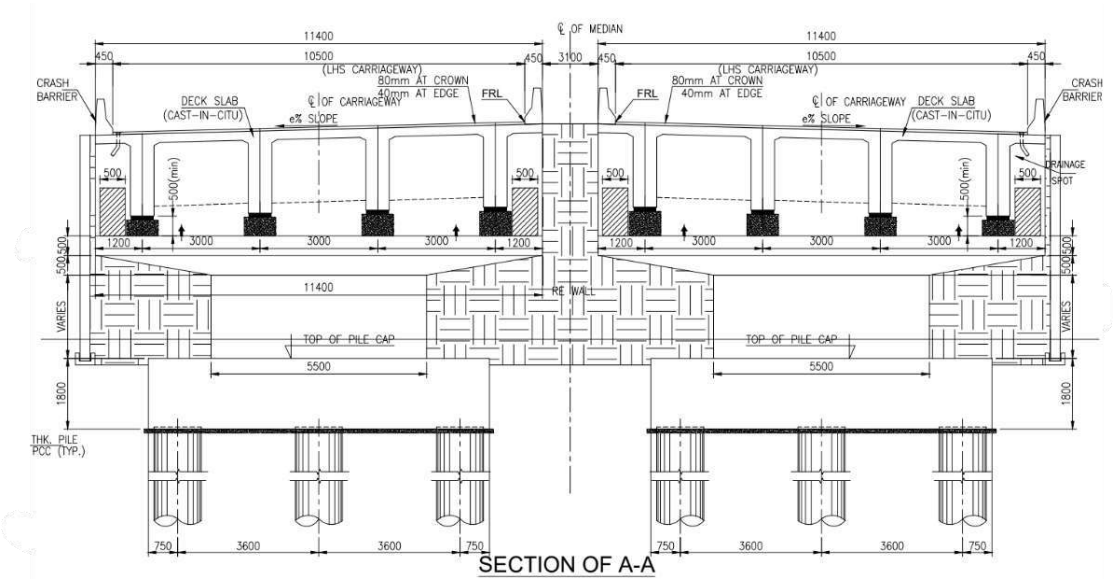
Figure 9.4: Overall Cross Section of Flyover

Table 9.12: Overall Cross Section Details of VUP/PUP

Description	Dimensions
Carriageway	2x 10.5.0 M (Including kerb shyness)
Crash Barrier	2x0.0.45 = 0.90 m
Median	1.50 m
Sub Total	25.90 M (Extra Widening if required)



(a) Elevation



(b) Cross-Section

Figure 9.5: X-section & Elevation of VUP

9.5 Widening Proposal

9.5.1 General

The proposal for widening of existing road (KDP road) is governed by mainly on the condition of the existing bridge and existing alignment, available and proposed Right of Way, encroachments, if any, settlements, habitations and distance between adjoining existing / proposed bridge structures.

The design parameters proposed to be adopted for the project in accordance with NRS 2070 with design speed of 100 Kmph (desirable) except at 5 sections where the design speed is restricted to 75 Kmph (absolute minimum).

The widening schemes adopted for the project road is given in following sections

9.5.2 Bridge Widening Proposal

The consultant has reviewed several options for widening of existing bridge and finally adopted for the new bridges as part of 4 laning of the project. They have also discussed all the schemes with the client and collected the details of preceding Kanchanpur – Kamala section.

9.5.2.1 Retain / Widen existing bridge

Following consideration is made in this option.

The existing bridges are proposed to be retained as far as possible subject to structural checks and adequacy and widening to the desired width of roadway cross section on U/s side. This bridge be used for traffic from Pathlaiya towards Kamala (RHS). The new bridge will be proposed on D/S side of existing bridge. This bridge will be for traffic from Kamala towards Pathlaiya (LHS). The substructure and foundation of the new bridge structure will be aligned with same or alternate spans of existing bridge so that linear waterway is not obstructed. New bridge for service road will have to be provided on U/S side of existing bridge with separate substructure and foundation where service roads are required otherwise New bridge for pedestrian movement will have to be provided on U/S side of existing bridge with separate substructure and foundation

Indicative Cross Section of new bridge on D/s of existing bridge and existing bridge for RHS traffic is given in **Figure 9.8 & Figure 9.9**.

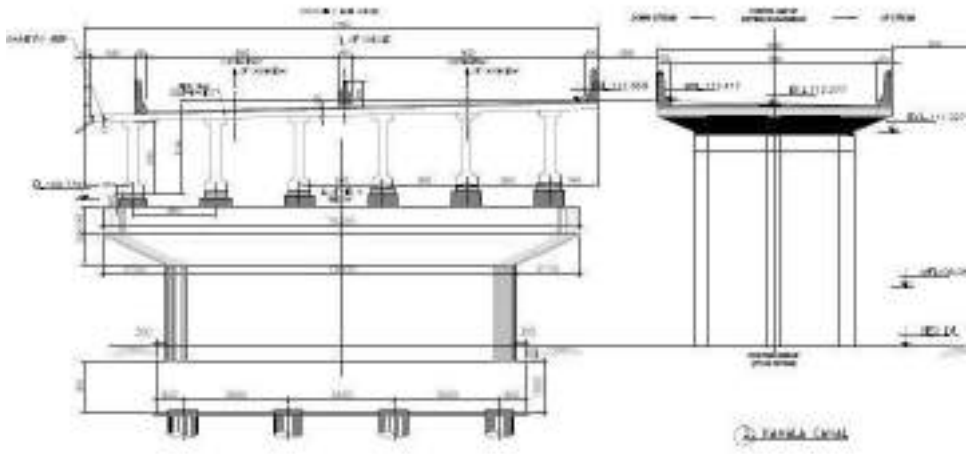


Figure 9.6: General arrangement of New Bridge D/S to Existing Bridge

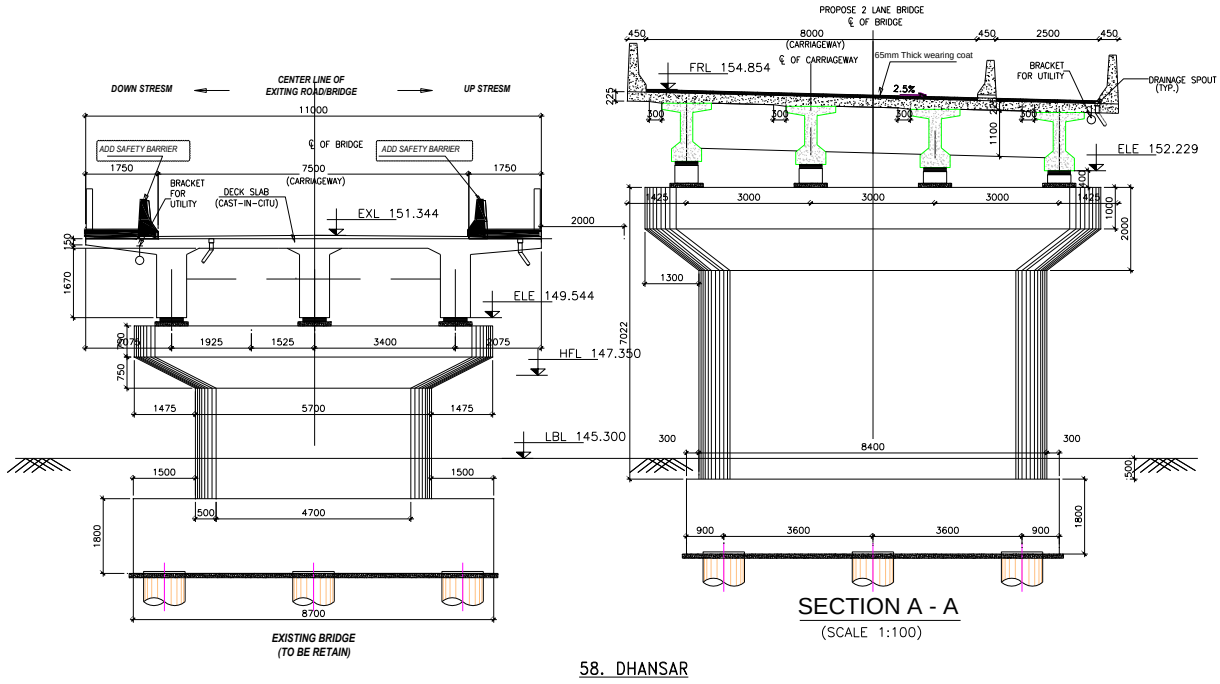


Figure 9.7: General arrangement of New Bridge U/S to Existing Bridge

9.5.2.2 Temporarily Retained existing bridge & New Bridge at D/S

Following consideration are made in this option;

The existing bridges are proposed to be retained for sometimes taking into account the existing structural condition and c/w width of 5.5 m wide. In this case a new bridge with or

without service road as per the requirement will be constructed in U/S or D/S side of the existing bridge keeping a sufficient gap from the existing bridge as per structural requirement. The approaches of the bridge will be with eccentric widening and the median width various from 4.0m on approaches up to the edge of crash barrier on inner side of the U/S and D/S bridge. The LHS or RHS bridge will be proposed with independent foundation and substructure.

Indicative Cross Section of new bridge on D/S is given in **Figure 9.8.**

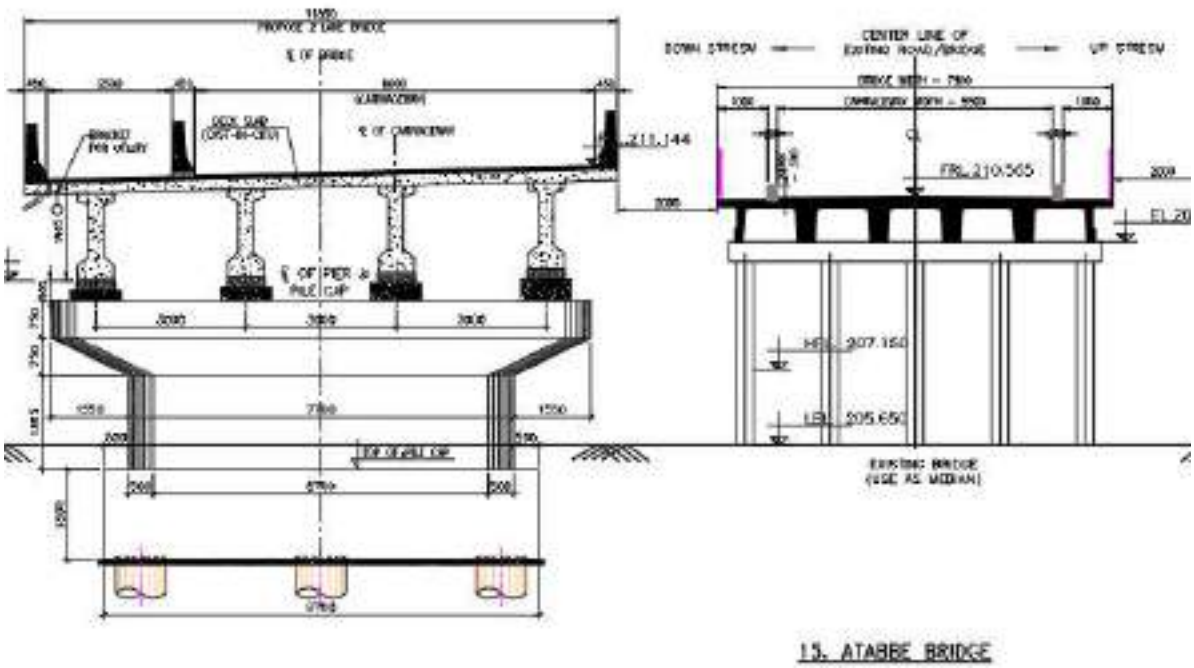


Figure 9.8: General arrangement of New Bridge at D/S sides of Existing Bridge

9.5.2.3 Demolish existing bridge & construct 2 new bridge structures side by side at that location

Following consideration is made in this option.

The existing formation level for Amu-1 and Terakilo need to be raised by more than 5m due to the proposed Elephant underpass below these bridges. In these cases, the existing bridges are to be dismantled and proposed bridge with the raised formation level are to be constructed at the location of the existing bridge. The similar pattern is followed in the case of bridge over topping, like in Belgachhi Bridge. The approaches of the bridge will be with concentric widening and the median width will be 4.0. The proposed new bridges gap to be kept in such way that in both the approaches of each bridge the 4.0 m median width can be continued.

Indicative Cross Section of new bridge on D/S and U/S are given in F**igure 9.11.**

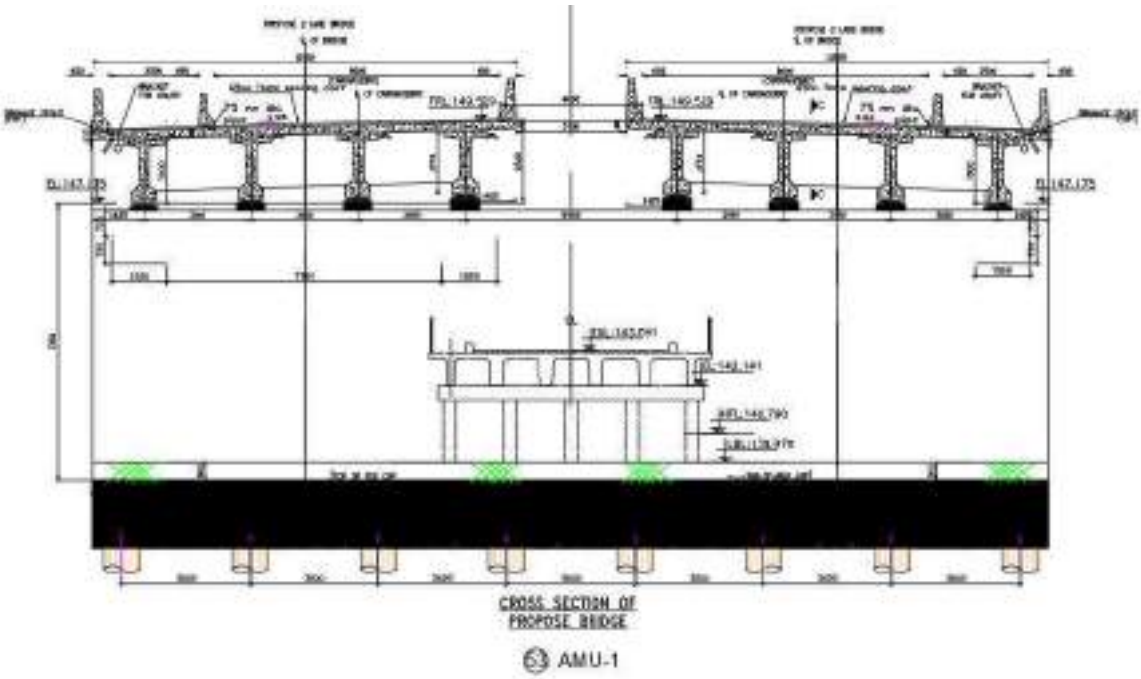


Figure 9.9: General arrangement of bridge where existing bridge have to be demolished

9.5.2.4 Demolish existing bridge & construct box culvert at that location

Following consideration is made in this option.

There are ten bridges along the project corridor where it has been noticed that water flow is very less throughout the year. After necessary hydrological calculation it has been established that the hydrological demand is very less for these bridges and if we continue to keep it as normal bridge then due to mandatory free board requirement the formation level raised. So with discussion with the client, it has been decided that as per the hydrological demand the necessary box culvert provided at these bridge locations. The width of the culverts governed by the highway geometry.

Indicative Cross Section of new bridge at these locations are given in **Figure 9.10.**

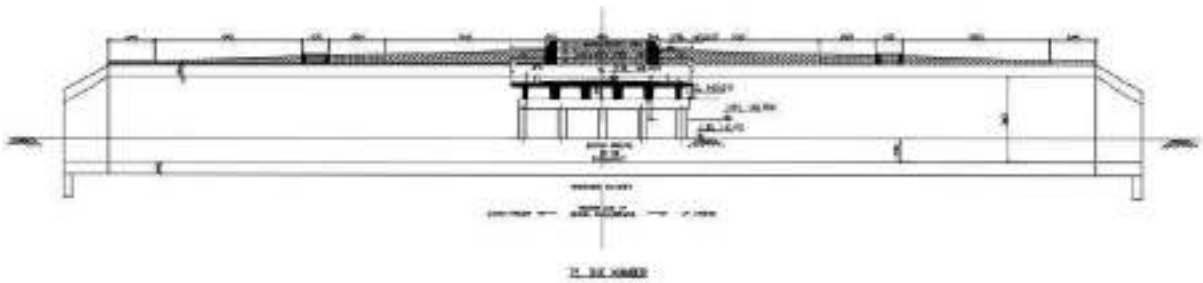


Figure 9.10: Bridge replaced with Box Culvert

Table 9.13: List of Bridges Proposed to be demolished

S.N.	Bridge Name	Chainage (Center of structure)	Exiting Deck Level (A)	Exiting Bridge	LBL	HFL	FRL at MEDIAN	Up Stream Bridge Width	Down Stream Bridge Width	Remarks
1	Ratu Chahara	266+136	226.552	Demolish	224.16	225.11	227.134	26.90		Box Culvert
2	Junga Pul-2	271+145	210.943	Demolish	206.32	207.82	213.160	26.90		Box Culvert
3	Belgachhi (DhungreKhola)	274+925	197.74	Demolish	195.21	197.32	200.274	11.85	11.85	Overtopping
4	Tuteshwor-1	275+630	192.477	Demolish	188.67	190.90	193.854	11.85	11.85	< 25 m
5	Tuteshwor-2	275+856	192.537	Demolish	187.03	188.23	193.288	11.85	11.85	< 25 m
6	Marha Kholsi Pul	278+358	191.729	Demolish	187.79	189.36	192.065	26.90		Box Culvert
7	Jarlahi (Kholsi Pul)	280+574	188.672	Demolish	184.98	186.71	189.664	11.85	11.85	< 25 m
8	Amuwa	285+721	168.595	Demolish	164.06	167.09	170.144	11.85	11.85	Overtopping
9	Betini	294+013	149.61	Demolish	146.97	148.25	150.373	26.90		Box Culvert
10	Dumdume	295+383	143.941	Demolish	139.71	142.32	145.511	17.55	17.55	< 25 m
11	Bastipur	296+286	142.88	Demolish	140.22	141.19	143.378	50.00		Box Culvert
12	Basatol	302+777	144.493	Demolish	141.92	142.76	144.930	26.90		Box Culvert
13	Sukhapokhar	305+773	139.937	Demolish	136.88	137.51	140.323	26.90		Box Culvert
14	Godari	311+587	130.591	Demolish	128.45	130.79	133.744	11.85	11.85	< 25 m
15	Gairi Khola	314+998	138.532	Demolish	137.15	137.87	139.617	26.90		Box Culvert
16	Lachkan	319+345	128.718	Demolish	125.87	127.45	130.404	11.85	11.85	< 25 m
17	Dhou	327+255	134.333	Demolish	132.56	132.96	134.872	50.00		Box Culvert
18	Amu - 1	329+752	143.091	Demolish	139.97	140.79	148.524	11.85	11.85	Elephant Crossing
19	Amu-2	330+972	145.99	Demolish	142.88	144.22	148.524	26.90		Box Culvert
20	Rampul	344+094	153.638	Demolish	149.85	151.78	154.734	11.85	11.85	< 25 m
21	Unasi	348+995	156.32	Demolish	149.58	152.62	156.706	17.55	17.55	Poor Condition

S.N.	Bridge Name	Chainage (Center of structure)	Exiting Deck Level (A)	Exiting Bridge	LBL	HFL	FRL at MEDIAN	Up Stream Bridge Width	Down Stream Bridge Width	Remarks
22	Terhakilo	353+628	148.554	Demolish	146.48	149.12	155.784	11.85	11.85	Elephant Crossing
23	Pasaha Branch	357+428	146.251	Demolish	142.53	143.64	147.953	26.90		Box Culvert
24	Bangandi	358+477	147.714	Demolish	142.87	144.22	148.024	11.85	11.85	Poor Condition
25	Dhungre-1	364+437	162.778	Demolish	159.58	160.59	163.389	26.90		Box Culvert
26	Dhungre-2	364+693	162.59	Demolish	157.09	159.01	163.181	26.90		Box Culvert
27	Dui Number	366+341	165.152	Demolish	160.96	161.92	165.621	50.00		Box Culvert
28	Ek Number	366+530	165.257	Demolish	162.88	163.62	165.670	50.00		Box Culvert

9.5.3 Rehabilitation Scheme for Bridges

a) Bridges recommended retaining

Structural deterioration may take place due to aging of materials, varying environmental conditions, damage due to impact of heavy vehicles etc., thus reducing the load carrying capacity of existing bridges. In the total stretch of 130 km, detail condition survey of 75 bridges was completed. The bridges that are going to retain have to be rehabilitate. The requirement for the rehabilitation is for two reasons. First is functional purpose and second for safety and strength requirements. For the functional purpose footpath of some bridges have to be dismantle to widening the exiting carriageway up to 7m. For the safety, side railing of exiting bridges is proposed to replace by crash barrier similar to new bridge. In some bridges it is found that wearing course have to be replaced, expansion joints have to be replaced that are proposed. In Kamala Canal, cracks in pier are observed that have to be rehabilitated. Similarly decks of the Kamal canal is dislocated that are proposed to readjust. The recommendation for the existing bridges is shown in the **table 9.14** below.

b) Bridges recommended temporarily retained

There are 26 numbers of bridges, that's recommended to temporarily retained, but the condition of those bridges are in question except 11 numbers of steel plate girder bridges. Therefore it is recommended to replace those bridges after construction of proposed brides on priority basis. For the time being those bridges have to be maintained. Those bridges comprise precast RCC C-Girder and cast in situ RCC T-Girder. In general all C-Girder bridges are in very poor condition due to spaling of cover concrete, formation of cracks in girder, seepage of rain water from deck slab and separation of girders from each other. Some C-Girders are rehabilitated by FRP strips at bottom of Girder and some FRP on fashion of strip and Bandage. Those FRP was also detached in some places. In T-Girder bridges there are spaling of concrete, handrail and slab edge broken. Expansion gaps are filled with debris. Some bridge have foundation protection problem. Steel plate girder bridges are comparatively in good condition, but there is also seepage of rain water from deck, cracking of deck concrete and excessive vibration. Normally handrails and wearing concrete of all steel plate girder bridges have to be replaced. There was thick wearing concrete due to numbers of times overlaying of wearing concrete. Though, it is recommended to remove thick overlaid wearing concrete by thin one.

Table 9.14: List of Bridges Proposed to be rehabilitated

S.N.	Bridge Name	Chainage (Center of structure)	No. of Span	Span Arrangement	Bridge Length	Superstructure	Substructure	Foundation	Carriageway Width	Total Width	Recommendations for Exiting Bridge
1	Kamala	237+022	24	26.65	639.6	RCC I-Girder	RCC Wall Type	Well	7	7.9	Regular observations of cracks (girder); Replace: wearing coat & expansion joint; Repair: Deck slab, pedestal, pier stem; Replace: Handrail & Kerb with crash barrier
2	Kamala Canal	338+105	5	14.1	70.5	RCC Slab	RCC Frame	Unknown	7	7.9	Replace wearing, expansion joint; Replace kerb & handrail with crash barrier; Repair pier & bearing stopper
3	Charnath	241+744	15	21.4	321	RCC I-Girder	RCC Wall Type	Unknown	7	8	Regular observations of girders, clean bed deposit; Replace: Kerb & handrail with crash barrier
4	Baluwa	245+228	7	16	112	RCC I-Girder	RCC Wall Type	Unknown	7	8	Replace: Kerb & handrail with crash barrier
5	Jagadav Branch	250+760	1	26.6	26.6	RCC I-Girder	RCC Wall Type	Unknown	7	8	Regular observations of grouted girder; Replace: Kerb & handrail with crash barrier
6	Jagadav	251+090	4	21.5+2*26.5+21.5	96	RCC I-Girder	RCC Wall Type	Unknown	7	8	Regular observations of grouted girder, Clean River bed deposit; Replace: Kerb & handrail with crash barrier
7	Jalad	252+478	10	26.6	266	RCC I-Girder	RCC Wall Type	Unknown	7	8	Replace: Kerb & handrail with crash barrier
8	Aurahi	254+663	12	26.6	319.2	RCC I-Girder	RCC Wall Type	Unknown	7	8	Regular observations of grouted girder; Replace: Kerb & handrail with crash barrier
9	Basai	256+186	4	21.5+2*26.5+21.5	96	RCC I-Girder	RCC Wall Type	Unknown	7	7.9	Replace: Kerb & handrail with crash barrier
10	Barahari	260+921	3	23.5+28+23.5	75	Continuous Steel Plate Girder	RCC Trestle Type	Unknown	7.5	10.74	Replace: expansion joint; Demolish inner edge of kerb and provide crash barrier

S.N.	Bridge Name	Chainage (Center of structure)	No. of Span	Span Arrangement	Bridge Length	Superstructure	Substructure	Foundation	Carriageway Width	Total Width	Recommendations for Exiting Bridge
11	Ratu	265+345	6	38.5+4*33+38.5	209	PSC I-Girder	RCC Hammer Head	Pile	7.5	11	Demolish inner edge of kerb and provide crash barrier
12	Bhapsi	268+310	4	12.5	50	RCC T-Girder	RCC Wall Type	Unknown	7	8.5	Demolish inner edge of kerb and provide crash barrier
13	Maraha	277+266	8	15+2*18+2*15+2*18+15	132	RCC Continuous T-Girder	Precast Columns forming wall with cast-in-situ RCC Cap	RCC Pile (found pile in similar type bridge)	5.5	7.9	Demolish footpath separator & handrails (LHS). Construct crash barrier at left edge and at the position of separator at RHS. Widen carriageway to 6.25m.
14	Bankhe	282+758	6	15+4*18+15	102	RCC Continuous T-Girder	Precast Columns forming wall with cast-in-situ RCC Cap	RCC Pile (found pile in similar type bridge)	5.5	7.9	Demolish footpath separator & handrails (LHS). Construct crash barrier at left edge and at the position of separator at RHS. Widen carriageway to 6.25m.
15	Lakhandei	300+466	12	15+4*18+2*15+4*18+15	204	RCC Continuous T-Girder	Precast Columns forming wall with cast-in-situ RCC Cap	RCC Pile	5.5	7.9	Demolish footpath separator & handrails (LHS). Construct crash barrier at left edge and at the position of separator at RHS. Widen carriageway to 6.25m. Protect river bed and foundation.
16	Bagmati East	312+474	1	11.3	11.3	RCC T-Girder	RCC Wall Type	Unknown	5.5	7.9	Demolish footpath separator & handrails (LHS). Construct crash barrier at left edge and at the position of separator at RHS. Widen carriageway to 6.25m.
17	Bagmati West	313+825	1	11.57	11.57	RCC Slab	RCC Wall Type	Unknown	6.55	7	Demolish handrail & construct crash barrier at edge of deck maintaining 6.25 m wide carriageway.
18	Dhansar	339+342	8	20.5	164	RCC T-Girder	RCC Wall Type	Well	7.5	11	Repair: approach slab of right bank
19	Barahakilo	354+655	3	11.25	33.75	RCC T-Girder	RCC Wall Type	Unknown	5.5	7.9	Demolish footpath separator & handrails (LHS). Construct crash barrier at left edge and at the position of separator at RHS. Widen carriageway to

S.N.	Bridge Name	Chainage (Center of structure)	No. of Span	Span Arrangement	Bridge Length	Superstructure	Substructure	Foundation	Carriageway Width	Total Width	Recommendations for Exiting Bridge
											6.25m. Replace expansion joint.
20	Baijura	362+882	4	11.5	46	RCC T-Girder	RCC Wall Type	Unknown	5.5	7.9	Demolish footpath separator & handrails (LHS). Construct crash barrier at left edge and at the position of separator at RHS. Widen carriageway to 6.25m. Replace expansion joint.
21	Tin Number	365+725	3	11.5	34.5	RCC T-Girder	RCC Wall Type	Unknown	5.5	7.9	Demolish footpath separator & handrails (LHS). Construct crash barrier at left edge and at the position of separator at RHS. Widen carriageway to 6.25m.

9.5.4 River Bank Protection

A stream whose bed and banks are composed of loose granular material, that has been deposited by the stream and can be picked up and transported again by the current during the floods are susceptible to erosion. As the Terai region is composed of gravel and alluvial soil, such types of bank cutting/ erosion is expected, especially at river facing to bank. Therefore, at such rivers, river bank protection work is suggested. As the elliptical guide bund are found more efficient than others, the same is proposed. The design of such types of river training work is based on IRC: 89-1997. The alignment shall be such that, the pattern of flow remains as uniform through all the spans of the bridge as far as be possible. Both divergent guide buns and convergent guide bunds are proposed as per the requirements. The length of the guide bunds has been proposed considering maximum obliquity of the current and the permissible limits to which the main channel of the river can be allowed to flow near the approach embankment. At the downstream length of guide bund are provided 0.2 times the length of the bridge but not less than 10m. There are 33 numbers of bridges required guide bund and or bank protection that may be composed of both earthen and gabion (mostly). At some bridge locations, masonry bank protection also required. The lists of bridges that have required bank protection are presented in **Table 9.15**. The Lakhandei Bridge requires bed protection also. For this bridge, 0.5m thick gabion mattress covering entire length of bridge has been proposed for bed protection.

Table 9.15: List of Bridges Proposed with Bank Protection.

S.N.	Chainage (Bridge Center)	Bridge Name	Total Length of Bridge (in m)	Up Stream Bridge Width (in m)	Down Stream Bridge Width (in m)	Exiting Bank Protection	Condition	Recommended River Protection	Remarks
1	237+022	Kamala Bridge	640		17.55	Earthen Bank + Masonry wall	OK		
2	238+095	Kamala Canal	45		11.85				
3	241+744	Charnath	321		11.85	Earthen + Gabion	Insufficient	Enlarge & Maintain	
4	245+228	Baluwa	112		11.85	Earthen + Gabion	Insufficient	Enlarge & Maintain	
5	250+760	Jagadav Branch	20		11.85				
6	251+090	Jagadav	53.2		11.85	Earthen + Gabion	Insufficient	Enlarge & Maintain	
7	252+478	Jalad	266		11.85	Earthen + Gabion	Insufficient	Enlarge & Maintain	
8	254+663	Aurahi	319.2		11.85	Earthen + Gabion	Insufficient	Enlarge & Maintain	
9	256+186	Basai	96		11.85	Earthen + Gabion	Insufficient	Enlarge & Maintain	
10	258+735	Sukhajor	44		11.85	NO		Masonry + Earthen	
11	260+921	Barahari	75	11.85		A little Gabion	Insufficient	Masonry + Earthen	
12	265+345	Ratu	226		11.85	Earthen + Gabion	Insufficient	Enlarge & Maintain	
13	266+136	Ratu Chahara	12	26.90					
14	268+310	Bhapsi	75		11.85	NO		Masonry + Earthen	
15	269+373	Atabbe	28.5		11.85			Earthen	

S.N.	Chainage (Bridge Center)	Bridge Name	Total Length of Bridge (in m)	Up Stream Bridge Width (in m)	Down Stream Bridge Width (in m)	Exiting Bank Protection	Condition	Recommended River Protection	Remarks
16	270+871	Janga Pul-1	125		11.85	Earthen	Insufficient	Earthen + Gabion	
17	271+145	Janga Pul-2	18	26.90					
18	271+514	Gadhanta	75		11.85	No	Insufficient	Earthen + Gabion	
19	274+925	Belgachhi (DhungreKhola)	40	11.85	11.85			Earthen + Gabion	
20	275+630	Tuteshwor-1	20	11.85	11.85			Earthen	
21	275+856	Tuteshwor - 2	20	11.85	11.85				
22	277+266	Maraha	165		11.85	No		Earthen + Gabion	
23	278+357	Maraha Khols iPul	18	26.90					
24	278+913	Dholan	38		11.85			Earthen	
25	280+574	Jarlahi (KholsiPul)	20	11.85	11.85				
26	281+990	Batuwa	28.5		11.85			Earthen	
27	282+758	Bankhe	102		11.85	No		Earthen + Gabion	
28	285+721	Amuwa	25	11.85	11.85				
29	290+215	Phuljor	125		11.85	No		Earthen + Gabion	
30	291+868	Kalinjor - 1	28.5		11.85				
31	292+703	Kalinjor - 2	66		11.85	No		Earthen + Gabion	
32	294+013	Betini	12	26.90					
33	295+383	Dumdume	25	17.55	17.55				
34	296+286	Bastipur	18	50.00					
35	300+466	Lakhandei	204		11.85	Earthen + Gabion	Insufficient	Enlarge & Maintain + Bed protection	Bed protection Required

S.N.	Chainage (Bridge Center)	Bridge Name	Total Length of Bridge (in m)	Up Stream Bridge Width (in m)	Down Stream Bridge Width (in m)	Exiting Bank Protection	Condition	Recommended River Protection	Remarks
36	301+948	Chapani	66		11.85	Earthen + Gabion	Insufficient	Enlarge & Maintain	
37	302+777	Basatol	6	26.90					
38	305+773	Sukhapokhari	18	26.90					
39	307+753	Rai Bridge	38		11.85	Earthen + Gabion	Insufficient	Enlarge & Maintain	
40	310+019	Dumajor	40		11.85				
41	311+587	Godari	20	11.85	11.85				
42	312+474	Bagmati East	25		17.55				
43	313+121	Bagmati	363		17.55	Earthen, Masonry & Gabion	OK		
44	313+825	Bagmati West	25		17.55				
45	314+170	Gairi	35		11.85	No		Masonry + Earthen + Gabion	
46	314+998	Gairi Khola	3	26.90					
47	317+698	Paurahi	66		11.85	No		Earthen + Gabion	
48	319+345	Lachkan	20	11.85	11.85				
49	323+590	Katha Ko Pul	25		11.85				
50	325+067	Chandi	165		11.85	Earthen	Insufficient	Enlarge & Maintain	
51	327+255	Dhou	3	50.00					
52	328+021	Jungle Tole	20		11.85				
53	329+752	Amu - 1	25	11.85	11.85				
54	330+985	Amu - 2	18	26.90					
55	332+811	Kathi	30		11.85				
56	333+733	Lamaha	66		11.85	No		Earthen + Gabion	

S.N.	Chainage (Bridge Center)	Bridge Name	Total Length of Bridge (in m)	Up Stream Bridge Width (in m)	Down Stream Bridge Width (in m)	Exiting Bank Protection	Condition	Recommended River Protection	Remarks
57	334+473	Kali Khola	33		11.85				
58	339+342	Dhansar	164	11.85		No		Earthen + Gabion	
59	342+268	Lamopul	25		11.85				
60	343+584	Bhamara	33		11.85				
61	344+094	Rampul	20	11.85	11.85				
62	347+209	Bakeya	352		11.85	Earthen, Masonry & Gabion	OK		
63	348+947	Unasi	35	17.55	17.55	No		Earthen + Gabion	
64	353+598	Terhakilo	41	11.85	11.85	No		Earthen	
65	354+646	Barahakilo	35		11.85				
66	357+227	Pasaha	165		11.85	No		Earthen + Gabion	
67	357+449	Pasaha Branch	18	26.90					
68	358+470	Bangandi	35	11.85	11.85				
69	360+869	Balganga	66		11.85	No		Earthen + Gabion	
70	362+882	Baijura	46		11.85				
71	363+585	Dudhaura				May be in Design			Bridge Under Construction
72	364+458	Dhungre - 1	18	26.90					
73	364+713	Dhungre - 2	18	26.90					
74	365+725	Tin Number	35		11.85				
75	366+341	Dui Number	18	50.00					
76	366+530	Ek Number	12	50.00					

Chapter 10: Road Safety Assessment and Improvement Proposals

10.1 Background

Road safety assessment (RSA) and Road safety audit are used interchangeably in road safety investigation domain of any highway. Road safety assessment is primarily been undertaken to assess the degree of safety been perceived by the road users that being discerned based on pre-specified parameters and pre-requisites. It is a formal process to evaluate the safety performance of an existing or a planned road project. This assessment of road safety is of utmost importance; be it the design stage, construction stage or the maintenance stage of given facility.

The road safety assessment (RSA) or road safety audit has been done by the consultant for the Kamala-Dhalkebar-Pathlaiya (KDP) section (130km) of Mahendra Highway both prior to the design stage and post design stage. Pre-design stage road safety audit report of existing KDP highway had been completed in July 2022. Post design stage RSA has been conducted based on the degree of improvements been proposed and inducted in the detailed design..

10.2 Methodology

Below is the process adopted in assessing the prevailing existing conditions in regard of road safety, identifying and analysing the available gaps and proposing the improvements in the design with the design team;

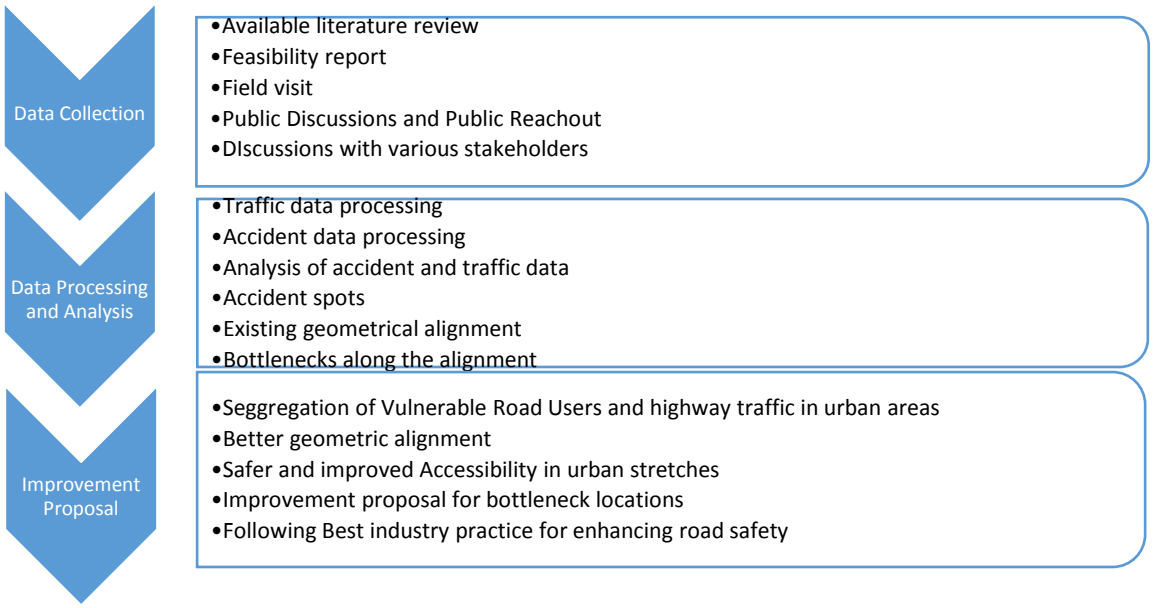


Figure 10.1: Flow of Road Safety Audit Process

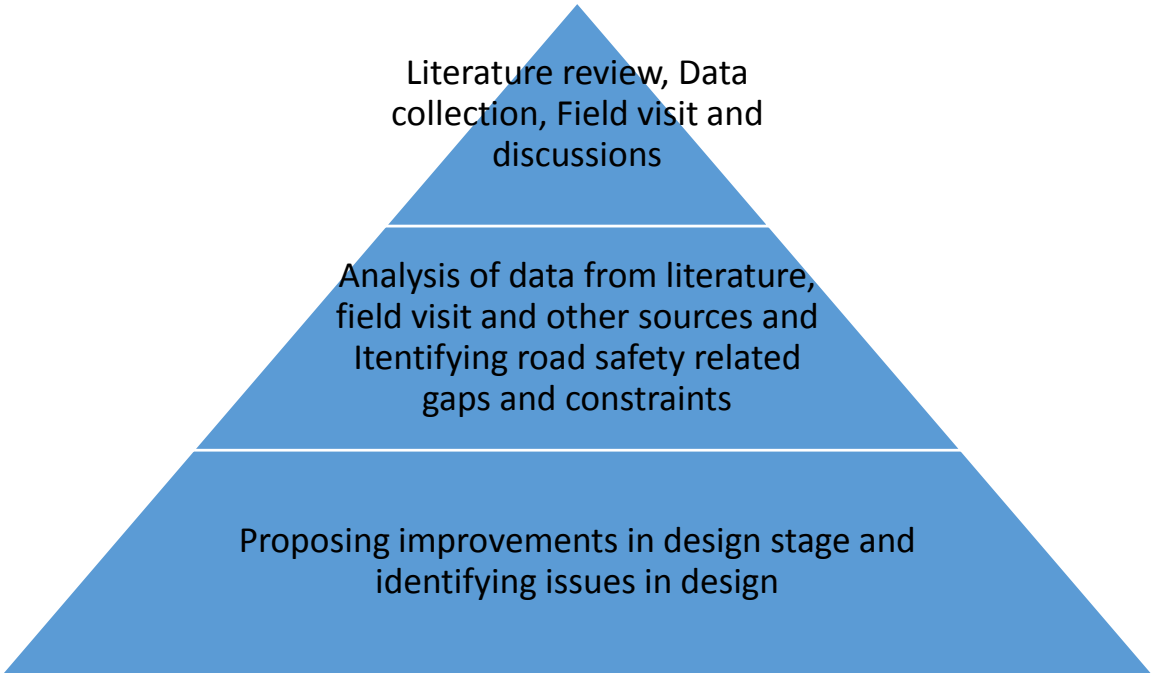


Figure 10.2: Process of Road Safety Audit

As part of methodology, to start with, a literature review was done from all available resources like feasibility study report, earlier studies like “iRAP Road Safety Assessment in high-risk road network in Nepal”, ADB funded “Road Safety Audit Main Report” by PWC, TOR of bid document etc.. Later field visits were made to assess the site conditions in road safety context. Discussions and dialogue with locals was made in regard to their travel behaviour and needs. Various stakeholders like traffic, police, PWD departments were also reached out for their inputs and at last but not least several rounds of interactions and discussions were held with in-house design team.

As a second phase, data collected from various sources whether in digital format as textual, statistical (e.g. accident and traffic data), or inputs from site from public and from stakeholders was analysed and processed. Analysis and other input data processing results were used in identifying the issues and need for the improvements. For example, safety measures need to be adopted for avoiding bottlenecks in to be retained narrow bridges, facilities to be provided for safer mobility of vulnerable road users in urban sections, safe cattle crossings, improvement of major and minor junctions and safety provisions in high speed rural sections etc.

Finally, all the improvement proposals as discussed in the above paragraph are being included in the detailed design report and drawings for review and implementation.

10.2.1 Literature Review

10.2.1.1 ADB – Road Safety Audit Main Report by PWC

An ADB funded Road Safety Audit of entire East-West highway was conducted by PWC (Pricewaterhouse Coopers) back in July, 2021. This report has been reviewed and it was found that almost all the issues and concerns regarding risk areas have been incorporated, as have been recognized / observed during the consultants' safety audit. Some issues like highway alignment, curve/alignment delineation, signage and markings, and road side hazards etc. have been suitably modified and incorporated in the design as pertinent requirement of proposed four laning of the project. Major issues raised in the report are as below:

1. Narrow bridges and culverts which are proposed to be retained shall pose very high risk safety threat due to lack of lateral clearance, discontinuity of carriageway width, insufficient line of sight, etc.
2. Major Junctions to be modified as on medium risk due to various reasons like urban settlement, VRUs, restricted line of sight etc.
3. Minor Junctions and Access roads to be modified as on medium risk due to same reasons as mentioned above including side road vertical profile improvement.
4. Pedestrian facility issues being on very high risk due to absence of proper pedestrian refuge islands, footpaths, foot-over bridges and obstacles on entry/exit points.
5. Cyclists and motorcycle related issues being on very high risk due to absence of separate dedicated right-of-way or cycle/motorcycle paths in settlement zones.
6. Bus pickup / drop point being on high risk as buses / small passenger vehicles stopping on main carriageway and creates risk of vision obstruction for the pedestrian crossing in front or rear of bus resulting in conflict between pedestrian and high speed traffic.
7. Sight distance being on very high risk due to trees overhanging and forest areas on curve sections.
8. Animal crossing on high risk due to presence on domestic animals on roadway and wild animals crossings in jungle areas.

10.2.2 iRAP Road Safety Assessment in high-risk road network in Nepal

iRAP (International Road Assessment Programme) is a registered charity dedicated to saving lives by eliminating high risk roads throughout the world. iRAP works in partnership with governments, road authorities, mobility clubs, development banks, NGOs and research organisations to:

- Inspect high-risk roads and develop Star Ratings, Risk Maps and Safer Roads Investment Plans
- Provide training, technology and support that will build and sustain national, regional and local capability
- Track road safety performance so that funding agencies can assess the benefits of their investments.

iRAP has done study on high-risk strategic road networks in Nepal including Kamala-Dhalkebar-Pathlaiya section and submitted report in May 2022. The parameters on which star rating is given are as below:

a. Operational speed
b. Road section geometry
c. Intersection density
d. Centre line median
e. Road delineation
f. Road side Hazards
g. Road condition
h. Roadside encroachments
i. Pedestrian facilities etc.

The above section study outcome is briefed below:

The study indicates that 26% (approx. 34 kms) of the road length is rated 3-star or better for vehicle occupants, 23% for motorcyclists, 2% for pedestrians, and 13% for bicyclists. Rest 74% (approx. 96kms) of the road length is given below 3-star rating.

It indicates that maximum length of the project road is on high risk from road safety context and that has been addressed in the proposed design of the project highway.

10.3 Road Safety Audit

Road Safety Audit of the existing project highway was done back in May-June 2022 and a detailed study was conducted on road safety aspects. A detailed road safety audit report was prepared and submitted to the client in July 2022. The report was comprehensively prepared, outlining the existing shortcomings in road safety contexts which need to be addressed and to be incorporated in proposed design of the project highway.

Following objectives have been ascertained and incorporated in detailed design from the road safety audit;

1. Minimizing risk of crashes presently occurring / may occur on existing road,
2. Minimizing the risk of crashes on the adjacent road especially at intersections,
3. To recognize the importance of safety in road design so that the needs and perceptions of all road users are met,
4. To reduce the long term costs of the given project highway, bearing in mind that unsafe designs may be expensive (or sometimes impossible) to correct at a later stage,
5. Enhancing awareness of road safety engineering principles by all involved in the process of designing,
6. To advance the awareness of providing safe road schemes for non-motorized as well as motorized road users.

10.3.1 Factors Contemplated in Safer Design

Prevailing factors appraised and contemplated in design for safer design of proposed highway post safety audit;

1. Location specific accident statistics and analysis (accident data can't be acquired discrete to intersections, villages, urban agglomerate, bridges etc),
2. Pedestrians' location specific count and pedestrian movement behaviour,
3. Pedestrian friendly design like footpaths, footpaths with railing, zebra crossing with ramps at junctions and foot-over-bridge (FOB),
4. Bicycling behaviour centric locations,
5. Bus alighting and boarding points,
6. Clear visibility while maintaining safe stopping sight distance to be minimum in non-urban sections,
7. Additional and special safety provisions at locations - 'to be retained' narrow bridges at par to best practices,
8. Proposed flyovers and VUPs / PUPs to lower down conflicts points, thereby improve overall safety, enhance the capacity of junctions and Level of Service (LOS),

Table 10.1: Summary of Safety Issues and Measures adopted in Design

S. No.	Primary Factors Contemplated	Closest Measures adopted in Design	Specification and Codes
1.	Region / District level accident data analysis and safety measures proposed. Location specific accident statistics and	Crash barriers, Impact attenuators	Nepal Road Standard (NRS) – 2070, Indian Road Congress (IRC): 119 – 2015, IRC: SP 84

S. No.	Primary Factors Contemplated	Closest Measures adopted in Design	Specification and Codes
	analysis (accident data can't be acquired discrete to intersections, villages, urban agglomerate, bridges etc)		
2.	Pedestrians' location specific count and pedestrian movement behaviour	Zebra crossing, Foot-over-bridge, Traffic calming measures etc.	Traffic Sign Manual, Dept. of Roads (DoR), NRS – 2070 and IRC: 35 - 2015
3.	Bicycling behaviour centric locations	Bicycle tracks and relevant signages	NRS – 2070, IRC: 11 - 2015
4.	Bus alighting and boarding points	Bus-bays and stops	Nepal Road Standards - 2070
5.	Clear visibility and/ or obstructions while maintaining safe stopping sight distance to be minimum in non-urban sections	Improved geometric design, hazard warning of unusual layout ahead, adequate signage and pavement marking	Nepal Road Standards – 2070, IRC: 73, Traffic Sign Manual (DoR), IRC: 67 – 2012, IRC: 35 - 2015
6.	Additional and special safety provisions at locations - 'to be retained' narrow bridges	Crash barriers, Impact attenuators, adequate hazard warnings, signage and pavement marking	Nepal Road Standard (NRS) – 2070, Indian Road Congress (IRC): 119 – 2015, IRC: SP 84, Traffic Sign Manual (DoR), IRC: 67 – 2012, IRC: 35 - 2015
7.	Lower down conflicts points, thereby improve overall safety, enhance the capacity of junctions and Level of Service (LOS)	Junction improvement, provision of flyovers, VUP / PUP, adequate signage and pavement marking	Nepal Road Standards (NRS) -2070, IRC: SP – 41, Traffic Sign Manual (DoR), IRC: 67 – 2012, IRC: 35 - 2015
8.	Insufficient information for the road users	Improved signage plan and pavement marking	Traffic Sign Manual (DoR), IRC: 67 – 2012, IRC: 35 - 2015
9.	Fixed hazards on or by the roadside	Removal of hazards to the extent possible. For narrow bridge locations; improvements added as suggested in point 6 above	Nepal Road Standard (NRS) – 2070, Indian Road Congress (IRC): 119 – 2015, Traffic Sign Manual (DoR), IRC: 67 – 2012, IRC: 35 – 2015
10.	Cattle and Animal crossings	Elephant and cattle underpass being provided	
11.	Access control	Direct access has been minimized specially in urban areas via service road and / or footpath and curb	Nepal Road Standard (NRS) – 2070, IRC: 62

S. No.	Primary Factors Contemplated	Closest Measures adopted in Design	Specification and Codes
12.	Night visibility in urban regions	Street lighting has been proposed in urban / habituated locations including major junctions, bridges, flyovers / VUP / PUP, Bus bays and truck lay-byes	IS: 1944 (Part-V) – 1981 and other international standards
13.	Traffic control and adequate delineation of project highway	Signages, Pavement markings, Highway delineators are proposed as per codes and requirement for traffic safety	Nepal Road Standards – 2070, Traffic Sign Manual (DoR), IRC: 67 – 2012, IRC: 35 - 2015

10.3.2 Accident / Crash Analysis and Result

During road safety audit, Accident data was obtained and analysed. Post analysis it was found that43% of accidents from FY 2015-16 to 2020-21 occurred inMaithila, Chandrapur and Charnath (Maithila-17%, Chandrapur-15% and Charnath-11%).Lalbandi and Harivan in Salohi region experienced 9% and 8% of total accidents on the stretch. While bridge locations had around 9% of total accidents.

Table 10.2: Accident proportion by Place

S. No.	Place	Region	Proportion of Total Accidents (%)
1.	Maithila	Dhanusha	17%
2.	Chandrapur	Rothat	15%
3.	Charnath	Dhanusha	11%
4.	Lalbandi	Salohi	9%
5.	Harivan	Salohi	8%
6.	Bridge Locations	Combined	9%

Dhanushdham, Bagmati, Maisthan, Bardiwas, Nijgarh, and Ishwarpur each had around 2% accidents occurrence seen while rest of around 58 locations had 1% or less than 1% accident occurrence of total number of accidents in last six fiscal years.

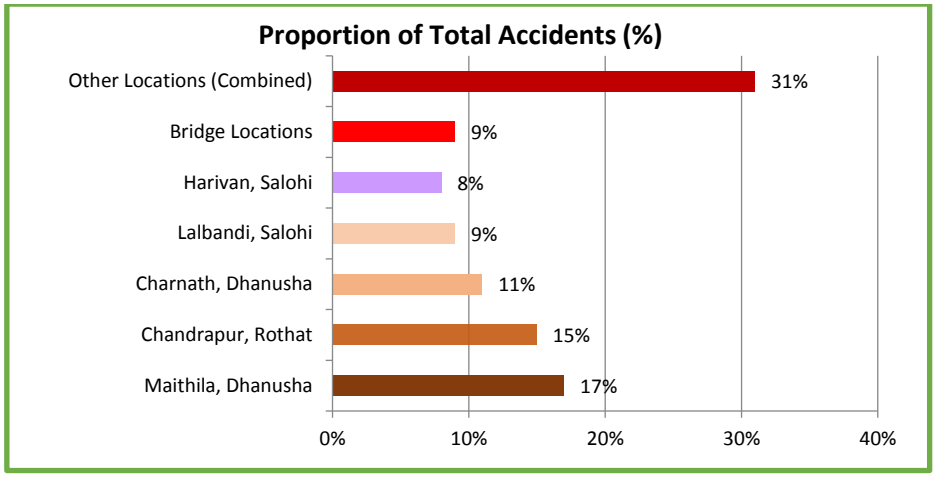


Figure 10.3: Proportion of Accidents by Place

It is also to be noted that VRUs (Vulnerable Road Users) are being the most affected in accidents with proportion of 55% (most of them are motorcycles) involved in accidents while 35% vehicular traffic involved in accidents.

Maithila, Chandrapur and Charnath locality seems to be accident hot-spots and special attention has been given in the proposed design for these locations in providing facilities in order to minimize accidents in design.

10.3.3 Narrow Bridges to be retained

There are total 76 existing bridges in the project stretch out of which 1 bridge (Dudhaura) is already under construction. Out of remaining 75 bridges 62 bridges have carriageway width of less than 7 m. Amongst these 62 bridges 43 bridges have been proposed to discard for future use and replace them with new bridges with sufficient carriageway width based on their locations either in rural areas or urban areas. 9 bridges have been proposed to be replaced by box culverts based on hydrological calculation with sufficient width for traffic movement. Only remaining 10 bridges will be retained for future traffic movement in one direction (i.e., two lane) but their carriageway width will be extended to 7 m by removing footpath over the bridges. There are 2 numbers of existing bridges viz. Ratu and Barahari with 7m wide carriageway width which have been proposed to be used as Service Road lanes.

The List of Narrow bridges having width less than 7m but to be widened to 7m during construction is provided in the **Table 10.3** below.

Table 10.3: Narrow Bridges to be Retained (High Risk)

Case – I Narrow Bridges to be Retained (High Risk)			
S. No.	Chainage	7m CW	< 7m CW
1.	237+022	Kamala Bridge	
2.	238+105	Kamala Canal Bridge	
3.	241+744	Charnath Bridge	
4.	245+228	Baluwa Bridge	
5.	250+760	Jagadev Branch Bridge	
6.	251+090	Jagadev Bridge	
7.	252+478	Jalad Bridge	
8.	254+663	Aurahi Bridge	
9.	256+186	Basai Bridge	
10.	268+310	Bhapsi Bridge	
11.	258+735		Sukhajor Bridge
12.	269+373		Atabbe Bridge
13.	270+871		Janga Pul-1
14.	271+145		Janga Pul-2
15.	271+514		Gadhanta Bridge
16.	277+266		Maraha Bridge
17.	278+913		Dholan Bridge
18.	281+990		Batuwa Bridge
19.	282+758		Bankhe Bridge
20.	290+215		Phuljor Bridge
21.	291+868		Kalinjor-1 Bridge
22.	292+705		Kalinjor-2 Bridge
23.	300+466		Lakhandei Bridge
24.	301+948		Chapani Bridge
25.	307+750		Rai Bridge
26.	310+015		Dumajor Bridge
27.	312+474		Bagmati East Bridge
28.	313+121		Bagmati Bridge
29.	313+815		Bagmati West Bridge
30.	314+170		Gairi Bridge
31.	317+685		Paurahi Bridge
32.	323+575		Kathi Ko Pul
33.	325+054		Chandi Bridge
34.	328+005		Jungle Tol
35.	332+798		Kathi Bridge
36.	333+733		Lamaha Bridge
37.	334+460		Kali Khola Bridge
38.	342+250		LamoPul
39.	343+570		Bhamara Bridge
40.	347+190		Bakeya Bridge
41.	354+638		Barahakilo Bridge
42.	357+205		Pasaha Bridge
43.	360+850		Balganga Bridge
44.	362+862		Baijura Bridge
45.	365+705		Tin Number Bridge

Out of the above list of bridges in Table-2, there are 6 bridges with narrow width, to be retained and proposed with service road. These shall be on very high risk of potential accident locations due to sudden merging of proposed one direction, two lane traffic with service road (approx. 17m) into narrow bridge (approx. 7m) in maximum 200m straight length. This scenario shall observe severe conflicts and may result in accidents. At the same time, it will greatly reduce the four lane capacity, thereby sudden reduction level of service (LOS). It shall also result in development of queue in such locations as there shall be no overtaking sight distance availability. This issue has been taken care of while providing solution specific to bridge and its location.

The table 10.4 below shows such bridges with narrow carriageway width, to be retained, as proposed and with proposed service road.

Table 10.4: Narrow Bridges to be retained with SR (Very High Risk)

Case – II Narrow Bridges to be Retained and with SR (Very High Risk)			
S. No.	**Chainage**	**7m CW**	**< 7m CW**
1.	237+323	Kamala Bridge	
2.	238+398	Kamala Canal Bridge	
3.	313+930		Bagmati East Bridge
4.	314+230		Bagmati West Bridge

10.3.4 Narrow Bridges Safety Measures based on Category

Table 10.5: Narrow Bridges Close to Curves / On Curve

Case – I Narrow Bridges Close to Curves / On Curve (High Risk - Visibility and Line of Sight Issue)

S. No.	Chainage	7m CW	< 7m CW
1.	237+022	Kamala Bridge	
2.	241+744	Charnath Bridge	
3.	245+228	Baluwa Bridge	
4.	250+760	Jagadev Branch Bridge	
5.	252+478	Jalad Bridge	
6.	313+121		Bagmati Bridge
7.	313+815		Bagmati West Bridge
8.	323+575		Kathi Ko Pul
9.	334+460		Kali Khola Bridge

Safety Measures:

1) Chevron Turn Signs,
2) No-U Turn Sign,
3) Object Hazard Marker Sign,
4) No- Overtaking Sign,
5) Narrow Bridge Sign,
6) Solid Pavement Marking on curve
7) Bar Marking
8) Applicable taper with delineation

Table 10.6: Narrow Bridges on Straight Portion

Case – II Narrow Bridges on Straight Portion (Low Risk)			
S. No.	**Chainage**	**7m CW**	**< 7m CW**
1.	238+105	Kamala Canal Bridge	
2.	251+090	Jagadev Bridge	
3.	251+090	Jagadev Bridge	
4.	254+663	Aurahi Bridge	
5.	256+186	Basai Bridge	
6.	268+310	Bhapsi Bridge	
7.	258+735		Sukhajor Bridge
8.	269+373		Atabbe Bridge
9.	270+871		Janga Pul-1
10.	271+514		Gadhanta Bridge
11.	277+266		Maraha Bridge
12.	278+913		Dholan Bridge
13.	281+990		Batuwa Bridge
14.	282+758		Bankhe Bridge
15.	290+215		Phuljor Bridge
16.	291+868		Kalinjor-1 Bridge
17.	292+705		Kalinjor-2 Bridge
18.	300+466		Lakhandei Bridge
19.	301+948		Chapani Bridge
20.	307+750		Rai Bridge
21.	310+015		Dumajor Bridge
22.	312+474		Bagmati East Bridge
23.	314+170		Gairi Bridge
24.	317+685		Paurahi Bridge
25.	325+054		Chandi Bridge
26.	328+005		Jungle Tol
27.	332+798		Kathi Bridge
28.	333+733		Lamaha Bridge
29.	342+250		LamoPul
30.	343+570		Bhamara Bridge
31.	347+190		Bakeya Bridge
32.	354+638		Barahakilo Bridge
33.	357+205		Pasaha Bridge
34.	360+850		Balganga Bridge
35.	362+862		Baijura Bridge
36.	365+705		Tin Number Bridge

Safety Measures:

1) Object Hazard Marker Sign,
2) No- Overtaking Sign,
3) Narrow Bridge Sign,
4) Bar Marking

Thereby looking above solutions, it may be inferred that proposed design shall minimize the risks of retained narrow bridges as well as may serve better level of service.

10.3.5 Road side Settlement and Ribbon Development

There were several road side settlements was found during site visit. Although the project highway was aligned away from the settlements during inception but gradually in due course of time, cultivated land near highway in village/town regions and /or side access roads had seen the change in land use to commercial / residential. This change in land-use or ribbon development along the highway has caused high risk of accident prone zones. These locations have been treated accident preventive measures including pedestrian Zebra crossings, refuge islands (in-case site permits), signages, markings and foot-over-bridge post relevant analysis. Specially pedestrians, cyclists, motorcyclist are susceptible to accidents in these locations. The significant settlements observed are as shown below:

Table 10.7: Settlement / Urbanized locations

S.N.	Place Name	Length, m
1	Goddard Bazar	1000
2	Ganesh Nath	1600
3	Ganesh Nath-5	200
4	Bhiman Bus stop	300
5	Dharapani Chowk	2200
6	Puspalpur Chowk	800
7	Dalmatia	700
8	Ram-Laxman Chowk	200
9	Radha Krishna Mandir Road	700
10	Dhalkebar	1200
11	Dhalkebar 400KV Substation Road	1600
12	Jamunibaas Bus stop	1000
13	Dhumasan Road BKS	200
14	Laalgadh	2400
15	Bardibas	2400
16	Gaushala	200
17	Banke station	400
18	Phuljhor	300
19	Ranigunj Chowk	1400
20	Laalbandi Chowk	2600
21	Nawalpur Chowk	1400

S.N.	Place Name	Length, m
22	Ganesh Chowk	600
23	Ganesh Chowk-2	600
24	Harion	3800
25	Naya Road	2800
26	PuranoChauki	1100
27	Karmaiya Road Junction	350
28	Kali Mandir	350
29	Chandrapur	2600
30	Chandranigahapur	2600
31	Nijgadh	3400
32	Dhansar	300
33	Pathalaiya	1300
	Sum	**42600**

10.3.6 Major and Minor Junctions

There are several major and minor junctions along the project stretch. The major junctions are Birendrabazar, Bhiman Bus stop, Dharapani chowk, RamLaxman chowk, Dhalkebar, Bardibas (Right), Bardibas (Let), Gaushala chowk, Lalbandi chowk, Harivan, Chapur (Chandranigahpur), Fast Track junction and Pathalaiya. The junctions are reviewed from traffic during RSA for their geometry and traffic conflicts. Junctions are reviewed and based on traffic density, geometry, turning movement counts, line of sight and accident history; recommendation have been made. Improvements of junctions have been finalized and designed accordingly. Like Dhalkebar and Pathalaiya junctions roundabout is improved and while at Bardiwas junction, Flyover is provided. This section has been detailed in the report in later portion.

10.3.7 Human behavior consideration

Human behaviour / psychology, being a prime factor in road safety, has been predominantly kept in mind while designing highway facilities, and prior to finalizing the geometrics. Drivers, no matter of which transportation mode, have always different level of perception (e.g. mental conditions during DUI), differing reaction times to a given situation and have different type of responses. Although these and responses to such other parameters don't have large deviation from mean. At the same time these responses also depends on type of vehicle and condition of vehicle including roadway condition.

Roadway conditions / geometrics etc. carefully designed adopting best practices and codes (that includes international codes too), in order to best align large driver population mean behaviour for ensuring safe and smooth mobility on project highway.

10.3.8 Sharp Curves and Poor Line of Sight

Sharp curves are very unsafe especially in the night time since they do not have proper curve delineation. Also curves on high embankments without delineation and barrier protection to check vehicle run-off at high speed on curves are on very high risk and modified on priority. Sharp curves and other obstructions like trees and corner buildings also hinder proper visibility and restrict safe sight distances for stopping and overtaking.

Safety Solution for locations at Sharp Curves and Poor Line of Sight:

1) Delineation
2) Speed reduction
3) Signage and marking

Location and Quantities of Protection Barriers (MBCB):

S. No.	Crash Barriers	Length
1	MBCB at embankment more than 3 m high, m	62866.40
2	MBCB at TCS 4, TCS 5 and TCS 6, m	25201.6
3	Concrete Crash barrier at VUP approaches, m	17315

10.4 Geometric Layout of Proposed Highway

The project highway has been designed for the speed limit of 100 kmph and specifications and codes used for the same are detailed in the last section of this report. Alignment has been designed based on the available right of way of 50m and aligning with existing geometry to the maximum extent possible. For attaining the design speed of 100 kmph and maintaining the safe stopping sight distance of 180m and intermediate sight distance of 360m; curve improvements have been made with few exceptions where land acquisition constraints persists. Following are the curves designed for the alignment.

Table 10.8: Curve Statistics on Project Highway

S. No.	Radius (m)	Length of Curve (m)	Frequency of Curve Occurrence (Nos.)	Percent frequency of Curve Occurrence	Percent Length
1	12000	314	1	1%	0.79%
2	10000	34	1	1%	0.09%
3	8000	321	5	3%	0.80%
8	5000	3,423	8	5%	8.57%
16	4000	779	3	2%	1.95%
19	3400	736	1	1%	1.84%

S. No.	Radius (m)	Length of Curve (m)	Frequency of Curve Occurrence (Nos.)	Percent frequency of Curve Occurrence	Percent Length
20	3200	1,288	1	1%	3.22%
21	3100	1,406	1	1%	3.52%
22	3000	4,933	34	21%	12.35%
56	2800	1,373	1	1%	3.44%
57	2600	2,193	2	1%	5.49%
59	2550	1,402	1	1%	3.51%
60	2500	615	3	2%	1.54%
63	2400	1,077	1	1%	2.70%
64	2300	447	1	1%	1.12%
65	2250	223	5	3%	0.56%
70	2220	1,949	1	1%	4.88%
71	2200	95	2	1%	0.24%
73	2000	6,218	51	31%	15.56%
124	1850	279	1	1%	0.70%
125	1500	1,367	2	1%	3.42%
127	1000	1,913	11	7%	4.79%
138	980	699	1	1%	1.75%
139	710	639	1	1%	1.60%
140	700	352	1	1%	0.88%
141	600	132	1	1%	0.33%
142	550	523	3	2%	1.31%
145	530	159	1	1%	0.40%
146	500	3,490	11	7%	8.73%
157	490	461	1	1%	1.15%
158	465	348	1	1%	0.87%
159	400	396	2	1%	0.99%
161	370	135	1	1%	0.34%
162	160	101	1	1%	0.25%
163	80	136	1	1%	0.34%

As per Nepal Road Standard – 2070, 370m is the minimum radius with max. superelevation while 530m is the minima from passenger comfort criteria. While IRC: SP 84, allows 400m desirable minimum and 250m as absolute minimum radius in plain and rolling terrain.

Geometric alignment of the project highway has been designed having almost 85% curves with radius >900m, 97% curves with radius >450m and around 3% curves (2% in terms of length) of radius <=400m.

Safety measures for curves with radius <=400m:

a. Crash Barrier on outer side of curve,
b. Chevron Turn Signs,
c. No-Over taking signs,
d. Solid Lane Markings

e. Curve Delineation

Curves of radius 2000m covers 51 locations (31%) with 15.56% of total curve length, which is good from high speed traffic safety viewpoint.

Few locations had design restrictions specifically due to land constraints and had to be designed with compromised speed. The said locations are mentioned table 9.

There is a location on the highway near Dhalkebar intersection, having sharp curve. This is being currently not improved due to non-availability of land. But due to existing sharp curve turn alignment and non-availability of land, the Dhalkebar intersection has been designed for very small radius S-curve compromising the safety and defying the very intent of the proposed highway.

This section of proposed highway, shall bring an unpleasant and kind of unwelcome surprise for the driver. It shall un-intentionally add to non-uniformity, dis-continuity and hence dis-comfort for the drivers. This sudden, un-expected and abrupt change in highway geometry shall pose a safety threat for the traffic in this portion. This section may become a crash spot and on very high risk. The proposed speed at this region has been reduced drastically to 40 kmph from 100 kmph with a S-curve. It is highly recommended to propose a re-alignment in order to avoid existing curve deficiency and hence crash susceptibility near Dhalkebar intersection.

Appropriate safety treatment has been provided at this intersection and has been entailed in section 10.5.

All the curves having radius up to 450m and all high embankments with height 3m or more are being provided with safety barriers for protection against vehicle run-off from the highway.

Vertical curves have been introduced in flyovers, VUPs / PUPs generally. Other portions is mostly on plain and rolling terrain and all natural topography, wherever needed, has been tweaked to adjust vertical curves in order to maintain adequate clear sight distances, safety and comfort as per specifications and codes. Rest of the alignment geometry shall perform well from road safety context.

Locations of narrow bridges that need to be retained; alongside providing appropriate safety measures, a taper of 1 in 50 and a minimum of 1 in 20 has been used as per IRC: SP 84 to gradually merge or diverge from and to proposed highway.

10.5 Speed Management and Control

Although the project highway has been designed for speed of 100 kmph with exceptions at some locations due to land constraints; the speed management and control of high speed rash driving especially in urban sections is pertinent and of utmost importance for minimizing crash susceptibility and crash severity.

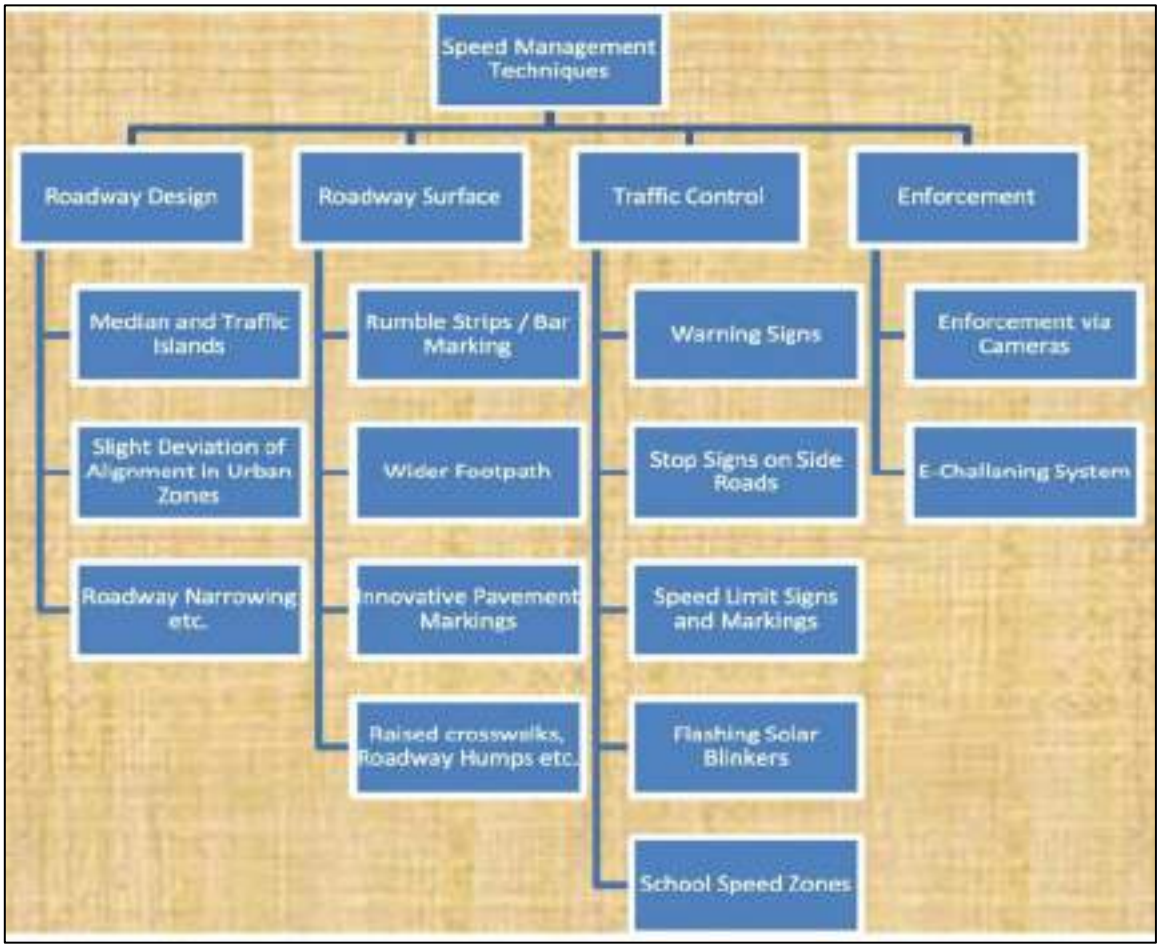


Figure 10.4: Speed Management Techniques

Over speeding is the characteristic / attitude of driver who exceeds the legal speed limit of given highway. Speed mostly don't allow driver the required space and time to respond to a conflict and the things gets more severe in case there is flaw in the design or if one of the candidates involved accident is errant and traffic rules' violator.

Speeding is a complex problem, involving the interaction of many factors including public attitudes, road user behaviour, vehicle performance, roadway design and characteristics, posted speed limits and enforcement strategies. Accordingly, an interdisciplinary approach involving engineering, enforcement, and education is needed to reduce speeding-related crashes, fatalities and injuries. This comprehensive approach is speed management.

Speed management involves a balanced effort: defining the relationship between speed, speeding and safety; applying road design and engineering measures to obtain appropriate speeds; setting speed limits that are safe and reasonable; applying enforcement efforts and appropriate technology that effectively targets crash producing speeders and deters speeding; effectively marketing communication and educational messages that focus on high-risk drivers; and, soliciting the cooperation, support and leadership of traffic safety stakeholders.

As it is evident that speed plays the major role among factors contributing to crash occurrence and the crash severity. Hence speed management and control strategy has been developed and must be implemented on the project highway to make sure that the project highway is safe once upgraded.

Speed management and control measures adopted on the proposed highway are as below:

1. Reduced speed regulation specific zones
2. Traffic calming techniques
3. Traffic regulatory signage like stop, yield, side road etc.
4. Roadway design
5. Public awareness
6. Law enforcement

Reduced speed regulation specific zones

Along the project road, speed reduction zones have been identified and shall be regulated by fixing reduced speed signage for speed control. The reduced speed zones and normal speed zones are tabulated below:

Table 10.9: Reduced Speed Locations

S. No.	Chainage (Km)	Restricted Speed Limit (Kmph)	Region
1	245+300 – 245+600	75	After Baluwa bridge
2	256+950-257+450	40	Dhalkebar
3	274+600-275+200	75	Belgachi
4	301+300 -301+900	75	Chapani
5	339+400- 339+800	75	Dhansar
6	357+300-357+500	75	Pasaha

Traffic calming techniques

There are methods of alerting the drivers of probable hazard ahead. Some of them have been proposed along the project highway in order to control speeding in urban areas / settlement areas, narrow bridges, geometrically compromised locations etc. some of the methods are given below;

- Bar marking / Rumble strips
- Zig zag hazard marking
- Footpaths with steel railing
- RRPM across the roadway
- Yellow Box marking at At-Grade junctions
- Gateway effect

The schematic layout showing bar marking to be applied on the Road as per IRC 35 is presented vide **Figure 10.5** below.

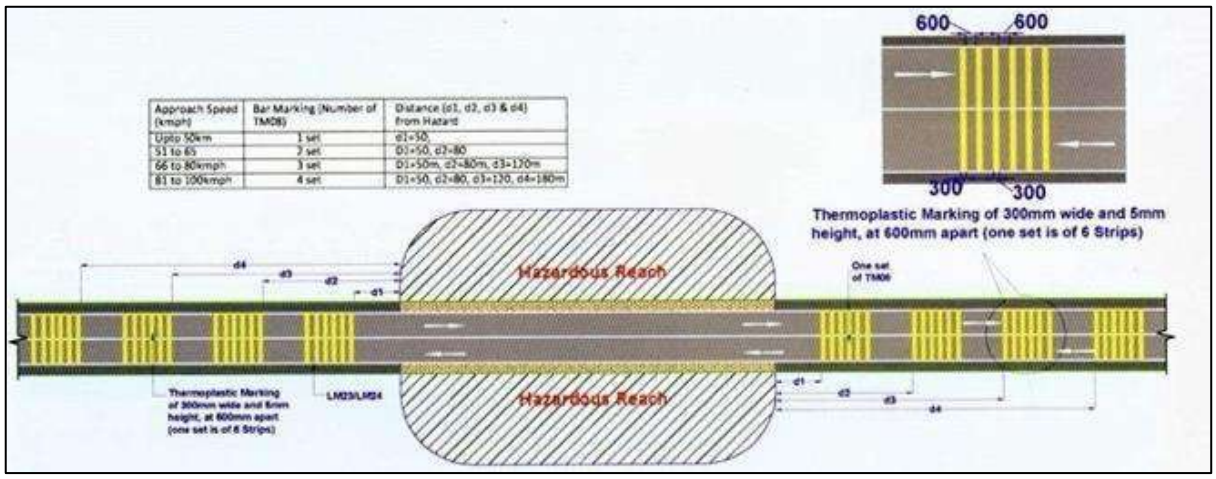


Figure 10.5: Bar Marking in Hazardous Locations (Source: IRC-35)

Thermoplastic Bar marking (as shown in figure 5) along with RRPM (Retro-reflectorized Raised Pavement Marker) at the end of last set (across the traffic movement) have been provided both sides of hazardous reaches like Dhalkebar, Narrow bridges, Urban / Settlement zones, dangerous curves and other such locations.

Pedestrian footpath with or without railing in urban and habituated / settlement zones, also works as speed reduction treatment while providing safe refuge and mobility for the pedestrian and physically disadvantaged. Footpaths along with steel railing and ramps (at major junctions only) provided in the following areas.

Table 10.10: Locations where Footpath is provided

Kamala Bridge, Portaha, Goddar
Birendra Bazar
Dharapani, Kanchhi Bazar
Puspalpur, Lalbhitti
Dhalkebar Flyover
Jamunibas
Bardibas
Raniganj, Saralahi
Laalbandi, Sarlahi
Nawalpur
Harion
Rautahat
Chapur
Lachaktol, Nijgadh Bazar
Pathlaiya

Retro-reflectorized raised pavement markers (RRPM) shall be provided on start of grade-separators, flyovers, bridges, taper sections at both end of narrow bridges, end of last set of bar markings – across the traffic movement (additional may also be provided for extra effect), junctions, both sides of zebra crossings and at curves.

Retro-reflectorized raised pavement markers (RRPM) shall be provided on start of grade-separators, flyovers, bridges, taper sections at both end of narrow bridges, end of last set of bar markings – across the traffic movement (additional may also be provided for extra effect), junctions, both sides of zebra crossings and at curves. The RRPM Treatment proposed on curve locations is presented vide **Figure 10.6** below.

Figure 10.6: RRPM Treatment on Curves, Junctions and Hazard locations

RRPM Location:

S. No.	Road Studs	Nos.	Total
1	Cat eye		5387
	a) On the bridge portion, 9m c/c	1316	
	b) on the 200 approaches of bridges, 18m c/c	3378	
	c) at the taper section of 6 lane to 4 lane, 9m c/c	693	
2	Median marker as per IRC 79-2019 (Fig. 7)	25897.4	25897

Yellow box markings may also be provided at At-Grade junctions to convey message to drivers to slow down and no-stopping at the junction. It also serves the purpose to alert drivers of possible hazard location. Its prohibitory type marking. The typical layout showing Prohibitory yellow marking at junction locations is presented vide **Figure 10.7** below

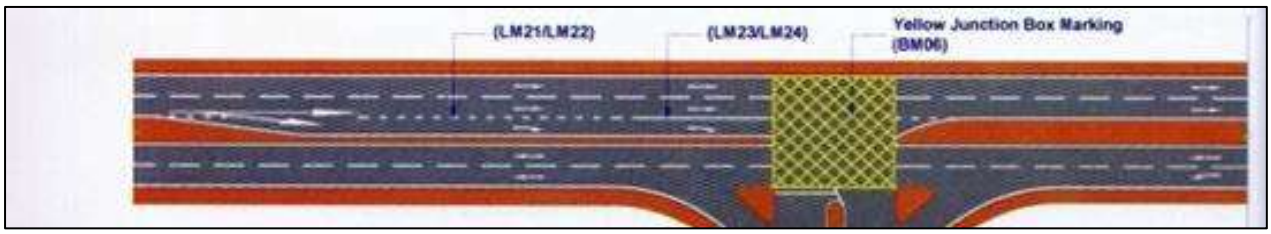


Figure 10.7: Prohibitory Yellow Junction Markings

All the above treatments including others near hazard location works as Gateway treatment. Gateway treatment may include pavement markings, signage, landscaping, footpaths, steel railings etc. This treatment is generally implemented at the beginning of any hazard location or zones where non-motorized traffic and vulnerable road users (VRUs) volume is significant compared to through traffic volume.

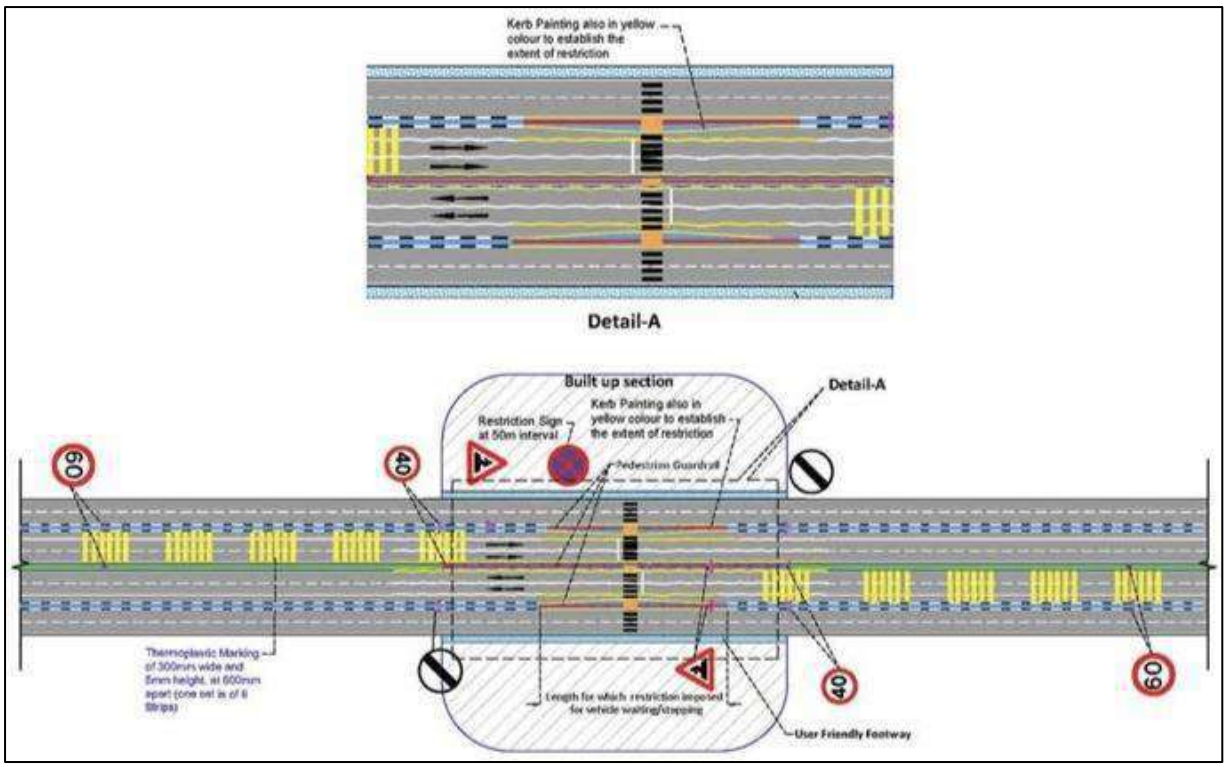


Figure 10.8: Gateway Treatment

Traffic Regulatory Signage

As evident from the name, traffic regulatory signage are used to reinforce, or designate traffic rules, regulations, requirements which either works all times or specific times. The disregard of these signage should be contemplated as traffic rule violation. Traffic regulatory signage like Yield, Stop, and Give Way signs, Speed limit and Vehicle control signs, Prohibitory signs, Compulsory direction signs, No Parking signs works as regulating the traffic and also tends to control speeding. These shall be provided along the highway as per specifications and requirement of site.

Road Design

Project highway has been designed considering traffic safety as the prime factor while all other parameters been taken as sub-sets to traffic safety. Mainly project highway has been designed for enhancing mobility, saving travel time, boosting more accessibility, and comfort for the users. While traffic safety been treated as the super-set of all these and other design parameters.

- Mobility
- Accessibility
- Time saving and

- Comfort

The relation among these and other design factors can be understood from the **Figure 10.9** given below, wherein the funnel depicts the Traffic Safety under which all the design parameter used to pour-out the final roadway design;

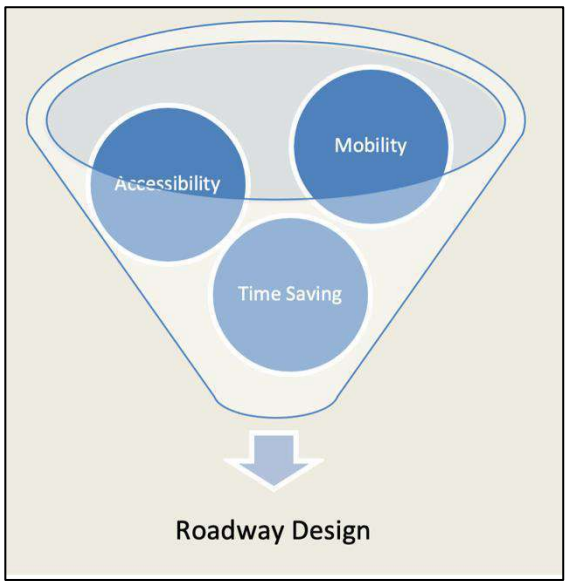


Figure 10.9: Safety Funnel for roadway design

The project highway has been designed such that it tends to calm traffic at sensitive locations and avoid over-speeding. Such measures are design of entry / exits, median openings, storage lanes, footpaths etc.

Lastly public awareness and law enforcement, although is not the part of design but serves deep impact on checking speeding on the highway.

10.6 Access Realization and Control

The primary goal of designing a highway or roadway is providing and enhancing accessibility and connectivity of urban conglomerates. Although for high speed roadways, like our designed Kamala-Dhalkebar-Pathlaiya project highway, mobility factor supersedes the accessibility as high speed roadways are designed for connecting major urban centres and business districts and weighs more on speed, time and mobility.

Local small urban areas, villages and other significantly populated zones were studied and also social impact studies were referred to assess the accessibility requirement along the project highway.

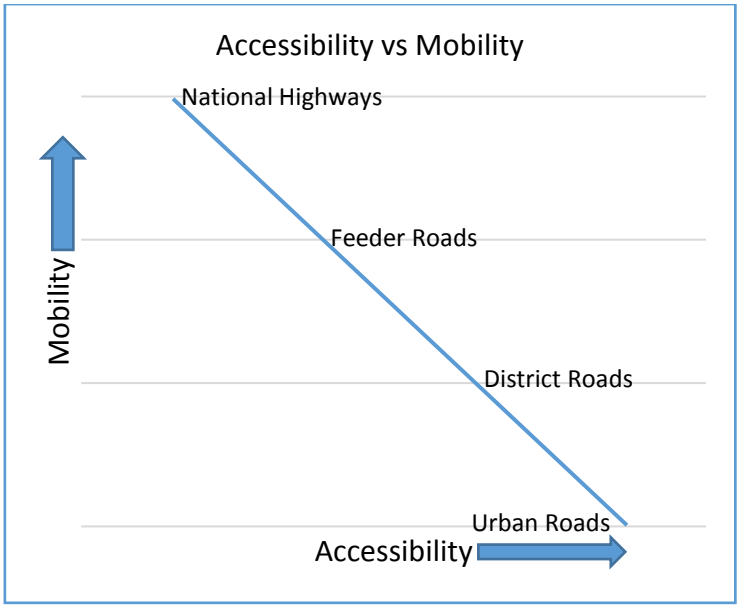


Figure 10.10: Accessibility and Mobility

During the design of the project highway; lower population and low density areas like semi-urban centres, big villages etc. have been properly and safely connected from main highway via design of minor junctions, major junctions, service roads and grade separators. This way issue of accessibility been addressed adequately on the project highway.

But when a road is made highly accessible, issue of deficient mobility comes into picture and at the same time design standards deviates to allow low speed inter-connecting roadway design. The safety guidelines also changes from that of high speed-lower accessibility roadway to low speed-high accessibility roadway. It is to be understood that in rural context gaining access to business, goods, and contacts will often require a lot of mobility while on contrary in urban context, accessibility to various needs generally involve shorter length trips and hence lesser mobility.

10.6.1 Intersections

The project highway has been suitably designed to cater the need of user in the context of accessibility and mobility. While highway has been designed for faster mobility (designed for speed 100 kmph and posted speed maximum 80 kmph), accessibility to surrounding business areas, urban conglomerates, and villages has been assured via designing service roads, slip roads, entry / exits, flyovers, vehicular underpass, pedestrian underpass, foot-over-bridges, zebra crossings and also design of major and minor junctions etc.

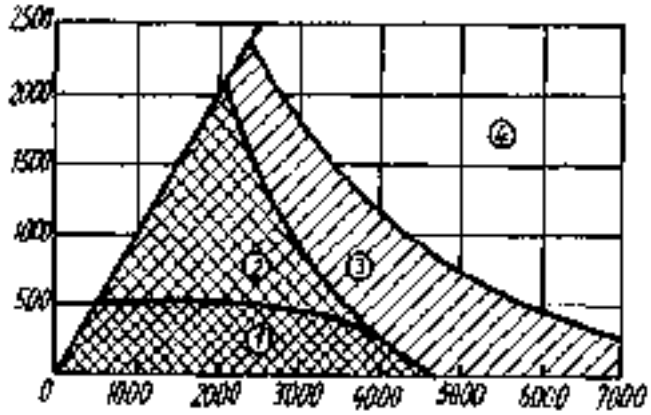
10.6.1.1 Intersection Design

Intersections on highways are points of accessibility / connectivity to adjoining community, villages, businesses, and contacts. Intersections are generally a major bottleneck to smooth flow of traffic and may become a major accident spot. They are the critical element of roadway design and their design depends on several factors. Design factors are given below;

Table 10.11: Intersection design factors

S. No.	Design Factors	Sub-Factors
1	Human factors	- Driving habits - Ability in taking decisions - Reaction time - Pedestrian use and habits
2	Traffic considerations	- Design and actual capacity - Design hour turning movement - Size and operating characteristics of vehicles - Types of movements - Vehicle speed - Public transit movement - Traffic mix
3	Road and environmental considerations	- Character and use of abutting property - Vertical and horizontal alignment at intersection - Sight distance - Angle of intersection - Conflict area - Geometric features - Traffic control devices - Lighting equipment - Safety features - Environmental conditions

Intersections on the project highway have designed considering the above factors and the traffic volume on the highway and turning traffic volume. The traffic count have been done and peak PCU (Passenger car units) calculated. Nepal Road Standard - 2070 has been referred for the design of intersections.



1. Simple intersection
2. With channelizing islands on secondary road
3. With channelizing islands on both roads
4. Grade separated intersections

ADT on Main Highway, PCU

Figure 10.11: Graph for Selection of Intersection type

Following points were kept in mind while designing the intersections;

- Uniformity and simplicity
- Minimise conflict points and potential severity of conflicts. General 4 arm junctions have 32 conflicts points. These may be reduced by introducing either 'space separation' or 'time separation' of traffic at the given intersection. The project highway shall not adopt time separation (signalized) because stopping the main carriageway traffic to complete halt may defeat the purpose of the improving level of service of the project road. Hence space separation (grade or at grade intersection design) method has been adopted.
- Cross road traffic shall be either 'STOP 'controlled or shall 'YEILD / GIVEWAY' to main project highway traffic depending on the availability of land for the provision of slip road / acceleration lane.
- Visibility funnel / clear intersection sight distances (IRC: 35) shall be ensured in case non-availability of land for dedicated deceleration / acceleration lanes.

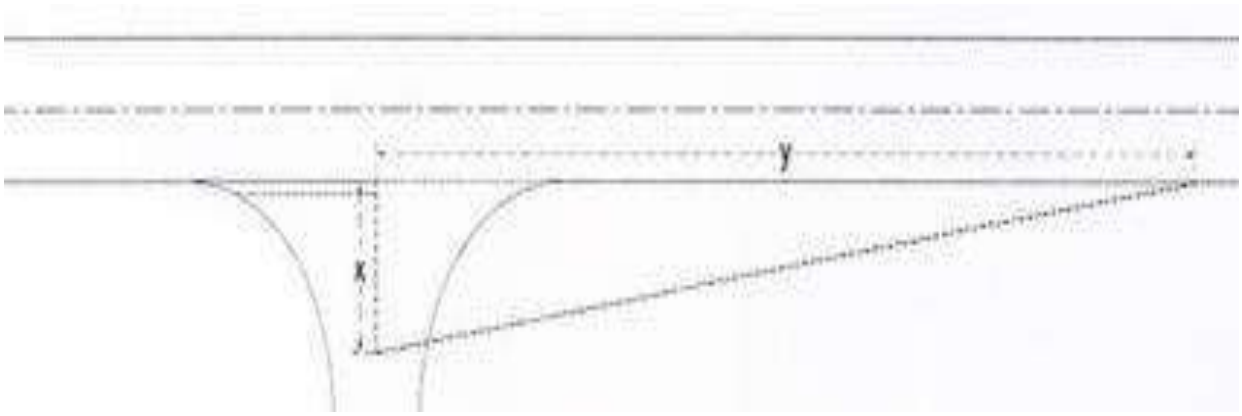


Figure 10.12: Visibility Funnel for Clear Line of Sight at Intersections

Where Y shall be fixed at 90m and X at 4.5 to 3m for the design speed of 100kmph of the project highway.

- Alignment to be straight and gradient not more than 2% has been ensured.
- Intersecting road at junction shall be corrected for grade so that minimum 30m is of the same level as that of main carriageway. The figure explaining grade correction criteria for cross road is presented as **Figure 10.13** below

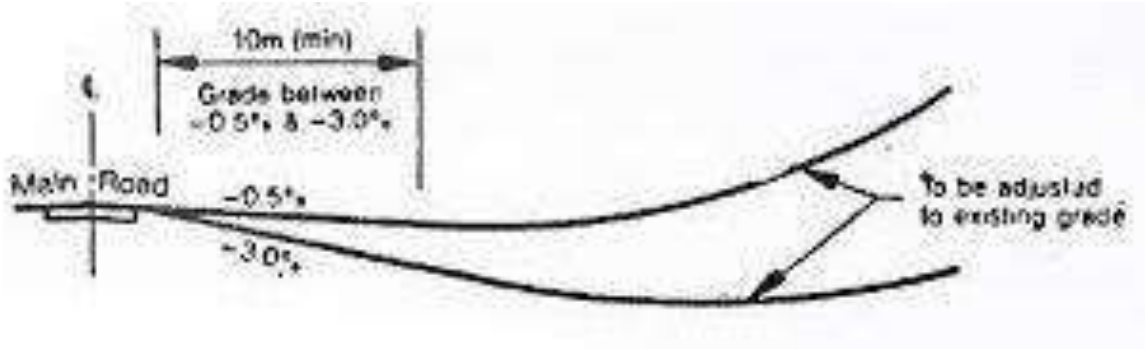


Figure 10.13: Grade correction of cross road

- The sight distance shall be at best adopted as at least twice the safe stopping sight distance.
- Cross roads shall be made as perpendicular as possible to the main carriageway. The arrangement for cross road to be proposed perpendicular to main road is provided vide **Figure 10.15** below

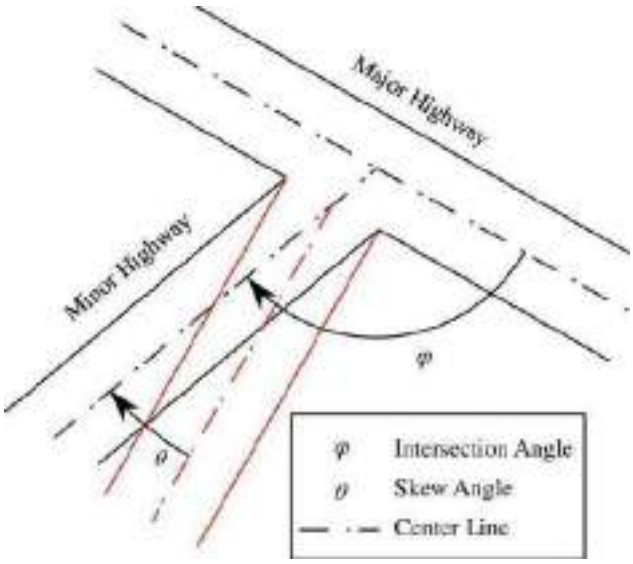


Figure 10.14: Aligning cross road

- Channelizing islands, in case designed, shall start from the edge of paved shoulder.

- Storage lanes in median for right / U turn shall not be less than 55m with taper of 25m. Length of storage lane shall be increased to cater peak hour turning traffic volume.
- Traffic control devices shall be provided on intersections as suggested by IRC: 35 for pavement markings and Traffic signs manual for signages.
- Deceleration and acceleration lanes shall be worked out based on guidelines suggested in Nepal Road Standards – 2070.

10.6.1.2 Major Intersection – Layout and Details

Major intersections on the project highway have been identified based on the traffic survey and subsequent analysis. The traffic density of cross roads and that of main highway was the basis of selection of type of intersection. **Table 10.12** below shows the list of major junctions on the project highway including that of grade separated intersections.

Table 10.12: List of Major Intersections

S.N.	Location	Chainage	Intersection Type
1	Goddar Bazar	239+740	Four Legged
2	Birendra Bazar-1	243+640	**VUP+2PUP**
3	Bhiman Chowk	246+250	Four Legged
4	Dharapani Chowk	247+650	Four Legged
5	Kanxi Bazar	248+730	Four Legged
6	Puspalpur Chowk	252+050	Four Legged
7	Laalbhiti Chowk	254+000	Four Legged
8	Shreepur Chowk	255+100	Four Legged
9	Dhalkebar	257+250	**Roundabout**
10	Dhalkebar 400KV Substation Road	258+180	Four Legged
11	Jamunibaas Bus Stop	259+800	Four Legged
12	Bardibas	267+100 to 267+300	**At Grade**
13	Ranigunj Chowk	291+300	Four Legged
14	Laalbandi Chowk-1	294+200	**VUP+2PUP**
15	Nawalpur Chowk	299+540	**VUP+2PUP**
16	Hariwan	303+000	Four Legged
17	Hariwan Bazar	304+190	**VUP+2PUP**
18	Naya Road	307+050	**VUP+2PUP**
19	Karmaiya Road Junction	311+900	Four Legged
20	Bagmati River Bridge	313+400	Four Legged
21	Chapur	326+560	**At Grade**
22	Nijgadh	345+000	Four Legged

S.N.	Location	Chainage	Intersection Type
23	Nijgadh-1	345+300	**At Grade**
24	Nijgadh-2	346+050	Four Legged
25	Fast Track Junction	348+600	**Interchange**
26	Dhansar	357+850	T-Junction
27	Pathlaiya Junction	367+000	**Roundabout**

Total of twenty seven (27) major junctions were identified and five (05) of these have been proposed as grade separated intersections as shown in table 12. Rest of the seventeen major intersections have been designed at-grade.

Typical layouts of various major intersections have been shown in figures below (***Please refer to drawings and quantity section for precise type of signage, markings and locations***);

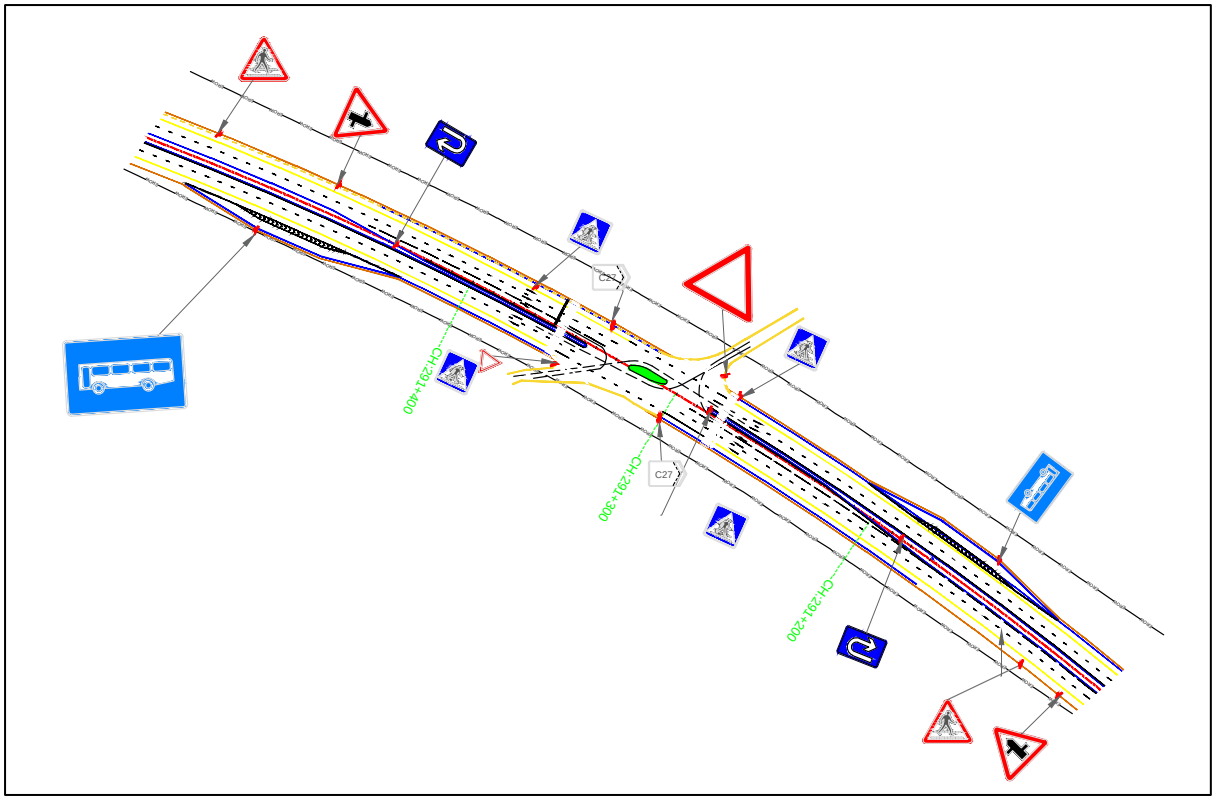


Figure 10.15: 4-Legged Intersection (Km 291+300)

In order to minimize right angle conflicts, which are having higher degree of accident probability and crash severity, At-grade major intersections have been designed with U-Turn manoeuvre both side for 4-legged junction as shown in figure 15 & 16. It allows gradual merging, diverging and again merging and diverging after U-Turn manoeuvre.

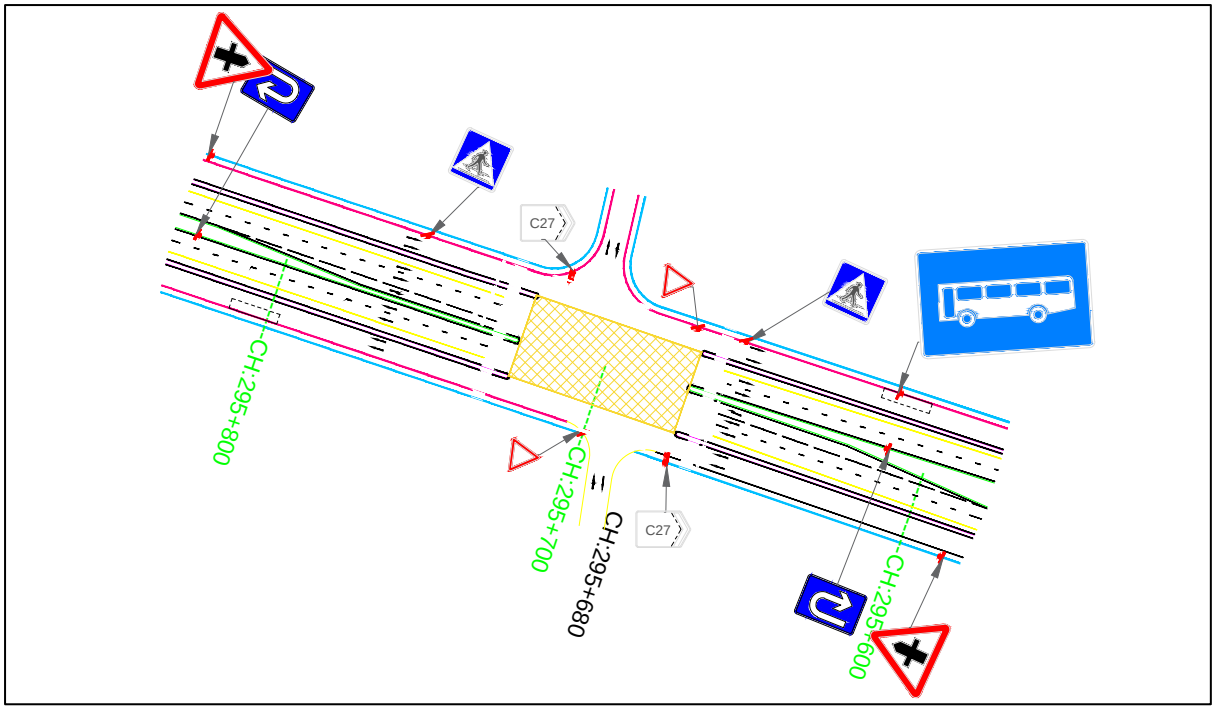


Figure 10.16: 4-Legged Intersection (Km 295+680)

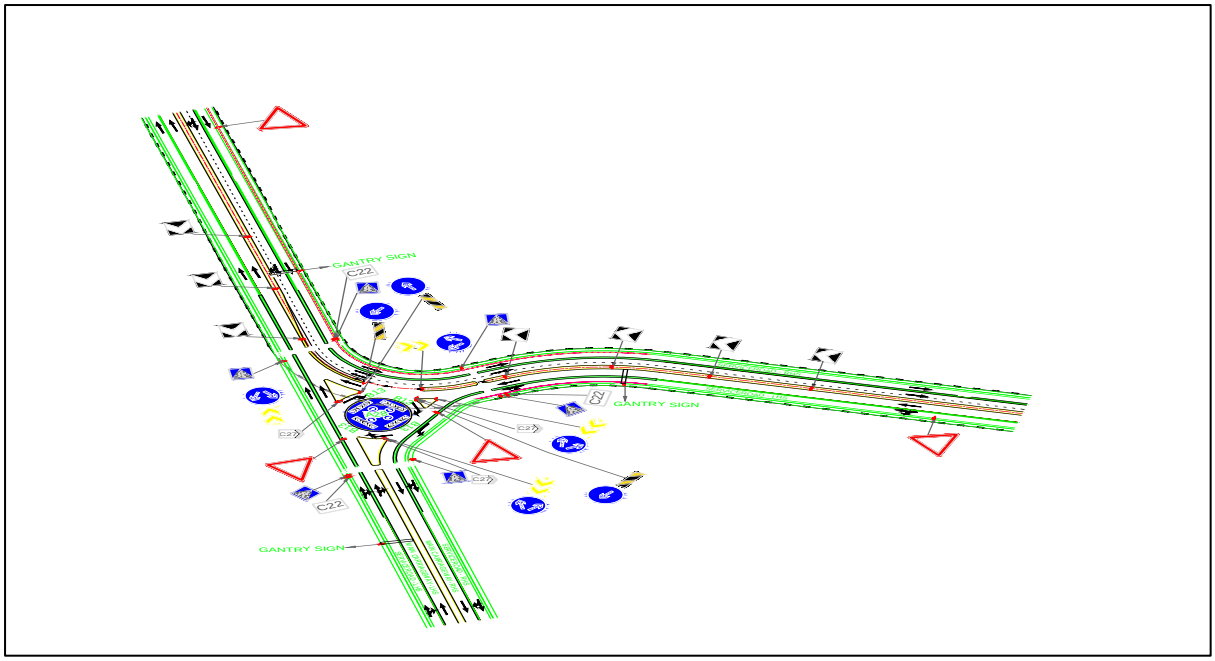


Figure 10.17: Dhalkebar Intersection

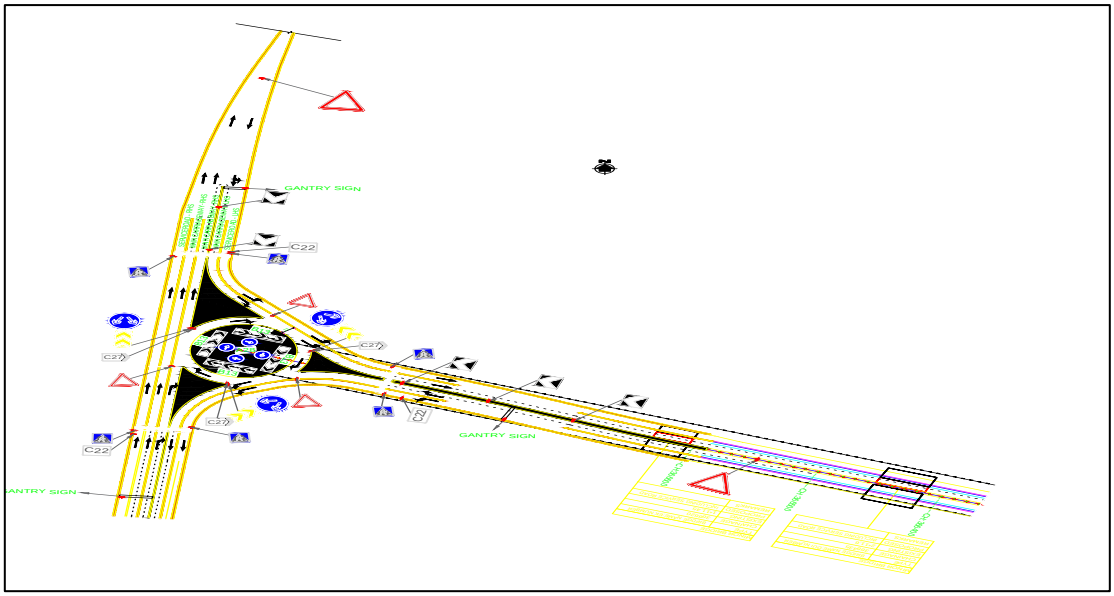


Figure 10.18: Pathlaiya Intersection

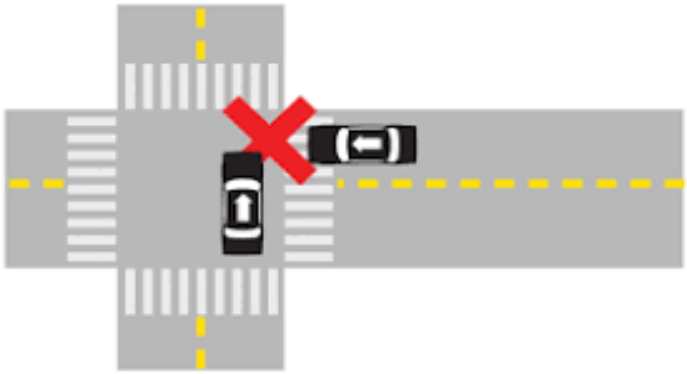


Figure 10.19: Conflict to be avoided

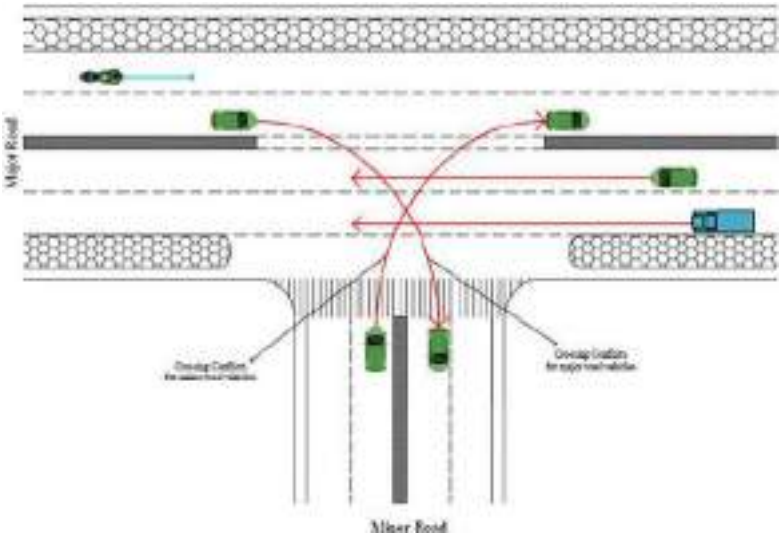


Figure 10.20: Typical Layout of Minor Junction

10.6.1.3 Minor Intersection – Details and Typical Layouts

Warrants for design of minor intersections are identical with that of major intersections.. The only exception is comparatively far less traffic density and fewer turning movements leading to milder traffic conflicts.

Below is the list of minor junctions identified on the project highway. These minor intersections shall be improved as per the guidelines provided in Nepal Road Standards and IRC: SP-84.

Table 10.13: List of Minor Intersections

S.N.	Chainage	Access		S.N.	Chainage	Access	
		Left	Right			Left	Right
1	238+050	1		28	244+700	1	
2	238+075		1	29	244+700		1
3	238+150	1		30	245+000	1	
4	238+175		1	31	245+400	1	
5	238+400		1	32	245+600	1	
6	238+750	1		33	245+700	1	
7	238+900	1		34	246+625	1	
8	238+925		1	35	246+625		1
9	239+350	1		36	246+850	1	
10	239+450	1		37	246+850		1
11	239+550	1		38	247+000	1	
12	239+850		1	39	247+250		1
13	239+900		1	40	247+300	1	
14	240+350		1	41	248+000		1
15	240+650		1	42	248+150	1	
16	240+750		1	43	248+400	1	
17	241+100	1		44	249+100		1
18	241+575		1	45	249+300		1
19	242+650		1	46	249+500	1	
20	242+750	1		47	249+800	1	
21	242+850		1	48	249+900	1	
22	242+925	1		49	250+200		1
23	243+250		1	50	250+750	1	
24	244+050	1		51	251+200	1	
25	244+250	1		52	251+200		1
26	244+325		1	53	251+500	1	
27	244+300	1		54	251+500		1

S.N.	Chainage	Access		S.N.	Chainage	Access	
		Left	Right			Left	Right
55	251+850	1		85	263+900	1	
56	251+900		1	86	263+200		1
57	252+875	1		87	263+200	1	
58	252+875		1	88	264+350	1	
59	253+200	1		89	264+675	1	
60	253+350		1	90	264+675		1
61	255+900	1		91	264+900	1	
62	255+900		1	92	264+900		1
63	256+650	1		93	265+500	1	
64	256+650		1	94	265+500		1
65	257+050	1		95	265+850		1
66	257+050		1	96	265+950	1	
67	257+600	1		97	266+000		1
68	257+800	1		98	266+300		1
69	258+000		1	99	266+500	1	
70	258+700	1		100	266+500		1
71	258+700		1	101	266+700	1	
72	260+425	1		102	266+700		1
73	261+050	1		103	266+800	1	
74	261+100		1	104	266+800		1
75	261+300	1		105	267+000	1	
76	261+450	1		106	267+000		1
77	261+450		1	107	267+175	1	
78	261+550	1		108	267+250		1
79	261+850		1	109	267+300	1	
80	262+350	1		110	267+300		1
81	262+350		1	111	267+450	1	
82	262+750	1		112	267+450		1
83	262+900		1	113	267+700	1	
84	263+650	1		114	267+700		1

S.N.	Chainage	Access		S.N.	Chainage	Access	
		Left	Right			Left	Right
115	267+900	1		146	291+800		1
116	267+900		1	147	291+900	1	
117	268+100	1		148	292+250	1	
118	268+100		1	149	292+250		1
119	268+875		1	150	293+000		1
120	269+750		1	151	293+375	1	
121	270+350		1	152	293+725	1	
122	271+000	1		153	293+725		1
123	271+375	1		154	294+000	1	
124	271+375		1	155	294+000		1
125	272+150		1	156	294+550	1	
126	275+300	1		157	294+550		1

S.N.	Chainage	Access		S.N.	Chainage	Access	
		Left	Right			Left	Right
127	275+300		1	158	294+700	1	
128	279+300	1		159	295+150		1
129	279+300		1	160	295+350	1	
130	279+950	1		161	295+350		1
131	281+500	1		162	296+200	1	
132	282+600		1	163	296+200		1
133	283+200	1		164	297+100	1	
134	283+500		1	165	297+100		1
135	284+775	1		166	298+850	1	
136	287+250	1		167	299+100		1
137	288+200	1		168	299+100	1	
138	289+250	1		169	299+200	1	
139	289+250		1	170	299+350		1
140	289+850	1		171	299+700	1	
141	289+850		1	172	299+850	1	
142	290+100	1		173	300+050	1	
143	290+600	1		174	300+300	1	
144	290+700		1	175	300+300		1
145	291+800	1		176	300+750	1	

S.N.	Chainage	Access		S.N.	Chainage	Access	
		Left	Right			Left	Right
177	300+750		1	206	305+950		1
178	301+300	1		207	306+050	1	
179	301+300		1	208	306+250		1
180	301+650	1		209	306+350	1	
181	301+650		1	210	306+520		1
182	301+800	1		211	306+520	1	
183	302+000	1		212	306+720		1
184	302+150	1		213	306+910		1
185	302+150		1	214	307+180	1	
186	302+300	1		215	307+370	1	
187	302+300		1	216	307+370		1
188	302+800		1	217	307+970	1	
189	302+850	1		218	307+970		1
190	302+900		1	219	308+440	1	
191	303+250	1		220	308+500		1
192	303+250		1	221	308+600	1	
193	303+400	1		222	308+710		1
194	303+400		1	223	309+040		1
195	303+700	1		224	309+380	1	
196	303+700		1	225	309+580		1
197	303+900		1	226	309+850	1	
198	304+500	1		227	309+850		1
199	304+500		1	228	309+980	1	
200	305+000	1		229	310+020	1	

S.N.	Chainage	Access		S.N.	Chainage	Access	
		Left	Right			Left	Right
201	305+300	1		230	310+020		1
202	305+300		1	231	310+070	1	
203	305+400	1		232	310+100		1
204	305+625	1		233	310+370	1	
205	305+725	1		234	310+370		1

S.N.	Chainage	Access		S.N.	Chainage	Access	
		Left	Right			Left	Right
235	310+550	1		266	314+710	1	
236	310+790		1	267	314+850	1	
237	310+810		1	268	315+070	1	
238	311+200		1	269	315+400		1
239	311+450	1		270	315+800	1	
240	311+500	1		271	317+400		1
241	311+550		1	272	324+550		1
242	312+020		1	273	324+600	1	
243	312+070		1	274	324+740		1
244	312+070	1		275	325+120	1	
245	312+140		1	276	325+280		1
246	312+170	1		277	325+440	1	
247	312+220		1	278	325+477		1
248	312+300	1		279	325+680	1	
249	312+300		1	280	325+830		1
250	312+450	1		281	326+030	1	
251	312+450		1	282	326+160	1	
252	312+500	1		283	326+160		1
253	312+550		1	284	326+270	1	
254	312+790	1		285	326+270		1
255	312+840	1		286	326+340	1	
256	312+910	1		287	326+350		1
257	313+300	1		288	326+450	1	
258	313+310		1	289	326+450		1
259	313+790	1		290	326+690	1	
260	313+790		1	291	326+730	1	
261	313+830		1	292	326+740	1	
262	313+860		1	293	326+740		1
263	314+250	1		294	326+840		1
264	314+430	1		295	326+900	1	
265	314+570	1		296	326+900		1

S.N.	Chainage	Access		S.N.	Chainage	Access	
		Left	Right			Left	Right
297	327+010	1		321	344+550	1	
298	327+020		1	322	344+570		1
299	327+210		1	323	344+760		1
300	327+250	1		324	344+910	1	
301	327+370		1	325	344+980		1

S.N.	Chainage	Access		S.N.	Chainage	Access	
		Left	Right			Left	Right
302	327+510		1	326	345+000	1	
303	327+620	1		327	345+150		1
304	327+620		1	328	346+460		1
305	329+330		1	329	346+610	1	
306	335+250		1	330	346+730		1
307	336+550		1	331	346+880	1	
308	339+100	1		332	346+960		1
309	342+140	1		333	347+360	1	
310	343+190		1	334	350+950	1	
311	343+440		1	335	353+950	1	
312	343+600	1		336	355+900	1	
313	343+600		1	337	357+350	1	
314	343+680		1	338	358+980	1	
315	343+850	1		339	362+100	1	
316	344+030		1	340	363+700	1	
317	344+220		1	341	365+950	1	
318	344+400		1	342	366+350	1	
319	344+440	1		343	366+450	1	
320	344+450		1	344	366+600	1	

Typical examples of minor intersections are shown below. (***Please refer to drawings and quantity section for precise type of signage, markings and locations***).

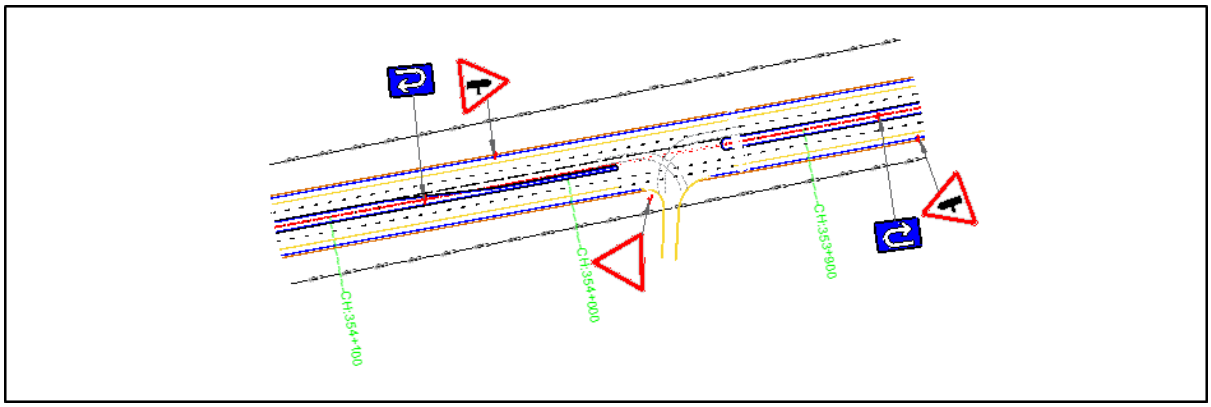


Figure 10.21: Example of 3-Legged Intersection (Km 353+950)

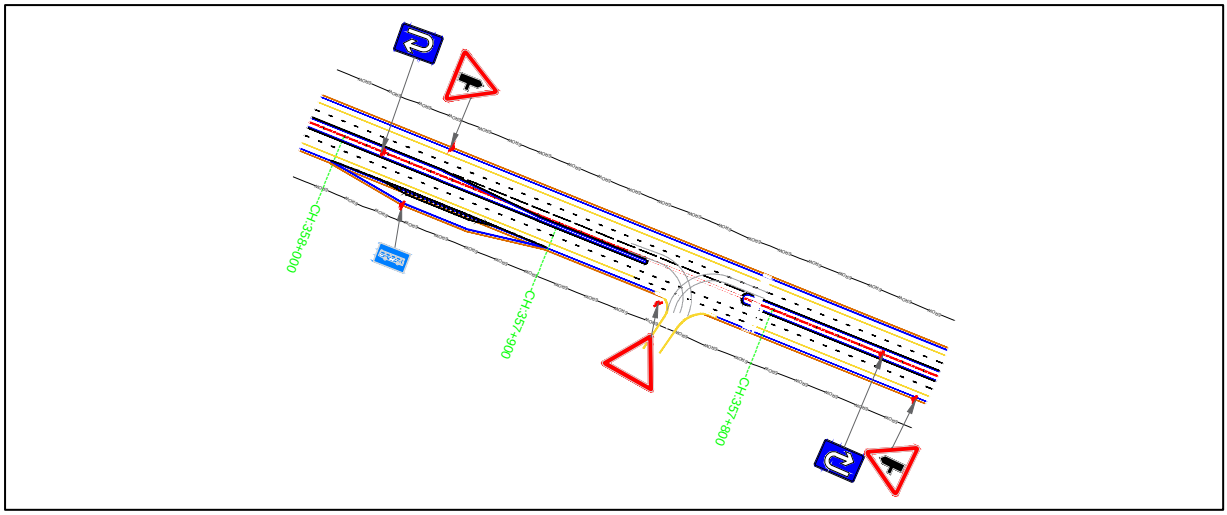


Figure 10.22: Example of 3-Legged Intersection (Km 357+850)

10.6.2 Service Road Plan and Operation

Based on the road safety audit report, service roads location and their design have been planned for pedestrian and vulnerable road users' and overall traffic safety, minimize crashes and delay along settlements / urbanized areas, and hence improve level of service. Location of service road both sides has been tabulated as below.

Table 10.14: Location of Service Roads

S.N.	Location	Full Width SR Chainage		Service Road Length (m)	Side of Service Road	Total Service Road Length (m)
		From	To			
1	Goddar	239+400	239+900	500	Both	1000
2	Birendra Bazzar	243+000	244+100	1100	Both	2200
3	Dharapaani	247+500	247+800	300	Both	600
4	Dhalkebar	256+440	258+300	1860	Both	3720
5	Bardibas	266+400	268+100	1700	Both	3400
6	Lalbandi	294+150	296+300	2150	Both	4300
7	Nawalpur	299+100	300+050	950	Both	1900
8	Harion	303+600	304+800	1200	Both	2400
9	Naya Road	306+600	307+500	900	Both	1800
10	Karmaiya	311+850	312+300	450	Both	900
11	Bagmati East	312+300	312+625	325	Left side	325
12		312+625	312+785	160	Both	320
13		312+785	313+450	665	Left side	665
14	Bagmati West	313+450	313+650	200	Both	400
15		313+650	313+870	220	Left side	665
16	Chapur	325+350	327+300	1950	Both	3900
17	Nijgadh	344+250	346+800	2550	Both	5100
18	Unasi bridge Left Approach	348+870	349+060	190	Both	380
19	Pathlaiya	366+300	366+687	587	Both	1174
			Total Length	**17957**		**34704**

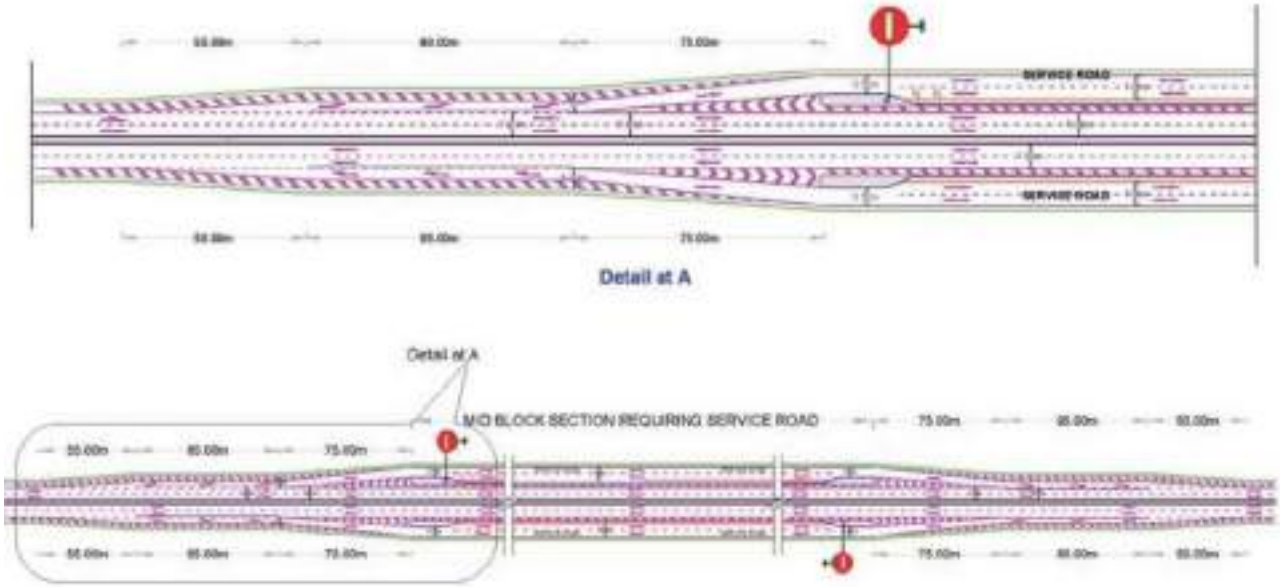


Figure 10.23: Typical Entry / Exit arrangement with Service Road

Suitable entry / exit points have been identified and designed based on guidelines in NRS 2070 and IRC: SP-84. Taper of minimum 1 in 15, deceleration lane at entry and acceleration lane and exit taper has been provided. For longer service road sections; intermittent entry / exit have been provided at minimum 500m intervals. Adequate traffic control devices and safety provisions have been ascertained while designing service road locations, entry / exit points and intermittent entry / exits.

10.6.3 Acceleration and Deceleration Lanes

At all intersecting roads, service road entry / exits, diversions, merging, truck lay byes, fuel stations etc., deceleration and acceleration has been provided as per codal provisions and availability of land. Nepal Road Standards, 2070 has following standards for the deceleration and acceleration lanes;

- For facilitating change of speed by vehicles diverging from or merging into high speed highway acceleration and deceleration lanes shall be provided.
- Acceleration and Deceleration lanes shall be provided at intersections, at bus shelter, at fueling and servicing stations, resting spots and other diversion and merging points such as narrow sections of bridges.

- These lanes shall be provided when future traffic on them is expected to be more than ADT of 1000 PCU.
- The width of these lanes shall be kept the same as the lane width of the highway.
- At the place of merging and diverging these lanes shall be provided with taper.

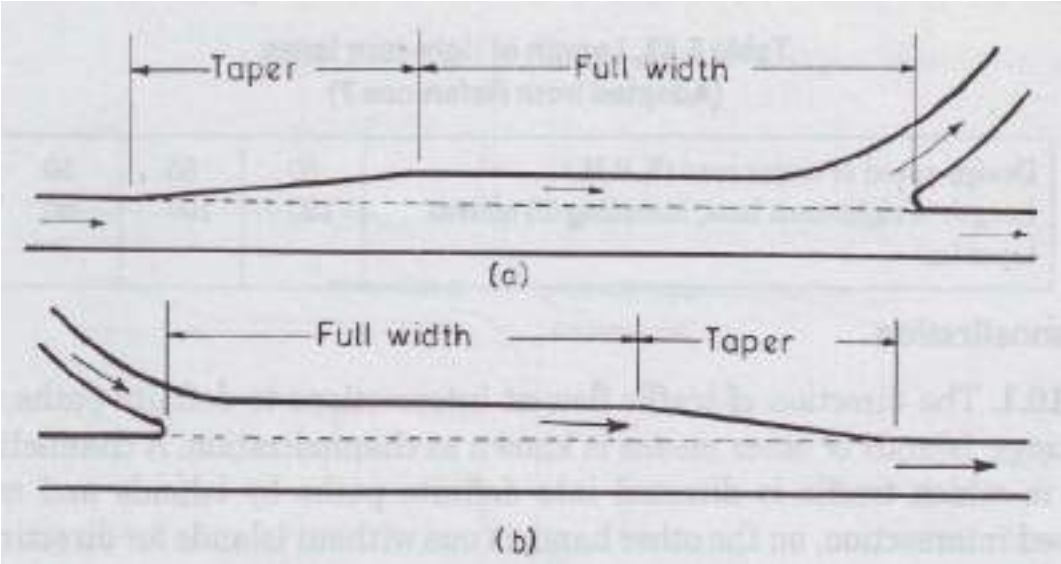


Figure 10.24: Deceleration and Acceleration Lanes (NRS - 2070)

Table 10.15: Acceleration, Deceleration and Taper Length (NRS - 2070)

Design Speed, km/h	Length of Accelerating Lane, m	Length of decelerating lanes, m	Length of taper, m
60	130	70	30
80	240	120	60
100	370	190	70
120	540	270	80

10.7 Street Lighting

Street lighting is very much important in the night time to enhance visibility of the drivers and hence minimizing accidents and crashes specially in the settlements / urbanized areas where high volume of local traffic including pedestrians and VRUs1.

Street lighting has been proposed all around the settlements / urbanized locations, major / minor intersections, bridges, flyovers, VUPs / PUPs, Bus Shelter, and Truck Lay-byes etc. as per the respective codal provisions.

[1] *Vulnerable Road Users*

- Rural highways should be designed with an open cross section and horizontal and vertical alignment of a fairly high type. Accordingly, they offer an opportunity for near maximum use of vehicle headlights, resulting in reduced justification for fixed highway lighting.

- Provision of artificial lighting shall be made on all stretches near populated areas, on major bridges, bus shelters, roads and railroads intersections (up to a distance of 250m from the point of intersections), and toll plazas

- Light mounting poles shall be at least 9m high (but mounting heights of 10 to 15 m are usually preferable). They shall be located outside the edge of the roadway or on wide central medians.

- Level of illumination shall be 30 lux.

- The ratio of minimum to average illuminations shall be about 0.4.

Figure 10.25: Street Lighting

10.8 Safety of Vulnerable Users Groups and Pedestrian Crossings

Developing high speed roads are need of the hour for reducing delay, saving fuel, timely delivery of perishable goods and improving the level of service and comfort. But on the other hand high speed highways generally have to pass through urban, built-up / settlement zones, communities and villages, where they have to encounter local slow moving traffic including vulnerable road users.

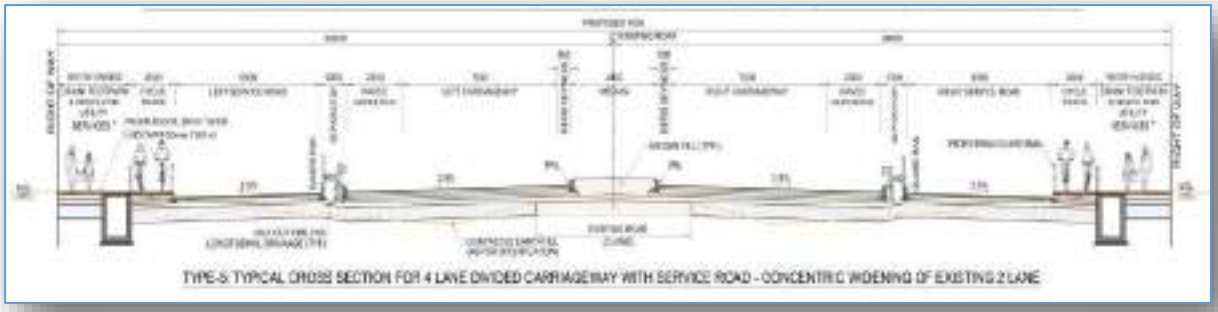
Globally, pedestrians constitute 22% of all road traffic fatalities, and in some countries this proportion is as high as two thirds of all road traffic deaths. Millions of pedestrians are non-fatally injured – some of whom are left with permanent disabilities. These incidents cause much suffering and grief as well as economic hardship.

Road traffic-related injuries and fatalities can be reduced by bringing changes to the road environment, reducing speed and traffic volume, and separating motorised vehicles from pedestrians and non-motorised vehicles. However, Nepal's current efforts are inadequate to lower traffic-related fatalities or injuries in the foreseeable future.

Safety of pedestrians and other vulnerable road users like that of bikes, cycles users other village local traffic like cattle-driven vehicles etc. have been kept in mind while designing the project highway. NRS – 2070 including IRC manuals have been referred for safe design for vulnerable road users. Based on the output of safety audit on the project highway and subsequent surveys, pedestrian and VRU friendly safe facilities have been designed on the project highway. Provisions of facilities for safety of vulnerable road users (VRUs) on the project highway are given below:

- Service roads designed at lower speed of 50 kmph
- Pedestrian friendly footpath
- Cycle / bike tracks
- Pedestrian guardrails
- Pedestrian zebra crossings at designed at most probable crossing points
- Foot-over-bridges at high volume of ped-crossing points
- Pedestrian underpass
- Safety measures near school zones
- Traffic control devices

All pedestrian and facilities related for the safety of VRUs have been designed keeping adequate sight distances so that pedestrians as well as drivers of closest vehicles (to VRUs) may easily and timely see and perceive the pedestrians and vice-versa. It is very important for timely taking decisions by the VRUs and subsequently selecting safe gaps for the on-road crossing. For the drivers too, it helps in timely applying breaks, in case required, for VRU safety and avoiding accidents.



Pedestrian Guardrails, footpath, median railings

Pedestrian guardrails have also been proposed (min. 1.2m ht. from footpath level) along the footpath and cycle track to keep the pedestrians away from entering the carriageway as well as guiding and channelizing them to the safe crossing points (e.g. zebra crossings or VUP/PUP or foot-over-bridge). In the urban / built-up areas; steel railing of min. 1.5m height shall also be provided in median in order to discourage on-road crossing of pedestrians except from dedicated crossing locations.

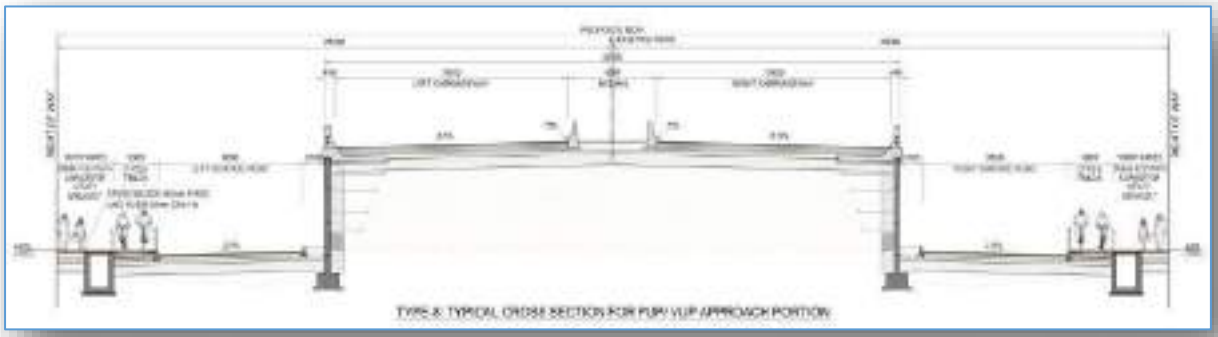


Figure 10.26: Proposed pedestrian and VRU friendly cross-sections

Pedestrian Zebra crossings

Pedestrian zebra crossing as per the specifications and guidelines of NRS and Traffic Sign Manual have been proposed on all at-grade intersections (major and minor) as well as on median opening locations which are close to villages and urban / built-up sections. Crossing across the median shall be designed inside the median nose as shown in **Figure 10-27** below.

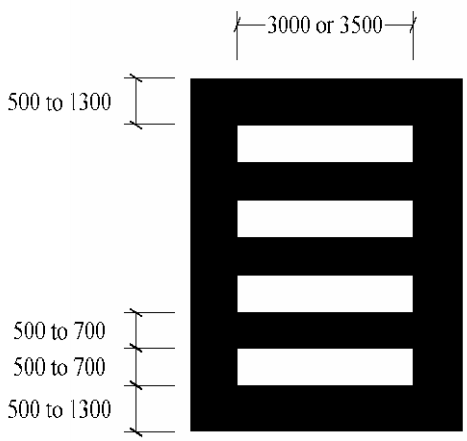


Figure 10.27: Pedestrian zebra crossing

Foot-over-bridge (FoB)

Foot-over-bridge shall be considered upon DoR's future study about pedestrian volume count density intersection-wise and requirement. The same shall be decided post construction of highway.

Pedestrian underpass

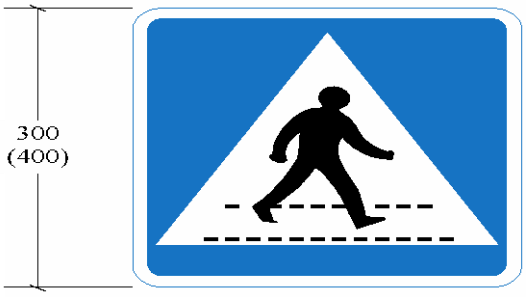
Pedestrian underpasses have been provided for the safe crossing of pedestrians, 2-wheelers, and other VRUs. These are designed in VUPs both sides via service roads. Pedestrian zebra crossings and crossing access from footpaths, have been also provided at these locations. It shall considerably reduce any probability of future VRU accidents and thereby enhance safety at the same time won't disturb the free flow movement of through traffic.

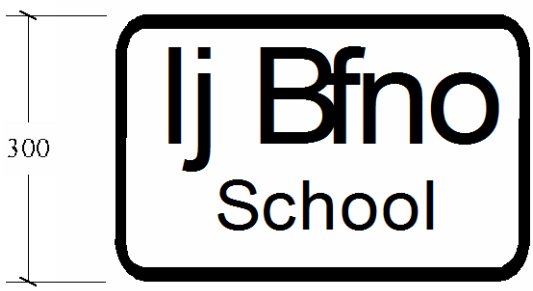
Safety Measures near school zones

Special treatment for school zones have been provided in the design. It includes following;

- Traffic alert
- Traffic calming
- Traffic control devices

School signage including reduce speed limit signs shall be provided minimum 200m and near school along with traffic calming techniques like bar markings with studs at the end bar marking set.





10.9 Safety Measures: Road and Roadside

Adequate safety measures have been proposed along the project road and roadside as per the best practices and standards. NRS 2070, and Traffic Sign Manuals, DoR have been referred. Indian Road Congress specifications and International standards have also been used wherein local standards are silent or international standards results in higher safety provisions for the project highway.

10.9.1 The Plan of Intersection for Urban Sections

Intersections in urban locations are either converted into grade-separated (VUP / Flyover) depending upon the intersection traffic volume and local traffic density or are designed as at-grade intersections as described in chapter 10.6.1. Intersections have been planned keeping following factors in mind.

1. Reducing conflicts
2. Minimize the severity of conflicts
3. Availability of adequate sight distance
4. Ease of access
5. Safety of pedestrian and VRUs

Please refer to chapter 10.6.1 for details.

10.9.2 Safety Treatments along Urban Sections

Urban locations along the project highway as identified during survey and safety audit, have been designed ensuring the safety of local traffic specially pedestrians, 2-wheelers, 3-wheelers, and physically disadvantaged persons. Urban locations have been listed in section 10.5 and other sections of this report.

Safety treatments specially been provided in urban sections have been given below;

1. Grade-separation (Flyover / VUP / PUP)
2. Reduced speed zone

3. Traffic calming techniques (Bar marking, Zig-zag markings etc.)
4. Service roads
5. Footpath
6. Cycle tracks
7. Pedestrian guard rails
8. Median railings
9. RCC Crash barriers on bridges / flyover / VUP / PUP
10. Street lighting
11. Pavement markings
12. Signage
13. Road edge delineation

Figure 10.28: Typical urban section of highway

10.9.3 Safety Treatments along Rural Sections

Rural sections of the project highway have been designed with following treatments for the safe movement of high speed traffic;

1. Crash Barriers (MBCB) on high embankments and curves with radius <=450m
2. Curve delineation and chevron signs
3. Object hazard marker signs and chevron markings ahead of fixed objects
4. Retro-reflectorized pavement markings as per specifications
5. Traffic signages
6. Animal and cattle safe crossings

Figure 10.29: Object hazard marker, Crash Barrier, Chevron signs, and safety markings in Rural sections

10.9.4 Safety Treatments at Merging and Diverging Sections

Points of merging and diverging shall be suitably designed by providing taper and deceleration lane for diversion from main-traffic and acceleration lane and taper for merging back to main-traffic. Related pavement markings and signage for diversion and merge have been provided in the design. These shall be as per guidelines of NRS – 2070 and other international standards, in case necessary. Following treatments overall shall be provided at merging and diverging points (weaving lanes);

1. Side road sign (minimum 200m ahead of diversion point)
2. Side road destination informatory sign (May be provided on same post of side road or only destination sign board with arrow shall be used)
3. Traffic calming bar and zig-zag marking, in case of high volume of local traffic
4. Chevron sign board and chevron pavement marking at the gore point
5. Side traffic merging sign minimum 180m ahead of side road traffic merging point

6. Yield sign board at the left hand side of taper for side road traffic to yield for the main traffic
7. Bar marking / mild speed breaker at the end of acceleration lane, in case insufficient length of acceleration and taper for side road traffic to merge
8. Studs (RRPM) as per the specifications (IRC: SP 84) [2]

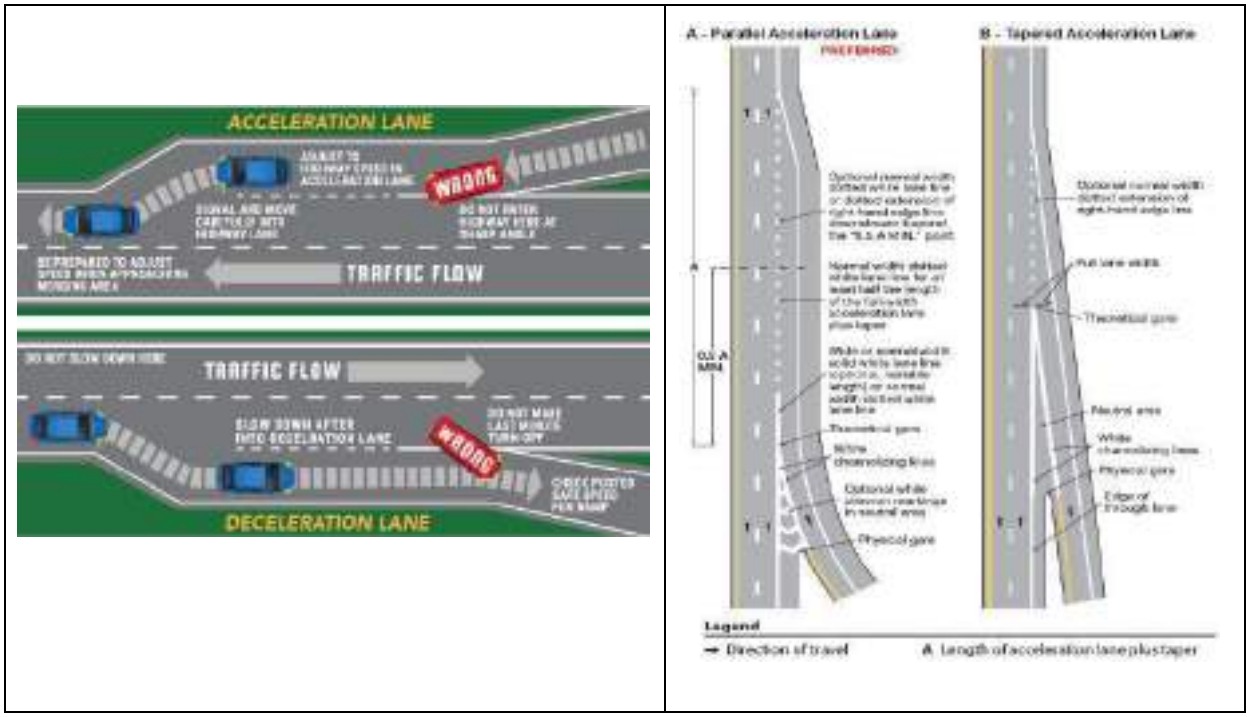


Figure 10.30: Merging and diverging

10.10 Traffic Calming Measures for the Project Road

Traffic calming measures like reduced signage, rumble strip / bar markings, zig-zag side markings reflectorized raised pavement markers (RRPM) / Studs etc. shall be provided in zones sensitive to accidents as identified during road safety audit. it has been described in detail in section 10.5 in Speed Management and Control.

10.11 Road Safety Facility Installation

10.11.1 Definition of Traffic Safety Facility

The road safety facilities also are intended to maintain the smooth flow of traffic throughout the stretch of the roadway while ensuring the safety of the passengers and pedestrians and VRUs.

[2] *Studs and RRPM are used interchangeably in the report*

[2] *NRS doesn't have sufficient info in this regard*

10.11.2 Traffic Signs

Traffic signs are to be placed for keeping the traffic regulated, informed and maintaining smooth flow while ensuring the safety of users all the time. Roadway traffic signs shall always be kept un-obstructed and the unobstructed sight distance to view sign is called the clear visibility distance. Sight line of signs should be clear of any vegetation / tree / bushes and other object like other traffic safety devices or building, wall, etc. The roadway traffic signage are divided into following three categories;

1. Regulatory / Prohibitory signs
2. Warning / Cautionary signs
3. Information or Guidance signs

10.11.2.1 Regulatory / Prohibitory Signs

These signs are intended to regulate the law or prohibit the driver of certain condition. The regulatory / prohibitory / mandatory signs for example are STOP and GIVE Way signs, SPEED LIMIT or Vehicle Control signs, Compulsory direction signs, No Parking, No Stopping signs, Prohibitory signs etc.

Regulatory / prohibitory signs should be carefully placed for the location of restriction and also the begin and end of restriction and direction of restriction shall be clearly known before placement of signs. These signs are normally sited at or near the place where the instruction applies.

10.11.2.2 Warning / Cautionary Signs

These signs as clear from the name, warns or cautions the drivers of hazard ahead. The common examples of warning signs are Sharp Curve Ahead, Steep Gradient Ahead, Narrow Bridge Ahead, Side Road, Cross Road, Traffic Merge Ahead, Reduced Carriageway, Pedestrian Crossing, Gap in Median, Rumble strip, Speed breaker, Hazard marker, Chevron signs etc.

10.11.2.3 Information / Guidance Signs

These signs are intended to give information to the road user regarding their location or facilities available in the vicinity or about the destination. Major classification of information and guidance signs is, Direction and place identification signs, Facility information signs, Parking signs, other useful information signs, Flood gauge etc.

10.11.3 Pavement Marking

Pavement marking is the most important, simple to comprehend, clearly visible and a psychological obvious safety barrier guiding road users throughout the length of highway.

10.11.4 Protection Safety Facility

Such facilities shall be provided in order to prevent vehicles moving in wrong direction, outside of the road or in opposite lane. These facilities shall be installed on the project highway to avoid head-on collision between the cars moving in the opposite directions and structures to protect passengers, pedestrians and major facilities around the road safely facility.

Type of Protection Fence

- Flexible (bendable) protection fence

These fences absorb the energy of impact with slight deformation when cars collide into them. Examples of flexible protection fences are beam type protection fence and cable type protection fence.

- Hard protection fence

The purpose for these types of fences is to keep the car inside the fence rather than to absorb the impact energy by deformation. Examples for such type of fences are concrete wall type (New Jersey type, F type, etc.).

10.11.5 Crash Cushion Systems

Crash cushions systems shall be provided on the project highway at locations of fixed hazard like that of cement concrete Jessey Barriers (CC Barriers) on narrow bridges to absorb the impact and keep the vehicles in the main carriageway even after the impact / crash.

These crash cushions help recover the vehicles in the original driving lanes safely by stopping or changing the direction after absorbing the impact energy when vehicles collide with them. These devices also notify about the dangerous objects in advance so that the drivers can react promptly (e.g. reducing speed or changing lane).

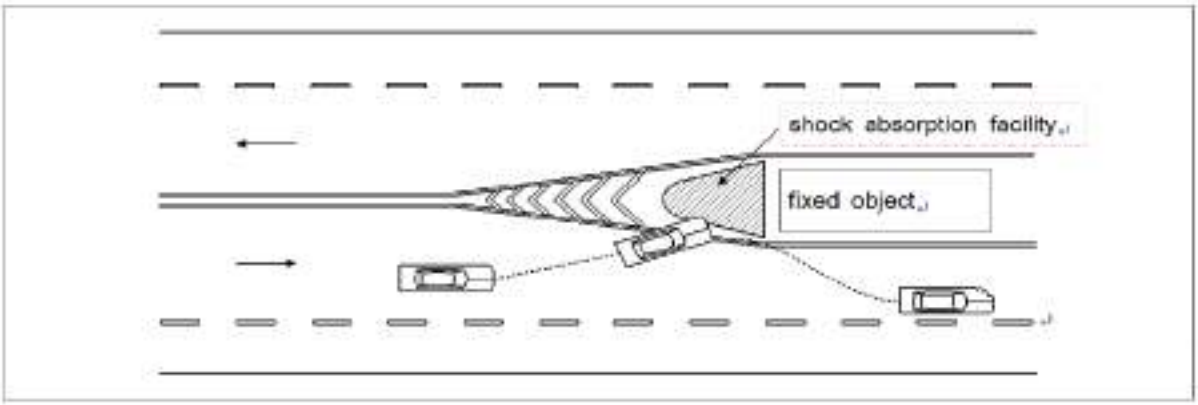


Figure 10.31: Crash Cushion (Impact Attenuator)

10.11.6 Visibility Enhancement Facility

Visibility enhancement facilities have been provided along the project highway for the safety of traffic not only during day-time but also during night time. These facilities are retro-reflective and alert and guide the drivers of the pavement edges, curve edges, high embankment, hazardous fixed object to keep away etc.

Delineators

These are structures to guide vehicles safely and smoothly by guiding road alignment or changing the geometric condition in front using reflecting objects in linear or circular road zone in day and at night. These structures therefore Inform drivers visually the road alignment in combination with road surface signs.

Chevron Signs

These signs notify drivers of the alignment and degree of curve of the road at sharp horizontal curve areas where vision is limited. These signs can provide more efficient vision guidance than vision guide signs depending on the road and topographic condition.

10.11.7 Raised Pavement Markers (Road Studs)

Raised pavement marker (Road Studs) have also been detailed in the section 10.5 (Speed Management and Control). These devices help to execute the function of road surface sign during night time or bad weather condition. These devices also warn erring drivers that veer too close to the road edge through audible noise when the vehicle tires come in contact with these devices.

10.11.8 Emergency Parking

These are areas for emergency shelter when a vehicle is out of order on a road with limited shoulder. These prevent traffic volume decrease by removing defected vehicle from the main lane and hence prevent crashes.

10.11.9 Bus Shelters in the Service Road

To ease access and control un-intended and un-safe flow of local buses and public; bus shelter and bus shelters with bus-bays were engineered at suitable locations. Bus shelter are provided without bus-bays in the service road sections. Typical bus shelter without lay bye has been shown in figure below:

Figure 10.32: Bus Shelter without Lay-bye

The list of bus shelter and bus bay with bus shelter have been listed in the **Table 10.16** below

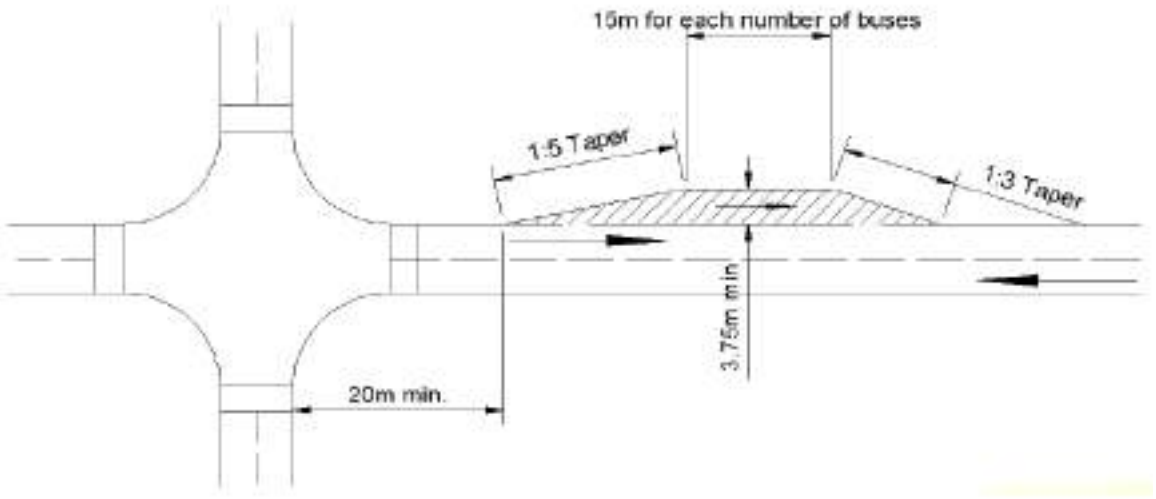
Table 10.16: List of Bus shelter and Bus Bay

S. No.	Chainage (m)	Side of Road	Bus Bay/ Bus Shelter
1	238+200	Left	
2	239+600	Left	
3	239+900	Right	
4	243+300	Left	
5	243+350	Right	
6	246+350	Right	Bhiman chowk
7	246+200	Left	Bhiman chowk
8	247+550	Right	
9	247+750	Left	
10	253+800	Left	
11	256+900	Left	
12	257+900	Right	
13	259+750	Left	Jamunibas
14	259+950	Right	

S. No.	Chainage (m)	Side of Road	Bus Bay/ Bus Shelter
15	261+050	Left	
16	264+900	Left	
17	265+100	Right	
18	266+850	Left	
19	267+400	Right	
20	271+350	Left	Jungle
21	279+300	Right	Jungle
22	279+950	Left	Jungle
23	283+200	Left	Jungle
24	290+000	Right	
25	291+200	Left	
26	291+450	Right	
27	294+800	Left	
28	295+050	Right	
29	299+450	Left	
30	299+700	Right	
31	304+100	Left	
32	304+300	Right	
33	307+000	Left	
34	307+200	Right	
35	308+000	Left	
36	309+300	Right	
37	312+800	Left	
38	313+600	Right	
39	314+600	Left	
40	326+500	Left	
41	326+700	Right	
42	339+100	Left	Jungle
43	345+500	Right	
44	345+700	Left	
45	353+150	Left	Jungle
46	354+000	Left	Jungle
47	357+800	Left	Jungle
48	366+500	Left	
49	366+600	Right	

10.11.10 Bus Bay in the Main Carriageway

Typical bus shelter with lay bye has been shown in figure below:



10.11.11 Truck Lay-Bye

Truck lay-byes have been proposed in the following locations as rest areas for the commercial (truck) traffic. The typical layout, design and other details shall be provided in the separate drawings. Pavement markings, signages etc. shall be as per the standard and specifications.

Table 10.17: Locations of Proposed Truck Lay-Byes

S.N.	Chainage	Sides	Reason for Truck-Layby
1	268+700	Left	Survey and Past trend of parking
2	324+300	Right	
3	327+800	Left	
4	347+800	Right	
5	366+300	Right	

10.12 Traffic safety and traffic management during construction

Since the project road is existing and shall be widened to four lane divided carriageway; the traffic shall be continued to ply on the highway during construction. Hence safety of the traffic and construction workers during construction becomes very important. Contractor has to ensure adequate safety measures and traffic management in place during construction as per best available technical provisions. IRC SP: 55 should be referred to for ensuring safer traffic diversions and traffic management during construction. Contractor shall have to produce proper traffic diversion and traffic control plans prior to start of any construction work. These plans shall have to be verified and corrected, if required by the competent authority.

Contractor shall have to place required construction zone diversion signage, temporary pavement markings, flag-men, traffic diversion cones / drums / jersey barriers / railings etc. at the site of construction as per the standard specifications and codes.

Few typical layouts as per IRC SP: 55 has been shown below;

1. Typical Layout – 2 lane to 4 lane (Eccentric Widening) – Fig. 10.1
2. Typical Layout – 2 lane to 4 lane (Shifting of Traffic from one carriageway to other) – Fig. 10.2
3. Typical Layout – 2 lane to 4 lane (Concentric Widening) – Fig. 10.3
4. Typical Layout – 2 lane to 4 lane (Concentric Widening) – Fig. 10.4
5. Typical Layout – 2 lane to 4 lane (Concentric Widening) – Fig. 10.5
6. Temporary Diversion for Reconstruction of CD work – Fig. 10.10
7. Roadwork in Junction area – Fig. 10.11
8. Work at Centre of Carriageway – Fig.. 10.12
9. One Direction for Major Work at the Centre of Road – Fig. 10.13
10. Stage -1 of Flyover / VUP construction – Fig. 10.15

10.13 Project site pictures and proposed improvement

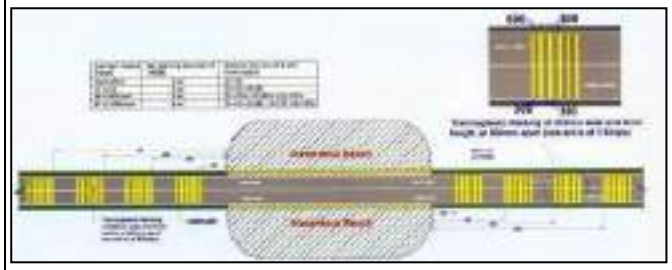
Project highway pictures have been shown in the table below along with the anticipated improvement after proposed safe design of four lane divided carriageway;

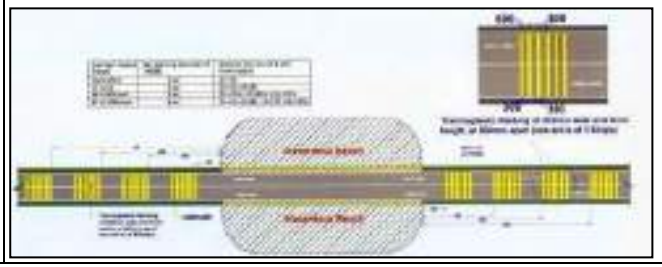
Table 10.18: Site Pictures and Anticipated Improvement

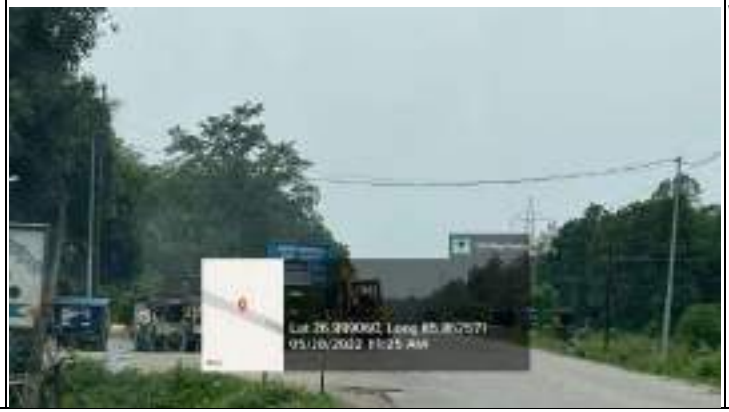
S. No.	Chainage / Location	Existing Site Picture / Condition	Anticipated Improvement
1.	237+022 Kamala Bridge		- New Bridge on Southern side with Service Road (But SR shall be kept close for Traffic till SR post bridge not taken up in future) - Better lateral clearance and visibility at entrance - Service road with footpath for enhanced accessibility and mobility for local traffic - Signage, delineation and pavement marking for improved safety, visibility and informed user

S. No.	Chainage / Location	Existing Site Picture / Condition	Anticipated Improvement
2.	238+000 Kamala Canal		- New Kamala canal bridge on LHS - Curve improvement with provision of crash barrier in between Kamala river and canal - Signage, delineation and pavement marking for improved safety, visibility and informed user
3.	243+000 Birendra Bazar		- Vehicular Underpass (VUP) along with #2 PUP (Pedestrian Underpass) at both ends of VUP are proposed at Birendra Bazar location. It shall improve safety, and accessibility of local traffic along with improvement of Level of Service (LOS) overall for the through traffic. - Service road and junction improvement for all access roads and cross roads - Local traffic and local bazar shall be segregated from main carriageway via service road with separator - Signage, delineation and pavement marking for improved safety, visibility and informed user

S. No.	Chainage / Location	Existing Site Picture / Condition	Anticipated Improvement
4.	246+500 Bhiman, Dharapani		- Junction improvement for all access roads and cross roads. SR is being provided in Dharapani settlement from Km 247+500 for 300m - Local traffic and local bazar shall be segregated from main carriageway via service road with separator in Dharapani settlement - Signage, delineation and pavement marking for improved safety, visibility and informed user
5.	253+800 Lalbhiti Settlement		- Curve improvement including clearing obstruction in order to maintain clear line of sight and safe stopping sight distance - Junction improvementof minor access roads for smooth accessibility for local traffic and pedestrian comfort - Signage, delineation and pavement marking for improved safety, visibility and informed user

S. No.	Chainage / Location	Existing Site Picture / Condition	Anticipated Improvement
6.	257+200 Dhalkebar Junction		Service Road and Junction improvement for local traffic segregation and speed reduction / traffic calming mechanism to be implemented. Proper curve delineation and signage shall be provided 

S. No.	Chainage / Location	Existing Site Picture / Condition	Anticipated Improvement
7.	266+500 BardibasSettlement		- Junction improvement for all access roads and cross roads including that of Bardibas Sindhuli Chowk. SR is being provided in Bardibas settlement from Km 266+400 to Km 268+100 for 1700m - Local traffic and local bazar shall be segregated from main carriageway via service road with separator in Bardibas settlement - Signage, delineation and pavement marking for improved safety, visibility and informed user - Since the minor bridge at Bhapsi (Km 268+310) is being retained and proposed bridge on South side is not provided with service road while Service Road is proposed nearby in Bardibas settlement; a sudden and abrupt Merge and Diverge shall pose potential Safety threat at this location. Therefore Speed reduction / traffic calming mechanism to be implemented. Proper taper edge delineation and signage including chevron signs shall be provided both sides of bridge. 

S. No.	Chainage / Location	Existing Site Picture / Condition	Anticipated Improvement
8.	271+400 Gaushala Chowk		- Junction improvement for turn traffic segregation and speed reduction / traffic calming mechanism to be implemented. - It is recommended that traffic shall not be allowed to diverge again to 2-lane with paved shoulder carriageway. Instead the traffic shall be guided to move in single lane movement in such closer narrow bridge locations using 'chevron' pavement markings and other safety measures. (It is recommended that on narrow bridges (< 7m) to be retained and which are comparatively close, i.e. less than 1000m and/or where those are on curves with radius < 500m; traffic shall not be allowed to diverge again to 2-lane with paved shoulder carriageway. Instead the traffic shall be guided to move in single lane movement in such closer narrow bridge locations using 'chevron' pavement markings and other safety measures. (Pavement shall although be constructed as per the design and available land for 2-lane paved shoulder).)

S. No.	Chainage / Location	Existing Site Picture / Condition	Anticipated Improvement
9.	275+300 Tuteshwar Mahadev Temple		- Junction improvement and Slip Road of min. 200m shall be provided. - Adequate signage including that of Temple sign shall be provided.

S. No.	Chainage / Location	Existing Site Picture / Condition	Anticipated Improvement
10.	294+100 Lalbandi Settlement		- Vehicular Underpass (VUP) is proposed at Km 294+900 Lalbandi Junction with #2 PUP (Pedestrian Underpass) at both ends. It shall help mitigate local traffic safety and accessibility issues. It shall improve safety, and accessibility of local traffic along with improvement of Level of Service (LOS) overall for the through traffic. - In order to deal with heavy local traffic and VRUs; Service Road is proposed from Km 294+150 to Km 296+300 (2150m). - Junction improvement for all access roads and cross roads including that of Lalbandi Chowk. - Local traffic and local bazar shall be segregated from main carriageway via service road with separator in Lalbandi settlement - Signage, delineation and pavement marking for improved safety, visibility and informed user

S. No.	Chainage / Location	Existing Site Picture / Condition	Anticipated Improvement
11.	299+545 Navalpur Settlement		- Vehicular Underpass (VUP) is proposed at Km 299+545 Navalpur Junction with #2 PUP (Pedestrian Underpass) at both ends. It shall help mitigate local traffic safety and accessibility issues. Along with improving safety, and accessibility of local traffic, it shall also improve of Level of Service (LOS) overall for the through traffic. - In order to deal with heavy local traffic and VRUs; Service Road is proposed from Km 299+100 to Km 300+050 (950m). - Junction improvement for all access roads and cross roads including that of Navalpur Chowk. - Local traffic and local bazar shall be segregated from main carriageway via service road with separator in Navalpur settlement - Signage, delineation and pavement marking for improved safety, visibility and informed user

S. No.	Chainage / Location	Existing Site Picture / Condition	Anticipated Improvement
12.	304+190 Hariwan Settlement		- Vehicular Underpass (VUP) is proposed at Km 304+190Hariwan Junction with #2 PUP (Pedestrian Underpass) at both ends. It shall help mitigate local traffic safety and accessibility issues. Along with improving safety, and accessibility of local traffic, it shall also improve of Level of Service (LOS) overall for the through traffic. - In order to deal with heavy local traffic and VRUs; Service Road is proposed from Km 299+100 to Km 300+050 (950m). - Junction improvement for all access roads and cross roads including that of Hariwan Junction. - Local traffic and local bazar shall be segregated from main carriageway via service road with separator in Hariwan settlement - Signage, delineation and pavement marking for improved safety, visibility and informed user

S. No.	Chainage / Location	Existing Site Picture / Condition	Anticipated Improvement
13.	307+100 Nayaroad Settlement		- Vehicular Underpass (VUP) is proposed at Km 307+050 Nayaroad Junction with #2 PUP (Pedestrian Underpass) at both ends. It shall help mitigate local traffic safety and accessibility issues. Along with improving safety, and accessibility of local traffic, it shall also improve of Level of Service (LOS) overall for the through traffic. - In order to deal with heavy local traffic and VRUs; Service Road is proposed from Km 306+600 to Km 307+500 (900m). - Junction improvement for all access roads and cross roads including that of Nayaroad Junction. - Local traffic and local bazar shall be segregated from main carriageway via service road with separator in Nayaroad settlement - Signage, delineation and pavement marking for improved safety, visibility and informed user

10.14 Star Rating for the Proposed Design Highway

Star rating as identified by the iRAP star rating has been revisited again after the proposed design of the Kamal-Dhalkebar-Pathlaiya to four-lane standard as detailed in this report. This design shall improve the rating of the proposed highway as obvious but there are still few sections to be immediately addressed to improve star rating further. Star rating of the proposed design KDP highway has been detailed below;

Table 10.19: Star Rating of Proposed Design Highway

S. No.	Parameters Revisited	Before Improvement[3]		After Improvement (Design Highway)	
		Highway Characteristics	Star Rating	Highway Characteristics	Star Rating
1	Operational speed	Average 50 kmph	3 Star (80% Length)	Average 75 kmph	4 Star (85% Length)
2	Road section geometry	60% - 70% Straight	5 Star (65% Length)	Almost 80% straight or close to straight without superelevation	4 Star (90% Length)
3	Intersection density	Almost all are directly in access of main traffic	2 Star (50% length)	#5 Junctions with VUPs and reset are Improved to minimize conflicts and safety	3 Star (50% Length)
4	Narrow Bridges	Narrow	2 Star (50% length)	They shall have now one-way traffic but shall pose threat of accident because of sudden merge for at least 37 bridges at higher speed.	2 Star (50% Length)
5	Centre line median	99% – Nil	2 Star (99% Length)	Throughout the Stretch	5 Star (99% Length)
6	Road delineation	Pathetic	2 Star (99% Length)	Throughout the Stretch	5 Star (99% Length)
7	Road side Hazards	Considerable	3 Star (50% Length)	Almost nil or with adequate safety measure	5 Star (99% Length)
8	Dhalkebar Junction	Busy and unsafe	2 Star (Junction)	Hazardous location – compromised	2 Star (Junction)

[3] *From iRAP Study of Strategic Roads in Nepal, May 2022*

S. No.	Parameters Revisited	Before Improvement[3]		After Improvement (Design Highway)	
		Highway Characteristics	Star Rating	Highway Characteristics	Star Rating
				horizontal and vertical curve	
9	Road condition	Pathetic	2 Star (90% Length)	Smooth and better riding quality	5 Star (99% Length)
10	Roadside encroachments	Considerable	2 Star (10% Length)	Removal of encroachments	4 Star (99% Length)
11	Pedestrian facilities etc	Nil	2 Star (99% Length)	FoB, PUP, Zebra crossings, footpaths, cycle track etc.	4 Star (90% Length)

[1]*From iRAP Study of Strategic Roads in Nepal, May 2022*

The table above shows that post improvement of the project highway, the project highway shall have high level of service (LoS) for the traffic that shall ply on the highway and also these improvement shall reflect in the reduction of accident probability on the highway. Following points have been concluded from the analysis and table above;

1. Post improvement, Project Highway shall have Star Rating of between 3 and 5.
2. Dhalkebar junction and narrow bridges shall continue to be hazardous locations for the project highway with Star Rating less than 3.
3. Post improvement, almost 90% project length shall have 4 star ratings in terms of road geometry, road delineations, roadside hazard, roadside encroachments, pedestrian and VRUs facilities etc.
4. These measures shall reduce accidents statistics to almost by 50% specially for pedestrians and VRUs. These statistics may be justified based on data analysis but the accident data was not available for highway stretch wise.
5. Only Dhalkebar junction, narrow bridges and higher speed may be a threat to accidents in these regions.

10.15 Design Standards

Detailed design for up-gradation of Kamala-Dhalkebar-Pathalaiya section is intended to be designed as Asian Highway Standard (Class-II). The highway design and road safety parameters have been taken from the Nepal Road Standards, 2070. Apart from this following codes shall also be referred for design from road safety context as there are several existing

challenges like topography, existing road features to be maintained, wild-life, socio-economic parameter, cultural significance etc. have to be accounted for;

1. Road Safety Audit Manual, Dept. Of Roads, Ministry of Work and Transport, Nepal
2. Traffic Signs Manual, Dept. Of Roads
3. Nepal Road Standards, 2070
4. IRC SP – 88 (Manual on Road Safety Audit)
5. IRC SP - 84 (Manual of Specifications and Standards for Four Laning of Highways)
6. IRC – 35 (Code of Practice of Road Markings)
7. IRC – 67 (Code of Practice of Road Signs)
8. IRC – 99 (Guidelines for Traffic Calming Measures in Urban and Rural Roads)
9. IRC – 119 (Guidelines for Traffic Safety Barriers)
10. IRC SP – 55 (Guidelines on Traffic Management in Work Zones
11. IRC – 79 (Recommended Practice for Road Delineators)
12. IRC – 103 (Guidelines for Pedestrian Facilities)
13. IRC SP – 44 (Highway Safety Code)
14. Indo Highway Capacity Manual (HCM)
15. Manual of Uniform Traffic Control Devices (MUTCD)

Chapter 11: Bill of Quantities and Cost Estimate

11.1 Introduction

The project execution shall be in two phases; phase I: upgrading works and phase II: performance-based maintenance works. The first phase shall be construction phase including Defects Notification Period (DNP) for development of the project road from two lanes to four lanes and service lanes, structures, bridges etc. The second phase will consist of maintenance works of all activities to be carried out to achieve and keep the road assets. The project cost in addition to construction and performance-based maintenance cost shall also include cost of relocation of utilities, resettlement costs of public and private properties.

The total project cost of the project is comprised of cost of road upgrading works and cost of construction and maintenance of various types of structures such as bridges, culverts, VUPs, PUPs etc. The cost of any structure will consist of costs of various works items necessary for the structures. The cost of any work items is calculated by multiplying its quantity with the unit rate obtained from analysis of rates. The calculation of unit rate of any item is calculated by using approved norms and rates of different types of labors, materials and equipment hire charges.

The following assumptions have been mainly taken in to consideration, while working out Bill of Quantities and Cost Estimate for the project.

- Widening of existing two-lane carriageway to four lane divided road with 4m wide median as well as Paved shoulder and Earthen shoulders on both sides.
- The Concentric widening has been proposed except at Bridge locations for entire length of the project road in order to avoid land acquisition. Both main carriageways and service road carriageway to be constructed from Subgrade level considering existing pavement condition and loss of utilization of existing pavement.
- Replacement of few weak and narrow bridges with new two-lane standard bridges, retaining of remaining existing bridges considering the existing condition in order to arrive at reasonable construction cost. Provision of protection works at Abutment and in the approaches.
- Re-construction of existing culverts in order to provide adequate waterway and clearance for periodic cleaning.
- Replacement of all existing Causeways with Box culverts having suitable size for providing adequate waterway w.r.t. hydrologic calculations
- Construction of Elephant Crossings at selected locations in forest area

- Construction of Vehicular underpass, and Pedestrian Underpass with Reinforced Earth Retaining wall approaches at selected important junctions in Urban areas
- Development of junctions as per codal provisions at Major and minor junction locations for entire length
- Provision of safety measures at locations identified during road safety assessment and road side appearances for guiding road users
- Whenever applicable mechanized construction plants such as hot mix batching plants, pavers, concrete batching plants have been assumed for determining the cost
- Prefabricated and pre cast elements have been proposed as far as possible
- It has been assumed that, required amount of water for construction purpose will be available within reasonable lead

11.2 Data Collection

The team of quantity surveyors of the Consultant worked out the requirement for carrying out rate analysis, work out Bill of quantities and Cost Estimate for the project development. The data collected by the team are as described below.

11.2.1 Collection of Schedule of Rates

The entire length of project road is traversing through five Districts of the country namely Dhanusha, Mahottari, Sarlahi, Rautahat and Bara. The length of traverse through each district is different with each other. The Consultant collected latest wages for skilled and unskilled labors and rates for construction materials approved by respective district authorities from web portals of District Rate Fixation Committee of all five districts. Similarly, machinery hire charges approved by DoR was also collected from the DoR web portal. Those rates (labors and materials) which are not available in respective approved district rates have been taken from Kathmandu district rate or prevailing market.

11.2.2 Collection of Market Rates

The consultant also visited market of each district to collect prevailing rates of the material and machinery for comparison purpose. The Consultant adopted prevailing market rate for certain machinery hire charges and construction materials for which, the approved rates are not available with District Rate Fixation Committee.

11.3 Analysis of Unit Rates

11.3.1.1 General

Rate Analysis must reflect prevailing market price, wages of skilled and unskilled labour and reliable cost estimate and is prepared based on considering the district rates for the labour and material, market price of construction material and norms for the rate analysis of GoN. For that purpose, the following relevant items have been duly taken into considerations:

• Standard / Special Norms of Government of Nepal • Market prices of special materials • Availability of materials • Availability of local construction materials	• Wages of skilled and unskilled labour approved by Concerned District Administration Offices (Districts of Dhanusha, Mahottari, Sarlahi, Rautahat and Bara) • Construction equipment and their hiring rates • Contractual overhead / profit • Value added tax (VAT)

The unit rates of items are based on the approved norms of Department of Roads, Government of Nepal. The norms for items which are not included in the approved norms are taken as per the norms adopted in the similar past projects. Unit rates include three major components, which are labour, materials and the equipment involved in the works. Cost of materials at site are inclusive of transportation cost including loading and unloading of the material.

11.3.1.2 Basic Rates for Labour

The Labour rates for cost estimation are collected from District Rate Fixation Committee of Dhanusha, Mahottari, Sarlahi, Rautahat and Bara Districts. The Rates for the fiscal year 2078/2079 which are approved by the District Administration Offices of above all five districts are collected and adopted. As the project road traversing with different in each district, the weighted rate for each class of labor (i.e. skilled and unskilled) with respect to length of project road in each district has been worked out and adopted for working out Cost estimate.

11.3.1.3 Desitrict Rates for Construction Materials

The rates for cost estimation are based on Dhanusha, Mahottari, Sarlahi, Rautahat and Bara District Rates for the fiscal year 2079/2080. The construction materials rates of each districts are averaged using weighted average method considering length of road falling in each district. The weighted average rate for the construction material has been adopted for working

out rate of each item of works. In case of the items for which rates are not approved by the District Administration Offices, market rates or approved rates of adjoining districts or the road head are taken. For locally available materials such as water, firewood, gravel, pebbles aggregate etc., the local rates of such items have been taken into consideration.

11.3.1.4 Rates of Construction Equipment Hire

The equipment hire rates are taken from the latest rates provided by the Mechanical Branch of the Department of Roads. The cost for collection and production of the construction materials like sand, stones, aggregate, surfacing chips, gravel material and crushed stone base were based either on the respective district rates or on the DoR Norms for respective items, whichever is less. Few rates were also calculated based on the machine/equipment involvement for activity and were already used practice in the earlier DoR projects; and the prevailing rates quoted by the contractor in the road project of the area.

11.3.1.5 Rates for relocation of Utilities

There are mainly three types of utilities along the road requiring relocation i.e.

i) electric/telephone poles/transformers,
ii) water supply pipes &
iii) public utilities / government utilities / temples

It is proposed to relocate above mentioned utilities by providing funds under the Provisional Sum item and rates for these have been worked out as under.

Electric Supply Lines: There are mainly 440 volts and 11 KVA lines along the road requiring reallocation. It needs to reallocate about 2069 nos. of electric poles. Costs are worked out with the NEA rates after accounting for salvage value of materials.

11.3.1.6 Comparison of Rates with on-going Contracts

The basic district rates and the unit rate analysis as mentioned above provide the theoretical prices. Actual prices are generally reflected in the rates in the awarded / on-going contracts of the projects vicinity of the Project Road. The Consultant collected rates from selected on-going contracts in the vicinity and compared the same with rates obtained from the above-mentioned methods.

11.4 Quantity of Works

The estimate of quantities has been carried out on the basis of drawings prepared based on the design of highway, bridges and other structures. The following considerations have been made while determining the quantities of works:

The quantities and the costs of the project works for different construction activities have been divided into groups of major activities such as; road works, bridge construction works, culverts, VUPs and PUPs, bridge maintenance and rehabilitation works, relocation of utilities etc. Further, road works have been subdivided into Site Clearance, Earthworks, Pavement Works, Road Furniture and Traffic Safety Measures, Environmental Mitigation etc., Similarly, Structures construction works have been subdivided into foundation, sub-structure, super-structure, river training works etc. Day Works and Provisional Sums have been determined and included in the cost estimate.

While calculating quantities of works and their units, provisions made in Standard Specification for Road and Bridge Works-2073 (With Second Amendment 2078) have been followed.

11.5 Bill of Quantities

The quantities for various items of works for road works, bridge works, grade separators including flyover/ vehicular underpass/ pedestrian underpass/ cattle underpass, protection works, junction improvement works, animal crossings including elephant crossing, road side appurtenances including road marking/ signages/ barriers etc. have been worked out by the team of the Consultant. The method adopted for working out Bill of quantities for various items of works has been described below:

- The earth work quantities like road in embankment have been computed based on the data collected by Total Station downloaded into MX Road software.
- The quantities for earthwork in cutting have been computed in accordance with soil profile prepared based on out-put obtained from the vertical profile design on the existing carriageway portion carried out using MX Road software.
- The quantities for road pavement, base, sub-base etc. for main carriageway and service roads have been calculated through applicable cross sectional template developed in MX Road software. The quantity for bituminous layers of new pavement has been calculated considering uniform width and depth for entire road and compared with an output of MX Road software.
- The quantities for pavement layers for minor and major junctions has been calculated based on detailed drawings prepared for major junctions and typical

drawings prepared for minor junctions. The quantity for earthwork has been provisioned for junction improvement on lump sum basis.

- The quantities for structures have been calculated based on Detailed General Arrangement Drawings (GAD) and relevant detailed drawings prepared for Super structure, sub structure and foundation using design output of STADD Pro for abutment and piers of the bridges. The same methodology for computing quantities has been adopted for Flyovers, Vehicular underpasses, Pedestrian Underpasses, Cattle underpasses, medium size animal crossings, elephant crossings and culverts.
- The quantities for drainage, protection of embankment & protection against tank bund and river training works are computed based on typical drain drawings and tentative drainage plan.
- The road furniture quantities have been worked out based on junction improvement scheme and road signage plans.
- The quantities for providing safety features have also been made considering proposals prepared under road safety measures at selected locations.
- Quantities for bus shelters, bus laybys and truck lay-bye has also been worked out using typical drawings prepared for the same.
- Provision of Way side Amenities has been made in separate sub-head.

As per the detailed calculations, the quantities of major works for the project road arrived at are provided under separate Volume I-E for reference.

11.6 Standard Provisions

The following provisions have been included in the project cost estimate, which are as per suggestions provided by DOR during discussion held for this project;

Contingencies	: 4%
Financial Contingencies (Price escalation)	: 10%
Physical Contingencies	: 10%
VAT	: 13%

Considering above all charges, total project cost has been arrived at for the entire project road.

11.7 Cost Estimate

The cost of construction items has been determined by multiplying worked out quantity of the item with its rate from rate analysis. The Estimate for road works including provisions made

for urban and rural road sections, road signages, road markings etc. has been worked out in detail adopting rates for items arrived at from Rate Analysis. The rate for selected items has been considered from Market inquiry for which rates are not available in Rate Analysis. The cost estimate for Bridge works including Culverts, Bridges having RCC Super structure, bridges having PSC Super Structure, Bridges having RCC & PSC Super Structures, Vehicular Underpasses, Pedestrian Underpasses, Special Bridges, rehabilitation of selected existing bridges, demolition of selected bridges, has been worked out adopting rates from Rate Analysis.

The total project cost arrived at for entire road has been presented in **Table 11.1** below;

Table 11.1: Total Project Cost for Kamala – Dhalkeber – Pathlaiya Road

KDP Project Stretch		**TOTAL**
Project length excluding 900m for KTFT interchange		**129.487 Km**
Item No.	**Description of Works**	**Amount (NRs.)**
1	**Part IA: Insurance**	**26,08,58,792**
	Part IB : General Item	52,70,14,702
2	**Part II : Road Works**	
2.01	Site Clearance (Including Dismantling Works)	40,74,74,743
2.02	Earthwork	3,47,57,90,600
2.03	Pavement Works(Main Carriageway)	12,67,15,89,732
2.04	Median	67,10,63,065
2.05	Pavement works (Service Road)	99,50,02,840
2.06	Footpath	17,28,16,695
2.07	Cycle Track	16,44,12,093
2.08	Busbay including shelter	10,04,69,947
2.09	Truck Lay Bye	1,81,29,915
2.10	Major Junction	26,09,77,529
2.11	Minor Junction	32,78,60,954
2.12	Retaining Wall	78,97,42,500
2.13	Toe Wall	16,10,94,905
2.14	Drain	78,18,71,999
2.15	Traffic Furniture	1,24,68,40,687
	Sub-Total Of Part II : Road Works	**22,24,51,38,205**
3	**Part III : Bridge Works**	
3.1	Foundation	3,45,21,40,789
3.2	Sub-Structure	90,15,65,688
3.3	Super-Structure	2,32,08,69,732
3.4	River Training and Protection Works	25,67,91,531
3.5	Miscellaneous Works	4,77,12,824
	Sub-Total Of Part II : Bridge Works	**6,97,90,80,564**
4	**Part III : Bridge to Culvert Works**	**73,64,87,905**
5	**Part IV : Culvert Works**	**2,16,03,63,703**
6	**Part V : VUP & PUP Works**	
	A. Structure Works (VUP)	
6.A.1	Foundation	23,13,94,932
6.A.2	Sub-Structure	4,95,86,939

KDP Project Stretch		TOTAL
Project length excluding 900m for KTFT interchange		**129.487 Km**
6.A.3	Super-Structure	11,09,15,259
6.A.4	Miscellaneous Works	10,09,379
	Sub-Total Of A	**39,29,06,509**
	B. Structure Works (PUP)	
6.B.1	Foundation	31,89,593
6.B.2	Sub-Structure	16,88,12,971
6.B.3	Super-Structure	64,97,898
	Sub-Total Of B	**17,85,00,462**
	C. RE Wall	**1,05,64,26,239**
	Sub-Total Part V (A+B+C)	**1,62,78,33,210**
7	**Part VII :Cost of Bridge Maintenance & Rehabilitation Works**	**4,06,53,629**
8	**Part X: Performance Based Maintenance Woks and Services**	**1,57,99,08,785**
9	**Part XI : Schedule of Day Works**	**2,43,58,746**
10	**Part XII : Provisional Sums**	**74,23,10,123**
	Total of 1A+1B + 2 + 3 + 4 + 5 + 6 + 7 + 8 + 9 + 10	**36,92,40,08,363**
	Provisional Sum	**74,23,10,123**
	Total excluding Provisional Sum	**36,18,16,98,240**

The total Civil Cost of the Project excluding VAT @13% arrives at **NPR 36,181.70 Crore** i.e. **NPR 279.42 Crore per km**.

It has been discussed and agreed with DOR and WB that, the Project Road to be divided in six packages for implementing the upgradation to four lane divided road.

The detail of all six packages decided for procurement is as tabulated below for reference.

11.8 Operation and Maintenance of the Project Road

The Project road has be maintained after completion of the Construction Period officially announced by the Client. The 5 years Maintenance period including 1 year of Defect Notification Period has been included in the Construction Contract prepared in consultation with the Department of Road (DOR). The Contractor shall maintain road asset without any claim during Defect Liability Period fixed under the Contract Document.

11.8.1 Operation Services

The Contractor shall provide maintenance services including activities required to maintain the satisfactory condition of created road assets. The Contractor shall assure its durability as well as maintain the road to provide comfortable riding condition to the Road users. The maintenance services include the following but not limited to;

- Road and Land Width
- Road roughness
- Control of potholes and cracking
- Drainage
- Rutting & Raveling
- Visibility of Road Signs and Markings
- Response time to rectify defects that compromise the safety of road users
- Vegetation Control
- Edge Break
- Depression
- Shoulder Condition
- Condition of Culverts and Bridges

11.8.2 The Scope of Services under Maintenance Period

The scope of services be provided by the Contractor includes all activities required to maintain the operational service level and any other requirement of the Contract. It includes the Management tasks and physical works associated with the following road assets and other items:

- Pavement of Main Carriageway and Service road
- Shoulders
- Drainage system
- Vegetation Control
- Side Slopes (Embankment & Cutting)

- High Embankment Slope Protection
- River Training Works
- Structures
- Traffic Signs, road markings, road marker stones, delineators and road furniture
- Traffic Management

11.8.3 The Scope of Services under Maintenance Period

The contractor shall focus on following activities during Maintenance period which are as listed below:

- Establishment of Maintenance Unit
- Mobilization of Key Personnel
- Specifications and Work Methods and implementation of Mobile Maintenance Team
- Preparation of Emergency Procedure and Contingency plan
- Road Management Data Base
- Detailed Maintenance Program including routine and Periodic Maintenance
- Handover

The contractor shall perform contract works as per the method and requirement specified in the Conditions of Contract and Specifications detailed out. The employer shall verify all contractor's activities during handing over the Project which includes,

- Road surface Condition with respect to Roughness
- Road Deflection Measurement
- Culvert & Bridge Conditions
- Condition of road signs and markings

11.8.4 Routine Maintenance

Under routine maintenance works, following activities to be performed by the Contractor to meet the Specified Operational Service Levels;

- Deploy Management and Working Personnel as required
- Provide committed vehicles, equipment, materials, consumables, tools and any other resources required to carry out routine maintenance works
- Carry out regular inspections, condition survey including Roughness measurement & Falling Weight Deflection measurement at an interval specified in the contract, monitoring, identifying defects and reporting if all conditions of road and culvert/ bridges at specified interval

- Scheduling maintenance works to meet required operational service levels
- Provide effective traffic management for entire length undertaken to ensure public safety and safety of the Work force
- Notify the Client where third party is the reason for damage to the road assets
- Notify the Client of any new or unusual events or circumstances affecting the road assets on immediate basis
- Carry out repair and remedial works to rectify the defects including surface dressing, shoulder dressing, pot hole repairs, surface painting, repair of damaged culvert/ bridge components, traffic signs etc.
- Carry out remedial works of damage or any deficiencies those are beyond the allowable threshold and bring the road asset to specified operational service level
- Prepare and submit Maintenance Report of the works on weekly and Monthly basis

11.8.5 Periodic Maintenance

Under periodic maintenance works, following activities to be performed by the Contractor to meet the Specified Operational Service Levels;

- Prepare the Plan for road maintenance based on results of the condition survey including Roughness measurement & Falling Weight Deflection measurement for entire road. The maintenance include overlay, potholes rectification, restoration of shoulder edge, replacement of road signs, road marking, road studs fixing, fixing of delineators, kerb painting etc.
- Prepare the Plan for maintenance of culverts/ bridges/ VUP/ PUP/ Drainage based on observations made during Condition survey for entire length, the maintenance shall include replacement of bearing if any, protection work of the foundation, restoration of river training works etc.

11.9 Contract Packaging

For the purpose of contract packaging the total cost of the project works has been sub-divided into following sections/packages.

Chapter 12: Social & Resettlements Issues

12.1 Background

The Strategic Road Connectivity and Trade Improvement Project (SRCTIP) aims to improve the efficiency and safety of selected transport infrastructure, enhance the cross-border trade, and strengthen the capacity for Strategic Road, improve the economic status of the people through improvement of road Network management in Nepal. As a part of the Nepal government's initiatives with assistance of the World Bank to develop the transportation infrastructure in Nepal, it is proposed to widen Kamala – Dhlakebar – Pathlaiya section of the Mahendra Highway from existing 2-lane road to 4-lane didived road. The improvement shall also involve the provision of service roads in urban / semi-urban areas either on the one side or on the both sides depending up on the nature of the settlements. This will necessitate also either widening of the existing bridges or the construction of new bridges for additional two-lane road. The length of this stretch is approximately 130 Km.

12.2 Objectives:

The main objectives of the consultancy services include, inter alia, the followings:

- To Conduct detailed survey, investigations, and engineering design of Mahendra Highway (Kamala – Dhalkebar – Pathlaiya Section, 130 Kms) and 76 bridges incorporating road safety features and relevant environmental and social measures based on the ESMP.
- To identify of the loss of private and public structures, temples, religious trees, and water bodies within Right of Way (RoW) for proposed development.
- To conduct alternative analysis of the alignments, design, construction techniques, etc. showing, inter alia, environmental and social risks and impacts for each alternative.
- To integrate relevant environmental and social measures and recommendations of road safety assessment and audit analysis, e.g., wildlife crossings, safety features, etc. into the detailed engineering designs and bid documents.

The detailed Scope of the Consultancy Services includes, inter alia, the following:

i) to conduct the necessary environmental and social assessment with due consultations of the relevant stakeholders as well as coordinate with separate the ESIA consultants appointed by DOR, during the design processes. Identify sensitive areas and features

such as wildlife corridors, cultural heritages, natural habitats and/or critical habitats, etc. as well as screen for potential direct, indirect and induced impacts, and mitigation measures including cost.

ii) The Consultant will coordinate, interact and share information on design and assessment on environment and social aspects with the ESIA consultant. Integration of environmental and social findings and recommendations from the ESIA consultants in the Detailed Design, Cost Estimate, and Bid Documents.

iii) Prepare detailed designs and drawings for the road pavement and structures necessary for construction of a safe, efficient, and resilient road and standard and special engineering technical specifications for each work item, applying sound engineering practices and integrating environmental and social measures in accordance with the ESIA/ESMP prepared separately and the WB's ESF 2017 and Government's related regulations and policies.

12.3 Methodology

The consultant's Social-Environment team reviewed the feasibility study Report prepared for the Project Road Kamala-Dhalkebar-Pathalaiya (KDP) thoroughly. Besides, the consultant team visited the Kamala-Dhalkebar-Pathlaiya road section of the East-West highway several times to collect necessary data from the field and to assess the possible environmental / social impacts of road upgradation works. The team conducted a detail survey to assess the effect of proposed upgradation works on public and private houses and other structures, religious trees, water bodies, waiting sheds (pratikshyalaya), Chautara, and forest areas. In this way, the data presented here are primary data collected from the site as well as secondary data taken from relevant documents published by the Government and other Agencies. Regarding secondary data, the demography of the project influenced area has been taken from the population census of 2021 and ethnicity/caste composition has been calculated with the help of the population census, 2021 and other relevant publications. Similarly, different educational status of project-influenced local bodies (municipalities and rural municipalities) for the year 2021 have been calculated statistically. The data of existing junctions and proposed Vehicular Underpass/ Flyovers have been extracted from the survey carried out for entire project road section and detailed design carried out by the Design Team.

12.4 Baseline Information:

12.4.1 Demography of the Project Area

The total population of the project zone of influence i.e., project-influenced municipalities is 862951 where the population of males is 429093 and that of females is 433857. The percentage of males and female population are 49.72 and 50.28 respectively. The population of the project zone of influence with the total household number (district and municipality wise) is presented vide **Table 12.1** below:

Table 12.1: Demography of the Project Influenced Area

Municipalities	Total Households	Male Population	Female Population	Total Population
1. Dhanusa				
Ganeshman Charnath	9400	21982	22918	44900
Dhanushadham	10959	26337	26698	53035
Mithila	10522	23715	23693	47408
2. Mahottari				
Bardibas	15938	34179	34174	68353
Gausala	16090	36367	36641	73008
3. Sarlahi				
Ishworpur	13776	34124	34502	68626
Lalbandi	15960	33555	33952	67507
Hariwan	11120	25283	26050	51333
Bagmati	10785	22454	23005	45459
4. Rautahat				
Chandrapur	17237	41245	42105	83350
Brindaban	8237	24994	25150	50144
Gujara	9682	26391	27698	54089
5. Bara				
Nijgarh	8455	18006	18584	36591
Jitpur Simara	23677	60461	58687	119148

Source: Census, 2021

12.4.2 Ethnic/caste Composition

The project-influenced area has multi-ethnic composition. Janajati, Brahmin/Chhetri, Madhesi, and, Dalit are dominant groups in the area. The data collected and provided in **Table 12.2** indicate that, Newar Janajati has the lowest number of households, except at Jitpur Simra municipality in the Project Influence Area.

Table 12.2: Ethnic/caste Composition of Project-influenced area (Number of Households - HHS)

Municipalities	Brahmin/Chettry (HHS)	Dalit (HHS)	Newar (HHS)	Janajati (HHS)	Muslim (HHS)	Madeshi (HHS)	Total (HHS)
1. Dhanusha							
Ganeshman	1804	1511	252	3105	210	2518	9400
Dhanushadham	2104	1761	294	3620	245	2935	10959
Mithila	2020	1691	282	3476	235	2818	10522
2. Mahottari							
Bardibas	8823	3415	0	3415	0	285	15938
Gausala	8907	3448	0	3448	0	287	16090
3. Sarlahi							
Ishworpur	5740	2132	328	3936	410	1230	13776
Lalbandi	6650	2470	380	4560	475	1425	15960
Hariwan	4633	1721	265	3177	331	993	11120
Bagmati	4494	1669	257	3081	321	963	10785
4. Rautahat							
Chandrapur	5386.56	2770	308	6926	308	1539	17237
Brindaban	2574.06	1324	147	3310	147	735	8237
Gujara	3026	1556	173	3890	173	864	9682
5. Bara							
Nijgarh	4604.96	528	528	2642	75	75	8455
Jitpur Simra	12895.51	1480	1480	7399	211	211	23677

Source: Calculated value for 2021

The data available in publications provide only district-wise number of caste/ethnicity households. Therefore, the Consultant used the total household number of each influenced local level body as obtained from the population census, 2021. Thus, the Consultant calculated caste/ethnicity household data of project-influenced municipalities with reference to the percentage of district-level caste/ethnicity data. The calculation is based upon the following formula:

Number of caste/ethnic households in a local body = Percentage of particular caste/ethnic group of the district* total household number of local level body (census, 2021 data) /100

Education Status of Municipalities in Project Influence Area

There is different educational status of 14 municipalities in five different districts falling in the Project Influence Area. The educational statuses include Illiterate, Basic, SLC, +2 & Graduate & above. The Education status collected for Project Influence Area has been presented in **Table 12.3** below.

Table 12.3: Education Status of Project Influenced Municipalities (above 5 years population)

Municipalities	Total Population above 5 yrs, 2021)	Illiterate	Basic	Secondary	SLC	2	Graduate & above
1. Dhanusa							
Ganeshman Charnath	39067	9610	16174	3946	4571	3086	1680
Dhanushadham	46146	11352	19104	4661	5399	3646	1984
Mithila	41250	10147.5	17078	4166	4826	3259	1774
2. Mahottari							
Bardibas	58408	5432	22604	5899	8703	7535	8236
Gausala	62385	5802	24143	6301	9295	8048	8796
3. Sarlahi							
Ishworpur	58758	11634	26030	5582	6111	5758	3643
Lalbandi	57799	11444	25605	5491	6011	5664	3584
Hariwan	43951	8702	19470	4175	4571	4307	2725
Bagmati	38922	7707	17242	3698	4048	3814	2413
4. Rautahat							
Chandrapur	70606	12144	32408	7978	7202	6566	4378
Brindaban	42477	7306	19497	4800	4333	3950	2634
Gujara	45819	7881	21031	5178	4674	4261	2841
5. Bara							
Nijgarh	31208	5149	13295	3464	3776	3745	1810
Jitpur Simara	101621	16767	43291	11280	12296	12195	5894

Source: Calculated value based on statistical analysis (in reference to 2021 census, feasibility study, and 2011 census)

There is no separate data for population of above-5years age group in preliminary report of census, 2021. Therefore, the ratio of above-5years age group included in the census report, 2011 has been used to calculate the above-5years age group with respect to total population in influenced municipalities in 2021. Based on this calculated value and percentage of district-wise educational status of influenced districts included in available reports, the educational statuses of different project influenced municipalities has been calculated and presented in above table.

12.4.3 Household Income

The average annual household income of the project influence area is NRs. 578,448 whereas the per capita income is NRs. 108,732. According to Nepal Living Standard Survey (CBS, 2011), the below-poverty line per capita income of Nepal is NRs. 19,261. This indicates that, the Project Influence Area has better economic status then that of the Country. The household income of the project-influenced area is as presented **Table 12.4** below:

Table 12.4: Household Income along the Project Road

Districts	Total Income	Household Income	Per Capita Income	Total Household	Total Population
Dhanusha	11,22,25,800	5,01,008	91,763	224	1,223
Mahottari	3,75,38,000	6,70,321	1,41,120	56	266
Sarlahi	10,05,81,000	5,98,696	1,11,509	168	902
Rautahat	5,72,29,150	5,10,975	96,508	112	593
Bara	8,11,43,268	7,24,493	1,37,298	112	591
Total	**38,87,17,218**	**5,78,448**	**1,08,732**	**672**	**3,575**

12.4.4 Household Expenditure

The average annual household expenditure in the project-influenced area is NRs. 334,426. Likewise, the per capita expenditure is NRs. 62,863. The household expenditure of the project-influenced area is presented in **Table 12.5** below:

Table 12.5: Household Expenditure

Districts	Total Expenditure	Household Expenditure	Per Capita Expenditure	Total Household	Total Population
Dhanusha	6,74,69,760	3,01,204	55,167	224	1,223
Ddhanusha Dhanusha	6,74,69,760	3,01,204	55,167	224	1,223
Mahottari	5,42,71,270	9,69,130	2,04,027	56	266
Sarlahi	2,23,60,855	1,33,100	24,790	168	902
Rautahat	3,41,32,000	3,04,750	57,558	112	593
Bara	4,65,00,120	4,15,180	78,680	112	591
Total	**22,47,34,005**	**3,34,426**	**62,863**	**672**	**3,575**

12.4.5 Occupation Status

The Project Road traverses through the terai region of Nepal, which is well known for its agricultural fertility. The main occupation of the study area is agriculture followed by household chores, service, trade, foreign jobs, wage labor, etc. Among the total population, 21.1% population is involved in agriculture activities. Similarly, the people engaged in household activities are 20.7% of total population. The service is the main source of income and people involved in this occupation are of 15.4%. The people engaged in foreign job and wage labor is almost similar, which is 8.8% and 8.7% respectively. The occupational status of the Project Influence Area is provided in **Table 12.6** below:

Table 12.6: Occupation Status

Occupation	Dhanusa (%)	Mahottari (%)	Sarlahi (%)	Rautahat (%)	Bara (%)	Total (%)
Agriculture	26.6	9.7	20.4	20.1	17.5	21.1
Service	10.5	26.1	14.6	17	20	15.4
Trade	11.4	14.8	10.7	11.2	11.9	11.5
Wage labor	8.8	7.4	8.4	11.7	6.8	8.7
Foreign Job	10.3	5.7	10.7	5.3	7.5	8.8
Household Chores	19.3	22.7	21.2	19.6	23.1	20.7
pension	0.8	1.1	1.1	2.5	1.9	1.4
Aged people	7.5	5.7	7.4	7.1	5.4	6.9
Unemployed	4.9	6.8	5.5	5.3	5.8	5.4
Total	100	100	100	100	100	100

12.5 Primary Data Based on Site survey

12.5.1 Land Use Pattern

The land in the project area is being used for various purposes. The Land use patterns in project area observed are: Cultivation, Barren & Cultivation, River & Cultivation, Barren, Forest & Cultivation; Barren, Settlement; Settlement & Cultivation etc. The Land Use along the Project Road noticed during survey by the Consultant's team is as presented in detail vide **Table 12.7** below:

Table 12.7: Land Use Pattern along the Project Road

S.N.	Chainage		Land use type	Remarks
	From (m)	To (m)		
1	237000	237500	Cultivation	Bridge
2	238200	238900	Barren+Cultivation	
3	239900	242600	River +Cultivation	
4	244600	245700	River+Cultivation	
5	248600	251100	Barren+Forest+Cultivation	
6	253900	254700	Barren+River+Cultivation	
7	255200	256000	Cultivated +River	
8	259700	260700	Cultivated+Barren+River	
9	261400	262200	Cultivated+Barren	
10	264900	265400	River+Cultivation	
11	289800	290200	River+Cultivation	
12	291500	293400	River+Cultivation	
13	299900	300900	River+Cultivation	
14	301500	302500	River+Cultivation	
15	238900	239900	Settlement	GodarBazzar
16	242600	244600	Settlement	Birendrabazar
17	251100	251800	Settlement	Pushpalpur
18	254700	255200	Settlement	Dhalkebar
19	260700	261400	Settlement	Mithila

S.N.	Chainage		Land use type	Remarks
	From (m)	To (m)		
20	265400	267900	Settlement	Bardibas
21	289600	289800	Settlement	Phuljor Bus Stand
22	293400	296000	Settlement	Lalbandi
23	298700	299900	Settlement	Nawalpur
24	300900	301500	Settlement	Hariwon
25	302500	304800	Settlement	Hariwon
26	312600	315500	Settlement	Bagmati
27	324800	327400	Settlement	Chandrapur
28	365400	366500	Settlement	Pathlaiya
29	237500	238200	Settlement+Cultivation	
30	245700	248600	Settlement +Cultivation	Dharapani Bazar
31	253000	253900	Settlement+Cultivation	Pushpalpur
32	256000	259700	Settlement+Cultivation	Dhalkebar
33	262200	264900	Settlement+Cultivation	Lalgadh
34	290200	291500	Settlement+Cultivation	Ranigunj
35	304800	312600	Settlement+Cultivation	Karmaiya
36	343400	346600	Settlement+Cultivation	Nijgadh
37	267900	289600	River+Forest	
38	296000	298700	Forest	
39	315500	324800	Forest+River	
40	324700	343400	Forest	
41	346600	365400	Forest+River	

12.5.2 Loss of Land

The right of way of the project road is 50m (25m on each side of the alignment), which has already been acquired by the Government for the road development in the past. If the proposed highway cross-sectional elements and other structures are designed to be constructed within the available ROW, there are no need to acquire additional land. However, farmers cultivating lands within ROW will have to be compensated for their crops, if the same is to be destroyed at the time of construction.

12.5.3 Affected Assets

The widening of the road project will have a social and environmental impact to a lesser or greater degree. Such impacts to be assessed with close observation and survey of the road section.

12.5.4 Anticipated impact

Due to the road expansion, the poor and vulnerable people including Rai, Limbu, Magar, Dalit, Tamang, Pahari, Madeshi residing on both the sides of the road is affected largely. They will lose their trade and residential structures. The result of the Survey, as assessed by the consultant is narrated below:

12.5.5 Affected Private Structures

Total Sixty-Nine (69) structures (Tahara with tile, thatched, and zinc sheet roofed and 1 RCC house) are found, which shall be influenced by the proposed road expansion works. The influenced structures are lying in 10 municipalities of 5 districts namely Dhanusha, Mahottari, Sarlahi, Rautahat, and Bara along the project road. Almost all the structures, except 9 structures (Residential use only), at Chandranigahapur Municipality ward no. 6 are of both residential and commercial use. Tamang, Rai, Limbu, Magar, Pahari, Dalit, and Madeshi are the residents of influenced area. The details of the influenced structures are given below in the **Table 12.8** and details of costing for resettlement/relocation is presented vide **Volume-B.**

Table 12.8: Affected Private Structures along the Project Road

SN	Municipality	Number of the influenced structure	Nature of the influenced structure (Tahara & Rcc)	Alignment Right/Left	Chainage	Remarks
A. Danusha						
1	Ganeshman Charnath	12	Tile roofed, Zinc sheet roofed, open hut, Garage with zinc sheet (all taharas)	L-10, R-2	237+344-245+200	Trade & Residential Use
2	Dhanusha Municipality	1	Tile roofed	L	246+355	Trade use
3	Mithila Municipality	11	Tile roofed-10, thatched roof-1, bamboo wall, mud wall	L-8, R-3	253+950-263+695	Trade & Residential Use
B. Mahottari						
4	Bardibas Municipality	11	Tile roofed, Muddy & bamboo wall	R	271+300-279+950	Trade & Residential Use
5	Gaushala Municipality	4	Tile roofed, Muddy & bamboo wall	L	279+950	Trade & Residential Use
C. Sarlahi						
6	Ishworpur Municipality	8	Tile & Zinc sheet roofed, muddy and bamboo wall	L-4, R-4	289+242-290+00	Trade & Residential Use
7	Lalbandi Municipality	6	Zinc sheet & tile-roofed tahara	L-4, R-2	291+251-294+258	Trade & Residential Use
8	Hariwan Municipality	5	4 zinc sheet & tile-roofed Tahara and 1 RCC house	L	301+238-303+620	Trade & Residential Use
9	Bagmati Municipality	2	2 tile-roofed tahara	L	310+418-311+136	Trade & Residential Use
D. Rautahat						

SN	Municipality	Number of the influenced structure	Nature of the influenced structure (Tahara & Rcc)	Alignment Right/Left	Chainage	Remarks
10	Chandrapur Municipality	9	9 Thatched roof tahara	R	334+143	Residential Use by Pahari Ethnic group
Total		69				

Source: Field Survey, 2022

12.5.6 Affected Public Structures

As per the survey and assessment, total of 47 waiting sheds, and 11 other types of structures (temporary police posts, triangular and, circular-shaped structures) influenced for widening of existing two-lane road to four lane divided road. These influenced structures are located in 11 municipalities of 5 districts along the Project Road. The list of such Structures identified during survey are provided in detail vide **Table 12.9** below and their details of costing for relocation/resettlement is presented vide **Volume-B.**

Table 12.9: Affected Public Structures along the Project Road

SN	Municipality	Waiting shed (Pratichhyalaya)	Other public structures	Nature of other public structures	Chainage range	Remarks
A. Dhanusa						
1	Ganeshman Charnath	4	1	Temporary Traffic police post	237+344-245+60	
2	Dhanusha Municipality	2	2	Triangular shaped structure	246+225-250+485	
3	Mithila	11	5	Circular and triangular-shaped structure and a police post	253+950-265+00	
B. Mahottari						
4	Bardibas	2	1	Police post with chautara	271+300-282+675	
5	Gaushala	1	-	-	282+675	
C. Sarlahi						
6	Ishworpur	1	-	-	290+00	
7	Lalbandi	3	1	Triangular shaped structure	290+537-299+547	
8	Hariwan	9	-	-	300+790-307+116	
9	Bagmati	8	-	-	309+500-312+598	
D. Rautahat						

SN	Municipality	Waiting shed (Pratichhyalaya)	Other public structures	Nature of other public structures	Chainage range	Remarks
10	Chandranigahapur	1	1	Triangular shaped structure	326+600-327+635	
E. Bara						
11	Nijgadh	5	-	-	343+409-345+900	
Total		47	11	-		

12.5.7 Affected Religious Trees, Water Bodies and Chautara:

As per the survey and assessment made the Consultant's team, total 159 religious' trees (Bar/Pipal) shall be affected in 12 municipalities of 5 districts for entire length of the Project Road. In addition, 5 ponds and 9 Chautara shall also impacted for widening of existing two-lane road to four lane divided road. As far as possible, the religious trees may be transplanted or relocated in order to keep sentiments of local people intact. The list of such affected religious trees, water bodies and chautaras identified by the Consultant's team has been prepared and presented in **Table 12.10** below and details of costing for resettlement/relocations is presented vide **Volume-B.**

Table 12.10: Affected Religious Trees, Water Bodies and Chautara

SN	Municipality	Religious trees (pipal/Bar)	Water bodies (pond)	Chautara	Nature of Chautara	Chainage range	Remarks
1. Dhanusha							
1	Ganeshman Charnath	4	-	1	Chautara with Pakhe tree	237+344-245+700	
2	Dhanusa Municipality	7	1	1	Chautara with Ashok trees	246+225-250+485	
3	Mithila	44	1	1	Chautara with Ashok trees	251+610-265+00	
2.Mahottari							
4	Bardibas	12	-	2	Chautara with Ashok trees	266+148-269+300	
3. Sarlahi							
5	Ishworpur	2	-	-	-	289+970-290+00	
6	Lalbandi	13	2	1	Chautara with Pakad tree	293+711-296+90	

SN	Municipality	Religious trees (pipal/Bar)	Water bodies (pond)	Chautara	Nature of Chautara	Chainage range	Remarks
7	Hariwan	40	-	2	Chautara with Sami trees	300+790-307+720	
8	Bagmati	21	-	1		308+00-312+964	
4. Rautahat							
9	Chandrapur	10	1			313+500-329+00	Pond within Jana Yekata Community forestry
10	Gujara	1	-	-	-	338+00	
5. Bara							
11	Nijgadh	5	-	-	-	345+900-357+00	
12	Jitpur Simara Sub-Metropolitan	2	-	-	-	357+100-366+00	
Total		159	5	9			

Source: Field Survey, 2022

12.5.8 Affected Temples:

It is observed during detailed survey by the Consultant's team that, total 24 temples affected due to widening of existing two-lane road to four lane divided road. The types of temples identified are: Mahadev; kamala Maharani; Hanuman; Dihabar & Bhola Baba; Hanuman Temple; Ganesh; Shriram; Shiva; Krishna; Hanuman; Mahadev; Rajdevi; Bramasthan Temples etc. The List of affected Temples due to proposed improvement of the Project Road has been prepared and presented in **Table 12.11** below and details of costing for resettlement/relocation is presented vide **Volume-B.**

Table 12.11: Affected Temples along the Project Road

SN	Chainage	Ward no.	Name of the temple	Left/Right	Remarks
Ganeshman Charnath Municipality					
1	237+344	8	Mahadev & Kamala Maharani	R	
2	237+344	8	Hanuman	L	
3	238+400	7	Dihabar & Bhola Baba	L	
4	239+00	7	Ganesh Temple	L	
5	244+400	1	Hanuman Temple	L	
Mithila Municipality					
6	254+038	4	Harihar Baba	R	
7	257+063	6	Hanuman	R	

SN	Chainage	Ward no.	Name of the temple	Left/Right	Remarks
8	257+115	6	Shriram	R	
9	260+400	8	Shiva Temple	R	
10	261+283	9	Krishna Temple	L	
11	264+160	10		L	
Bardibas Municipality					
12	275+331	5	Hanuman	L	
Lalbandi Municipality					
13	290+537	17	Mahadev	L	
14	293+711	6	Shiva Temple	R	
15	295+310	6	Shiva Temple	L	
16	295+580	9	Hanuman Temple	L	
Hariwan Municipality					
17	301+205	4	Bramasthan	L	
18	301+238	4	Mahadevsthan	L	
19	301+290	4	Krishna Temple	R	
20	301+628	4	Rajdevi Temple	L	
21	305+00	11	Hanuman Temple	R	
Nijgadh Municipality					
22	346+800	8	Shiva Temple	R	

12.5.9 Loss of public utilities

During detailed survey conducted by the Team, no drinking water pipes are found to be affected due to improvement of the existing road. However, electric poles and solar panels will be affected due to widening of existing two-lane road to four lane divided road in entire length of the Project Road and their details of costing for relocation is presented vide **Volume-B.**

12.5.10 Junctions / Flyovers/ Crossings / Service Roads

The Project Road Section either crosses or being crossed by various National, Provincial, and Local roads for entire length. Similarly, the road is provided with no. of accesses to the adjacent settlements, land plots including private properties in urban and rural sections. The survey team and Engineers' team of the Consultant, have identified no. of junctions (four-leg and three-legs) existing on the Project in the initial stage of the DPR preparation. These junctions /intersections and other accesses are being adequately designed to cater the specific site conditions and anticipated traffic volume. The Consultant have identified major junctions, minor junctions depending up on prevailing cross traffic movement observed. The Consultant have also identified and proposed Flyover and Vehicular Underpass at locations having significant cross traffic movement at present as well as anticipated in future in selected Urban areas. Similarly, in urban / semi-urban areas service roads either on the one side or the both sides depending on the settlement scatteredness have also been proposed in order to separate through and local traffic for smooth and safe movement of through traffic. The list of

junctions (either Major or Minor) based on topographic survey data and traffic survey analysis has been prepared and presented vide **Table 12.12** below:

Table 12.12: Junctions along the Project Road

Sr No	Name of Location	Chainage (km+m)	Intersection Type	Remarks
1	Goddar Bazar	239+740	Four Legged	
2	Bhiman Chowk	246+250	Four Legged	
3	Dharapani Chowk	247+650	Four Legged	
4	Kanxi Bazar	248+720	Four Legged	
5	Puspalpur Chowk	252+050	Four Legged	
6	Laalbhiti Chowk	254+000	Four Legged	Staggered
7	Shreepur Chowk	255+100	Four Legged	
8	Dhalkebar 400KV Substation Road	258+180	Four Legged	
9	Jamunibaas Bus Stop	259+800	Four Legged	
10	Bardibas-1	268+880	Three Legged	Right
11	Bardibas-2	270+350	Three Legged	Right
12	Bardibas-3	271+380	Four Legged	
13	Bardibas-4	281+500	Three Legged	Left
14	Ishworpur-1	283+180	Three Legged	Left
15	Ishworpur-2	289+230	Three Legged	Left
16	Ishworpur-3	290+000	Three Legged	Left
17	Ranigunj Chowk	291+300	Four Legged	Staggered
18	Lalbandi-1	294+900	Four Legged	Staggered
19	Lalbandi-2	295+700	Four Legged	
20	Lalbandi-3	300+760	Three Legged	Right
21	Hariwon-1	301+620	Four Legged	
22	Harion-2	303+000	Four Legged	
23	Bagmati-1	309+380	Three Legged	
24	Bagmati-2	309+850	Three Legged	
25	Bagmati-3	310+400	Four Legged	
26	Karmaiya Road Junction	311+900	Four Legged	
27	Bagmati River Bridge	313+400	Four Legged	
28	Chandrapur-1	314+720	Three Legged	Left
29	Chandrapur-2	317+400	Three Legged	Right
30	Chandrapur-3	324+540	Three Legged	
31	Nijgadh-1	339+100	Three Legged	Left
Sr No	**Name of Location**	**Chainage (km+m)**	**Intersection Type**	**Remarks**
32	Nijgadh-2	342+120	Three Legged	Left

33	Nijgadh-3	343+180	Three Legged	Right
34	Nijgadh-4	346+000	Three Legged	Right
35	Nijgadh-5	346+720	Three Legged	Right
36	Nijgadh-6	347+600	Three Legged	Left
37	Nijgadh-7	350+950	Three Legged	
38	Nijgadh-8	353+150	Three Legged	
39	Nijgadh-9	353+950	Three Legged	Left
40	Jitpur, Simara-1	355+900	Three Legged	Left
41	Jitpur, Simara-2	357+830	Three Legged	Left
42	Jitpur, Simara-3	362+080	Three Legged	Left

12.6 Improvement Proposal

The Consultant have carried road safety audit and also analyzed social impact mitigation measures during detailed design of the road and bridge for entire length. The Consultants' Social Expert and Road Safety Expert have worked in tandem for preparing proposals for improving the proposed four lane divided road having utmost safety and may provide safe and comfortable ride to the road user. The proposals are prepared in form of Flyovers, Vehicular Underpasses, Pedestrian Underpasses, Cattle Underpasses, Tractor/ Trolley crossing, Median Size Animal Crossing, Elephant Crossing, road appurtenances in form of road marking, road signages, speed breakers etc. The proposals worked out are described parawise below:

12.6.1 Flyovers

The Flyovers are required to mitigate the problem of vehicular density and to maintain the safeguard of the local population in densely populated area. The Social Expert and Road Safety Expert have identified most busy crossings in densely populated areas, where Flyovers have been proposed. The proposal has been presented and mutually agreed with the Client while carrying out Detailed Design of the road. The list of Flyovers proposed along the Project Road has been provided in **Table 12.13** below:

Table 12.13: List of Proposed Flyovers

S.N.	Chainage (Center of Structure)	Location	Span Length (m)	Number of Proposed Spans	Total Length (m)	Width of structure (m)	Remarks
1	257+210	Dhalkebar Junction	30	17	510	23.4	Junction with Road Towards Janakpur
2	267+280	Bardibas Junction	30	32	960	23.4	Junction with Kathmandu road & Jaleshwor road
3	326+560	Chapur Junction	30	22	660	23.4	Junction with Gaur Road
4	367+000	Pathalaiya Junction	30	13	390	23.4	Junction with Kathmandu - Birgunj Highway

12.6.2 Vehicular Underpasses (VUP) & Pedestrian Underpasses (PUP)

The Consultant have assessed and worked out the list of major junctions in urban sections, where the cross-traffic movement is observed significantly. The Traffic Engineers' team have assessed all such locations in detail and selected few locations for provision of Vehicular Underpass along with Pedestrian Underpass in both the approaches. The pedestrian underpasses are proposed to facilitate the local people and small vehicle for cross movement in short distance without disturbing through Heavy vehicles. Such arrangement shall avoid conflict of local small vehicles/ pedestrians and through heavy vehicles will ultimately eliminate fatal accidents. The List of proposed Vehicular Underpasses along with Pedestrian Underpasses the both approaches finalized in consultation with the Client has been presented vide **Table 12.14** below.

Table 12.14: List of Proposed VUP and PUP along the Project Road

S.N.	Chainage (Center of Structure)	Location	Span Length (m)	Number of Proposed Spans	Total Length (m)	Width of structure (m)	Remarks
1	243+650	Birendra Bazar	20/8	01/01	20/8+8	26.8	
2	294+200	Lalbandi Bazar	20/8	01/01	20/8+8	26.8	
3	299+550	Nawalpur Junction	20/8	01/01	20/8+8	26.8	
4	304+200	Hariwan Bazar	20/8	01/01	20/8+8	26.8	
5	307+050	Naya Road Junction	20/8	01/01	20/8+8	26.8	
6	345+300	Nijgadha Bazar	20/8	01/01	20/8+8	26.8	

12.6.3 Service Road in Urban and Semi Urban Sections

The team of the Consultant carried out detailed survey of land use along the Project Road during Conceptual Design stage of the Project. The Consultants' survey/ designer team verified existing settlement areas with data collected through topographic survey and drone survey and assessed intensity. The Consultant prepared the list of Urban and Semi Urban sections along the Project Road and prepared Typical Cross Sections having Service road with different width to cater current and forecasted merging/ diverging local traffic. The Service with different width and configuration (i.e., with or without foot path on out edge) are proposed either on one side or both sides depending up on the settlement noticed in such urban/ semi urban section. The Consultant submitted various Typical Cross Sections prepared for Urban and Semi Urban sections and received in-principle concurrence of the Client before proceeding ahead for detailed design in such Urban and Semi urban sections. The List of Service Road with different configuration proposed in Urban/ Semi Urban section along the Project Road has been presented vide **Table 12.15** below.

Table 12.15: List of Service Road proposed in Urban/ Semi Urban Sections

Sl no	Design chainage		Side	Remarks
	From	To		
1	237300	237970	Right	Kamala bridge
2	237900	239250	Both	Godar
3	239250	240200	Both	
4	242765	244820	Both	Birendrabazar
5	246000	247750	Both	Bhiman
6	247750	249075	Both	Dharapani chowk
7	251500	251990	Both	Puspalpur
8	253200	255900	Both	Bishrampur
9	255900	257960	Both	Dhalkebar
10	257960	260720	Both	Ranatol
11	260720	261260	Both	Bhandari Bajar
12	261260	263010	Both	Lalgarh
13	263010	268372	Both	Bardibas
14	290110	291490	Both	Raniganj,Sarlahi
15	293520	296320	Both	Lalbandi
16	298900	308500	Both	Nawalpur,Ganeshpur,Sukhepokhri,
17	308500	309550	Both	Milachowk
18	309550	310500	Both	Dumdume
19	310500	312000	Both	Sakhuwanitol
20	312000	315950	Both	Rautahat
21	324400	327630	Both	Chandranigahpur
22	343490	349070	Both	Nijgar
23	365630	366878	Both	Pathlaiya

12.7 Conclusion and Recommendation

12.7.1 Conclusion

Baseline information on Kamala-Dhalkebar-Pathlaiya (KDP) road section has been collected from secondary data through different reports related to the Project Road section as well as from primary data collected during actual survey of the project road and its corridor. The Statistical analyses have been made on these data for calculating various social parameters. The secondary data cover the demography of influenced municipalities (2021); caste/ethnic composition of households; education status; occupational status; household income & expenditure. The primary data includes the influenced private and public structures; influenced religious trees, water bodies, and Chautara. The survey result shows that, total of 69 private structures, 24 temples, 47 waiting sheds, and 11 other types of structures are found to be influenced by widening of existing tow lane road to four lane divided road with central verge. Besides, altogether 159 religious trees are found to be affected by the road improvement proposals. The survey also indicates that, 5 ponds and 9 Chautara also will have impacts by widening of existing two-lane road to four lane divided road. Considering traffic forecast/ demand, cross traffic movement in urban areas, local demand, observation of wild life crossing movement and nature/ intensity of development in urban/ semi urban areas; facilities like flyovers, vehicular underpasses, pedestrian underpasses, cattle crossings, service roads, medium size animal crossing, elephant crossing etc. are proposed to be included as part of the Project Road improvement.

12.7.2 Recommendation

- At important junctions within major settlements public toilets provisioned.
- Depending on traffic volume, population density, and area of the settlement's provisions for flyovers, vehicular underpasses, pedestrian crossings, tractor/ animal crossings, and service roads made along the project road.
- Important junctions proposed to be designed and constructed based on specific site condition to avoid unnecessary delays and to enhance safety.
- As far as possible influenced temples and religious trees proposed to be shifted away from work zone and reconstructed/ transplanted.

12.8 Site Photographs

The images of private structures, public structures, religious trees, Chautara, and ponds captured during the field survey are shown below.

Kamala Bridge

Interacting with local people

Temple

Religious tree and small temple

Temple within RoW at Parthaha

Interacting with people at the side of Partha temple

Traffic post

Interacting with people

Religious tree and temple

Small trade

Temple at Bardibas 5

Interacting with people at Bardibas 10 for the anticipated loss of structure

Small trade within RoW	Religious tree -peepal
Interacting with people of influenced area	Interacting with people of influenced area
Pond	Hut of Pahari ethnic group within RoW

Huts of Pahari ethnic group at Chandrapur-6	Small trade within RoW at Jitpur Simara

Chapter 13: Environment Impact Assessment

13.1 Background

Nepal's transport sector is heavily dominated by road-based transport, which accounts for almost all domestic passenger and freight movements. Roads are a pre-requisite of most economic activity and provide links between towns and regional centres throughout the country, and increasingly into them or remote hill areas.

Kamala- Dhalkebar section(21km)of Mahendra Highway was constructed in 1970'swith the assistance of Government of India and the section from Dhalkebar to Pathlaiya (109 Kms) was constructed later with the assistance from then USSR. Later in 1990's both of these sections were upgraded to two lane standards. The existing bridges at Kamala- Dhalkebar section are of two-lane standard while the bridges at Dhalkebar -Pathlaiya section are of intermediate lane (5.5 m width) standard and as a result the bridges are now bottlenecks to the traffic.

In order to enhance road capacity and efficiency in the road transport, Government of Nepal, Development Cooperation Implementation Division (DCID) for Strategic Road Connectivity and Trade Improvement Project (SRCTIP) Department of Roads (DoR) intends to upgrade the Kamala- Dhalkebar- Pathlaiya Section (KDP), 130Kms of Mahendra Highway. Department of Roads (DoR) has already hired the joint venture EPTISA Servicios de Ingenieriaand STUP Consultants Private Limited, Madrid Spain in association as sub-consultant with Udaya Consultancy, Geocom International, Sundar Kriti Consultant and Rays Consult Private Limited.

This report is for the assessment of the environmental aspects of the project vicinity area. The Environmental study examined the potential environmental impacts during the project pre-construction, construction and post construction stages of the project.

Moreover, the study will identify the potential impact mitigation measures and their associated cost as well. The detail of the environmental Management included in the Environmental Impact Assessment Report which is on the process of assessment.

13.2 Project Location

Mahendra Highway, also called East-West Highway runs across the Terai geographical region ofNepal, from Mechinagar in the East to Bhim Datta in the West, cutting across the entire width of thecountry. It is longest highway in Nepal. It links Eastern border with India to Western

border with India. The East point is at Kakarbhitta. It is also an Exit point to Northeast India including Darjeeling and Sikkim. The West Point isat Mahendra Nagar. It is linked with Northwest India including Kumau, Nainital of Uttarnchal. The major destinations along and around the Highways are Kakarbhitta, Bhadrapur, Dharan, Janakpur, Narayanghat, Butwal, Shiddarthnagar, Nepalganj, Bardiya, Mahendranagar, etc.

The project road section is Kamala- Dhalkebar- Pathlaiya (KDP), 130 Kms of Mahendra Highway. This project stretches cover Dhanusa, Mahottari, Sarlahi, Rautahat,Siraha Bara districts. This project road section including 76 bridges with 4 lanes.

13.3 Objective & Scope of Services and Work Plan

13.3.1 Objective of Work

The main objective of the consulting services (the Services) is to carry out the detailed engineering survey, investigations and design of roads and bridges for the upgradation of Kamala- Dhalkebar – Pathlaiya section of Mahendra Highway.

The main objectives of the consultancy services include, inter alia, the followings:

- To make the identification of the environmental baseline condition in the vicinity of the project area
- To integrate relevant environmental measures to manage and mitigate the potential impacts of Environmental sector while on the construction and post construction/Operation stage of the Project
- To recommend the Environmental Impacts mitigation measures.

13.4 Environmental Baseline of the project Area:

This is the baseline for the Kamala- Dhalkebar- Pathlaiya (KDP), 130 Kms of Mahendra Highway. The effect of road development within such large areas also very diverse and site-specific. Therefore, analysis of baseline data was based on a site-specific approach, with consideration of environmentally and socially sensitive areas and valued environmental and social components within the existing highway.

13.4.1 Physical Environment

Physical components in the KDP segment (or the project area) include features such as topography and geomorphology, land use, regional geology (soil type and distribution, slope stability, seismicity), hydrology and natural drainage, climate, groundwater, air quality, etc. Reviewing the baseline information and consideration of potential interactions between project

(highway upgrades and operations), other linear infrastructure development and physical environment the following valued environmental components were identified:

- Topography (banks lope stability and soil erosion);
- Natural drainage and watershed management(flooding);
- Soil, and
- Atmosphere (Air and noise pollution).

Topography, Geomorphology and Seismicity

The East-West Highway is situated within two geographic regions: Gangetic Plains (Terai Region) and Churia Range. It crosses three physiographic units: Terai (northern edge of Gangetic Plain), Churia Range (Siwalik)and Dun Valleys with variations in elevations from less than 200m above sea level, up to 700m above sea level, with rock and soil types mostly of alluvial nature. The proposed road alignment passes on the loose soils of the fluvial sediments of the Indo-Gangetic Plans. The road alignment is located south of the Main Frontal Thrust in Nepal. Drift geology showed that the road alignment lies on residual and old alluvial soild eposits. The slope stability in rocks of the KDP is stable and stability of soil conditions is good.

The area consists of the molasses sediments derived from denudation of the tectonically uplifted Himalayan range. These sediments were deposited by the fluvial systems, which show overall coarsening upward succession with individual beds showing fining upward succession. These molasses sediments were deposited during middle Miocene to early Pleistocene. The project area rocks form the southernmost hill range extending east to west are co-linear to the main Himalayan range with varying thickness (Dhital, 2015). This thickness is comparatively less towards the eastern part of the Himalayan range as compared to western counterpart, ranging from 20 km to the west to less than 1 km in the east (Dhital, 2015).

River beds provide various construction materials which will be sufficient for road construction. In general, the road alignment lies in low soil hazard zone. The main influencing components for occurring of the medium soil hazard are soil depth, land use pattern and the soil slope. The slope stability is good, so, necessity for realigning any of the subsection is not envisaged on account of geological consideration.

Bank slope conditions may be recommended as Valued Environmental Components that can be affected during road upgrades, specifically, during bridge construction and in the result of collection the materials for road construction in river beds. Not only direct, but indirect and cumulative effects may impact the banks lope stability, including high siltation and possible flooding in the monsoon season. This issue is addressed by the Environmental Protection Act

(2019), Soil and watershed conservation act (1982) and Water resources act (1992), which ensure control of erosion, landslide sand sedimentation in road development projects. Bank slope instability and soil erosion will serve as indicators of adverse impacts, associated with road development, which can be monitored during and after road upgrades and bridge construction (impact monitoring). It is recommended to extract materials for road construction at least one km upstream from each bridge along the highway to prevent the adverse impact of bank erosion.

Natural Drainage and Watershed Management

The drainage network in the KDP corridor is represented by many rivers. Major rivers are Kamala River, Bagmati River and Bakaiya River. Other water-bodies are represented by springs, canals and ditches.

The KDP road lies in the Siwaliks and Terai regions. The Siwaliks region is known to have limited ground water availability. However, the Terai region has abundant ground water resources to supply drinking and other domestic purposes. The seasonal range of depth to water table in the Terai varies from 0 to 10 metres belowground surface. The quality of ground water in this area should be monitored closely, as the presence of arsenic and other minerals have been detected in several areas.

The climate of the region is tropical with hot and wet summer, with maximal temperatures reaching up to 42^0 C and winter minimal temperatures of 16^0 C. Annual rainfall is very high in many areas along the highway, in the range of 1,500 – 1,750 mm per year. Rainfall is more intensive during monsoon season (in June –September) with large local variations relevant to orography and specifics of local conditions. Heavy rainfall occurs on some sections of the southern Himalayan slopes. Rainfall is also high along the Chure range. Regions close to the Indian border receive about 1,500 mm rain in a year, while at the foothills of Chure the annual rain fall reaches 2,000 mm. On the northern side of the Chure the rainfall diminishes again. In the lee-ward side of the ranges, rainfall is reduced due to rain shadow effects. There is no effect of flood in most ofthe areas that it touches, but it has caused widespread suffering to the people in Terai and northern districts of Bihar. In 1993, people have seen the worst destruction by the Bagmati River. Poor water management, lack of proper weather for ecasting and awareness were the main cause of mass destruction.

Climate change will increase monsoon rainfall and intensity, melting of glaciers and snowmelt, and increase flood risks nationwide. Snow and ice coverage has declined by 40 percent due to warmer temperatures, reducing a critical buffer to surface water shortages in major river

basins. Droughts will become more common and can reduce spring outflows, while also increasing risk from forest fires which degrade watersheds.

Lowland areas in the Terai have highly productive alluvial aquifers (250m deep) and robust recharge, although aquifers are often transboundary and can be impacted by groundwater pumping in India. Groundwater availability is variable in the Siwalik's hard rock aquifers, and productivity and recharge is moderate. Groundwater springs in the Siwalik sustain dry season river flows. The Kathmandu Valley has highly productive, but complex, alluvial aquifers (10-300m deep). The high Himalayas have no groundwater potential.

In the Lal Bakaiya River basin, the mean annual precipitation is 1,434 mm at Gaur (in the south), 2,040 mm at Nijgad (Bhabar area), increasing with altitude. This area experiences frequently high intensity rainfalls and flash floods, which are highly localized. Between 1954and 2010, damages from floods in this basin were reported 21 times or every 2-3 years. Mostly flood events were highly localized. The river floods areas within Nepal include Gaur Municipality and Brahmapuri area. Only 3 floods in 1971, 1993 and 2010 were regional in term of area coverage.

Taking into account the high level of rainfall in the Terai Region, the water network is abundant in the project area and water may cause drainage problems along the highway, especially during wet monsoon seasons, associated with water-logging. The areas of possible water-logging should be identified and mitigation measures proposed at the planning and design stages. The capacity of rivers for transport of water, especially in the places of bridges must be considered taking into account climate change scenarios, transportation by rivers of high amount of silt and other associated issues.

Climate change also can contribute to the severity of the floods; because it is predicted in climatic scenarios that rainfall amount might be increased in terai region, especially in the monsoon season. Meteorological stations in terai region show increasing level of precipitation in July from 1970 to 2009. The frequency and intensity of rainfalls is also increased, as well as rainfall causing rise in flash flood and debris flows. Escalation in total rainfalls intensity facilitated an increase in number of landslides. In such scenarios, more floods can be expected along the highway and design of the drainage structures should be made accordingly to prevent seasonal disasters in specific areas of the Lal Bakaiya and Bagmati River basins. The impact of climate change reveals that there will substantially increase in the number of extreme rainfall events and in the frequency and magnitude of extreme river flows.

Most of the bridges and culverts along the KDP corridor are old, many of them damaged and in need of urgent replacement or restoration to ensure movement of vehicles. In the summer of 2017, one of the bridges in the Bara District broke, causing delays of vehicle movement, and turned to the earth road through the river bed, which is possible in the dry season, but can paralyse traffic in the next wet season. Proper management of natural water drainage, affecting the road structures and surrounding environment, is vital in the terai region, because any interruption of natural drainage flow may cause not only technical traffic congestion and de lay problems, but also may lead to ecological disaster (for example, degradation and loss of Sal forests due to waterlogging and social catastrophes (destructive flooding of settlements and agriculture with loss ofincome and assets and lives of local inhabitants, in some cases). Appropriate planning and maintenance of such structures have extreme importance during design and development of the highways.

Siltation is another serious problem, which is very significant in terai Region. Bridge construction and culvert parameters should consider the impact of siltation and develop designs, which prevent the accumulation of silt near bridges and in culverts, as siltation can cause improper functioning of culverts and can result in strengthen in go flood in effects.

Soils

Soils along the KDP Road are mostly of residual or old alluvial deposits, represented by boulder and cobble, sands and silts. Soils are mostly stable, but it is possible their erosion mostly along river banks. River bank protection is required during the construction of bridges and other road infrastructure. Extensive soil erosion and landslides in upper catchments of the large rivers (Bagmati and Lal Bakaiya) have produced a high silt yield

Such “exposure” of fine soil particles from the upper catchment area to the flat plains provided conditions for the formation of fertile plains, beneficial for agriculture development. Thus, the Terai region is known for its abundant agricultural production and fertile soils. Soil is an extremely important element of local economy and livelihoods of local agricultural communities. Agriculture along KDP section occupies more than 60% of land-cover area: in the proximity of the road (ROW and DIA). Soils are valued by people; protection of soils is addressed in the Soil and watershed conservation act (1982), Environmental Protection Act (2019) and Waterr esources act (1992).

Land Use

Land within the 50m RoW is already government-registered land, acquired by the government. Land use within the 300m direct impact area of the KDP corridor is as tabulated in **Table 13.1** below.

Table 13.1: Land use in direct impact area

S.N.	Chainage		Land use type	Remarks
	From (m)	To (m)		
1	237000	237500	Cultivation	Bridge
2	238200	238900	Barren+Cultivation	
3	239900	242600	River+Cultivation	
4	244600	245700	River+Cultivation	
5	248600	251100	Barren+Forest+Cultivation	
6	253900	254700	Barren+River+Cultivation	
7	255200	256000	Cultivated+River	
8	259700	260700	Cultivated+Barren+River	
9	261400	262200	Cultivated+Barren	
10	264900	265400	River+Cultivation	
11	289800	290200	River+Cultivation	
12	291500	293400	River+Cultivation	
13	299900	300900	River+Cultivation	
14	301500	302500	River+Cultivation	
15	238900	239900	Settlement	GodarBazzar
16	242600	244600	Settlement	Birendrabazar
17	251100	251800	Settlement	Pushpalpur
18	254700	255200	Settlement	Dhalkebar
19	260700	261400	Settlement	Mithila
20	265400	267900	Settlement	Bardibas
21	289600	289800	Settlement	Phuljor BusStand
22	293400	296000	Settlement	Lalbandi
23	298700	299900	Settlement	Nawalpur
24	300900	301500	Settlement	Hariwon
25	302500	304800	Settlement	Hariwon
26	312600	315500	Settlement	Bagmati
27	324800	327400	Settlement	Chandrapur
28	365400	366500	Settlement	Pathlaiya
29	237500	238200	Settlement+Cultivation	
30	245700	248600	Settlement+Cultivation	Dharapani Bazar
31	253000	253900	Settlement+Cultivation	Pushpalpur
32	256000	259700	Settlement+Cultivation	Dhalkebar
33	262200	264900	Settlement+Cultivation	Lalgadh
34	290200	291500	Settlement+Cultivation	Ranigunj
35	304800	312600	Settlement+Cultivation	Karmaiya
36	343400	346600	Settlement+Cultivation	Nijgadh
37	267900	289600	River+Forest	
38	296000	298700	Forest	
39	315500	324800	Forest+River	
40	324700	343400	Forest	
41	346600	365400	Forest+River	

Water and Atmosphere (Air and Noise, Solid Waste Management etc.)

Water quality in the KDP corridor was tested from tube well water at Simara Bazar. The drinking water quality from the tube well showed that all the physical parameters are within National Drinking Water Quality Standards, (NDWQS), and the limit as prescribed by GoN. However, the biological parameters of fecal coliform were found exceeding the acceptable standards in the water sample collected from the tube-well at Simara Bazar. At present, air quality on the roads is very low due to high traffic flow, poor road conditions, destructed soil, car combustion and lack of mitigation measures. Pollution in road development projects is one of the evident direct impacts affecting water and soil. The dust pollution along the KDP section is visible in the dry seasons. Other pollutants also can be considered as indicators taking in to account the ir importance for public health and coverage by regulatory framework. Arsenic contamination in drinking water is reportedly high; it was estimated that 3.5 million people in the region are directly exposed to 10 and 50 µg/L. The information on air pollution from the project site is scant.

There are many adverse effects from road construction/upgrade and operations on air quality. Some of the mare dust and gas emission, air pollution from vehicles, etc. Dust emission is most prominent in the dry season, when the effect of pollution is visible on the distancein1kmandmore in open places.

Information's on-air quality in some sections of the Raxual- Amlekhgunj Petroleum Pipeline Area is shown in Table. The air quality monitoring data shows that the Total Suspended particulate (TSP) in the ambient air at Simara, particularly at the site, by the side of Hotel Samyak, along the Tribhuvan Highway, exceeds the National Ambient Air Quality Standard (NAAQS), whilst the TSP concentration at Amlekhgunj (inside NOC staff quarters) was found to be within the national standards. Birgunj has higher carbon monoxide and lead concentration in the air as compared with other parts of the country located in middle hills. However, the air quality data for carbon monoxide and lead concentration in Birgunj was within the tolerance limit. The observed levels of PM10, PM2.5, SO2, NOx, benzene, and ozone in both the locations were found lower than there commended safe level.

In study done by the National Health Research Council in 2004, Total Suspended particulate (TSP) and Particulate matter of size less than 10micron (PM10) levels in the ambient air at Birgunj were shown to exceed several times the national standard.

Noise pollution is a major annoyance particularly for the people living in roadside settlements close to the highway. Research findings indicate that the noise produced by the vehicles plying

the highway is mostly exceeding 70DB(A), disturbing the people as well as wild life in many cases. Noise associated with pipeline construction will be short-term in the project area but cannot be fully mitigated. Therefore, residual noise impacts during construction are expected.

For baseline information, noise level monitoring was conducted at two different locations within the project area. One at Simara (infront of Samyak Hotel) and other one at Amlekhjung (inside NOC staff quarter area) using sound level meter (CENTER 320) and calibrator (CENTER 326) takes 6 hours' data. The result of the monitoring is illustrated in Table below. The measured minimum and maximum range of noise at two stations ranged from 98.3-52.0 dBA.

Table 13.2: Noise Quality Data (Average 6 hours)

Location	Time	ObservedValue(dBA)					
		Lmin	Lmax	Leq	L90	L50	L10
Simara in front of Hotel Samyak	08:30-09:30	64.7	95.2	78	69.2	74.4	80
	10:40-11:40	68.6	98.3	81.2	72.2	75	83.4
	13:00-14:00	60.5	88.7	76.9	74.5	77.6	81.4
	18:00-19:00	54.1	97.9	66.1	59.6	65.2	73.5
	20:00-21:00	52	86.4	58.4	60.1	63.5	68.5
	21:00-22:00	48.9	83.6	56.2	62.4	66.3	69.7
Amlekhjung-inside NOC staff quarter area	11:10-12:10	58.4	88.4	67.9	62.7	66.2	72
	13:00-14:05	55.4	91.2	68.7	60	67.8	71.5
	15:10-16:10	61.2	88.4	70.9	64.7	66.7	73.5
	18:30-19:30	52.4	81.4	65.4	60.1	65.8	70.9
	21:15-22:10	47.3	68.8	50.9	52.3	55.8	60.1
	23:00-00:00	48.8	76.5	52.5	51.8	54.6	61.1

Source: EIA Report of Raxaul – Amlekhgunj Petroleum Pipeline Project

The Environmental Protection Act (2077), Motor Vehicle and Transport Management Act (1993), Soil and Watershed Conservation Act (1982) and Water Resources Act (1992) promote necessary mechanisms to prevent air, liquid and solid pollution. Nepal vehicle pollution standard and national standards on air quality

Ensure the implementation of mitigation measures in road development projects. The Environmental Protection Act (2076) only is relevant to noise control.

It is impossible to avoid impact of roads on air quality. However, mitigation technics to minimize adverse effects on environment and human health are well known. Mitigation measures include minimizing effects through different actions: air quality control, water springing during construction in the excavation sites, replanting of trees, management road sides, emission and dust control. In the Terai region, in places with dense forest cover the effect of air pollution is invisible a distance of 150-200 m from the road, because broad-leaved trees serve as natural shield, filtrating air and preventing dust exposure. Therefore, as one of preventive measures, plantation of trees can be recommended, with their high capacity to stop the spread

of dust and consume carbon dioxide. Local native trees are the best solution to mitigate adverse dust emission effects.

Solid and liquid pollution is another issue, especially during construction stage as well as chemical pollution. Quarries and borrow areas can be recommended for proper management of waste, chemical and other hazardous materials during construction.

Ponds near to the Road alignment:

The project area is riched with the ponds around the environment. The following are the ponds around the alignment.

Table 13.3: Ponds Detail within RoW

S.N.	Description	Chainage		Length	Side of Ponds	Number of Ponds	Pond Edge Distance from Center Line of Alignment (m)	Remarks
		Start	End					
1	Ponds	242600	242750		LHS	1	22.16	
2	Ponds	242765	242865		RHS	2	19.12	
3	Ponds	242960	243050		RHS	1	22	Under VUP approach at Birendra Bazar
4	Ponds	243000	243150		LHS	1	20.9	Under VUP approach at Birendra Bazar
5	Ponds	247870	247900		LHS	1	7.8	
6	Ponds	255190	255310		LHS	1	18.5	
7	Ponds	293620	293720		LHS	1	14.45	
8	Ponds	295310	295370		RHS	1	15	
9	Ponds	301000	301080		LHS	1	12	
10	Ponds	304920	304950		LHS	1	24.95	
11	Ponds	304960	305000		LHS	1	17.15	

13.4.2 Biological Environment and Selected Valued Environmental Components

Key issues that should be considered during the selection of evaluating for biological environment include their importance for people and regulatory requirements. The Environmental Components for Biological Environment in the project area consist of environmentally sensitive areas, terrestrial and aquatic habitats, threatened and endangered species.

Environmentally Sensitive Areas

Parsa National Park, with an area of 637 km2, borders the road in Pathlaiya - Nijgadh section for a distance of 18 km. In history, this area served as a vacation site for the Rana Rulers of the country. In 1984, it has been gazetted as a wildlife reserve to preserve the habitat for wild Asian elephant and a variety of other fauna. It is contiguous with Chitwan National Park in the west. It gained National Park status in 2017.

In 1976 the Parsa Wildlife Reserve was established on an area of 175 km2in the Chure Bhavar Region, mostly to preserve patches of sal forest and wildlife connection with Churia Range, bordering Chitwan National Park on the west. In 1984, the area of Wildlife Reserve was increased up to 499 km2. The tropical and subtropical forests (Terai Mixed Hardwood Forest) of the reserve mainly consist of Sal trees (Shorea robusta), about 90% of the Park's forests. The major trees in the riverine forests are Khair (Acacia catechu) and Simal (Silk-cotton tree) (Bombax ceiba). More than 300 plant species have been found in the Park. There is a 14 km road section of the KDP road that is located along the southern border of the Parsa National Park that separates the park from private lands on other side of the road.

The forests in Parsa National Park are mainly composed of tropical and subtropical species. Sal forests compose about 90 percent of the reserve's vegetation. Along the banks of the rivers, riverine forests are found containing species like Khair (Senegalia [Acacia] catechu) and Silk cotton tree (Bombax ceiba). In the north-eastern part of the reserve, at higher altitudes, Sal and Pine forests are occurring. On the southern slope of the Siwalik hills, the forests are dominated by pine. Sabai grass is commercially important species, grows well on the southern face of the Churia hills.

Figure 13.1: Map Showing the Parsa National Park in Green Colour

Parsa National Park supports populations of critically endangered animal (Chinese pangolin) and endangered animals such as the Royal Bengal Tiger, and the Asian Elephant and the Indian Hog Deer. It also has many charismatic animals such as Gaur(vulnerable), Sloth Bear (vulnerable), Barking Deer (vulnerable), Sambar (vulnerable), Nilgai (least concerned), Common Leopard(vulnerable), Chital (least concerned) or Spotted Deer (least concerned), Striped Hyena (least concerned), Palm Civet (least concerned), Jungle Cat (least concerned), and Terai Gray Langur (near threatened) and many others. More than 80 mammal species were recorded in the Parsa National Park. The population of resident elephants in the park is about 40-50 animals. Elephants often cross highway, especially during monsoon season and then in August – November. There are around 500 bird species in the reserve, including two critically endangered bird species, the White-rumped vulture (Gyps bengalensis) and Slender-billed vulture (Gyps tenuirostris). Many reptile and amphibian species inhabit the area of Parsa Wildlife reserve, including two crocodile species, several turtle species and many snake species.

The existing KDP road segment has no wildlife crossings to allow wildlife movement from one side of the road to the other. The improvement of the KDP road segment will have provision for wildlife crossings in areas identified by the park authorities that are known to have high number of wildlife movement. Initial discussions with park authorities identified potentially at least 3 wildlife crossings along the 14km stretch of the KDP road within the borders of the Parsa National Park and 5 crossings outside the national park with the dense forest having frequent wildlife movement area. This further assessed and verified in the ESIA team. Other measures such as fencing, including guiding fences will also studied and considered as among one of the measures.

In 2013, the tiger recovery program started in the reserve, because the tiger density in Parsa was assessed as just 0.78 tigers per 100 square km, compared to Chitwan National Park with 3.84 tigers per 100 sq. km (Lamicchane et al., 2017). Prey density also was much lower in Parsa Wildlife Reservice compared to Chitwan National Park as a result of widespread hunting and habitat degradation due to livestock grazing. After Nepal's commitment to double the size of tiger population by 2022, the Parsa Wildlife Reserve was engaged in this conservation initiative. And just from 2013 to 2016, the tiger population increased in the reserve from 0.78 to 1.38 individual per 100 sq.km (Lamicchane et al., 2017). On the opinion of researchers and Park's staff the tiger population can recover rapidly in the Parsa after relocation of local village, controlled poaching and connectivity to a source population in the Chitwan National Park.

Wildlife Crossing Areas or Movement Corridors

Wildlife Crossing Areas or Movement Corridors may be impacted directly by road construction and indirectly through cumulative and induced impacts, associated with road development and operations through increased rates of wildlife road mortality and traffic wildlife collisions, creating safety problems for people also. Usually, traditional migratory corridors are associated with areas rich by biodiversity, such as protected areas and wildlife habitats. Several wildlife crossing areas presented along KDP section, including elephant passing points in Parsa National Park, they serve as migratory and movement corridors and not only for Asian Elephants, but also for other charismatic and common species.

Main type of natural terrestrial habitats along the highway represented by forests. Sal is a dominant species in the sub-tropical forests [Terai-mixed Hardwood Forest] of the Terai Region. The road passes through 6 different patches of forest habitats with total length in 88 km. Forest habitats are represented in 8 of 10 districts along the road, but most significant patches are found road area. Significant number of trees will be affected directly during road upgrades and widening in the result of habitat clearance and road construction.

Table 13.4: Tree species, indicating impacts of the road upgrades on forest

Local Name	Scientific Name	Types	Family	IUCN Category
Amala	*Phyllanthus emblica*	NTFP	Anacardiaceae	
Aanp	*Manginifera indica L.*	Fruits	Moraceae	
Asarey (Currey tree)	*Murraya koenigii*	NTFP	Rutaceae	
Aule / Khatpat	*Garuga pinnata*	Timber	Buseraceae	
Badkaule/ Badkaula	*Casesria graveolens*			
Bahr	*Ficus banghalensis*	Ornamental	Moraceae	
Bakaino	*Melia azedarach*	Fodder	Meliaceae	
Banjhi	*Anogeissus latifolia*	Timber	Combrataceae	
Bayar	*Zizyphus mauritiana*	Fruit	Rhamnaceae	
Bhalayo	*Semecarpus anacordium*		Anacardiaceae	
Bhorla	*Bauhinia vahlli*	Climber	Fabaceae	
Bot Dhayaro	*Lagerstroemia parviflora*	Timber	Lythraceae	
Chatiwan	*Alstonia scholaris*		Apocynaceae	
Dabdabe	*Gaurga pinanata Roxb.*	Timber	Burseraceae	
Gutel / Velor	*Trewia nudiflora*	Timber	Euphorbiceae	
Hullure/ Hallude	*Lennea coromandelica*	Timber	Anacardiaceae	
Indrajau	*Holarrhena antidysenterica*	NTFP	Apocynaceae	

Local Name	Scientific Name	Types	Family	IUCN Category
Jamun	*Syzigim cumini*	NTFP/timber	Mythaceae	
Karma/haldu	*Adina cardifolia*	Timber	Rubiceae	
Kadam	*Anthocephalus chinensis*	Timber	Rubiceae	
Khair	*Acacia Catechu*	NTFP/timber		
Kharane	*Symplocos paniculata*	NTFP	Symploceceae	
Khirro	*Sapium insigne*	-	Euphorbiceae	
Kushum	*Cartharmus tincrotrius*	Timber	Compositae	
Kumbi/ Kumbhi	*Careya arborea*	Timber	Lecythidaceae	TH
Kyamun	*Hedychium ellipticum*	Timber	Zingiberacease	
Lampate	*Duabanga grandiflora*	Timber	Sonneratiaceae	
Mahauwa/ Mahuwa	*Madhuca Longifolia*	NTFP/timber	Sapoteceae	
Masala	*Eucalyptus comaldulensis*	Timber	Myetaceae	
Paan/ Pan/ Loro	*Ehretia laevis*	-	Cordiaceae	
Padke	*Albizia odoratissima*	Timber	Fabaceae	
Peepal/Pipal	*Ficus religiosa*	Ornamental	Moraceae	
Rajbrikshya	*Casia fistula*	Timber	Fabaceae	
Sal	*Shorea robusta*	Timber	Dipterocapaceae	
Saj/Asna	*Terminilia alata*	Timber	Combretaceae	
Sati Sal	*Dalberzia latifoloa*	Timber	Fabaceae	
Simal	*Bombax ceiba*	Timber	Bombaceceae	
Sindhure	*Mallatus philippensis*	Timber	Euphorbiaceae	
Siris (seto)	*Albizia procera*	Timber	Abaceae	
Siris (Rato)	*Albizia leebak*	Timber	Abaceae	
Sisoo	*Delberzia Sisoo*	Timber	Fabaceae	
Taaki/ Tanki	*Bauhinia malabarica*	Fodder	Fabaceae	
Tatari	*Dillenia pentagyna*	Timber	Dillenianceae	VU
Teak	*Tectona grandis*	Timber	Verbenaceae	

Source: Field Visit, 2022.

Forests of the project area ensure habitats for many wildlife species, including, at least, 40 mammal species, 5 reptile species, 2 amphibian species, more than 300 bird species, occur in forest habitats of the project area. The list of species, detected in the project area.

Aquatic Habitat

There are several potential impacts to aquatic resources during road construction and operation. These are direct disturbance and loss of biodiversity, pollution, draining of wetlands, contamination of watercourses with disposal materials and others. Many water-courses and wetlands are situated in the proximity of the Pathlaiya – Kamala section. They can be severely affected at the construction stage, when disposal of significant amount of construction materials is required

Importance to people:

Aquatic habitats serve as a source of wellbeing for local communities, providing fresh water for communal, industrial and household needs, serving as a source of water for irrigation, ensuring many goods such as fish and edible plants, securing beautiful sites for recreation activity, serving also for many cultural and religious traditions and rituals. Aquatic habitats are very important in the Terai Region and in particular along KDP section because they provide habitats for many important species, ensuring livelihoods of local communities (fish, birds, mammals).

Regulatory requirements: Environmental Protection Act (2019), Soil and watershed conservation act (1982) and Water resources act (1992) and corresponding rules regulate protection of aquatic resources and fishery. Water Resource Strategy (2002), National Wetland Policy (2012) and Irrigation Policy (2013) address issues relevant the water quality and conservation of wetlands. However, the issues of preventing drainage of sewage into rivers and mitigation of adverse impacts on water-resources remain unsolved.

Surface water quality: Surface water quality is important to people, wildlife, fish, terrestrial plants and ecosystems. The surface water quality can serve as indicator of changes in aquatic ecosystems.

Key for ecosystem function: Aquatic habitats form local climate and provide water for existing ecosystem functions. They serve as migratory and dispersal corridors for many wildlife species, aquatic and terrestrial. Many globally and nationally threatened and endangered species inhabit wetlands, including of crocodile, amphibian species, turtle species, many fish species with around 25 in number.

Fish habitat: Fish in the rivers and wetlands may serve as indicator group of species. Fish habitats can be monitored upstream and downstream areas, especially in the bridge construction localities with measurement of biophysical parameters (hydrology, flow characteristics, water and sediment quality, aquatic macrophytes and benthic invertebrate communities) and water quality parameters (dissolved oxygen, turbidity, pH, temperature, etc.).

Umbrella indicator:

Springs in the study area originated from Churia hill locating at the North of the highway. Thus, majority of springs have low flow in dry season and are ephemeral type. Springs remain dry after monsoon or when rainfall stopes. Artificial ponds are water logged and local residents

are using them as buffalo bath. Neither fish nor herpetofauna observed in these sampling sites. Majority of fish species and herpetofauna recorded in the study are common or least concern species. However, amphibians and reptiles could bear little impact though no such amphibians or reptiles observed during study time. There are higher chances of road kill while amphibians and reptiles cross the highway. Moreover, reptiles crawl and speed of crossing is slower hence well-function wildlife underpass could mitigate the impact. Bridges present in the highway unanimously serve as wildlife underpasses. Despite this, maintenance of existing bridges and updating of existing bridges into new suggest to build wildlife friendly bridges and other cross-road structures such as culverts and reptile/amphibian tunnels to minimize the number of roadkill animals along the road, to prevent vehicle-wildlife collisions, to reduce movement barriers and habitat fragmentation along the road.

Threatened and Endangered Species

Importance to people: Nature Conservation National Framework for Sustainable Development (2015) and Nepal National Biodiversity Strategy and Action Plan (2014) provide detailed description of aims and objectives on biodiversity conservation in country for next decades. These documents underline the importance of biodiversity for national and local economies. Wild plants and animals serve as source of biological resources providing food, fiber, fodder and many other products, they also serve for medical, ornamental, education, spiritual and cultural purposes. At the same time, biological species, and especially globally threatened and endangered species attract to the country significant number of visitors from around the World, contributing considerable resources for the conservation, ecotourism, hospitality sectors and overall development of the country's economy. Nepal is a lucky country, which can manage these important resources by sustainable ways, obtaining benefits for current and future generations.

Indicator species: are usually cover the set of species typical for community, indicating particular environmental conditions and serving as an early warning indicator of environmental changes. Such species also reflect the effects of disturbances or the efficiency of mitigation measures applied. The table of indicator species has been provided below. In total 14 species were designated in the project area as indicator species, which might be affected by road upgrades and construction of bridges including 8 mammal species, 2 bird species and 4 reptile species.

Table 13.5: Indicator species selected from the set of threatened and endangered fauna occurring in the KDP corridor, including KDP segment (project area) (Source KDP SEIA,2020)

Species	Status and population trends	Associated Issues
Asian Elephant Elephas *maximus*	EN (IUCN), EN (NE): <150 adults in Nepal	Several movement corridors may be affected during the upgrading of the KDP road since elephants are known in Parsa National Park.
Bengal Tiger *Panthera tigris*	EN (IUCN); EN (NE): Stable due to conservation efforts	Affected movement corridors in Parsa NP, disturbance, habitat fragmentation, effect on prey species
Nilgai *Boselaphus tragocamelus*	LC (IUCN); VU (NE): declining	Affected movement corridors and terrestrial habitats, disturbance, high road mortality
Chital *Axis axis*	LC (IUCN); VU (NE): declining	Affected movement corridors and terrestrial habitats, disturbance, high road mortality
Terai Grey Langur *Semnopithecus hector*	NT (IUCN); LC (NE): No population dynamics data	Affected movement corridors and terrestrial habitats, high road-mortality in project area
Indian Pangolin *Manis crassicaudata*	NT (IUCN); EN (NE): Decreasing	Affected movement corridors and terrestrial habitats, poaching, road mortality, barrier effect
White-rumped Vulture *Gyps bengalensis*	CR (IUCN); CR (NE): Declined	Can be attracted to roads for prey, possible road mortality
Bengal Florican *Houbaropsis bengalensis*	CR (IUCN); CR (NE): Declined	Indirect effects: habitat loss and fragmentation, poaching
King Cobra *Ophiophagus hannah*	NT (IUCN), VU (NE): decreasing?	Affected movement corridors and forest habitats, high road mortality in wet season, barrier effect, poaching

All selected species might be affected during road construction and upgrades, but by different ways. Some of them will be affected directly by loss of habitats, movement corridors and by high road mortality rates. Others will be affected indirectly in the result of habitat fragmentation and population isolation, declining prey species or due to opened access to the area with increased hunting and poaching.

Umbrella indicator: Umbrella indicator for this area was identified as an Asian Elephant, which require movement corridors, crossing the Kamala-Pathlaiya section in several places and needs the special coordinated strategies between several linear projects to ensure its movement corridors at the landscape scale.

Potential for the analysis of existing and post-construction conditions: Indicator species, including globally endangered species, will be used for the evaluation of efficiency for applied mitigation measures, for example, for efficiency of proposed and established cross-road structures and wildlife movement corridors in the area. “Before” and “After” impact monitoring

design is often used to explore effect of the road operations and efficiency of constructed cross-road structures on selected indicator species. There is a number of other methodical instruments that can be used to monitor effect of the road upgrades on threatened and endangered wildlife species during construction and road operations.

Some of these species, for example, like Gharial (Gharialis gangeticus), Bengal Florican (Eupodotis bengalensis), Gangetic Dolphin (Platanista gangetica), Clouded Leopard (Neofelis nebulosa), Tiger (Panthera tigris), Asian Elephant (Elephas meximus), Barasingha or Swamp Deer (Cervus duvauceli) are preserved only in several protected areas and few critical wildlife habitats. All sites, where such species found, should be protected. All these animals were found in the project area along the proposed KDP section and they need the special mitigation measures to minimize adverse effects of road development, direct, indirect and cumulative impacts. Some of these species may be identified as indicator and umbrella species to select mitigation measures, which will be suitable for other species in terrestrial or aquatic communities.

The area along the road was intensively developed during last 50 years in the time, when people from mountain regions moved to Terai after eradication of endemic malaria. Survey of the area showed that wildlife in many highly-populated areas is extirpated and replaced by few species, adapted to live in highly modified human environment. However, residual wildlife habitats along this section of the road still provide sufficient habitats and movement corridors not only for threatened and endangered species, but also for many other wild species, depending on the extent of natural habitats. Many local species of amphibians and reptiles still occur in natural terrestrial and aquatic habitats along the road and need special mitigation measures to prevent adverse effects on their populations and ensure their habitat connectivity for population processes, constructing or adapting existing engineering structures for road permeability.

Because East-West Highway in the project area operates for many years, wildlife poaching/trade is known in this region, but did not take the large scale, due to control and conservation of species within protected areas. However, domestic trade of pet species is quite developed. For example, parrots or other song or pet-bird species can be bought on the local market for 250-300 Nepali Rupees. Hornbill species (four species can be found in Eastern Terai region) are persecuted by local people in the project area for their beaks and other parts of the body that used in the traditional medicine (Basnet, 2005). Many ungulate animals are hunted for their meat (like deer, wild boar, nilgai and other antelopes). Over-hunting and poaching is actual problem in the project area that can be solved through enforcement of education and awareness programs.

Indirect impact on the threatened species is associated with land use change, driven by demographic and economic factors in plain Terai region after eradication of malaria and start of resettlement programs in 1960. Rapid population growth led to conversion of forests to cropland. Increased population density stimulated development of large urban and industrial centres. Many old growth forests were replaced by plantations with fast growing trees such as eucalypts (which are cut after 10-15 years) and teak (cut after 30 years). Plantations can be characterized by impoverished biological diversity; however, they still can serve as good corridors for wildlife migration. Old trees with cavities served as habitats for many species (for example, hornbills, woodpeckers, bears, squirrels, etc.) disappeared and natural habitats for mentioned and many other species were lost. So, remained natural habitats have enormous value for the protection of rich and diverse natural fauna and flora in the project area.

13.5 Anticipated Environmental Impacts and Mitigation Measures

Loss of Land

The field study shows that within the Right of Way (RoW) of 50m across the Kamala-Dhalkebar-Pathlaiya road section of Mahendra highway there is no need of the acquisition of land. Those who are cultivating the land will be compensated for their crops only if their crops are found growing at the time of the construction work.

Affected Asset

The widening of the road leaves a social and environmental impact to a lesser and greater degree. Such impacts can be assessed with close observation and survey of the road section.

Anticipated impact

Due to the road expansion, the poor and vulnerable including Rai, Limbu, Magar, Dalit, Tamang, Pahari, Madeshi residing at the side of the road will be affected largely. They will lose their trade and residential structures. Survey results as assessed by the consultant are given below:

Affected Private property

Altogether 69 structures (Tahara with tile, thatched, and zinc sheet roofed and 1 RCC house) is found to be affected by road expansion. Affected structures lie in 10 municipalities of 5 districts- Dhanusha, Mahottari, Sarlahi, Rautahat, and Bara. Almost all the structures except 9 structures (Residential use only) at Chandrapur municipality ward no. 6 are of both

residential and trade use. Tamang, Rai, Limbu, Magar, Pahari, Dalit and Madeshi are the residents of affected area. The details of the affected structures are given below in the table.

Table 13.6: Affected Private property

SN	Municipality	Number of the affected structure	Nature of the affected structure (Tahara & Rcc)	Alignment Right/Left	Chainage	Remarks
Danusha						
1	Ganeshman Charnath	12	Tile roofed, Zinc sheet roofed, open hut, Garage with zinc sheet (all taharas)	L-10, R-2	237+344-245+200	Trade & Residential Use
2	Dhanusha Municipality	1	Tile roofed	L	246+355	Trade use
3	Mithila Municipality	11	Tile roofed-10, thatched roof-1, bamboo wall, mud wall	L-8, R-3	253+950-263+695	Trade & Residential Use
Mahottari						
4	Bardibas Municipality	11	Tile roofed, Muddy & bamboo wall	R	271+ 300-279+950	Trade & Residential Use
5	Gaushala Municipality	4	Tile roofed, Muddy & bamboo wall	L	279+950	Trade & Residential Use
Sarlahi						
6	Ishworpur Municipality	8	Tile & Zinc sheet roofed, muddy and bamboo wall	L-4, R-4	289+242-290+00	Trade & Residential Use
7	Lalbandi Municipality	6	Zinc sheet & tile-roofed tahara	L-4, R-2	291+251-294+258	Trade & Residential Use
8	Hariwan Municipality	5	4 zinc sheet & tile-roofed Tahara and 1 RCC house	L	301+238-303+620	Trade & Residential Use
9	Bagmati Municipality	2	2 tile-roofed tahara	L	310+418-311+136	Trade & Residential Use
Rautahat						
10	Chandrapur Municipality	9	9 Thatched roof tahara	R	334+143	Residential Use by Pahari Ethnic group
Total		**69**				

Source: Field Survey, 2022

Affected public Structure

Now, 24 temples, 47 waiting sheds, and 11 other types of structures (temporary police posts, triangular and circular-shaped structures) are affected by the project. These affected structures lie in 11 municipalities of 5 districts.

Table 13.7: Affected public Structure

SN	Municipality	Waiting shed (Pratichhyalaya)	Other public structures	Nature of other public structures	Chainage range	Remarks
Dhanusa						
1	Ganeshman Charnath	4	1	Temporary Traffic police post	237+344-245+60	
2	Dhanusha Municipality	2	2	Triangular shaped structure	246+225-250+485	
3	Mithila	11	5	Circular and triangular-shaped structure and a police post	253+950-265+00	
4	Bardibas	2	1	Police post with chautara	271+300-282+675	
5	Gaushala	1	-	-	282+675	
6	Ishworpur	1	-	-	290+00	
7	Lalbandi	3	1	Triangular shaped structure	290+537-299+547	
8	Hariwan	9	-	-	300+790-307+116	
9	Bagmati	8	-	-	309+500-312+598	
10	Chandrapur	1	1	Triangular shaped structure	326+600-327+635	
11	Nijgadh	5	-	-	343+409-345+900	
Total		**47**	**11**	-		

Source: Field Survey, 2022

Affected Religious Trees, Water Bodies and Chautara

Altogether 159 religious trees (Bar/Pipal) are affected by the project in 12 municipalities of 5 districts. 5 ponds and 9 Chautara are also impacted by the KDP project. As far as possible the religious trees should be transplanted or relocated. The details of impact are given below in the table:

Table 13.8: Affected Religious Trees, Water Bodies and Chautara

SN	Municipality	Religious trees (pipal/Bar)	Water bodies (pond)	Chautara	Nature of Chautara	Chainage range	Remarks
Dhanusha							
1	Ganeshman Charnath	4	-	1	Chautara with Pakhe tree	237+344-245+700	
2	Dhanusa Municipality	7	1	1	Chautara with Ashok trees	246+225-250+485	
3	Mithila	44	1	1	Chautara with Ashok trees	251+610-265+00	
Mahottari							
4	Bardibas	12	-	2	Chautara with Ashok trees	266+148-269+300	
Sarlahi							
5	Ishworpur	2	-	-	-	289+970-290+00	
6	Lalbandi	13	2	1	Chautara with Pakad tree	293+711-296+90	
7	Hariwan	40	-	2	Chautara with Sami trees	300+790-307+720	
8	Bagmati	21	-	1		308+00-312+964	
Rautahat							
9	Chandrapur	10	1			313+500-329+00	Pond within Jana Yekata Community forestry
10	Gujara	1	-	-	-	338+00	
Bara							
11	Nijgadh	5	-	-	-	345+900-357+00	
12	Jitpur Simara Sub-Metropolitan	2	-	-	-	357+100-366+00	
Total		**159**	**5**	**9**			

Source: Field Survey, 2022

Affected Temples

Altogether 24 temples are found to be affected by the project. Types of temples are various: Mahadev; kamala Maharani; Hanuman; Dihabar & Bhola Baba; Hanuman Temple; Ganesh; Shriram; Shiva; Krishna; Hanuman; Mahadev; Rajdevi ; Bramasthan Temples.

Table 13.9: Affected Temples

SN	Chainage	Ward no.	Name of the temple	Left/Right	Remarks
Ganeshman Charnath Municipality					
1	237+344	8	Mahadev & Kamala Maharani	R	
2	237+344	8	Hanuman	L	
3	238+400	7	Dihabar & Bhola Baba	L	
4	239+00	7	Ganesh Temple	L	
5	244+400	1	Hanuman Temple	L	
Mithila Municipality					
6	254+038	4	Harihar Baba	R	
7	257+063	6	Hanuman	R	
8	257+115	6	Shriram	R	
9	260+400	8	Shiva Temple	R	
10	261+283	9	Krishna Temple	L	
11	264+160	10		L	
Bardibas Municipality					
12	275+331	5	Hanuman	L	
Lalbandi Municipality					
13	290+537	17	Mahadev	L	
14	293+711	6	Shiva Temple	R	
15	295+310	6	Shiva Temple	L	
16	295+580	9	Hanuman Temple	L	
Hariwan Municipality					
17	301+205	4	Bramasthan	L	
18	301+238	4	Mahadevsthan	L	
19	301+290	4	Krishna Temple	R	
20	301+628	4	Rajdevi Temple	L	
21	305+00	11	Hanuman Temple	R	
Nijgadh Municipality					
22	346+800	8	Shiva Temple	R	

Loss of public utilities

No drinking water pipes are found to be affected by the project. However, electric poles and solar panels impacted by the project.

Impacts on the ponds around the alignment:

There are number of ponds near to the road alignment. The ponds are public properties. The construction activities will hamper the ecological aspects of the project. The Land area of the

pond will get affect by the construction activities and may encroached the loand of the pond. There are following ponds near to the road alignment.

Table 13.10: Ponds within RoW

S.N.	Description	Chainage		Length	Side of Ponds	Number of Ponds	Pond Edge Distance from Center Line of Alignment (m)	Remarks
		Start	End					
1	Ponds	242600	242750		LHS	1	22.16	
2	Ponds	242765	242865		RHS	2	19.12	
3	Ponds	242960	243050		RHS	1	22	Under VUP approach at Birendra Bazar
4	Ponds	243000	243150		LHS	1	20.9	Under VUP approach at Birendra Bazar
5	Ponds	247870	247900		LHS	1	7.8	
6	Ponds	255190	255310		LHS	1	18.5	
7	Ponds	293620	293720		LHS	1	14.45	
8	Ponds	295310	295370		RHS	1	15	
9	Ponds	301000	301080		LHS	1	12	
10	Ponds	304920	304950		LHS	1	24.95	
11	Ponds	304960	305000		LHS	1	17.15	

The impacts can be mitigated by the following measures:

- Construction should not hamper the ponds.
- There should not throw the construction materials in to the ponds
- Safe measures like gabion wall should be constructed to protect the pond land area
- No waste should be discharged in the water sources like ponds near to the road alignment
- The use of different types of grasses could be used to stabilize and heal erosion damages,
- The erosion near to the pond need to be protected

13.6 Environmental Impacts during Construction Stage

The existing road upgraded to an Asian Highway Class II, 2-lane, double bituminous surface treatment (DBST) pavement, 50m right-of-way (ROW), 12m formation width, 7m carriage width, and 2.5m shoulders. The key upgrading activities include geometry improvement, pavement upgrade, drainage improvement, retaining structures, slope protection/stabilization. About14 km of road that upgraded will pass through buffer zone, of Parsa National Park. The PNP is the habitat of some endangered species as well as endemic species, and therefore it is considered as biodiversity critical habitat. According to the WB ESP Framework, development projects that likely to cause environmental impacts on biodiversity critical habitat should be assessed for its environmental impacts, and mitigation measures should be prescribed, to achieve at least no net loss of biodiversity. **Table 13.11** below presents the likely mitigation measures of project that may generate impacts on biodiversity.

Table 13.11: Likely mitigation measures of project that may generate impacts on biodiversity

No.	Suggested Mitigation Measures	Situation in Project Area	Project Actions
1	Minimizing habitat loss	The Project will not cause habitat loss in Parsa National Park (PNP) and buffer zone areas.	N/A
2	Identification of “set-aside” to avoid impacts on biodiversity, e.g. preserving certain percentage of significant habitat.	The Project will not cause habitat loss in wildlife reserve and buffer zone areas	N/A
3	Post-project restoration of impacted areas with appropriate native species	The Project will not cause habitat loss in wildlife reserve and buffer zone areas.	N/A
4	Offsetting biodiversity losses through the creation of effective long-term conservation of ecologically comparable area(s).	There is no significant biodiversity loss, since the project will not affect the critical habitat (the wildlife reserve).	All trees to be felled compensated at a rate of 1:25 and cared for the next 5 years. Efforts be made to further reduce the number of trees required for felling through geometric realignment, Compensation planting (which can be considered as biodiversity offset) undertaken in: (i) buffer zone, to replace tree loss; (ii) PNP, habitat improvement for elephant, and other wildlife; (iii) major river crossings for improving

No.	Suggested Mitigation Measures	Situation in Project Area	Project Actions
			elephant and birds habitat; (iv) along road, to improve general environment.
5	Compensating the direct users of the affected biodiversity, commensurate with the loss caused by the Project.	The Project will not cause direct impact on the wildlife reserve, but will cause loss of ……. trees as described above.	DOR will provide compensation on the loss of trees at a rate of 1:25 as required by the Ministry of Forest's Working Guideline for the Utilization of Forest Area to Other Use (2006).

13.7 Ecological Impacts

Loss of trees

Impact

The project road crosses many forested areas. However, all these areas are Community Forests and National Forests.

Mitigation

All trees to be felled compensated at a rate of 1:25 and cared for the next 5 years as required by the Ministry of Forest's Working Guideline for the Utilization of Forest Area to Other Use (2006). Before the felling of any trees, prior approval from the jurisdictional CFUG and clearance from the respective District Forestry Officer (DFO) must be obtained. Efforts made to further reduce the number of trees required for felling through geometric realignment, during construction survey when ground staking is performed by the Contactor and Engineer. The rates are based and fodder shrub on information provided by the Department of Forest. An additional 10% of trees have been included to address issues of low survival rate or plant mortality. Identification of plantation location and species of trees carried out by the respective local forestry office or community forestry user group (CFUG) following the payment of the budget for compensatory plantation is made by the DoR. A separate programme prepared by the the local forestry department/CFUG to implement the compensatory plantation.

A compensatory Plantation done against the tree cut for road upgrading, the tree planting will also aim at enhancing environmental quality in this area, including improving elephant habitat. The project is to develop fodder plantation (trees and shrubs) within Parsa National Park as food resources for elephants since this is considered to be able to improve elephant habitat within Parsa National Park area. The trees can be used as roosting place and nesting for birds and attract insect and other small creatures that provide food for birds. Road-side planting at selected areas along the road may also improve general environmental condition. Tree

planting planting fodder tree and fodder shrubs as food resources for elephants, tree species selection and tree planting location should consider wider environmental improvement for people as well as improving bird habitat considering that, and also wider environmental improvement considerations. The suggested locations of tree planting as follows:

1. Within the National Forest. The purpose of the tree planting is at least to replace the trees those have been cut for the Project. Tree selection will be decided by affected buffer zone community and agencies concerned.Usually economical consideration will be the priority, for instance by planting tree species those have commercial value. Agencies and organization involved include: Forestry Office, CFUG, the community.
2. Within the Parsa National Pak. The purpose of tree planting within PNP is for fodder trees and shrubs for the elephants, and for improving bird's habitat. The location within PNP will be decided during project implementation. Agencies and organization involved include: DNPWC, CFUG.
3. At major river crossing. The purpose of tree planting around the large river crossing is to atrract elephant herd to cross under the bridge as well as bird habitat (during bird migration season in winter, waterfowl will use various water bodies in the area including rivers). Besides, the survival rate of the trees would be better if planting is located close to rivers. Agencies and organization involved include: DOR, BZMC, BCN, and Municipalitiess.
4. Along the road. Planting of trees along the road in settlement areas may function as reducing noise as well as dusts from the road. The trees may improve general environmental conditions and bird habitat. Agencies and organization involved include: DOR, BCN, Municipalitys, and the community.

The budget required for felling the trees as well as compensatory afforestation will be borne by DOR. 25% of the afforestation requirement will be met by plantation of fodder trees for elephants. Hence 25% of the budget be utilized for fodder plantation activities.

Considering Government requirement for tree compensation at a rate of 1:25, the same number of trees will restore the previous function of trees, and the rest will have positive impacts for environmental improvement. The positive impacts will include: (i) additional income to the communities in the community Forest area, (ii) habitat improvement for elephant within the PNP and selected sites along large rivers with bridges, (iii) habitat improvement for resident and migrating bird within PNP and at selected sites along rivers, and (iv) environmental improvement through planting of trees along the road.NGO and community

involvement in tree planting is expected improvingsurvival rate of trees planted under this program.

13.7.1 Impact on Physical Environment

Air Emissions

Impacts

The potential sources of air pollution during the construction phase include: dust from earth works; emissions from the operation of construction equipment and machines; unpaved road travel, materials storage hauling, fuel combustion, and cooking and waste incineration inside labor camps.

Mitigation

Short-term direct impacts of fugitive dust emissions from materials storage, hauling and unpaved road travel will be mitigated through: i) vehicle restriction in terms of speed, weight, haul cover, and number; ii) surface improvement by adding gravel or slag on dirt road; and iii) surface treatment like watering to suppress dust. Emissions from storage and quarry areas will be controlled through wind speed reduction by installing wind breaks or covering, and water suppression will be implemented.

Emissions from construction equipment such as hot mix plants, stone crushers, diesel generators, haul trucks, pavers, graders, and rollers will be managed through regulatory compliance to emission standards and proper operation and maintenance. All hot mix and stone crushers will be located at least 1 kilometer from the nearest community and necessary permits and clearance secured prior to operation. All diesel generation sets will be fitted with stacks observing good engineering practice where height of stack = height of the nearest building + 0.2 ⊓ KVA (Kilo-Volt-Ampere).

No firewood for cooking and heating bitumen, and incineration of wastes will be allowed by the Contractor.

Air quality monitoring will be implemented by the Contractor and Engineer to ensure compliance to ambient air emission standards are maintained. The Contractors will monitor air quality within the construction camps and active road construction fronts, while the Engineer will monitor in settlement areas, as provided in the Monitoring Plan.

Noise Level

Impacts

During the construction stage, ambient noise will increase temporarily and intermittently in the close vicinity of active construction fronts and camps. These activities are expected to produce noise levels in the range of 80 - 95 dB (A) at a distance of about 5 m from the source.

Mitigation

Noise during construction phase will be mitigated through the following: i) siting noise sources away from the communities and sensitive ecosystems, the construction camp including all plants will be located at least 1 kilometer away from the communities; ii) timing of construction activities only between 7 am to 6 pm to avoid disturbance to nearby communities at night; iii) installation of acoustic barriers to confine equipment near sensitive sites like schools, hospitals, government offices, and inside the Parsa National park along active construction fronts. All construction workers exposed to elevated noise will be provided ear plugs and muffs exposure limited to no more than 8 hours at greater than 85 dB.

Similarly, air quality monitoring will be implemented by the Contractor and Engineer to ensure compliance to noise standards. The Contractors will conduct monitoring within the construction camps and active road construction fronts, while the Engineer will do the monitoring in settlement areas, as provided in the Monitoring Plan.

Vibration

Impacts

Blasting is not necessary for the construction of the road. However, there is likelihood human discomfort and damage to infrastructures (crack formation) due to the vibration caused by concrete breaking excavators used to lift the existing road surface, rollers and compactors used to resurface the existing road, and truck movements.

Mitigation

Mitigation measure to avoid discomfort is the timing of activities to avoid sensitive periods. If structural damage is observed, the Contractor will modify construction equipment or the construction method.

Loss of Productive Soil and Agricultural Lands

Impact

The conversion of agricultural land to allow the proposed road widening and soil borrowing for embankment formation will lead to loss in productive agricultural soil during the construction.

Mitigation

To minimize this impact, top soil (0-25 cm) from the productive land will be collected and stored for reuse as final dressing of embankment turfing or given back to the farmers upon request.

Borrow Pits and Quarry Sites

Impact

Various rivers along the road alignment contain abundant soils, stones, sand and gravels can be quarried from several location in rivers beds without developing large size, borrow pits and quarry sites. Soil erosion may arise if borrow area are not stabilized/restored properly.

Mitigation

The development of borrow pits and quarry sites will be governed by the following:

- Only wastelands will be used for borrowing and outside protected and forest areas, settlements, and water sources.
- Approval from authorities of government and landowners will be taken.
- Suitable size of borrow pits and quarry sites will be operated as per required volume of materials.
- Top soil will be stockpiled and preserved for the re-instatement of the site or used in the road embankment turfing.

Soil Contamination and Compaction

Impacts

During construction phase, several project activities pose risk of loss or impairment of productive agricultural lands. Soil may get contaminated from handling of construction materials such as stones, sand, gravels, bitumen, fuel, lubricants, paints, and disposal of solid and sewage. Soil compaction may take place in haulage roads, labor camps and workshop areas due to movement of construction vehicles, machineries and equipment.

Mitigation

To avoid this impact, an Environmental Management Action Plan (EMAP) that further details the EMP will be prepared and submitted by the Contractor no later than 30 days after the Notice to Proceed (NTP) for review and approval of the Engineer. The location, layout, and operation guidelines of construction camps, haulage roads, workshop and storage area for different materials will provide in the EMAP. Detailed guidelines on materials handling will include:

- The storage area will be paved with gentle slope to a corner and connected with a chamber to collect or recover any oil spills.
- All efforts will be made to avoid and minimize the solid and liquid wastes generation. Unavoidable solid and liquid wastes will be stored at designated places prior to disposal.
- To avoid soil contamination at the wash-down and re-fuelling areas, “oil interceptors” will be provided.
- Oil and grease spill and oil-soaked materials will be collected and stored in labeled containers (Labeled: WASTE OIL and hazardous sign be displayed).
- Restrict movement of construction vehicles, machinery and equipment in the designated haulage route.
- Efforts will be made to design approach roads through the waste/barren land and rocky area to reduce the compaction induced impact on soil.
- Farm land will be restored after the completion of road improvement activity.
- Temporary latrine pits will be provided in the construction camps and will be restored after the completion of activity.
- Solid waste generated from construction camp will be segregated into biodegradable and non-biodegradable wastes. The non-biodegradable and recyclable waste will be sold off. Efforts will be made to compost biodegradable wastes in small size compost pits by the Contractor.

Siltation and Contamination of Rivers

Impacts

Particularly during bridge construction, siltation from construction spoils and water contamination from oil spills may occur which could impair the beneficial use of the receiving rivers. Water bodies near construction camp are at risk of contamination from the disposal of sewage, solid waste, and construction material spills.

Mitigations

Mitigation measures to be implemented by the Contractor are:

- Prohibit disposal of excavated spoils and debris into river water.
- Bridge construction activities including pile driving will not be undertaken during monsoon season (June- September).
- All chemicals and oil will be stored away from water and concreted platform with catchments pits for spills collection.
- Arrange training program to all equipment operators, drivers, and warehouse personnel on immediate response for spill contamination and eventual cleanup. Further, emergency procedures and reports preferably written in easy-to-understand local dialect will be distributed to the equipment operators, drivers and warehouse personnel.
- Silt fencing and/or brush barrier will be installed for collecting sediments. Collected silt/sediment will be stockpiled for possible reuse.
- All wastes arising from the construction sites will be disposed in an environmentally accepted manner. Wastes will be collected, treated (e.g., sewage through septic tank) or stored (e.g. waste oil, lubricants, and paints) prior to disposal or transported to the approved disposal sites.
- No vehicle or equipment will be washed, parked or refueled near river water
- All labor camps will be located at least 500 meters from rivers and to the extent possible laborers will be locally recruited to avoid large camps.
- Sewage from labor camps will be treated through septic tanks. No untreated sanitary wastewater will be discharged into the river water.
- All impacted rivers will be monitored monthly during the active construction activity occurring in its reach. Upstream and downstream water quality parameters will be collected to determine the effectiveness of mitigation measures.

Hydrology and Drainage

Impact

Potential impacts hydrology and drainage are attributed to the risk of increasing sedimentation and siltation of waterways during construction phase.

Mitigation

Existing natural drainage system, including irrigation channels will not be disturbed. Causeways will be provided in each perennial and seasonal streams as well as rivulets. In

addition, adequate cross drainage structures will be provided to facilitate natural flow of water across road embankment. New bridge sites are selected because of the geologically stability and elevation to minimize risk of slope failure and bank cutting problem.

Construction Spoils/Waste

Impacts

Road construction generates substantial amount of waste which includes demolition debris, earth spoils, municipal waste and sewage from camps, fuels and lubricants, and rejected construction materials like bitumen, sand, gravel, and cement. These wastes post hazard to human health and safety.

Mitigation

As a component of the Environmental Management Action Plan, the contractor will provide details of monthly estimated amounts of waste by type, type of collection, treatment, and disposal.

13.7.2 Socio Economic Impacts

Occupational Health and Safety

Impacts

Road construction exposes workers to various physical hazards that may result to minor, disabling, catastrophic, or fatal injuries. Working close to rotating and moving equipment like hot mix plant operation, materials handling, motor pool repairs/machining and the like create trap hazards putting extremities at risk. Exposure to loud noise can cause temporary or permanent hearing impairment. Hand-arm vibration, electrical, welding/works, and working close to moving vehicles also expose workers to injuries.

Mitigation

Employers are required to implement precautions to protect the health and safety of workers. ESIA Report will presents the “Work Safety in Common Operation and Construction” to be implemented by the Contactor.

Hygiene in the Construction Camp

Impact

With the bias towards locally sourced labor, the construction camp required by the project is expected to be small, with less than 150 individuals staying at any single time. However, experience has shown that a poorly managed construction camp becomes hazardous to its

tenants. Poor hygiene in waste handling, food preparation, and sleeping quarters expose workers to vector-borne diseases.

Mitigation Measure

Consistent with the FIDIC requirements, the Contractor is responsible for: i) providing electricity, gas and water to the construction camp, ii) health and safety of personnel, in collaboration with local health officials, will ensure that medical staff, first aid facilities, sick bay and ambulance service are available at all times, iii) conduct STI, STD and HIV-AIDS awareness program, iv) providing sufficient supply of suitable food and water, and iv) take necessary precautions to protect personnel from insect and pest nuisance to reduce their danger to health.

The contractor will appoint in writing a safety officer no later than 30 calendar days after the issuance of Notice to Proceed. The safety officer will maintain records concerning health, safety and welfare, and damage to properties on monthly basis to form part of the environmental monitoring report to WB.

Impacts on Community Health and Safety

Impacts

These impacts pertain to those that take place outside the project boundaries, in this case the ROW and campsite, but are related to road construction and operation. Impacts on water quantity, and air and water qualities were discussed in other sections. Other impact on community health and safety related to road construction pertains to road crashes, structural safety, transport of hazardous materials, communicable and vector borne diseases, and emergency preparedness in case or road failures such as slides and flooding rendering villages inaccessible. Accident risks associated with increase in vehicular traffic, leading to accidental spills of toxic materials is magnified during construction.

Mitigations

Risk of road crashes will increase during construction when a construction related and transport vehicles, and workers are co-located along restricted construction fronts. During construction phase, the projected increase in the number of motorized road users traveling at higher speeds also increases the chances of injuries and fatalities from road crashes. To mitigate these risks, the contactor needs to adopt safety measures for workers and road users particularly those that are more vulnerable to crashes. Contractors need to emphasize safety among drivers; ensuring drivers have adequate skills, avoiding dangerous routes and times of day to reduce chances of crashes, speed control devices, and regular maintenance of vehicles

to avoid premature failure. The address the risk cause by increase in traffic, the Contractor will: i) minimize pedestrian interaction with construction vehicles, ii) install signage, visibility and overall road safety particularly near schools or where children are present, iii) coordinate with local emergency groups on location of active construction fronts to facilitate appropriate first aide, iv) use of local materials to the extent possible to reduce hauling distance, v) employ flag person to warn dangerous conditions.

Contractor's or its third party suppliers of fuel, lubricants, and bitumen will be required to demonstrate proofs of capability to handle spills to include: i) proper labeling of container content, hazards, and operator's contact details; ii) ensure the integrity of the packaging/containers and transport vehicle are commensurate to the hazardous material; iv) drivers and assistants are trained on transport and emergency procedures; v) operator has the means to respond to emergencies on a 24 hour basis.

The construction camps pose risk of communicable and vector-borne diseases not only among its workers but to the host communities through poor camp sanitation and living conditions, migrant workers might carry sexually-transmitted diseases such as HIV/AIDS. The Contractor will undertake health awareness and education through information and promoting individual protection. The Contractor will link with existing state and national health programs on STDs, HIV/AIDS, and immunization. Contractors will cause the provision of treatment of communicable diseases in community health care facilities, access to medical treatment, confidentiality particularly with respect to migrant workers. The Contractor, will implement mosquito, rodent, and arthropod-borne diseases control that will have the following components: i) prevention of propagation by eliminating all breeding habitats close to the camps, ii) elimination of all unusable impounded water; iii) increase water velocity in channels near camps; iv) judicious use of insecticides on building walls; v) promoting the use of mosquito nets; vi) monitoring and treatment of diseases and collaboration with health officials, vii) distribute educational materials among workers and host communities, and viii) proper handling and use of insecticides to minimize human exposure and spills.

Roads and bridges failures due to inadequate designs may cause injuries to community and other road users. This risk is mitigated through the compliance with appropriate engineering design standards by the design engineers and review and approval of engineering plans by the PWD. All new bridge constructions are designed to cope with a 100 year return period and withstand earthquakes usually experience I Seismic Zone 5.

13.7.3 Environmental Impacts During Operational Stage

The road project upgrading of existing road within the existing alignment, therefore clearing of forest areas that lead to habitat framentation will not occur. It is predicted that there is no major environmental impactsof the road during operational stage.

Ecological Impacts

Impacts

A common impact of road construction or improvement usually enhanced migrationofpeople to the project area through improved access brought about by the project. However, such in-migration is considered unlikely because the existing regulation on buffer zone. As mentioned earlier that the Buffer Zone Management Rules (1996) will prevent illegal occupation of the buffer zone area without legal ownership. The Rules alsoprohibit people to cut trees, clear forests or cultivate forestland within the buffer zone. Therefore, people encroachment into or to settle in the buffer zone is unlikely. During this time when the traffic is busy, the elephant may avoid and may not be able to cross the road. Therefore, there will be the need for alternative crossing for the elephant.

Mitigation

Several consultations were carried out with the local communities, Parsa Wildlife Reserve management, to assess the impact of road upgrading on the wildlife reserve. While significant impacts on the reserve is unlikely, measures to improve the present situation will be undertaken.A fourfold approach will be adopted to better facilitate elephant movement between their habitat patches, as well as improving the Parsa National Park conservation. Elephant movement in areas west of PNP willrequire the elephant passing the road alignment. The approach strives to facilitate elephant movement across the project road, enhance monitoring in the project area through establishment of checkposts, improve wildlife habitat through fodder plantation and build the capacity of the local community people to make them better stewards of the Parsa National Park and the wildlife in the project area.

Facilitate movement of wild life on the project area (Wild Life Crossing)

When the traffic still low (like the present time), elephant herd will continue crossing the road. When the traffic frequency becomes higher and the road become busier, the elephant usually will avoid it, and looking for safer crossing points. The following wildlife Animal Crossing have been proposed for the eacsy crossing of the wildlife in the road. Two types of wildlife crossing have been proposed in this alignment. 8 numbers of Elephant like big animal crossing and for

the medium sized animals 10 crossing have been proposed. The chainage and their crossing as well as size is as follow.

Table 13.12: List of Proposed Elephant Crossing Structures

S.N.	Chainage (Bridge Center)	Exiting Structure			Proposed Structure				Remarks
		Name of Bridges	Number of Spans	Span Length (m)	Total Length (m)	Number of Spans	Span Length (m)	Total Length (m)	
1	329+752	Amu - 1	3	11.34	34.02	1	34	34	Existing Road Level to be raised by 5.59 m
2	333+733	Lamaha	2	33	66	2	33	66	Sufficent Clearance at Structure
3	339+342	Dhansar	8	20.5	164	4	41	164	Restricted Vertical Clearance of 4.55 m at Structure
4	347+209	Bakeya	16	22.2	355.2	4	88+154+88+22	352	Sufficent Clearance at Structure
5	353+628	Terhakilo	4	11.4	45.6	1	35	35	Existing Road Level to be raised by 6.72m
6	357+227	Pasaha	5	33	165	5	33	165	Sufficent Clearance at Structure
7	358+477	Bangandi	10	11.36	113.6	4	25	100	Sufficent Clearance at Structure
8	363+585	Dudhaura	2	45.25	90.5				Bridge Under Construction with sufficient clearance

Table 13.13: List of Proposed Medium Sized Wild Animal Crossing Structures

S. N.	Chanage (Bridge Center)	Existing Bridge/ Causeway				Proposed Bridge Cum MAC Structure			
		Name of Bridge/ Causeway	Number of Spans	Span Length (m)	Total Length (m)	Number of Span	Span Length (m)	Total Length (m)	Remarks
1	271+514	Gadhanta	5	12.5	62.5	2	31.25	62.5	
2	274+925	Belgachhi (Dhungre Khola)	4	9.5	38	2	20	40	
3	275+630	Tuteshwor-1	2	9.5	19	1	19	19	
4	277+266	Maraha	8	15+2*18+2*15+2*18+15	132	4	33	132	
5	278+913	Dholan	4	9.5	38	1	38	38	
6	282+758	Bankhe	6	15+4*18+15	102	3	33+36+33	102	

S. N.	Chanage (Bridge Center)	Existing Bridge/ Causeway				Proposed Bridge Cum MAC Structure			
		Name of Bridge/ Causeway	Number of Spans	Span Length (m)	Total Length (m)	Number of Span	Span Length (m)	Total Length (m)	Remarks
7	285+721	Amuwa	2	9.5	19	1	19	19	
8	292+703	Kalinjor - 2	3	22	66	3	22	66	
9	317+698	Paurahi	3	22	66	3	22	66	
10	322+553	Causeway	1	160	160	1	8	8	Box Culvert with 3m Vertical Clearance

Beside these crossing following measures will also be adopted.

- Ensure riverbed will have flatbed along torrent, and no vertical drop in the bed.
- Plant more vegetation close to the bridge that will provide camouflage of the bridge structure
- Local vegetation should be planted so it looks like integral part of the forest, and the sidewalls of the structure be camouflaged.

Impacts on Physical Environment

Impacts

Impacts during the operation phase decreases dramatically in number and scale, and shift towards road safety. However, after construction the DoR's control over activities occurring on the road is also limited. Impacts expected to occur are deterioration of air quality from increase emissions from increase in traffic, risk of structural damage from increase in vibration, improve accessibility will increase the need to convert lands into built-area resulting loss in agricultural lands and congestion, deterioration of receiving water quality from oil laden runoff, and increase in road crashes.

Mitigations

During the project operation phase, the DoR has limited control over the road users and can only implement activities that will influence vehicle owners in controlling emissions. These activities include coordination with relevant agencies on the implementation of the Nepal Vehicle Mass Emission Standard, 2056 (2000), provision of informatory road signs reminding the motorist to properly maintain their vehicles to economize on fuel consumption and protect

the environment; and support development organizations (NGO, INGO and CBOs) to motivate the local communities to maintain greenery in the project area.

The principal noise sources are motor vehicle engines, exhaust, and tire to pavement contact particularly at speeds greater than 90 kph. This mitigated through: i) vegetation noise barriers as a component of compensatory afforestation; and ii) speed brakes near community areas and inside the Parsa National Park.

Increase in vibration due to the plying of heavy buses and trucks may damage the infrastructure. The DOR will coordinate with the Ministry to monitor truck loads as per Nepal Road Standard, 2027 B.S. (First Revision 2045 B.S.) and drivers made aware about the capacity of the road and bridges, and their consequences through signage.

To address this uncontrolled ribbon development along the project road, the DOR will encourage affected Municipalities to prepare and implement their respective development plans.

The DOR will implement its Length-Persons system wherein identified staff are made responsible for routine and recurrent maintenance of roads like cleaning up drains, soil deposited on the roads due to slope failure and erosion to maintain and sustain access.

During project operation phase, water quality deterioration may occur from oil-contaminated runoff however this is considered minimal owing to the low expected traffic volume.

The risk cause by increase in traffic to communities addressed early in the when road safety furniture has been integrating in the overall road design.

13.8 Environmental Management Plan

The Environmental Management Plan (EMP) contains the agreement between DOR and WB detailing the implementation of mitigation measures, monitoring program, cost estimates, and institutional arrangement to ensure that no significant adverse impacts results from the investment.

The basic objectives of the EMP are to:

- establish the roles and responsibilities of all parties involved in the project's environmental management;
- ensure implementation of recommended actions aimed at environmental management and its enhancement; and

- ensure that the environment and its surrounding areas are protected and developed to meet the needs of the local communities including other stakeholders and safeguard and the interests of the common people.

The EMP principally a guide on how to implement mitigation measures prescribed in this EIA report. The environmental mitigation measures have been differentiated into the following three stages: (i) design stage, (ii) construction stage, and (iii) operation and maintenance stage.

Design Stage:

(i) Principles of Mitigation Measures. The mitigation measures adopted during design or pre-construction stage are of preventive in nature with two basic objectives: (i) avoiding costly mitigation, and (ii) awareness among the stakeholders for environment protection while constructing and operating infrastructure services. During detailed design,the consultants conducted a census survey and assess the potential impacts and losses on properties and lands, and establish the baseline data for compensation. The detailed design has included all possible preventive measures to avoid or minimize slope instability, disruption of water systems, minimize disturbance to settlements, minimize forest loss, and affecting cultural assets and the aesthetic value of the landscape. The design has adopted the labour based and machine intensive approach, minimizing/avoiding blasting and use of mechanized method, as far as practical. Bio-engineering will be used for slope stabilization in an environment friendly manner, and plan for using local resources and manpower.

(ii) Inclusion of EMP requirements in BOQ. To become effective and verifiable, all provisions mentioned in the EMP will be reflected in the Bill of Quantity (BOQ) explicitly while issuing Tender Document for the Contractors. The contractors must clearly quote these activities in BOQ rate, and provide beforehand any comments in case of opposing these clauses.

Construction stage. Aside from adverse environmental impacts or negative impacts, there are also beneficial or positive impacts of the Project. The beneficial impacts will include: generation of employment, opportunities for new income-generating activities, and enhancement of technical skills. To address the adverse impacts, the executing agency will identify measures to avoid, minimize, or mitigate potentially adverse impacts and risks and, as a last resort, propose compensatory measures. Various physical, biological and socio-economic impacts have been summarized in the EMP.

Operational Stage. Following beneficial impacts are anticipated during operation stage: improved access to services and reduced total transportation cost and time, increase in land value, harnessing of potential local resources, increase in agriculture production, increase in opportunities of high value crops cultivation and commodities development, development of tourism and improvement in educational and health facilities. The adverse impacts have been analyzed categorizing them in compensatory, preventive and the mitigating measures. Various physical, biological and socio-economical impacts have been summarized in the EMP.

The EMP provides a basis for the implementation of environmental protection measures. This includes project monitoring, auditing, project management issues and the verification of predicted environmental impacts actually arising from the project implementation, institutional arrangement for implementation. It also incorporates the estimated budget for implementing the EMP.

The environmental protection measures of this subproject implemented during the preconstruction stage, construction stage and operational and maintenance stages of the project. The implementation of the mitigation measures the responsibility of the proponent. All preparatory activities related to site clearance and design works will complete during the reconstruction stages. The proponent will continue its environmental protection activities during the post construction or the operational stage as well.

A detailed EMP is prepared in ESIA and will form part of the biding documents. The costs for the mitigation measures other than the compensatory plantation are dealt under the engineering (civil works) and resettlement (compensation) estimate.

13.9 Environmental Monitoring Plan (EMoP)

A companion document of the EMP, the Environmental Monitoring Plan (EMoP) contain parameters, location, sampling and analysis methods, frequency, and compared to standards or agreed actions that will indicate non-compliances and trigger necessary corrective actions. More specifically, the objectives of the EMoP are:

- ensure that impacts do not exceed the established legal standards
- check the implementation of mitigation measures in the manner described in the EIA report
- monitor implementation of the EMP.
- provide an early warning of potential environmental damage

- check whether the proposed mitigation measures have been achieved the intended results, and or/ other environmental impacts occurred

The monitoring plan will be used for performance monitoring of the project. A monitoring plan defining all parameters to be monitored, with tentative location, project stages for measurements, implementation and institutional responsibility for different environmental components need to be prepared.

As a guiding principle in designing the EMoP, ambient monitoring to assess impacts on sensitive receptors like community areas and rivers will be conducted by the Supervision Consultant while point-of-source emissions and discharges are to be monitored by the contractor which is usually part of permit/clearance application and renewals.

13.10 Bio-Engineering

Bioengineering is an integral part of Green Road concept. It uses living vegetation, either alone or in conjunction with civil engineering structure and non-living plant material to reduce shallow-seated instability and erosion on slopes. Positive mechanical and hydrological properties of plants are utilized to control erosion and stabilize the slope. This is the most effective, low-cost measure. It can be applied in the failed zone of slope as a curative means and also for reducing the risks of future slope failure as a preventive measure.

Bioengineering is a sustainable approach where the combination of live and dead plants and plant parts are used as building materials for erosion reduction and upland slope prevention. The combination of vegetative engineering systems and civil engineering systems normally offers the most complete natural and cost-effective solution to the variety of instability problems affecting a site.

Under most circumstances, bio-engineering can be effectively combined with appropriate and low-cost geotechnical applications to provide the most cost-effective, integrated solution to slope stability problems. This is important for mountainous country like Nepal because, with the steep and dynamic slopes found in the Himalayas, most hill roads are engineered near to the margin of safety. Bio-engineering is the most affordable and effective way of enhancing civil engineering structures to increase stability as far as possible. The vegetative structures are also flexible, being capable of absorbing movement and recovering from damage. In this respect, bio-engineering is simply part of wise and sustainable asset management since it helps to ensure the life of physical structures, and reduces overall maintenance costs. On roadsides, plants reduce the supply of debris from degrading slopes,

which is one of the greatest contributors to road maintenance costs through blocked drains and damaged pavements.

Road bio-engineering is totally labor based approach providing benefits to the local people. It focuses on minimizing the damage to the natural environment as well as reducing the future maintenance costs. Major portion of the cost of the road construction goes toward the payment of wages to the local labor. Road construction approach incorporates social, environmental and technical issues. Due to these facts, it is getting increasingly prioritized by national and international organizations in hill road construction. The people's participation is most essential for the success of slope conservation works. The use of local materials motivates local people's participation.

The use of bioengineering in Nepal has been developed since its introduction in the Dharan-Dhankuta road project in the mid-1980s for the protection of roadside cuts slope. More importantly, the bio-engineering approaches were adopted in project not as an alternative to civil engineering measures but as an integration of vegetative methods with normal engineering practice. While operating Bioengineering techniques, there are considerable costs saving from 50-70 percent in road maintenance cost. There is standard manual on Bio-engineering published under Department of Roads (DoR): Roadside Bio-engineering both Reference Manual and Site Handbook, John Howell (1999).Existing manuals of DOR on bio engineering techniques are used to design such works. Bio-engineering work is proposed for overall road including major slide areas.

13.11 Climate Change Consideration

Climate change refers to any significant change in the measures of climate lasting for an extended period of time. Climate change may cause more flooding of roads, bridges and airport runways, especially in low land areas as a result of erratic rains. A range of adaptation responses can be employed to reduce risks through redesign or relocation of infrastructure, increased redundancy of critical services, and operational improvements. Roads, bridges, tunnels and railway lines will be vulnerable to increased precipitation, groundwater levels, temperatures and winds.

The upgrading of the project road is GoN adaptation to climate change for this road.

The detail engineering design of project roads have been done considering the potential effects of climate change. From a road development perspective in Nepal, impact of climate change mainly takes the form of concentrated high rainfall resulting in the accelerated surface run-off from slopes and increased flows in gullies, drainage channels, streams, and rivers.

These phenomena have a consequent effect on the stability and performance of road sections, bridges, and other structures. A checklist of climate change hazards for the two types of environments found in Nepal and the potential impacts on roads are presented in **Table 13.14**

The road section is particularly susceptible because of its location, which lies in the Terai plain and Siwalik foothills. Effects of climate change could include the possibility of flash floods/rapids, mud flows in rivers/streams, and an increase in incidence of landslides along the alignment close to the Siwaliks and flooding and inundation in the plain areas. Other existing roads in the Tera are also susceptible to flooding due to the limited drainage capability because of flat topography. Natural drainage pattern in the Terai makes the roads with an east-west alignment generally less susceptible to flooding than the roads with a north-south alignment. For this reason, particular consideration has been given in the detailed design of road formation and embankment heights and the size of waterways and soffit levels of bridges.

Table 13.14: Checklist for Climate Change Effects

Type of Environment	Natural Hazards and Climate Change	Possible Impacts	Adaptation Measures
Humid and sub-humid plains, foothills and hill country	Over 500 mm precipitation per year;	**Terai Roads:**	
	Resilient ecosystems and complex human pastoral and cropping systems;	Flash floods/rapids;	Srengthen river rivetment
	10-30% projected decrease in water availability in next 40 years;	Mud flows in streams and rivers;	
	Projected increase in droughts, heat waves and floods;	Increase in landslides along road alignments close to Siwaliks;	Physical and Bioengineering measures
	Increased erosion of loess-mantled landscapes by wind and water;	Flooding and inundation in plains, especially where the drainage capacity is reduced because of almost flat topography; and	etc
	Increased gully erosion;	Reduced bearing capacity of soils which become saturated.	
	Increased likelihood of landslides on steeper slopes;	**Hill Roads:**	

Type of Environment	Natural Hazards and Climate Change	Possible Impacts	Adaptation Measures
	Likelihood of decrease in overall agricultural productivity and compromised food production from variability, with rain-fed agriculture yield reduced by 30% or more by 2020;	Slope and gully erosion;	
	Increased incidence of forest and agriculture-based insect infestations; and	Torrential damage/washouts;	
	Occurrence of earthquake and other geophysical hazards.	Torrents and river action/erosion;	
		Attenuation of drainage capacity in side drains and culverts due to debris flow; and	
		Aggravation of unstable areas and increased landslides and landslips.	
Mountain ecosystems	Accelerated glacial melting, rockfalls/landslides and glacial lake outburst floods (GLOF), leading to increased debris flows, river bank erosion and floods and more extensive outwash plains and, possibly, more frequent wind erosion in inter-montane valleys;	**Hill Roads:**	
	Enhanced snow melt and fluctuating stream flows may produce seasonal floods and droughts;	Aggravation to slope instabilities and landslides;	
	Melting of permafrost in some environments;	Increase in Slope and gully erosion;	
	Faunal and floral species migration; and	Changes in drainage pattern;	
	Earthquakes, landslides and other geophysical hazards may also occur in these environments.	Impacts on land use and topography; and	
		Attenuation of drainage capacity in side drains and culverts due to debris flow.	

Source: Final Report, Road Connectivity Project, 2010

During detailed design, detail hydrological study/analysis was conducted to determine water ways, span/length and height (i.e., soffit, invert levels) of bridges and major cross-drainage works. Design flood has been calculated considering 20 years return period for cross drainage and 5 years for side drains. The road structures have been designed considering the probability of natural hazards (i.e., floods, earthquakes etc). Pavement surface has been designed considering the effect of temperature variation. Similarly, adequate expansion joints are provisioned in the design of bridges to account for the possible expansion and contraction due to temperature changes.

The Anticipated Components and Activities. Upgrading of the existing road to increase its resilience to climate change will include:

- Raising embankment and strengthening the road pavement- to avoid deterioration due to high flood,
- Strengthening the road surface- improving resistance to traffic wear and tear, and enhancing runoff, thereby reducing deterioration,
- Improving longitudinal and cross-drainage – to avoid surface flooding which contributes to road deterioration,
- Improving protection of road embankment – to avoid erosion of road works during extreme rainfall,

The condition of the existing road carriageway, shoulders and drainage required new construction in full length of road.

The proposed intervention can be considered as three components, which will involve the following activities:

(i) Road carriageway / upgrading of existing road:

The existing carriageway is single lane, mostly 6 - 7 meter wide, with earthen and river gravel surface in poor condition. The scope of urgrading of existing road is depending on the detailed assessment of the road condition, the following interventions are proposed:

- Construction of 500mm Subgrade overlaid by 200mm thick Granular Sub base for drainage purpose, provision of 250mm think Wet Mix Macadam as Base course over Granular Sub base as support to bituminous layers, Construction of 90/100mm Dense

Bituminous Macadam as binder layer over laid with 40/50mm thick Bituminous Concrete as a wearing course for Main Carriage way

- Construction of 500mm Subgrade overlaid by 200mm thick Granular Sub base for drainage purpose, provision of 150mm think Wet Mix Macadam as Base course over Granular Sub base as support to bituminous layers, Construction of 50mm Dense Bituminous Macadam as binder layer over laid with 40mm thick Bituminous Concrete as a wearing course for Service Road

(ii) Shoulder improvements:

As the existing road is earthen/gravel only the proposed road needs upgrading to bituminous paved standard. But for new construction 2.50 m shoulder has been provided in whole section.

(iii) Drainage:

- The drainage design and proposed drainage works have been reviewed hydro logically and hydraulically on the basis of extreme rainfall data of the year.
- The existing pipe has been replaced by RCC hume pipe due to climate change consideration (flash flood).

Chapter 14: Procurement

14.1 Procurement Approach

14.1.1 Introduction

The World Bank adopts different type of procurement in various countries now a days. Few of them are as briefed below:

- Contract for Construction (Traditional) – where design is provided by the Employer and construction bids are solicited. Under World Bank funding project and other MDB Project take FIDIC MDB Contract which is derived from FIDIC Pink Book and this Contract is very similar to FIDIC Red (Construction Works) book.
- Contract for Design and Build – where design and construction services are undertaken by a single entity selected on the basis of a competitive response to specific requirements detailing the project parameters.
- Contract on Hybrid Annuity Model (HAM) – Hybrid Annuity Model is a variant of PPP (Public Private Partnership) model. Under this model, the Authority pays 40% of the total Project Cost while remaining 60% amount is to be arranged by the Developer. The developer has to finance around 20 -25 % of remaining 60% amount and the balance amount to be raised as Debt. The Developer has to design, build and operate the Project for specified duration and hand over the Project to the Authority in the Condition as per the requirement specified in the Concession Agreement.

The Design / Build approach is beneficial where the works are complex or extensive. The benefit is gained by harnessing the specific expertise of bidders, in terms of experience, equipment and proprietary systems, to ensure harmonization of design of the works with construction methods. The Traditional approach i.e., Unit Rate Contract is appropriate for these works, which are neither complex nor extensive.

Considering complexity of design and Construction for two major river bridges named as Kamala bridge and Bagmati bridge, separate Contract for both bridge construction as on Design and Build basis.

14.1.2 Contract Packaging

Salient Features

The Kamala – Dhalkebar – Pathlaiya Road is 130.387km long, which starts from Kamala bridge (Km 236+500) and ends at Pathlaiya Roundabout Junction (Km 366+887).The road section with an estimated construction cost of about NPR 36.18 billion shall be proposed to be bid as Six Contract Packages on different modes. The modes decided are

1) Unit Rate (Traditional) Contract,
2) Design and Build Contract and
3) Hybrid Annuity Model (HAM) contract.

14.1.3 Post Qualification for Contract on Unit Rate (Traditional) Basis

Post qualification, rather than the lengthier and more complex prequalification process, has been successfully adopted as the normal procedure in Nepal for works. It is therefore considered that; the Post Qualification process should be adopted for the Procurement. It also saves time required for Prequalification Procedure.

14.1.4 Bidding Process

The bidding process for works has been developed, refined and standardized for Unit Rate (Traditional) Contract by the Department of Road (DOR) over many years. The standardised procedure which has been developed should be adopted: this involves the following –

I. Preparation of bidding documents
II. Publication of procurement notice
III. Issuance of bidding documents
IV. Pre-tender meeting
V. Receipt and opening of tenders
VI. Evaluation of tenders and recommendation for award

14.1.5 Contract Packaging

It has been discussed and agreed with DOR and WB that, the Project Road to be divided in six packages for implementing the upgradation to four lane divided road. Among six packages, three packages containing road and bridge construction shall be procured on Unit Rate (Traditional) basis whereas, one package inclusive of road and bridge construction shall be procured on HAM

Phase 1: Construction Period including upgradation of existing road, construction of service road, bridges, culverts, VUP/PUPs, animal crossings, elephant crossings and other facilities Total 36months.

Phase 2: Operation and Maintenance of the Road complying the specifications and standards defined in the Bid Document. The O&M Phase is 5 years inclusive of Defect Notification Period (DNP) of 1 year during which, the Contractor has to rectify the defects at his own cost. Whereas, the Contractor shall be paid lumpsum amount per Annum for remaining duration of O&M Phase. Thus, total duration for Operation and Maintenance Phase is fixed as 60 Months.

14.2.2 Design and Build Contract (Kamala and Bagmati River Bridges)

The total period for construction of Bridge along with its approaches for Kamala and Bagmati rivers is considered in Two Phases as stated below:

Phase 1: Construction Period including construction of new river bridge, rehabilitation of existing bridge, upgradation of approaches (road) and other facilities – Total 36 months

Phase 2: Operation and Maintenance of the Road complying the specifications and standards defined in the Bid Document. The O&M Phase is 5 years inclusive of Defect Notification Period (DNP) of 1year during which, the Contractor has to rectify the defects at his own cost. Whereas, the Contractor shall be paid lumpsum amount per Annum for remaining duration of O&M Phase. Thus, total duration for Operation and Maintenance Phase is fixed as 60Months.

14.2.3 Hybrid Annuity Model Contract (Nilgadh – Pathlaiya Section)

The Bid document and duration for HAM contract for Nijgadh – Pathliaya section is under discussion at World Bank and DOR level and shall be finalized in due course of time. Therefore, implementation schedule for Nijgadh – Pathlaiya sections is not being presented in this report.

14.3 Bidding Documents for Unit Rate (Traditional) Contract

The Bidding Documents have been prepared for each contract in the specified OCB format as follows:

PART I BIDDING PROCEDURES

1 Instruction to Bidders

2 Bid Data Sheet

3 Evaluation and Qualification Criteria

4 Bidding Forms

5 Eligible Countries

PARTY II EMPLOYER'S REQUIREMENTS

1. Summary Descriptions of Works
2. Standard Specifications
3. Special Provisions
4. Drawings
5. Personnel Requirements
6. Equipment Requirements

PART III CONDITIONS OF CONTRACT AND CONTRACT FORMS

1. General Conditions of Contract
2. Particular Conditions of Contract
3. Contract Forms

14.4 Evaluation and Comparison of Price Bids

For purpose of Evaluation and Comparison of the Tenders, following factors considered.

a) the bid price, excluding Provisional Sums and the provision, if any, for contingencies in the Summary Bill of Quantities, but including Day work items, where priced competitively;

b) price adjustment for correction of arithmetic errors

c) price adjustment due to discounts offered

d) converting the amount resulting from applying (a) to (c) above, if relevant, toa single currency

e) adjustment for nonmaterial nonconformities

f) assessment whether the bid is abnormally low in accordance

g) application of all the evaluation factors indicated in Section 3 in Bid Document (Evaluation and Qualification Criteria).

14.5 Criteria for other relevant factors in Evaluation

a) Adequacy of Technical Proposal

b) Completion Time

c) Technical Alternatives

d) Specialist Subcontractors

e) Quantifiable Nonconformities and Omissions

f) Multiple Contracts

14.6 Qualification of Bidders

The bidders shall satisfy the qualification criteria as proposed and stated in Bid Document as follows.

a) Eligibility
   - Nationality
   - Conflict of Interest
   - Government-Owned Entity
   - ADB & United National Eligibility)

b) Historical Contract Non-Performance

c) Financial Situation
   - Historical Financial Performance
   - Average Annual Turnover
   - Financial Resource)

d) Construction Experience
   - Contracts of Similar Size and Nature
   - Construction Experience in Key Activities