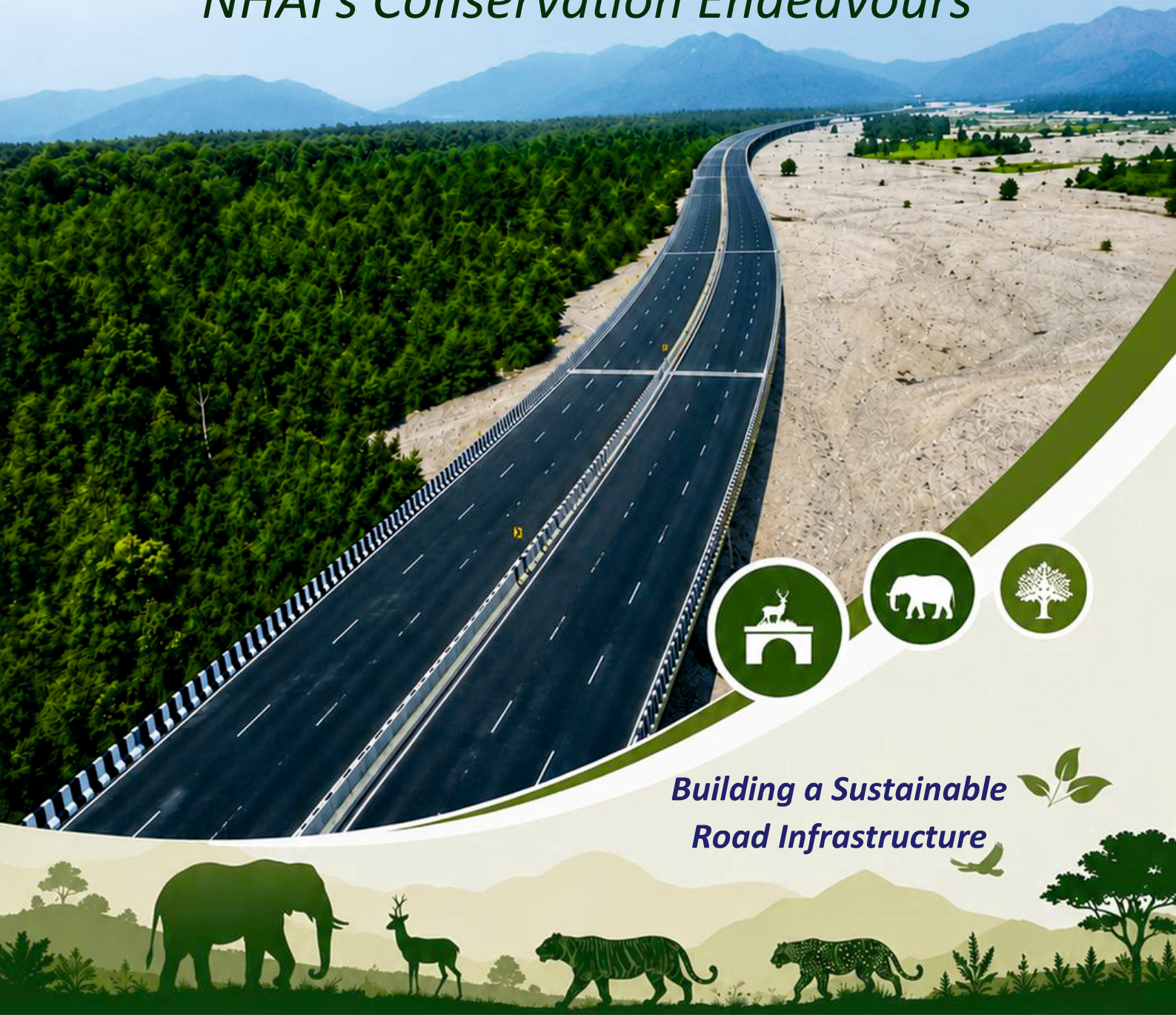
भारतीय राष्ट्रीय राजमार्ग प्राधिकरण
सड़क परिवहन एवं राजमार्ग मंत्रालय, भारत सरकार

National Highways Authority of India
(Ministry of Road Transport and Highways)

Wildlife Mitigation Measures & Structures

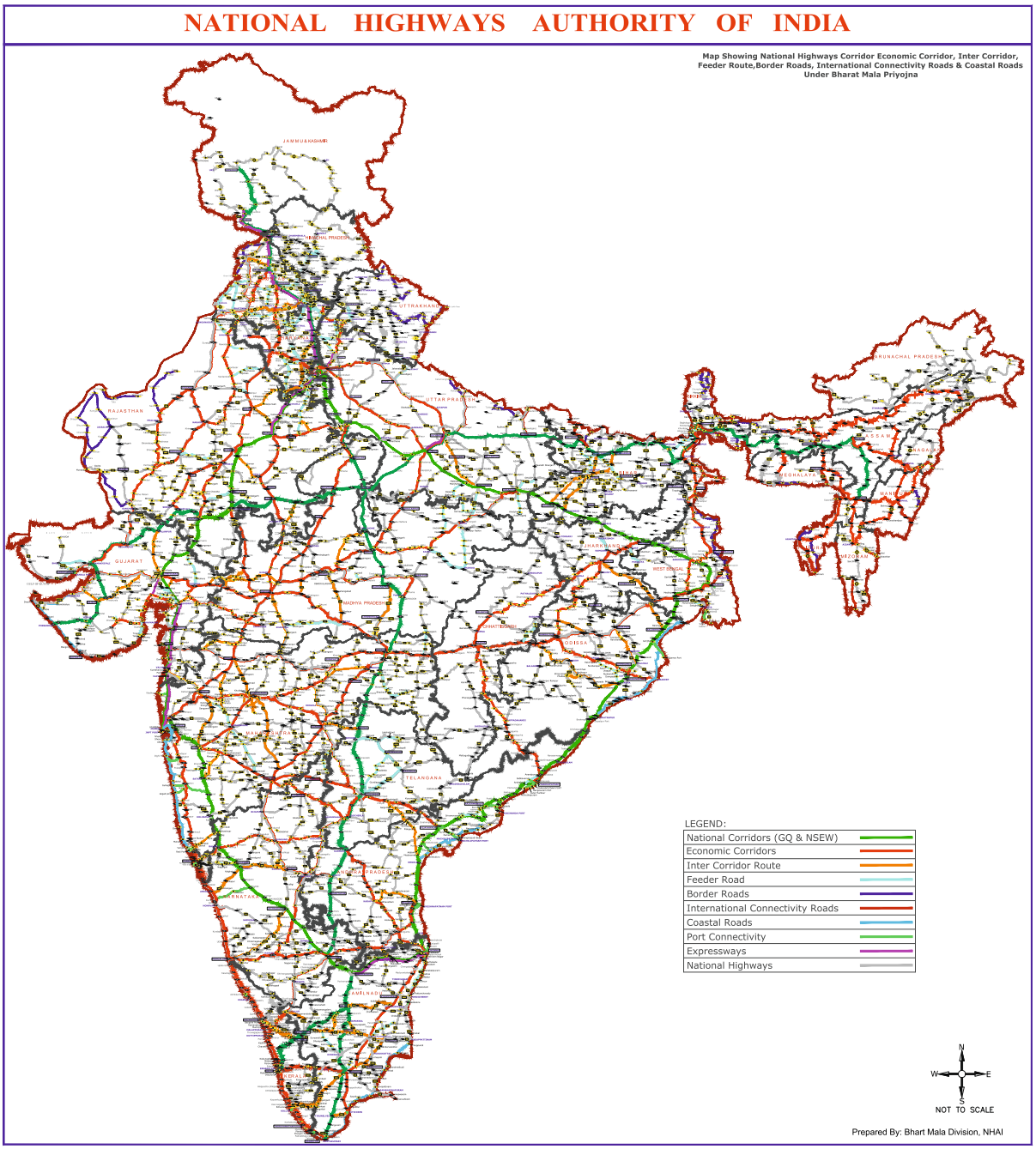
NHAI's Conservation Endeavours



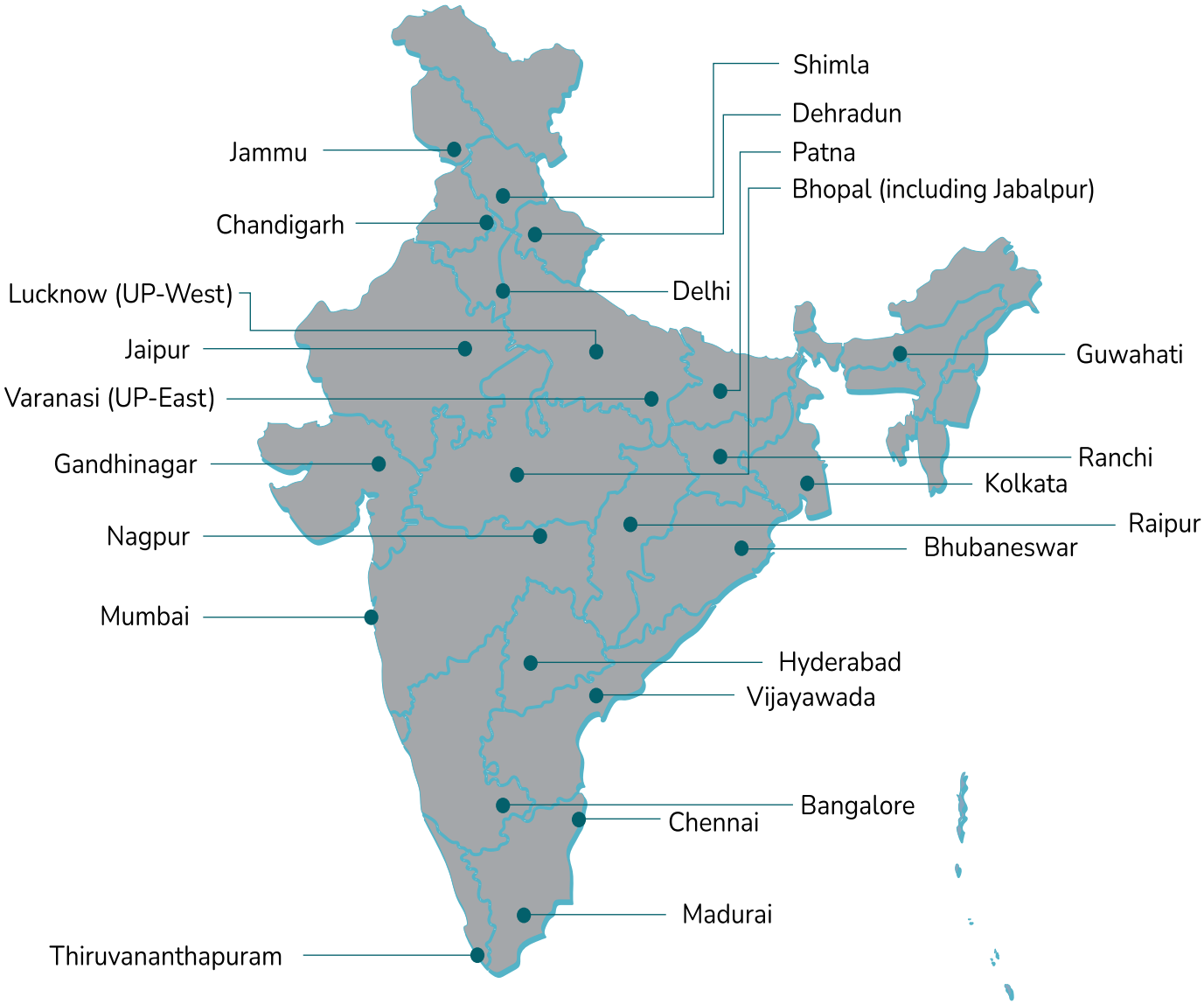
Building a Sustainable Road Infrastructure

Ensuring Safe Passage for Wildlife & Developing Sustainable Highways


NATIONAL HIGHWAYS AUTHORITY OF INDIA
NHAI


NATIONAL HIGHWAYS AUTHORITY OF INDIA
Map Showing National Highways Corridor Economic Corridor, Inter Corridor, Feeder Route,Border Roads, International Connectivity Roads & Coastal Roads Under Bharat Mala Priyojna
LEGEND:
National Corridors (GQ & NSEW)
Economic Corridors
Inter Corridor Route
Feeder Road
Border Roads
International Connectivity Roads
Coastal Roads
Port Connectivity
Expressways
National Highways
N
W
E
S
NOT TO SCALE
Prepared By: Bhart Mala Division, NHAI

REGIONAL OFFICES OF NHAI



*Map not to Scale

List of Acronyms and Abbreviations

Abbreviation	Full form
Addl. PCCF	Additional Principal Chief Conservator of Forests
BRO	Border Roads Organization
ADS	Animal Detection Systems
AVC	Animal Vehicle Collisions
CCF	Chief Conservator of Forests
CEC	Central Empowered Committee
CF	Conservator of Forests
CRZ	Coastal Regulation Zone
CZMA	Coastal Zone Management Authority
CZMP	Coastal Zone Management Plan
DAS	Distributed Acoustic Sensing
DC	Deputy Commissioner
DFO	Divisional Forest Officer
DM	District Magistrate
EAC	Expert Appraisal Committee
EC	Environmental Clearance
EIA	Environmental Impact Assessment
ESZ	Eco-Sensitive Zone
FAC	Forest Advisory Committee
FC Rules	Forest Conservation rules
GIS	Geographic Information System
GQ	Golden Quadrilateral
HWC	Human-Wildlife Conflict
IAA	Impact Assessment Agency
IBA	Important Bird Area
IUCN	International Union for Conservation of Nature
MoEF&CC	Ministry of Environment, Forest and Climate Change
NBWL	National Board for Wildlife
NGO	Non-Governmental Organization
NH	National Highway
MoRTH	Ministry of Road, Transport & Highways
NHAI	National Highway Authority of India
NHDP	National Highway Development Programme
NPV	Net Present Value
NTFP	Non-Timber Forest Products
NCZMA	National Coastal Zone Management Authority
PA	Protected Area
PIT	Passive Integrated Transponder
RCC	Reinforced Cement Concrete

Abbreviation	Full form
PCCF	Principal Chief Conservator of Forests
PMGSY	Pradhan Mantri Gram Sadak Yojana
PPP	Public Private Partnership
PWD	Public Works Department
RF/PF	Reserved Forest/ Protected Forest
RBS	Regional Base Station
SC-NBWL	Standing Committee National Board for Wildlife
SEAC	State-level Expert Appraisal Committee
SEIAA	State Environmental Impact Assessment Authority
SH	State Highway
SPCB	State Pollution Control Board
TOR	Terms of Reference
UAV	Unmanned Aerial Vehicle
UNESCO	United Nations Educational, Scientific and Cultural Organization

Disclaimer

The text and graphics in this publication has been taken from various sources. Effort has been made to list the sources under “References”. If any source has been missed out, we accept the oversight and state that all rights, credits, and intellectual property belong to their respective owners. No copyright infringement is intended. This publication meant for creating awareness on wildlife protection and conservation amongst stakeholders.

About the Report:

The National Highways Authority of India (NHAI), under the aegis of the Ministry of Road Transport and Highways, is guided by the vision of developing highway infrastructure in a manner that balances connectivity with environmental sustainability. In line with this approach, the present report titled *"Wildlife Mitigation Measures and Structures"* highlights NHAI's initiatives towards integrating wildlife conservation into highway planning, design, and implementation. The report focuses on addressing challenges such as habitat fragmentation, barrier effects, and wildlife–vehicle collisions through scientifically designed mitigation strategies.

This report documents various *engineering and ecological interventions*, including wildlife crossing structures such as underpasses, overpasses, culverts, and habitat-support measures like water holes, fencing, and vegetation management. It also outlines planning-level approaches such as ecological networks, buffer zone conservation, and alignment optimization to ensure minimal impact on sensitive habitats. Through region-wise case examples, the report demonstrates the practical application and effectiveness of these measures across different highway projects.

Covering recent initiatives and project implementations, the report reflects NHAI's commitment to incorporating environmental safeguards within infrastructure development. It emphasizes the importance of *integrating mitigation measures within Environmental Impact Assessment (EIA) and Environmental Management Plan (EMP) frameworks*, along with stakeholder engagement and expert involvement in decision-making.

Overall, the report aims to present a comprehensive overview of how wildlife conservation considerations are being mainstreamed into highway development, reinforcing NHAI's role in promoting ***sustainable and environmentally responsible infrastructure growth***.

Reporting Period: This report covers information pertaining to the period 2021 to 2026.

This report has been edited and validated by **Shri Ravikant Sinha, IFS Retd. Former Pr.CCF (HoFF), West Bengal and Dr. Anil Kumar Bharadwaj, IFS Retd. Former Pr.CCF (HoFF), Kerala** and would serve as a guiding tool for further capacity building of not only NHAI personnel but also others engaged in linear infrastructure development.

Feedback and Response:

Sh. Suneet Bhardwaj, IFS
GM (Environment & GHD),
Environment & GHD Division, NHAI.
Email: suneet@nhai.org
Telephone: +91 9418164519.

Dr. Nagin Nanda, IFS (Retd.)
Advisor (Environment & Clearances),
Environment Division, NHAI.
Email: naginnanda@nhai.org
Telephone: +91 7018021907, 9418500015.

सत्यमेव जयते

Message from Hon'ble Minister, Road Transport and Highways, Government of India.



SHRI NITIN JAIRAM GADKARI
Minister of Road Transport and Highways, Govt. of India.

Message

I extend my heartiest congratulations on the publication of the 'Report on Wildlife Mitigation Measures & Structures of the National Highways Authority of India (NHAI)', as a guidance document laying out the objectives and relevance of planning green infrastructure in the country, a testament to our commitment for creating inclusive infrastructure under the visionary leadership of Hon'ble Prime Minister, Shri Narendra Modi Ji.

'Development without destruction' and *'faster clearance but rigorous compliance'* is the key facet and operational focus of the Ministry of Road, Transport & Highways. The challenge, therefore, is to promote efficient and green infrastructure that facilitates economic growth and development, minimizes environmental impacts, and protects biodiversity and ecosystem functions. Roads and other linear infrastructure have become a pervasive component of the natural landscapes in India and their rapid expansion has the potential to change these landscapes.

I am glad to say that this report of NHAI showcases our progress in integrating inclusivity into every facet of our operations, from environment-friendly construction practices and resource efficiency, to biodiversity conservation, inclusive development and stakeholder engagement.

It reflects our commitment to building a road infrastructure that is environmentally responsible, green and resilient. As we advance, let us resolve to continue to enhance our wildlife and bio-diversity conservation endeavours, climate resilience, circular economy, and innovative technologies to minimize our environmental footprints, towards shaping a more sustainable and inclusive future.

Nitin Jairam Gadkari
Minister of Road Transport and Highways, Govt. of India.

सत्यमेव जयते

Message from Hon'ble Minister of State, Road Transport and Highways, Govt. of India.



SHRI AJAY TAMTA
Minister of State, Ministry of Road Transport and Highways, Govt. of India.

Message

I am immensely proud to witness the release of the Report on Wildlife Mitigation Measures & Structures of the National Highways Authority of India (NHAI), which highlights our continuous progress and firm dedication of building a sustainable road infrastructure. This endeavour also aligns seamlessly with the vision of our Hon'ble Prime Minister of India in promoting the 'Lifestyle for Environment' (LiFE) initiative. I passionately believe that inclusivity in road infra development which also takes care of our precious flora and fauna, holds the key to secure a better future for us and generations to come.

At NHAI, our focus on bio-diversity conservation, sustainability and inclusivity is deeply ingrained in our policies, strategies, and programs, all of which aim to strike a balance between economic growth, environmental preservation, bio-diversity conservation, and social development. Accordingly, integrating transport infrastructure with living landscapes has become the most urgent priority of the day for inclusive growth. This document is intended to share good practices and successful examples to help construct wildlife-friendly transportation systems.

NHAI's unwavering efforts toward environmental sustainability are evident in every project we undertake, ensuring the mitigation of environmental impacts. By collaborating with citizens, communities, and industries, we are building a transportation ecosystem that is resilient, efficient, and future-ready.

I am confident that our ongoing efforts will lead to long-term benefits for the environment, society, and economy, by strengthening India's position as a global leader in sustainable infrastructure. Together, let us pledge to build a greener, more inclusive, and future-proof transportation network for our nation.

Ajay Tamta
Minister of State, Ministry of Road Transport and Highways, Govt. of India.

सत्यमेव जयते

Message from Hon'ble Minister of State, Road Transport & Highways and Corporate Affairs, Govt. of India.



SHRI HARSH MALHOTRA
Minister of State for Ministry of Road Transport & Highways and Corporate Affairs, Government of India.

Message

I am pleased to learn about the release of the Report on Wildlife Mitigation Measures & Structures of the National Highways Authority of India (NHAI), which reflects our unwavering commitment to sustainable road infrastructure development. As we work towards strengthening India's road network, it is imperative that we integrate environmental and bio-diversity consciousness with technological advancements to create a resilient, future-ready transportation ecosystem. Sustainable infrastructure is not just about roads and highways—it is about fostering economic progress while safeguarding our natural and bio-diversity resources for generations to come.

As our lives are closely linked with the ability to travel and to transfer goods from one place to another, developments in road transportation sector are undeniably essential. We are also conscious of the fact that increased transportation opportunities can sometimes pose a conspicuous threat to the natural landscapes traversed by roads. It is essential, hence, to bring about ways to balance our needs and activities with respect to their effect on biodiversity and to ensure that transportation becomes 'greener' and more sustainable, so as to reduce its share in environmental threats.

Environmental protection, bio-diversity conservation and mitigation and sustainability have become the hallmark of NHAI's road building practices. The NHAI's intent is to encourage better, greener and more sustainable road systems across the expanses of our vast country. This holds true while considering not only the new road projects that are to be planned and constructed, but also the existing roads and motorways, and the way they are operated and maintained.

Bio-diversity conservation is a collective responsibility, and the role of collaboration cannot be overstated. As we move forward, our mission is clear—to build roads that drive prosperity while preserving our planet and especially our precious flora and fauna. With an unwavering commitment to sustainable progress, NHAI will continue paving the way for a greener and more inclusive future.

Harsh Malhotra
Minister of State, Ministry of Road Transport & Highways and Corporate Affairs,
Govt. of India.

सत्यमेव जयते

Message from Secretary, Ministry of Road Transport and Highways



SHRI V. UMASHANKAR, IAS
Secretary, Ministry of Road Transport and Highways.

Message

I am pleased to witness the release of National Highways Authority of India (NHAI)'s Report on Wildlife Mitigation Measures & Structures. Highways of the country serve as the backbone of GDP enhancement, social and economic progress, with National Highways although accounting for nearly 2% of the total road network but carrying over 40% of the country's road traffic. I am happy to note that NHAI in the last decade has strengthened its attention on bio-diversity protection and conservation while constructing green and resilient infrastructure, consolidating key policy initiatives and maintaining its record-breaking pace of road development. NHAI remains committed to embedding sustainable practices in infrastructure expansion wherein bio-diversity protection and mitigation is an integral part of all its developmental endeavours.

I am happy to note that the conservation community and the linear infrastructure development agencies are working together in creating unique opportunities to strategically promote linear developments for connecting people without compromising the quality of natural habitats that harbour wild animal and plant species. This document is intended to share good practices and successful examples to help construct wildlife-friendly transportation systems.

This report places the action being taken by the Government through NHAI to further India's commitments to the bio-diversity protection and conservation in ushering inclusive development in highways construction as the nation moves towards achieving the dream of ***Viksit Bharat.***

As we move forward, I am confident that these efforts will not only contribute to a green, resilient and inclusive transportation network but also unlock new opportunities, aligning with India's broader sustainability and conservation goals.

V. Umashankar, IAS
Secretary, Ministry of Road Transport and Highway,
Govt. of India.

सत्यमेव जयते

Message from Chairman, National Highways Authority of India



SHRI SANTOSH KUMAR YADAV, IAS
Chairman, National Highways Authority of India.

Dear Stakeholders,

I am pleased to present the NHAI's Report on Wildlife Mitigation Measures & Structures, covering bio-diversity and wildlife mitigation activities for the last five years. As a key player in the planning, execution, operation, and maintenance of India's road infrastructure, NHAI continues to integrate sustainability and bio-diversity conservation practices into all aspects of its operations. This report provides an overview of our initiatives and demonstrates our ongoing commitment to creating value for society, wildlife, nature, policymakers, and the nation.

NHAI remains resolute in its commitment to building sustainable infrastructure and continuously enhancing our sustainability performance. By integrating environmental responsibility, social equity, bio-diversity conservation and economic resilience into all our projects, we aim to set new benchmarks for inclusive road development in India.

The need to promote practices that integrate bio-diversity conservation concerns in infrastructure development are being universally acknowledged by the planners, transportation agencies and ecologists in most countries. The need is even more emergent in India where the challenge to maintain healthy, living landscapes with the benefits they deliver, at-times come in conflict with the expanding infrastructure development.

This practice document has been developed to respond to this challenge of bridging the conservation-development divide by offering smart solutions to promote development within integrated landscapes. The principles, practices and advisories contained in this document are strongly grounded in science and are based on the efficacy of tried and tested interventions on ground during the last five years.

From being a ready reference for quick hints on *'what impacts how'*, this practice guide is structured in a manner that provides detailed guidance for planning, locating, designing, implementing and operating smart green roads. The introductory section of the report sets the scene: it goes on to describe need for development but simultaneously portrays the potentially significant impacts and risks both for wildlife and the people. An overview of the regulatory requirements related to roads development is then given, focusing on the environmental and forestry laws and responsibility for their application. The spectrum of potential impacts typically linked to roads is then systematically described and illustrated.

Recognizing the need to improve road infrastructure planning, the document introduces and explains the hierarchy of mitigation measures that needs to be followed, prioritizing avoidance or prevention of impacts, followed by their minimization and adaptive management.

Later part of the report sets out engineering (structural) and non-structural options for mitigation, focusing on the priority need to keep landscapes permeable and connected, allowing and encouraging wildlife movements and thus the viability of populations in the long term. The document also emphasizes on the suitability of design of linear road Infrastructure in elephant and tiger habitats. Beyond engineering design options, non-structural measures are described to minimize impacts of noise and lights, and to use a range of media, including signages, early warning systems and other approaches to minimize safety risks both to people and the wildlife.

I extend my heartfelt thanks to the Environment Division for their unwavering dedication in producing this report. I would also like to acknowledge the invaluable contributions of our field teams whose collective efforts have made this action and publication of report possible.

We believe this report provides deeper insights into NHAI's bio-diversity conservation journey and highlights the progress we have made. We welcome your feedback and look forward to continually improving our sustainability and conservation practices as we move forward.

Sincerely,

Santosh Kumar Yadav, IAS
Chairman, National Highways Authority of India.

सत्यमेव जयते

Message from Member (Admin), National Highways Authority of India



SHRI VISHAL CHAUHAN, IAS
Member (Admin), National Highways Authority of India.

Dear Readers,

With immense pride and satisfaction; it is to state that the Environment Division of NHAI has prepared the Report on Wildlife Mitigation Measures & Structures by incorporating our conservation endeavours in the last five years. This report is a comprehensive reflection of NHAI's commitment to embedding bio-diversity and wildlife conservation into the core of its operations.

The report details the bio-diversity conservation efforts of NHAI's Head Office, 25 Regional Offices, and Concessionaires, emphasizing bio-diversity protection and conservation initiatives in the areas viz. Ecological Impacts of Road Infrastructure; Relevance of Mainstreaming Biodiversity Conservation in Road Infrastructure Development; Statutory Requirements; Wildlife Mitigation Planning at NHAI; Wildlife Mitigation Structures and Measures by NHAI and Way Forward.

This document is indeed a manifestation that the conservation community and the linear infrastructure development agencies are working together in creating unique opportunities to strategically promote linear developments for connecting people without compromising the quality of natural habitats that harbour our pristine wild animal and plant species. NHAI has over the period of last five years has spent a large amount of resources on mitigation related measures.

This speaks volumes of our commitment for the protection and conservation of bio-diversity and wildlife in the country and to mitigate and related impacts.

As we continue to expand India's highway network, we remain unwavering in our resolve to do so responsibly, ensuring that our infrastructure is not only world-class but also environmentally resilient. This report demonstrates our contributions to the UN Sustainable Development Goals (SDGs), particularly in areas such as biodiversity protection and conservation, sustainable infrastructure and inclusive growth.

We invite all stakeholders to explore this report and join us in our journey through a more sustainable and inclusive future.

Best wishes,

Vishal Chauhan, IAS
Member (Administration), NHAI.

Salient Features of the Report



- The report presents NHAI's approach to integrating wildlife conservation considerations into highway planning, design, construction, and operational stages, with approximately **₹19,700 crore** invested in wildlife mitigation infrastructure and related environmental safeguard measures across National Highway projects in the country in last five years.



- The report identifies and analyses key ecological impacts of linear road infrastructure, including habitat fragmentation, barrier effects, disturbance, and wildlife–vehicle collisions.



- In the report, a structured framework for wildlife mitigation planning is outlined, incorporating both structural measures (underpasses, overpasses, culverts, canopy crossings) and non-structural interventions (signage, fencing and speed regulation).



- In NHAI, the mitigation planning process has been guided by ecological sensitivity of project corridors, wildlife movement patterns, and technical feasibility of infrastructure design.



- The report serves as a reference framework for implementing environmentally responsible highway development, aligning infrastructure expansion with biodiversity conservation objectives and statutory environmental compliance requirements.



- A total of more than **2,150** wildlife mitigation structures have been constructed and/ or proposed along the alignment, comprising around **437** number of **animal underpasses**, **226** number of bridge-integrated crossings i.e., major bridge-cum-AUP and minor-bridge-cum AUP, **936** culverts adapted for faunal movement, approx. **111 canopy crossings** and other structure types.



- NHAI has implemented structural wildlife mitigation measures along National Highway corridors, including **animal underpasses** (**₹4,600 crore**), **animal overpasses** (**₹650 crore**), **viaducts** (**₹8,300 crore**), **tunnels** (**₹2,800 crore**), **major bridges** (**₹2,500 crore**), and **minor bridges** (**₹500 crore**) approximately to facilitate safe wildlife movement and maintain ecological connectivity.



- Implementation of non-structural wildlife mitigation measures such as noise barriers (**₹185 crore**), **reptile crossings** (**₹28 crore**), **rainwater harvesting (RWH) cum water holes (₹5 crore**), and other wildlife management interventions (**₹80 crore**) approx. to minimize disturbance and improve habitat conditions along highway stretches.



- Provision of Guide Fencing and Noise Barrier along 300+ km of the alignment to ensure effective channelization of wildlife toward crossing structures.



- Establishment of a monitoring framework like camera trapping has been employed for **monitoring wildlife movement patterns** and periodic evaluation.



- Ensures compliance with EC, FC, and NBWL conditions, with mitigation measures embedded across design, construction, and operation stages.



- Identification of wildlife-vehicle collision hotspots, with corresponding mitigation through speed regulatory boards and signages.







Photo Gallery



Hon'ble PM at Dehradun Expressway



Hon'ble PM's Visit to Bandipur Tiger Reserve



Hon'ble Prime Minister's Kaziranga Visit



Hon'ble Minister RT&H at 'Ek Ped Maa Ke Naam' Function



Hon'ble Minister RT&H at Excellence Awards Ceremony



Hon'ble Minister RT&H with the Hon'ble Prime Minister



Hon'ble PM at Kaziranga Elevated Corridor Bhumipujan



Hon'ble Ministers at 'Ek Ped Maa Ke Naam' Function



Release of NHAI's Sustainability Report by Hon'ble Minister RT&H



Hon'ble Minister of State RT&H at 'Ek Ped Maa Ke Naam' Function



Hon'ble Minister of State RT&H at Excellence Awards Ceremony



Hon'ble Prime Minister dedicating Dehradun Expressway to the Nation





'Ek Ped Maa Ke Naam' Function



Shri. V. Uma Shankar, IAS, Secretary MoRTH at Excellence Awards Ceremony



Shri. V. Uma Shankar IAS, Seceratery MoRTH at BRICS Transport Working Group Meeting



Shri. Santhosh Kumar Yadav IAS, Chairman NHAI at Excellence Awards Ceremony



Shri. Vishal Chauhan IAS, Member (Admin) NHAI at Excellence Awards Ceremony



Contents

Regional Offices of NHAI
List of Acronyms and Abbreviations 1
Disclaimer 3
About the Report 4
Message from Hon'ble Minister, Road Transport and Highways, Govt. of India 5
Message from Hon'ble Minister of State, Road Transport and Highways, Govt. of India 7
Message from Hon'ble Minister of State, Road Transport & Highways and Corporate Affairs, Govt. of India 9
Message from Secretary, Ministry of Road Transport and Highways 11
Message from Chairman, National Highways Authority of India 13
Message from Member (Admin), National Highways Authority of India 15
Salient Features of the Report 17
Photo Gallery 20
List of Tables 35
List of Figures 37

Chapter 1: NHAI and Sustainability 44
1.1 About NHAI 44
1.2 Mandates of NHAI 44
1.3 NHAI's Vision 44
1.4 NHAI's Mission 45
1.5 Organizational Structure at NHAI 45
1.6 Project Implementation and Development Mechanisms 45
1.7 NHAI applicable Statutes and Guidelines for Clearances 46
1.8 Sustainability at NHAI 47
1.8.1 Environmental Sustainability 48
1.8.2 Social Impact 49
1.8.3 Governance 49
1.9 NHAI's ESG Goals 50
1.10 Stakeholders Management 52
1.10.1 Wildlife & Biodiversity: An Important Stakeholder 52
1.10.2 Animal Safety 53
1.10.3 Stakeholder Communication and Responses 53

Chapter 2: Potential Ecological Impacts of Road Infrastructure 54
2.1 Guidelines for Roads in Natural Areas 57
2.2 Potential Impacts 59
2.2.1 Direct loss of habitat 59
2.2.2 Degradation of habitat quality 59
2.2.3 Habitat loss and fragmentation 60
2.2.4 Transformation 61

2.2.5 Isolation 62
2.2.6 Headlight glare 63
2.2.7 Road avoidance 64
2.2.8 Injury and mortality 64
2.2.9 Soil Erosion and Sedimentation 64
2.2.10 Impacts due to Noise Pollution 65
2.2.11 Impacts on Aquatic Ecosystems 66
2.2.12 Impacts on watershed due to road infrastructure 66
2.3 Modelling Barrier Effect on Indian Roads 67
2.3.1 Barrier to Movement 70
2.3.2 Disruption of natural processes 70
2.4 Increased human presence 71
2.4.1 Tourism 71
2.4.2 Fire 71
2.4.3 Increased human-wildlife conflict 72
2.4.4 Interventions of Invasive Species 72
2.5 Cause and Effect Relationships and Impact Types 72

Chapter 3: Statutory Framework Requirements for NHAI 76
3.1 Environment (Protection) Act, 1986 76
3.1.1 EIA Notification, 2006 and its amendment on 22nd August, 2013 77
3.1.2 Implementation of EIA & EMP 77
3.2 Wildlife (Protection) Act, 1972 79
3.2.1 Components of Wildlife Mitigation Plan 80
3.2.2 Components of Soil & Moisture Conservation Plan 80
3.3 Van (Sanrakshan Evam Samvardhan) Adhiniyam, 1980 81
3.4 PARIVESH 82
About PARIVESH 82
3.4.1 Enhanced PARIVESH Set-up for User Management customized for NHAI 83

Chapter 4: Relevance of Mainstreaming Biodiversity Conservation in Road Infrastructure Development 84
4.1 Wildlife Conservation: Approaches and Practice 84
4.2 Challenges of Managing Road Developments 84
4.3 Mainstreaming Biodiversity in Road Developments 85
Mainstreaming Approaches 86
4.4 'Smart and Green' Infrastructure 86
Green Infrastructure Principles 87
4.5 Progressive Trends in Linear Road Development Sectors in India 87
4.6 Road Network in India 88
4.7 Mitigation Principles 88
4.8 Mitigation of Impacts of Roads 90
4.8.1 Measures taken for Speed Control in Road Infrastructure 91
4.9 General Guidelines for Mitigating Impacts on Wildlife 91

Chapter 5: Wildlife Mitigation Planning at NHAI 96
5.1 Mitigation Planning 96
5.2 Mitigative Measures 98
5.2.1 Mitigating Fragmentation & Isolation 98
5.2.2 Mitigating the Barrier Effect 100
5.2.3 Preventing Vehicle–Wildlife Collisions 101
5.2.4 Mitigating Human Use Impacts 102
5.2.5 Mitigating Erosion 102
5.2.6 Integrating Climate Resilience in Wildlife Mitigation 102
5.3 Wildlife Mitigation Structures 103
5.3.1 Engineering Options 104
Viaduct 104
Animal Underpass 105
Animal Overpass 107
Land Bridge 109
Tunnels 110
Box Culvert 111
Pipe Culvert 114
Fencing 115
Minor Bridge cum AUP 116
Major Bridge cum AUP 117
Canopy bridge/ Monkey ladder 120
Noise Barrier 121
Reptile Crossing 123
Watch Tower 123
5.3.2 Non-Structural Options 124
Salt Licks 124
Water Holes 124
5.4 Mitigation Measures for Connecting Landscapes & Species 125
5.4.1 Landscape- Specific Measures 125
5.4.2 Species- Specific Measures 127
5.5 Mitigation Measures for Different Landscapes 128
5.5.1 Tiger Landscapes 128
5.5.2 Elephant Landscapes 130
5.6 Measures for Reducing Bird Hits 132
5.7 Mitigation Measures Specific to Reptiles and Amphibians 134
5.8 Retrofitting of Existing Structures to Function as Wildlife Crossing Structures 138
5.9 Implementation and Follow-up of Measures 138
5.10 Non-Structural Measures for Reducing Mortality: Signage & Warning Systems 139
5.10.1 Signage 139
5.10.2 Warning Systems 142
5.11 Measures for Noise Attenuation 142

Chapter 6: NHAI's Wildlife Mitigation Initiatives 152
Regional Office Bengaluru 153
Regional Office Bhopal 155
Regional Office Bhubaneswar 157
Regional Office Chandigarh (PB) 158
Regional Office Chandigarh (HR) 159
Regional Office Chennai 160
Regional Office Dehradun 163
Regional Office Delhi 166
Regional Office Gandhinagar 166
Regional Office Guwahati 167
Regional Office Hyderabad 167
Regional Office Jaipur 170
Regional Office Jammu 171
Regional Office Kolkata 172
Regional Office Madurai 172
Regional Office Mumbai 174
Regional Office Nagpur 175
Regional Office Patna 178
Regional Office Raipur 178
Regional Office Ranchi 180
Regional Office Vijayawada 182
Regional Office Kerala 183
Summary 183

Chapter 7: Trail-Blazers and Path-Makers 186
7.1 Bhopal Regional Office 186
7.1.1 Red Roads, Green Intent: NH-45 Bhopal–Jabalpur Highway 186
7.1.2 NH-44 through Pench Tiger Reserve 187
7.1.3 NH-46 Obedullaganj-Betul Section 189
7.2 Chandigarh (PB) Regional Office 192
7.2.1 NH-62 Four laning from Malout to Sadhuwali 192
7.3 Chandigarh (HR) Regional Office 193
7.3.1 NH-7 Yamunanagar–Panchkula PKG 3 Section 193
7.4 Dehradun Regional Office 194
7.4.1 Delhi–Dehradun Economic Corridor 194
7.5 Madurai Regional Office 200
7.5.1 NH-744A Madurai Ring Road 200
7.5.2 NH-785E Natham -Thuvarankurichi Section 201
7.5.3 NH-785 Chettikulam Natham Section 206
7.6 Chennai Regional Office 207
7.6.1 Bangalore - Chennai Expressway - Hills of Vellore 207
7.7 Mumbai Regional Office 208
7.7.1 NH-66 Mumbai Goa Highway 208

7.8 Nagpur Regional Office 210
7.8.1 NH-53 Bhandara Bypass -Securing the Tiger Corridor 210
7.8.2 NH-353B - Reconnecting the Tadoba-Kawal Tiger Corridor 211
7.9 Ranchi Regional Office 216
7.9.1 NH-33 Jamshedpur–Mahulia Section, Package IV 216
7.9.2 NH-43 Palma–Gumla Section 217
7.9.3 NH- 33 Jamshedpur – Mahulia Section, Package II 220
7.10 Delhi Regional Office 222
7.10.1 NH-119 Animal Underpasses on Behsuma - Bijnor Section 222
7.11 Jammu Regional Office 223
7.11.1 Wildlife Mitigation in Delhi–Amritsar–Katra Expressway 223
7.12 Vijayawada Regional Office 225
7.12.1 Bangalore-Kadapa-Vijayawada Greenfield Economic Corridor 225
7.12.2 NE-07 Bangalore-Chennai Expressway 227
7.13 Hyderabad Regional Office 233
7.13.1 NH 363 - Mancherial to Chandrapur 233
7.14 Jaipur Regional Office 238
7.14.1 Delhi-Vadodara Expressway 238
7.15 Bengaluru Regional Office 242
7.15.1 NH-948 Agara–Tataguni Cross stretch 242
7.16 Bhubaneshwar Regional Office 246
7.16.1 NH-55 Angul–Sambalpur Section 246
7.16.2 NH-130CD Greenfield Karki to Kaligura section 248
7.17 Guwahati Regional Office 251
7.17.1 NH-54E Udali to Manderdisa section 251
7.18 Gandhinagar Regional Office 257
7.18.1 NH-751 Pipli– Bhavnagar section 257
7.18.2 NH-8E Kagvadar–Una Section 260
7.19 Raipur Regional Office 264
7.19.1 NH-130A Eco-Economic Green Corridor: Urga–Pathalgaon 264
7.19.2 NH-130 CD Six-Lane Raipur–Visakhapatnam Economic Corridor 265

Chapter 8: Empirical Validation by Third Party - Landscapes Re-connected 268

8.1 Delhi - Dehradun Expressway 268
8.1.1 Findings 271
8.2 Pench Tiger Reserve 273
8.2.1 Objectives 273
8.2.2 Findings 274
8.2.3 Tigers of NH44 280
8.3 Conclusion 280

Chapter 9: Social-Media & Wildlife Conservation - Use of AI Tools 282
9.1 Volume & Spike Analysis 282
9.2 Launch Day Hourly Pulse 284
9.3 Theme Breakdown 284
9.4 Conclusion 285

Glossary 286

References 292

List of Tables:

Table 1	IRC Codes for Use of Alternate Materials & Technology in Road Construction	50
Table 2	Summary of Road Development Activities & Ecological Impacts on the Natural Environment	55
Table 3	Barrier effects of roads	68
Table 4	Potential Impacts of Roads on Wildlife	73
Table 5	Transportation induced impacts	92
Table 6	'Good Practice' guidance in the form of Do's and Don'ts for avoiding and regulating the impacts of linear infrastructure projects	94
Table 7	Placement of crossing structures across animal movement corridors of varying widths	127
Table 8	Ambient Noise Standards	144
Table 9	Types of Noise Barriers commonly used in Road Projects	145
Table 10	Components of the wildlife mitigation measures and structures	152
Table 11	RO Bengaluru - Number of structures and Expenditure incurred on mitigation	153
Table 12	RO Bhopal - Number of structures and Expenditure incurred on mitigation	155
Table 13	RO Bhubaneswar - Number of structures and Expenditure incurred on mitigation	157
Table 14	RO Chandigarh (PB) - Number of structures and Expenditure incurred on mitigation	158
Table 15	RO Chandigarh (HR) - Number of structures and Expenditure incurred on mitigation	159
Table 16	RO Chennai - Number of structures and Expenditure incurred on mitigation	160
Table 17	RO Dehradun - Number of structures and Expenditure incurred on mitigation	164
Table 18	RO Delhi - Number of structures and Expenditure incurred on mitigation	166
Table 19	RO Gandhinagar - Number of structures and Expenditure incurred on mitigation	166
Table 20	RO Guwahati - Number of structures and Expenditure incurred on mitigation	167
Table 21	RO Hyderabad - Number of structures and Expenditure incurred on mitigation	167
Table 22	RO Jaipur - Number of structures and Expenditure incurred on mitigation	170
Table 23	RO Jammu - Number of structures and Expenditure incurred on mitigation	171
Table 24	RO Kolkata - Number of structures and Expenditure incurred on mitigation	172
Table 25	RO Madurai - Number of structures and Expenditure incurred on mitigation	172

Table 26	RO Mumbai - Number of structures and Expenditure incurred on mitigation	174
Table 27	RO Nagpur - Number of structures and Expenditure incurred on mitigation	175
Table 28	RO Patna - Number of structures and Expenditure incurred on mitigation	178
Table 29	RO Raipur - Number of structures and Expenditure incurred on mitigation	178
Table 30	RO Ranchi - Number of structures and Expenditure incurred on mitigation	180
Table 31	RO Vijayawada - Number of structures and Expenditure incurred on mitigation	182
Table 32	RO Kerala - Number of structures and Expenditure incurred on mitigation	183
Table 33	Summary of Number of structures and Expenditure incurred on mitigation	184
Table 34	Wild Faunal species found around the NH72A	195
Table 35	Location details Animal Under Passes on 4-Laning of Angul–Sambalpur Section of NH-55	246
Table 36	List of Structures	248
Table 37	Volume & Spike Analysis	282
Table 38	Theme Breakdown	285

List of Figures:

Figure 1	Schematic representation (after Van der Zande et al. 1980) of wildlife impacts of road projects: Habitat modifications, animal movement restriction, mortality of animals, induced biotic and abiotic disturbances	59
Figure 2	Fragmentation linkages	60
Figure 3	Habitat fragmentation results in far greater reduction in area of available habitat for species in bisected patches	61
Figure 4	Road Effect Zone - Defined by ecological effects extending variable distances from road edges (Reproduced from Forman et al. 1997)	62
Figure 5	Metapopulations and Roads	63
Figure 6	Factors influencing barrier effects of roads	69
Figure 7	PARIVESH 2.0 Home Page	82
Figure 8	Effects of roads and rail tracks on individual animals and wildlife populations	89
Figure 9	Components of a road transportation corridor	90
Figure 10	Viaduct in Ganeshpur- Dehradun Project of NH 72 A (Pkg.2)	104
Figure 11	Animal Underpass in Four laning of Mancherial to Repallewada section of NH-363 Telangana	105
Figure 12	Underpass around Pench National Park, Maharashtra	106
Figure 13	Underpass in Pench National Park, Madhya Pradesh	106
Figure 14	Underpass around Pench National Park, Madhya Pradesh	107
Figure 15	Animal Overpass in Six lane Sargi-Basanwahi section of NH-130CD under Raipur-Visakhapatnam Economics Corridor in Chhattisgarh	107
Figure 16	Animal Over Pass-6L Greenfield Badakumari to Karki section of NH-130CD Road under Raipur-Visakhapatnam Economic Corridor, Odisha	108
Figure 17	Animal Overpass constructed across NH 363 in the Mancherial–Repallewada section in Telangana	109
Figure 18	Tunnel in Ganeshpur- Dehradun Project of NH 72 A (Pkg.2)	110
Figure 19	Tunnel: Chenani - Nashri Section in J&K	111
Figure 20	Box Culvert- 4 laning of Sangareddy- Nanded- Akola of NH-161 Section – Hyderabad-Telangana	112
Figure 21	Box Culvert in Four laning of Mallasandra to Karadi Section of NH 206 (Pkg. – 1)	112
Figure 22	Culvert structure constructed along the four-laning project of NH 75 near Meral, Jharkhand	113
Figure 23	Pipe Culvert- 4L Bangalore-Chennai Expressway from Baireddypalle to Bangarupalem Section of NE-7 in Andhra Pradesh under Bharatmala Pariyojana	114
Figure 24	Chain Link Fencing - Four Laning of Natham-Thuvarankurichi of NH-785 E in Madurai, Tamil Nadu	115

Figure 25	Minor Bridge cum AUP 4L in Bangalore-Chennai Expressway from Baireddypalle to Bangarupalem Section of NE-7 in Andhra Pradesh (Phase II /Package-II)	116
Figure 26	Minor Bridge cum AUP- 4L Bangalore-Chennai Expressway of Baireddypalle to Bangarupalem Section of NE-7 in Andhra Pradesh	117
Figure 27	Elevated Corridor around Pench National Park, Maharashtra	118
Figure 28	Elevated Corridor Pench National Park, Maharashtra	118
Figure 29	Elevated Corridor in Pench National Park, Madhya Pradesh	118
Figure 30	Group of Spotted Deer (*Chital*) utilizing an Animal Underpass (AUP)- NH 74 under the Ganeshpur–Dehradun (DDN) Highway Project in Uttarakhand	119
Figure 31	Canopy bridge-Six lane Sargi-Basanwahi section of NH-130CD under Raipur-Visakhapatnam Economics Corridor in Chhattisgarh (Package-CG-2)	120
Figure 32	Canopy bridge-6L Greenfield Karki to Kaligura section of NH-130CD Road (Package - OD-4)	121
Figure 33	Noise Barrier-Four laning of existing 2-lane stretch from Govindpur MHTG Border to Rajura section of NH-353B in Maharashtra	122
Figure 34	Sound and Noise barrier on animal crossing in Pench National Park, Madhya Pradesh	122
Figure 35	Sound and Noise barrier on animal crossing in Pench National Park, Madhya Pradesh	123
Figure 36	Water holes in Sanamavu Reserve Forest along Thorapalli Agraharam–Jittandahalli section of NH 844	125
Figure 37	Combined Structure for Elephant at Chila Motichur in RNP, NH-58, Haridwar-Dehradun-Section	131
Figure 38	Red table-top markings in Balance 11.96 Km. stretch (New NH-45) in Nauradehi Wildlife Sanctuary area, Hiran River to Sindooer River section, in Madhya Pradesh	140
Figure 39	Signage- Four laning of the Mancherial to Repallewada section of NH-363 in Telangana	141
Figure 40	Elephant Overpass in Rectification of black spot near Agara-Tataguni cross of NH-209 including EOP	154
Figure 41	Box Culvert in Chitradurga to Davanagere (CHPL) NH-48	154
Figure 42	AUP at Four laning of Ratapani stretch of Obedullaganj-Itarsi section of NH-46 in M.P.	155
Figure 43	Animal Overpass in Temagaon-Chhicholi, PKg-2 (Harda-Betul, NH-47)	156
Figure 44	AUP in Delinked Stretch of Seoni - MP/MH Border (MP 3) 6101/ 4 Laning of Seoni - MP/MH Border of NH-7 in MP	156
Figure 45	AUP in 6L Greenfield Badakumari to Karki section of NH-130CD Road under Raipur-Visakhapatnam Economic Corridor in Odisha (Package OD-3)	157
Figure 46	Monkey Canopy in 6L Greenfield Badakumari to Karki section of NH-130CD Road under Raipur-Visakhapatnam Economic Corridor in Odisha (Package OD-3)	158

Figure 47	Animal Under Pass- Four laning from Malout via Abohar to Sadhuwali of NH-62) in Punjab	159
Figure 48	Animal Overpass- 4L Yamunanagar Panchkula PKG 3 section of NH-07	160
Figure 49	Steel Wire Rope Fence in Sanamavu in Thorapalli Agraharam - Jittandahalli Section of NH-844	161
Figure 50	Steel Wire Rope Fence in Sanamavu in Thorapalli Agraharam - Jittandahalli Section of NH-844	161
Figure 51	Wildlife Signage Board- Improving the Alignment of Thoppur Ghat Section in Dharmapuri - Salem Section of NH-44	162
Figure 52	Animal Over Pass in Bengaluru Chennai Expressway	162
Figure 53	Hanging Solar Fence in Sanamavu RF-Thorapalli Agraharam - Jittandahalli section of NH-844	163
Figure 54	Noise Barrier in Ganeshpur DDN Project-Pkg.1	164
Figure 55	Elephant Underpass in Balance work of 4-laning of Haridwar – Dehradun Section of NH-72	165
Figure 56	EUP cum Noise Barrier in Ganeshpur DDN Project-Pkg.3	165
Figure 57	Animal Overpass in Four Laning of NH-363 from Repallewada to TS/ MH Border in Telangana	168
Figure 58	AUP in Four Laning of NH-363 from Repallewada to TS/ MH Border in Telangana	168
Figure 59	Box Culvert in 4 Laning of Sangareddy- Nanded- Akola of NH-161 Section	169
Figure 60	Box Culvert in 4 Laning of Sangareddy- Nanded- Akola of NH-161 Section	169
Figure 61	AOP in Delhi-Vadodara Expressway (Pkg.11)	170
Figure 62	AUP in Delhi-Vadodara Expressway (Pkg.11)	171
Figure 63	Animal Overpass with Noise Barrier in Four Lane divided Carriageway from Vadipatti to Thamaraipatti stretch of Madurai Ring Road section of NH-744 A	173
Figure 64	Check Dam in Four Laning of Natham-Thuvarankurichi section of NH-785 E	173
Figure 65	Animal Underpass in Four Laning of Chettikulam-Natham Section of NH-785	174
Figure 66	Animal Underpass in Solapur to Vjiayapur section of NH-13	175
Figure 67	SASEKARAN GAT- Animal Underpass in Construction of Mitigation measure structures on CH/MH Border to Wainganga Section of NH-6 (New NH-53) in Maharashtra	176
Figure 68	MARAMJOB- Animal Underpass in Construction of Mitigation measure structures on CH/MH Border to Wainganga Section of NH-6 (New NH-53) in Maharashtra	176
Figure 69	AUP in Construction of Six Lane Bhandara Bypass section of NH-53(Old NH-06) in Maharashtra	177
Figure 70	Signage Board in Four laning of Mahagaon to Yavatmal section of NH 361 in of Maharashtra	177
Figure 71	Box Culvert in (CG-2) (Lot-3/Odisha & Jharkhand/Package-2) Raipur-Vishakhapatnam in Chhattisgarh	179

Figure 72	AUP in (CG-2) (Lot-3/Odisha & Jharkhand/Package-2) Raipur-Vishakhapatnam in Chhattisgarh	179
Figure 73	Elephant Underpass in Operation and maintenance work for the stretch Rampur to Chauka Section of NH-33 in Jharkhand	180
Figure 74	Elephant Underpass in Operation and maintenance work for the stretch Rampur to Chauka Section of NH-33 in Jharkhand	181
Figure 75	Signages in Operation and maintenance work for the stretch Rampur to Chauka Section of NH-33 in Jharkhand	181
Figure 76	Minor Bridge cum AUP in 4L Bangalore-Chennai Expressway of Baireddypalle to Bangarupalem Section of NE-7 in Andhra Pradesh (Phase II /Package-II)	182
Figure 77	Red markings on Balance Nauradehi section	186
Figure 78	Noise Barrier in Four-Laning of the delinked stretch of NH-44 (Seoni–MP/MH Border)	188
Figure 79	Animal Underpass in Four-Laning of the delinked stretch of NH-44 (Seoni–MP/MH Border)	188
Figure 80	Noise Barrier cum AUP at Ratapani Wildlife Sanctuary in Four-Lane stretch of NH-46	190
Figure 81	AUP at Ratapani Wildlife Sanctuary in Four-Lane stretch of NH-46	191
Figure 82	Animal Under Passes in Four laning from Malout via Abohar to Sadhuwali of NH-62	192
Figure 83	Animal Over Pass in 4-Laning of Yamunanagar–Panchkula PKG 3 Section of NH-07	193
Figure 84	Wild Species documented using camera traps and Audio Moth acoustic recorders significantly indicating the purpose of underpass structures along the NH-72A corridor	196
Figure 85	Wildlife Mitigation Structures along the NH-72A Corridor	198
Figure 86	Glimpse of Inauguration Ceremony Delhi-Dehradun Economic Corridor	199
Figure 87	Animal Overpass in Four Laning of Madurai Ring Road Sec. of NH-744 A	200
Figure 88	Animal Overpass in Four Laning of Madurai Ring Road Sec. of NH-744 A	201
Figure 89	Habitat Improvement and Species Protection of Slender Loris	202
Figure 90	Check dam in Four Laning of Natham -Thuvarankurichi Sec. of NH-785 E	203
Figure 91	Kiluvi Plantation in Four Laning of Natham -Thuvarankurichi Section of NH-785 E	203
Figure 92	Thirukugalli Plantation in Four Laning of Natham -Thuvarankurichi Section of NH-785 E	204
Figure 93	Plantation in Four Laning of Natham -Thuvarankurichi Section of NH-785 E	204
Figure 94	Chain Link Fencing in Four Laning of Natham -Thuvarankurichi Section of NH-785 E	205
Figure 95	Warning Sign Boards in Four Laning of Natham -Thuvarankurichi Section of NH-785 E	205
Figure 96	Animal Underpass in Four Laning of Chettikulam Natham Section of NH 785	206

Figure 97	Animal Over Pass in Bangalore - Chennai Expressway	207
Figure 98	Monkey Ladder in Panvel-Indapur stretch of NH-66 (Mumbai-Goa Highway)	208
Figure 99	Bird nest at Karnala Bird Sanctuary in Panvel-Indapur stretch of NH-66 (Mumbai-Goa Highway)	209
Figure 100	Animal Under Pass 1 at Paladi on NH53	211
Figure 101	Animal Under Pass 2 at Paladi on NH53	211
Figure 102	Animal Under Pass at 74+194 Near Hardona Village (7m Span X 4.5m Height)	213
Figure 103	Animal Under Pass at 42+090 Near Akola Village (7m Span X 4.5m Height)	213
Figure 104	Noise Barrier on BHS @ AUP near Pendhari Rith	214
Figure 105	Animal Under Pass at 35+037 near Govindpur Village (14m Span X 4.5m Height)	214
Figure 106	Animal Under Pass near Pendhari Rith Village (50m Span X 5m Height)	215
Figure 107	Elephant Underpass in Four/Six Laning of Jamshedpur–Mahulia Section of NH-33 in Jharkhand (Pkg.-IV)	217
Figure 108	Elephant Underpass in 4-Lane of Palma–Gumla Section of NH-43 (Old NH-23)	218
Figure 109	Elephant Underpass in 4-Lane of Palma–Gumla Section of NH-43 (Old NH-23)	219
Figure 110	Elephant Underpass in 4-Lane of Palma–Gumla Section of NH-43 (Old NH-23)	219
Figure 111	Elephant Underpass in Four laning of Jamshedpur – Mahulia Sectionof NH-33 of Rampur–Chauka Section of NH-33 (Pkg.-II)	220
Figure 112	Elephant Underpass in Four laning of Jamshedpur – Mahulia Sectionof NH-33 of Rampur–Chauka Section of NH-33 (Pkg.-II)	221
Figure 113	Animal Underpass on NH-119 (Behsuma to Bijnor Section)	222
Figure 114	Animal Underpass on NH-119 (Behsuma to Bijnor Section)	222
Figure 115	Viaduct in Delhi–Amritsar–Katra Expressway	223
Figure 116	Minor Bridge in Delhi–Amritsar–Katra Expressway	224
Figure 117	RHS Viaduct (Span 23m*40m = 920.00m)	225
Figure 118	LHS Viaduct (Span 22m*40m = 880.00m)	226
Figure 119	Elephant Underpass (Span 2 No x 30m), Length: 60.0 m, Avg. Height: 7.0 m	228
Figure 120	Elephant Underpass (Span 20 No x 32.5m), Length: 650.0 m, Avg. Height: 7.5 m	228
Figure 121	Elephant Underpass (Span 44 No x 31.875m), Length: 1402.0 m, Avg. Height: 7.5 m	229
Figure 122	Elephant Underpass (Span 14 No x 32.5m), Length: 455.0 m, Avg. Height: 7.5 m	229
Figure 123	Elephant Underpass (Span 10 No x 31.875m), Length: 318.75 m, Height: 22.0 m	230
Figure 124	Elevated Viaduct (Span 6 No x 32.5m + 52 No x 65m + 12 No x 32.5m), Length: 3965.0 m, Height: 7.0 m to 50.0 m	230

Figure 125	Hume Pipe Culvert (2 No x 1.2m) at km 116+200	231
Figure 126	Minor Bridge cum AUP (Span 1No x 8m), Length: 8.0 m, Height: 7.1 m	231
Figure 127	Minor Bridge cum AUP (Span 2 No x 25m), Length: 50 m, Height: 11.0 m	232
Figure 128	Minor Bridge cum AUP (Span 1 No x 10m), Length: 10.0 m, Height: 7.4m	232
Figure 129	Tiger Pugmark	234
Figure 130	Tiger Movement at the Animal Overpass (Eco Bridge)	234
Figure 131	Animal Overpass (Eco Bridge) at Comp. No. 238 (From Km.94+400 to Km.94+550)	235
Figure 132	Animal photographs are captured by the CCTV installed by DFO; Asifabad at Overpass constructed on NH 363	235
Figure 133	Animal Underpass at Compartment No. 306	236
Figure 134	Wildlife Photos and Pugmarks of Tiger in and around the Compensatory Afforestation (CA) area of 33 Ha, CA contributes to the thriving wildlife and increased habitat	237
Figure 135	Animal Overpasses on Delhi-Vadodara Expressway – Package 11	239
Figure 136	Animal Underpasses on Delhi-Vadodara Expressway – Package 11	240
Figure 137	Elephant Overpass in NH-209 (New NH-948) near Agara–Tataguni Cross in Karnataka	242
Figure 138	EOP with pit for planting in NH-209 (New NH-948) near Agara–Tataguni Cross in Karnataka	243
Figure 139	Camera Trap of Elephants over EOP	244
Figure 140	Camera Trap of Leopard over EOP	245
Figure 141	Animal Underpass on 4-Laning of Angul–Sambalpur Section of NH-55 (Old NH-42)	247
Figure 142	Animal Underpass on 4-Laning of Angul–Sambalpur Section of NH-55 (Old NH-42)	247
Figure 143	AUP 1 x 30m in 6L Greenfield Karki to Kaligura section of NH-130CD Road (Pkg. - OD-4)	249
Figure 144	Monkey Canopy in 6L Greenfield Karki to Kaligura Sec. of NH-130CD Road (Pkg. - OD-4)	250
Figure 145	Light & Sound Barrier 6L Greenfield Karki to Kaligura Sec. of NH-130CD (Pkg. - OD-4)	250
Figure 146	Animal Underpass 4 - laning from Udali to Manderdisa Sec. of NH-54 E in Assam (AS-27)	251
Figure 147	HEC areas in the old NH-54 before the execution of wildlife mitigation structures	252
Figure 148	Major Bridges to facilitate the movement of wildlife particularly elephants	253
Figure 149	Minor bridges with additional bays for smooth passage of elephants	254
Figure 150	Opaque sheet barrier over the crash barriers for light prevention	255
Figure 151	Cautionary sign boards and Speed Limits	255
Figure 152	Cautionary Sign Boards for Elephant Corridor	256
Figure 153	Barbed wire fencing at cutting portions to restrict the movement of animals over the main carriageway	256

Figure 154	Elevated Corridor on Pipli– Bhavnagar section NH751 corridors	258
Figure 155	Animal Underpass on Pipli– Bhavnagar section NH751 corridors	258
Figure 156	Circular Platforms on Pipli– Bhavnagar section NH751 corridors	259
Figure 157	Water pond on Pipli– Bhavnagar section NH751 corridors	259
Figure 158	Cautionary signboards on Pipli– Bhavnagar section NH751 corridors	260
Figure 159	Lion Underpasses in Four-Laning of Kagvadar–Una Section of NH-8E (Pkg.-IV)	262
Figure 160	Cautionary Signboards in Four-Laning of Kagvadar–Una Section of NH-8E (Pkg.-IV)	263
Figure 161	EOP on NH-130A: 50m length, 2×25 m spans, 55m width	264
Figure 162	EUP on NH-130A: 2×11.6m width, 8m×30 m span	265
Figure 163	EUP on NH-130A: 2×11.6m width, 8m×30 m span	265
Figure 164	Wildlife Mitigation Structures on Raipur–Visakhapatnam Economic Corridor	266
Figure 165	Daily environment/wildlife/DDE-relevant posts, April 2026. The Apr 14 launch day (orange) shows a clear ~2x spike	283
Figure 166	Total social media volume vs. environment-relevant posts. Green = env/wildlife/DDE; grey = other NHAI chatter	283
Figure 167	Hourly env-relevant posts on Apr 14 (Launch Day). Peak activity of 273 posts/hr at 4:00 PM IST (inauguration window)	284
Figure 168	Theme breakdown across all env/wildlife posts, April 2026	284

Chapter 1: NHAI and Sustainability

1.1 About NHAI

The Ministry of Road Transport and Highways (MoRTH) was established in 2009 following the division of the former Ministry of Shipping, Road Transport, and Highways into two distinct entities: the Ministry of Road Transport and Highways and the Ministry of Shipping. The National Highways Authority of India (NHAI) is a nodal agency of MoRTH and is mandated to implement National Highways Development Project (NHDP) in a phased manner.

Road transport plays a pivotal role in the economic growth of a nation, influencing the speed, structure, and trajectory of development. National Highways are the arterial roads of the country for inter-state movement of passengers and goods. They traverse the length and width of the country connecting the National and State capitals, major ports and rail junctions and link up with border roads and foreign highways.

The National Highways Authority of India (NHAI) was established under the National Highways Authority of India Act, 1988, enacted by the Parliament. NHAI is tasked with the development, maintenance, and management of the National Highways assigned to it, as well as handling related and incidental matters. The organization became fully operational in February 1995 and serves as a nodal agency under the Ministry of Road Transport and Highways (MoRTH).

1.2 Mandates of NHAI

The NHAI operates as an autonomous organization under the MoRTH and is responsible for the development, maintenance, and management of national highways and any other highways vested in or entrusted to it by the Government of India (GoI). NHAI is mandated to implement National Highways Development Project (NHDP) which is India's largest ever highways project in a phased manner. Although National Highways constitute only about 2% of the road network, it carries 40% of the total road traffic.

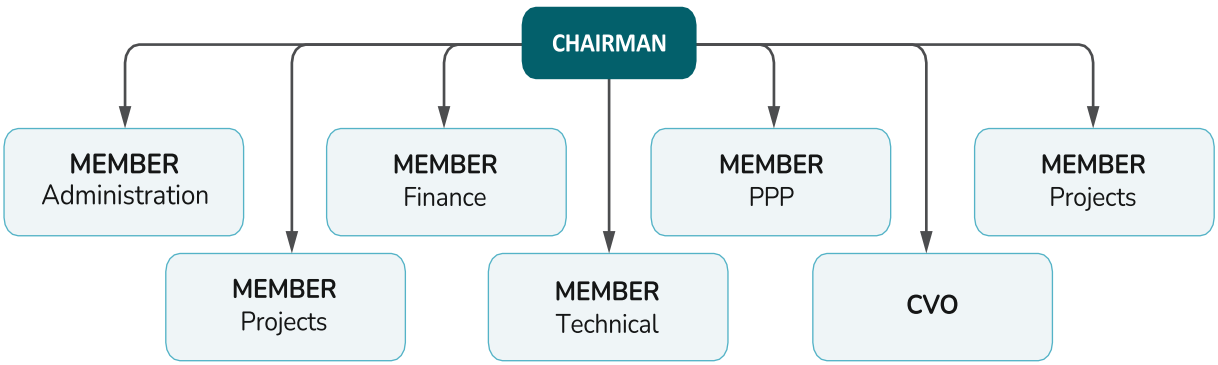
1.3 NHAI's Vision

NHAI envisages the vision to meet the nation's need for development and maintenance of National Highway network to global standards and to meet the user's expectations in the most time-bound and cost-effective manner, within the strategic policy framework set by the Government of India and thus, promote economic well-being and quality of life of the people.

1.4 NHAI's Mission

- To develop, maintain and manage National Highways vested in it by the Government.
- To regulate and control the plying of vehicles on National Highways for its proper management.
- To develop and provide consultancy and construction services in India and abroad and carry-on research activities in relation to the development, maintenance and management of highways or any other facilities there at.
- Provide such facilities and amenities for the users of the highways vested in, or entrusted to, it as is, in the opinion of the authority, necessary for the smooth traffic flow on such highways.
- Construct offices or workshops and establish and maintain hotels, motels, restaurants, and rest rooms at or near the high-ways vested in or entrusted to.
- To advise the Central Government on matters relating to highways.
- To assist on such terms and conditions as may be mutually agreed upon, any State Government in the formulation and implementation of schemes for highway development.

1.5 Organizational Structure at NHAI



The governance is spread as a three-tier structure at NHAI to manage the projects across India, i.e., Headquarters (HQ), ROs, and Project Implementation Units (PIUs). NHAI has 25 Regional Offices (ROs) that supervise 193 PIUs across India.

1.6 Project Implementation and Development Mechanisms

NHAI employs a comprehensive, consultative approach to road conceptualization and development. Before initiating a *Greenfield* project, NHAI is required, under the EIA Notification 2006, to conduct an Environmental Impact Assessment (EIA), prepare an EMP, and hold public hearings. The organization's sustainability strategy and approach further elaborate on these processes, which include the implementation of the Environment Management Plan (EMP) and land acquisition.

Once land acquisition commences, NHAI develops a strategy to oversee the construction and operation of the project throughout its life cycle. NHAI issues a tender to select a Concessionaire

(Road Developer) for the Engineering, Procurement, Construction (EPC), and Operations & Maintenance (O&M) of the project, based on specific qualification criteria. After a detailed selection process, NHAI awards the Letter of Award (LOA) to the chosen Concessionaire. The Concession Agreement outlines the scope of work, terms, and payment milestones based on project progress.

NHAI also appoints an Independent Engineer (IE)/ Authority Engineer (Consultant) to oversee and monitor the project, providing monthly and annual reports. Additional experts, consultants, and advisors are engaged as needed to support project management.

NHAI also ensures that all National Highway projects comply with applicable statutory provisions and environmental safeguards prescribed by relevant regulatory and statutory authorities. The project planning and implementation are also guided by technical and environmental guidelines issued by the MoRTH, the Ministry of Environment, Forest and Climate Change (MoEF&CC), and other competent authorities to ensure that highway development is undertaken in accordance with established environmental standards and sustainable infrastructure practices.

1.7 NHAI applicable Statutes and Guidelines for Clearances

In recent years, the regulatory landscape governing environmental, forest, and wildlife clearances for National Highway projects has undergone significant refinement to strengthen procedural discipline and ecological safeguards.

Development of road infrastructure, while critical for connectivity and economic advancement, has the potential to exert pressures on wildlife and natural ecosystems. Highway construction and operation may lead to habitat fragmentation, interruption of established animal movement corridors, and an increased likelihood of wildlife–vehicle collisions. Modifications to natural drainage regimes, along with noise, vibration, and artificial lighting, can further influence breeding, foraging, and migratory behaviors of various species. Over time, these changes may contribute to ecological stress and reduced habitat continuity if not systematically addressed.

Recognizing these potential impacts, the NHAI, as the nodal agency for national highway development, has progressively aligned its infrastructure planning with environmental stewardship principles. While continuing to deliver safe and efficient transport corridors, NHAI integrates ecological assessments, impact mitigation strategies, and wildlife-sensitive design interventions into project planning and execution to minimize adverse effects and promote sustainable infrastructure development.

A key circular issued by the MoRTH on May 6, 2025, mandates a predefined sequence of statutory clearances for all National Highway projects put out for bidding from 1 June 2025 onwards, requiring that Environmental Clearance (EC) and Wildlife Clearance (WLC) are in place before bids are invited, and Forest Clearance (FC) is secured prior to the Letter of Award (LoA), alongside

a minimum 90 % acquisition of right-of-way, to reduce downstream delays and contractual disputes during execution.

The requisite statutory clearances are obtained in accordance with the notifications and guidelines issued by the MoEF&CC from time to time. The major statutory provisions are as under:

1. Environment (Protection) Act, 1986 and Rules framed thereunder.
   - For seeking Environment Clearance as per EIA Notification, 2006.
2. Van (Sanrakshan Evam Samvardhan) Adhiniyam, 1980 and Rules framed thereunder.
   - For seeking Forest Clearance in forest land diversion cases.
3. Wildlife (Protection) Act, 1972 with amendments.
   - For seeking Wildlife Clearance in matters of Protected Areas and/or Wildlife corridors.

The prescribed sequence of clearance by MoEF&CC is as under:

- Wildlife Clearance under Wildlife (Protection) Act, 1972 (amended).
- Forest Clearance under Van (Sanrakshan Evam Samvardhan) Adhiniyam, 1980 and Rules framed thereunder.
- Environment Clearance under Environment (Protection) Act, 1986.

Although a sequential procedure has been prescribed for securing aforesaid clearances, however, MoEF&CC process these clearances in parallel by maintaining the sequential order.

1.8 Sustainability at NHAI

Sustainable development in highway infrastructure focuses on meeting present transportation needs while safeguarding environmental, social, and ecological resources including precious bio-diversity for the future. In the context of national highway development, sustainability is not limited to reducing environmental impacts but also encompasses long-term resilience including climate resilience, safety, and responsible use of natural resources including bio-diversity protection and conservation. NHAI has increasingly adopted sustainability principles to ensure that highway projects contribute to economic growth without compromising ecological balance.

During construction, sustainable practices such as efficient material management and introduction of circularity i.e., using materials like Fly Ash, Reclaimed Asphalt Material, Construction and Demolition Waste etc., Reuse of excavated material etc., are encouraged. Dust suppression, Soil conservation measures, controlled drainage systems, and slope stabilization help to reduce air, water, and soil pollution, prevent erosion and protect adjoining ecosystems. Tree transplantation, plantation activity, compensatory afforestation, and development of green belts along the corridor further contribute to environmental restoration. Sustainable highway development also emphasizes on installation and use of Solar Panels and Solar Blinkers to contribute towards Renewable Energy transition. Wildlife mitigation structures and measures including soil and moisture conservation works also form the integral part of NHAI's sustainable practices.

NHAI has been increasingly aligning with Environmental, Social, and Governance (ESG) principles and Millennium Development Goals (MDGs) through various initiatives aimed at sustainable development, improving social outcomes, and ensuring transparent governance. NHAI has linked its operational obligations to include ESG principles in its operations, focusing on sustainable infrastructure, enhancing social benefits, and ensuring governance standards.

These initiatives not only enhance India's resilient road network but also help to achieve the country's overall Sustainable Development Goals (SDGs) by making roads safer, greener, and more accessible.

The NHAI although not mandated by mandate and Securities and Exchange Board of India (SEBI) guidelines, voluntarily prepares and releases its Sustainability Reports (SRs) every alternate year. These reports are prepared as per Global Reporting Initiatives (GRI) Protocol and are assured by third party assurer/ validator as per prevalent international practices.

The keyways in which NHAI has made progress in its ESG journey are:

1.8.1 Environmental Sustainability

Green Highways Initiative

NHAI has been promoting green highways by implementing extensive tree plantation along National Highways under the Green Highways (Plantation, Transplantation, Beautification & Maintenance) Policy, 2015.

Environmental Management and Wildlife Mitigation Measures

As part of its sustainability framework, NHAI integrates environmental safeguards through the preparation and implementation of Environmental Management Plans (EMP) and project-specific ***Wildlife Mitigation Plan (WMP) including Wildlife Passage Plans (WPPs).*** These plans incorporate measures such as wildlife underpasses, overpasses, fencing, canopy crossings, and other eco-friendly design interventions recommended by the Wildlife Institute of India (WII), Dehradun to minimize potential habitat fragmentation and facilitate safe wildlife movement across highway corridors.

Use of Renewable Energy

NHAI is incorporating solar energy for highway infrastructure, such as solar lighting systems and powering toll plazas with solar power. This helps reduce the carbon footprint of highway operations.

Waste Utilization in Construction

NHAI is increasingly using industrial by-products like fly ash and plastic waste in road construction to promote principles of circular economy and reduce environmental degradation.

Sustainable Materials & Technologies

The use of recycled materials and geosynthetics in road construction helps reduce resource consumption and increase road longevity.

1.8.2 Social Impact

Employment Generation

NHAI's highway projects create significant employment opportunities for local communities, contributing to economic development and poverty alleviation in rural and semi-urban areas.

Road Safety Initiatives

NHAI has implemented several programs under the Road Safety Initiative, including improving road designs, accident prone-zone mapping, and conducting safety audits to reduce accidents and ensure safer travel for the public.

Health and Education Support

NHAI undertakes Corporate Social Responsibility (CSR) initiatives, such as providing medical facilities and education for local communities affected by highway projects.

Infrastructure Accessibility

NHAI works to ensure better connectivity through its projects, improving access to essential services such as healthcare and education for undeserved and remote populations.

1.8.3 Governance

Transparency and Accountability

NHAI has been working to enhance transparency and fair practices in project procurement, contract management, and PPP. This ensures compliance with ethical standards and fosters competition in contract awards.

Use of Technology for Governance

NHAI's collaboration with the ISRO for satellite-based project monitoring ensures real-time tracking of road projects, enhancing transparency, efficiency, and timely delivery.

Digital Transformation

NHAI has been leveraging technology to introduce e-tendering, online monitoring, and grievance redressal systems, which promote governance and reduce corruption.

Public Grievance Redressal

NHAI is committed to addressing public concerns through platforms like NHAI Citizen App, which provides a channel for reporting road issues and grievances related to highways.

1.9 NHAI's ESG Goals

As India's leading authority on national highways, the NHAI is committed to fostering sustainable growth while ensuring the development of world-class infrastructure. With a mission to provide efficient, safe, and environmentally conscious road networks, NHAI aims to align its strategic objectives with the nation's broader goals for economic progress, social inclusion, and environmental stewardship. In line with these priorities, NHAI has outlined several key focus areas where it can make a significant impact. These areas include carbon neutrality, decarbonization, employee well-being, economic development, road safety, and digitalization.

NHAI's forward-thinking approach is designed to not only address current challenges but also to future-proof India's road infrastructure. By integrating sustainable practices like use of alternate materials, enhancing governance, and embracing technological advancements, NHAI is poised to lead the transformation of India's highways into a safer, greener, and more inclusive network.

Sustainable growth in the highway sector is underpinned by the technical standards and guidelines issued by the Indian Roads Congress (IRC), which have consistently emphasized principles of resource efficiency, environmental protection, safety, and long-term performance in road planning, design, construction, and maintenance.

Following are the IRC codes being followed for the material/ technology showcasing technical and sustainable approach:

Table-1: IRC Codes for Use of Alternate Materials & Technology in Road Construction

S. No.	Material/Technology	IRC Codes
1	Cement Treated Granular Layer	• IRC: SP: 37-2018 Guidelines for Design of Flexible Pavements.
2	Geo synthetic	• IRC: SP: 106-2015 Engineering Guidelines on Landslide Mitigation Measures for India Roads. • IRC: SP:59-2019 Guidelines for Use of Geosynthetics in Road Pavements & Associated Works. • IRC: SP: 48-2023 Hill Road Manual • IRC: SP: 56-2011 Recommended Practices for Treatment of Embankment & Road Slopes for Erosion Control. • IRC: SP: 113-2013 Guidelines for the Design & Construction of Geosynthetic Reinforced Embankments on Soft Subsoil.
3	Recycling	• IRC: SP: 120-2015 Recommended Practice for Recycling of Bituminous Pavements

S. No.	Material/Technology	IRC Codes
4	Modified Bitumen	• IRC: SP: 53-2010 Guidelines on Use of Modified Bitumen in Road Construction
		• IRC: SP: 107-2013 Specification for Bitumen Mastic Wearing Courses
5	Soil Stabilizer	• IRC: SP: 89- (Part II)-2018 Guidelines for the Design of Stabilized Pavements. • IRC: SP: 089-1-2010 Guidelines for Soil & Granular Material Stabilization Using Cement, Lime & Fly-ash.
6	Stone Matrix Asphalt	• IRC: SP: 79-2023 Specifications for Stone Matrix Asphalt
7	Fiber Reinforced Concrete Pavements	• IRC: SP: 46-2013 Guidelines for Design & Construction of Fiber Reinforced Concrete Pavements

Through adherence to MoRTH instructions and amended IRC guidelines the alternate materials and technologies are used in road construction for environmental conservation and sustainability. NHAI has issued Policy Circular No. 13.24/2022, dated 02 June 2022, mandating the extensive use of these alternate materials and technologies in road construction to optimize time, follow sustainable practices, and cost savings. IRC guidelines are available for the use of alternate materials and technology such as cement-treated base (CTB), cement-treated sub-base (CTSB), geo-synthetics, recycling, modified bitumen (CRMB, polymer-modified, natural rubber), soil stabilization, etc. in highway construction.

In alignment with these standards, the NHAI has been implementing and operationalizing sustainability-oriented practices across its projects well before the articulation of contemporary national sustainability frameworks. These practices include adoption of eco-friendly construction techniques, efficient material use, incorporation of environmental safeguards, and integration of measures to enhance resilience and reduce environmental impacts.

The sustained application of IRC codes by NHAI closely coincides with the Government of India's long-term vision for sustainable and inclusive development under ***Viksit Bharat 2047***, which prioritizes low-carbon growth, climate resilience, conservation of natural resources, and environmentally responsible infrastructure development. Accordingly, ongoing highway development efforts reflect a continuity between established technical standards and evolving national policy objectives, reinforcing the role of sustainable infrastructure as a key enabler of the country's long-term development trajectory.

1.10 Stakeholders Management

NHAI engages with its stakeholders throughout the entire year to improve the financial as well as operational efficiencies. Crucial sustainability matters are covered by NHAI through communications with internal and external stakeholders, these matters include both sustainable business as well as business as usual practices. These periodic communications help NHAI to identify issues and further communicate critical ESG concerns. NHAI operations include interactions with different stakeholders during day-to-day activities as well as at the time of project development.

NHAI has been engaging the stakeholders throughout the year with purpose of improving the operational and financial efficiencies. NHAI also covers important sustainability topics through communications with both internal stakeholders such as Ministry of Road Transport & Highways, Government of India, Central Ministries of Government of India and the State Governments through its Forest, Environment, Revenue, Water Resources Departments etc., Employees: Permanent and Contractual, Subject Matter Experts (SMEs) etc. and external stakeholders viz., Concessionaires, Authority/Independent Engineers, Suppliers and Contractors, Road Users, Industry and Trade organizations Communities and NGOs, and Regulators which encompass business sustainability and business as usual practices.

1.10.1 Wildlife & Biodiversity: An Important Stakeholder

The National Highways Authority of India (NHAI), in executing highway infrastructure across diverse ecological landscapes, acknowledges wildlife and biodiversity as integral stakeholders in project development. As highways traverse forests, wetlands, river corridors, and other environmentally sensitive areas, they interface with habitats that sustain diverse flora and fauna, enable seasonal migrations, and support ecological balance. Biodiversity, beyond its intrinsic importance, sustains critical ecosystem services such as water regulation, soil stabilization, pollination, carbon sequestration, nutrient cycling, preserving gene banks and climate moderation — functions that directly contribute to societal well-being and long-term economic growth.

Recognizing that biodiversity and wildlife are invaluable components of our national heritage and cannot speak for themselves, NHAI is making every possible effort to avoid or to minimize potential impacts of linear infrastructure on wildlife and biodiversity. This includes the incorporation of appropriate mitigation measures such as animal underpasses and overpasses, tunnels, canopy bridges, reptile crossings, and other wildlife-friendly infrastructure solutions etc. Through scientific baseline assessments, corridor-level ecological analysis, and incorporation of targeted mitigation measures within the Environmental Management Plan (EMP), potential impacts such as habitat fragmentation and movement disruption are systematically addressed in NHAI's operational domain. This proactive and inclusive approach ensures that infrastructure expansion advances national connectivity objectives while conserving ecological integrity and sustaining environmental resilience.

1.10.2 Animal Safety

Within the broader framework of road safety, protection of wildlife in ecologically sensitive stretches is accorded due importance in the operational domain of NHAI. Highways intersecting forested or rural landscapes are designed with dedicated crossing structures and regulated traffic controls to minimize accidental animal encounters. Strategic placement of crossing points, controlled speeds in vulnerable zones, and enhanced driver awareness mechanisms collectively contribute to reducing collision risks. By systematically integrating wildlife-sensitive design and traffic management measures into highway planning, road infrastructure can effectively reduce collision risks while maintaining ecological connectivity. This balanced approach reinforces the objective of creating safer roads that are responsive not only to human users but also to the surrounding natural environment.

1.10.3 Stakeholder Communication and Responses

NHAI regularly interacts with all the stakeholders to maintain enriching dialogue, which in turn helps NHAI to improve its operational and financial efficiencies. During these interactions, NHAI ensures that it addresses, key and context specific concerns of the stakeholders to make sure a holistic project development takes place.



Chapter 2: Potential Ecological Impacts of Road Infrastructure

Linear infrastructure such as highways, railways etc. have potential ecological impact due to its continuous footprint across diverse landscapes, including forests, wetlands, agricultural areas, and wildlife habitats. These projects at times intersect natural wildlife movement corridors, which may lead to wildlife populations having reduced access to critical resources such as water, forage, breeding grounds, and disrupt seasonal migratory routes. Such fragmentation impacts are likely to affect population viability, restrict genetic exchange, and alter long-term ecological processes.

High-speed vehicular traffic associated with highways increases the risk of wildlife–vehicle collisions, resulting in direct mortality across a wide range of species, including large mammals, small mammals, reptiles, and amphibians. In addition to direct impacts, the construction and operation of road infrastructure introduce secondary disturbances such as noise, artificial lighting, vibration, and increased human activity, which may cause behavioural changes, stress, and avoidance of otherwise suitable habitats by wildlife.

Road infrastructure development may also modify natural drainage patterns, soil structure, and vegetation cover, leading to localized changes in microhabitats and hydrological regimes. Vegetation clearance along the alignment may create edge effects, increase the likelihood of invasive species establishment, and facilitate human and livestock access into previously undisturbed areas. Over time, these cumulative impacts can reduce habitat quality and ecological integrity at a landscape scale.

Considering the long-term and sometimes irreversible nature of these impacts, it is essential to integrate wildlife mitigation and environmental management measures at the planning, design, construction, and operational stages of highway development. The incorporation of context-specific mitigation measures such as wildlife crossing structures, fencing, noise barriers, habitat enhancement, and systematic monitoring is critical to minimizing ecological impacts and ensuring that highway development is undertaken in a manner consistent with conservation objectives and sustainable development principles.

Table-2: Summary of Road Development Activities & Ecological Impacts on the Natural Environment. Source: Roads, Sensitive Habitats and Wildlife by Rajvanshi etal.2001

Project Activities	Ecological Impacts	Impacts on Wildlife
Design Phase		
• Selection of route alignment and design (road cross-section, vertical alignment, culvert and underpass design, enhancements). • Land consumption.	• Loss of wildlife and habitat and/or community welfare. • System of trade-offs often invoked.	• Trade-offs decided on in the absence of up-to-date technical information about the wildlife resource(s) to be traded undermines conservation efforts.
Construction Phase		
• Clearing of vegetation. • Rehabilitation and resettlement of property, resources, and local people. • Establishment of supporting infrastructure and construction camps. • Resource harvesting by project labourers (fuelwood and food).	***Changes in Vegetation & Ecology*** • Reduced plant cover. • Lowered plant diversity. • Adverse changes in species composition. • Disruption of succession and nutrient cycling. Invasion by exotic species. • Increased pressure on natural resources due to competition and exploitation. • Changes in faunal number and diversity.	***Habitat Loss, Fragmentation*** • Habitat loss. • Habitat disruption or fragmentation. • Habitat modification. • Decline in species sensitive to sedimentation. • Decline in prosperity of flow-dependent ecosystems.
• Water impoundment. • River/stream diversion and channelization. • Reclamation of pools, ponds, wetlands. • Extraction of water for construction.	***Water Quality and Hydrology*** • Modification of surface and groundwater flows. • Shifts in water balance due to extraction of water for construction. • Degradation in the quality of receiving waters due to increased sedimentation load and pollutants in surface runoff.	***Barrier effect*** • Obstruction of daily and migratory movements. • Under-utilization of habitat and resource competition.

	Soil Characteristics & Productivity	***Induced threats***
• Transportation of raw materials, pre-assembled components, machinery and labour to project site. • Mining, quarrying, dredging for obtaining raw materials. • Excavation and filling. • Blasting, rock cutting, drilling and/or tunnelling. • Road surfacing and construction of underpasses and culverts. • Restoration of exposed areas through planting and land stabilization. • Transportation of waste generated during construction. • Management of waste material at dumping sites.	• Compaction of soil. • Loss of productive soil. • Decline in porosity and permeability to water. • Decline in soil productivity. • Destabilization of slopes and erosion. • Mass movement of soil and rock in mountainous terrain. • Generation of tipped material due to imbalance between volumes of earth cut and filled. • Displacement of soil on dunes in desert ecosystems. • Loss of wet soils in riparian and marshy lands during construction of channel and underpasses. • Drainage of aquifers and alteration of ground water tables.	• Increased accessibility to pristine areas. • Increase in hunting and poaching incidences. • Increased probability of induced fire. • Increase in human–wildlife conflicts. • Increase in resource exploitation.
Operation Phase		
		Safety hazards & health impacts
• Movement of vehicles. • Transportation of goods and industrial products.	• Wildlife population depletion.	• Vehicle–wildlife collisions. • Decline in wildlife health due to air, water and noise pollution. • Competition for dwindling resources.

• Road maintenance.	***Air Quality*** • Pollution due to emission of NOX, SOX, PM10, CO and HC. • Pollution due to generation of particulates due to combustion of fuels, re-entrainment of road dust and material transformation.	***Long-term impacts on population/biodiversity*** • Increase in in-breeding and decline in size and population. • Reduction of genetic diversity. • Local extinction of species in isolated habitats.
	Noise pollution • Movement of traffic and the sound of horns and signals at crossing induce significant noise pollution.	• Changes in animal behaviour.

Understanding the nature of ecological impacts of road infrastructure is essential to the identification of measures to avoid, reduce or remedy them. The development of roads can impact wildlife in a variety of ways; these effects have been well studied and documented. (Jalkotzy et al. 1997; Seiler 2002; van der Ree 2015).

2.1 GUIDELINES FOR ROADS IN NATURAL AREAS

Recognizing that road infrastructure can affect wildlife, the National Board for Wildlife (NBWL) has established a policy priority framework to guide the planning and management of roads in natural areas. ***Guidelines for Linear Infrastructure Intrusions in Natural Areas: Roads and Powerlines*** by the NBWL, MoEF&CC, Govt. of India, applies to all roads that pass through any of the following areas, referred henceforth as ***'natural areas'*** viz. National Parks, Wildlife Sanctuaries, Tiger Reserves, Elephant Reserves and designated corridors, Community Reserves, Conservation Reserves, Reserved Forests, Protected Forests, Unclassified State Forests, Wetlands and rivers, Important Bird Areas, Ecologically Sensitive Areas, Coastal Regulation Zone and Grasslands of importance.

At a fundamental level, linear infrastructure projects (roads and powerlines) affecting all natural areas and sites shall perforce be evaluated and considered in order of priority: *Prevention, Realignment, Restoration,* and *Mitigation.*

Prevention:

By this principle, the foremost option for linear intrusion projects is to avoid altogether the major Protected Areas (PAs) or other designated critical wildlife habitats, critical tiger habitats,

recognized wetlands, and other natural areas listed by so planning the general route of the first line in the first place, even if the total length of the intrusion is increased in consequence. This ***Primacy of Prevention Principle*** recognizes that linear intrusions have a range of immediate and long-term harmful effects, both ecological and social, in natural areas of high ecological, amenity, and livelihood values, and suggests that in virtually all cases, intelligent and sustainable alternatives can be found that are socially and ecologically more appropriate.

Realignment:

Projects must investigate in detail and consider the possibility of alternative routes that avoid natural areas of such high ecological and amenity values. Such detailed consideration and alternative routes must be an integral feature of project proposal and implementation documents. Realignments can also be developed in a transparent manner in consultation with local communities affected by the routing and subject experts in ecology, wildlife, and environment, besides project engineers.

Restoration:

In ***natural areas,*** existing roads that are in disuse or evaluated to be inefficient or detrimental to their objects, shall be targeted for ecological restoration to their original or more natural condition, to enhance their ecological and amenity values. Restoration of roads should be through highest standards of ecological restoration, as defined by the *Society for Ecological Restoration International,* using local and diverse species native to the corresponding natural vegetation type and with minimal disturbance to landscape, soil, and vegetation.

Mitigation:

Mitigation, defined as measures to minimize detrimental effects of roads and powerlines on ecology, wildlife, local communities, and users, shall be considered only for existing structures and new cases where the above options have been comprehensively considered and overruled with adequate justification. These are also subject to requisite approvals from the MoEF&CC and statutory bodies such as NBWL, Forest Advisory Committee (FAC), and National Tiger Conservation Authority (NTCA), as relevant to each case.

In cases where, for convincing reasons, linear intrusions cannot be prevented, there are no alternatives, and realignments are impossible, it is imperative that mitigation measures are considered and included in the project planning, design, budget, implementation, and monitoring stages.

These ecological disturbances associated with road infrastructure manifest through multiple pathways, influencing both wildlife populations and the surrounding habitat conditions. The following sections outline the key categories of impacts that may arise due to road development in natural landscapes.

2.2 Potential Impacts

2.2.1 Direct loss of habitat

The construction of new roads destroys or damages vegetation such as trees, shrubs and grasses; this vegetation may provide valuable habitat for wildlife. Any linear development through a closed forest that would lead to loss of habitat would result in a reduced carrying capacity of the landscape to sustain wildlife. The degree of impact is likely to be proportional to the width and length of the disturbance corridor.

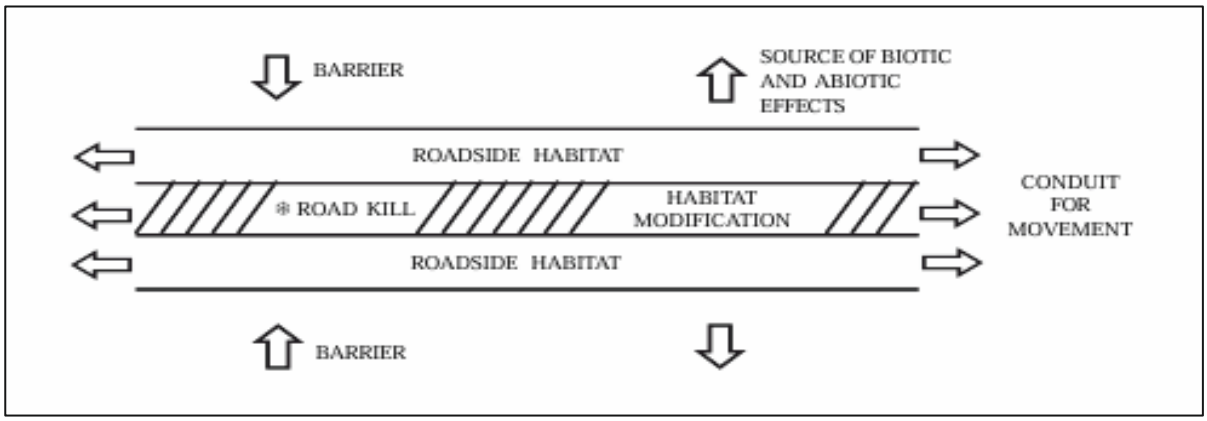


Figure-1: Schematic Representation (after Van der Zande et al. 1980) of Wildlife Impacts of Road Projects: Habitat Modifications, Animal Movement Restriction, Mortality of Animals, Induced Biotic and Abiotic Disturbances. Source: Roads, Sensitive Habitats and Wildlife by Rajvanshi etal.2001

Road or other linear projects can split up habitat by creating physical and psychological barriers for the wildlife. They may also encourage the in-migration of people who further alter and often eliminate wildlife habitat. The impact usually starts with a dirt track or forest access road with almost no effect on the surrounding ecosystem, then it widens to a single lane motorway. Sometimes expansion along existing routes may not be possible, and a new route has to be picked, causing additional loss and habitat changes.

2.2.2 Degradation of habitat quality

The condition of wildlife habitats adjacent to roads often suffers as a result of construction activities such as trenching and digging and the presence of construction camps. Impacts typically include invasion by exotic weeds, and pollution due to liquid or solid wastes or emissions. The effects of heavy metals such as lead from motor vehicle on trees and soils, and numerous chemical elements arising from roads, vehicles, fuels and corrosion, and wear and tear of vehicle components, are recognized impacts. In addition, the habitat may become less attractive to wild animals due to noise, lights or human presence.

2.2.3 Habitat loss and fragmentation

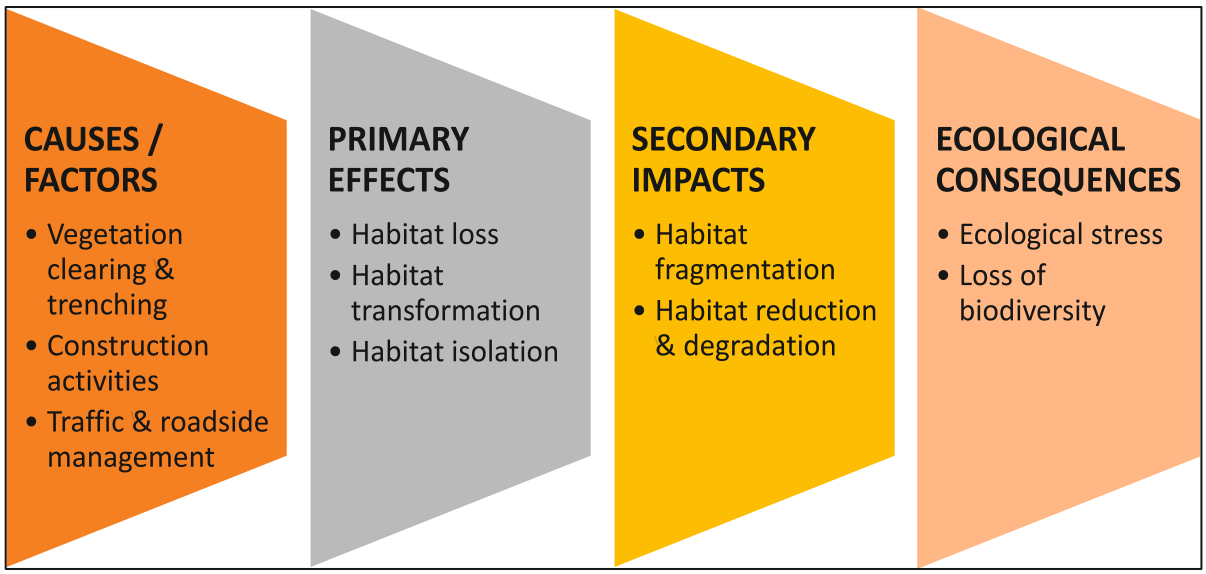


Figure-2: Fragmentation linkages.
Source: Roads, Sensitive Habitats and Wildlife by Rajvanshi etal.2001

Fragmentation of landscapes that include wildlife habitats is one of the driving forces behind the decline in biodiversity. Fragmentation is defined as the breakup of the habitats of plant and animal populations into smaller, more isolated units (Rikswaterstat 1993 and 1997). This definition encompasses terrestrial and aquatic habitats, including both ground-dwelling and arboreal species. Along with the road infrastructure, the other major drivers of habitat fragmentation include railway line, industrial development, mining activities, power transmission corridors, rapid urbanization and settlement expansion, agricultural intensification, irrigation canals, and other linear infrastructure projects.

A busy transport route can constitute an impenetrable barrier that animals of a species, particularly shy ones, cannot cross. Over time, the population becomes divided into a number of sub-populations separated by roads. Some of the sub-populations will be too small to be viable – it is well known that, below a certain critical number, populations are far more susceptible to likely extinction.

Roads dissect contiguous habitat patches, resulting in smaller patch sizes and higher edge-to-interior ratios, making them increasingly vulnerable to outside disturbance. The fragmentation process initiates a shrinking in available habitat, which in turn leads to a progressive reduction in species diversity in the landscape, with consequent isolation of species. The contraction in available habitat together with isolation becomes the most important impact (Harris 1984).

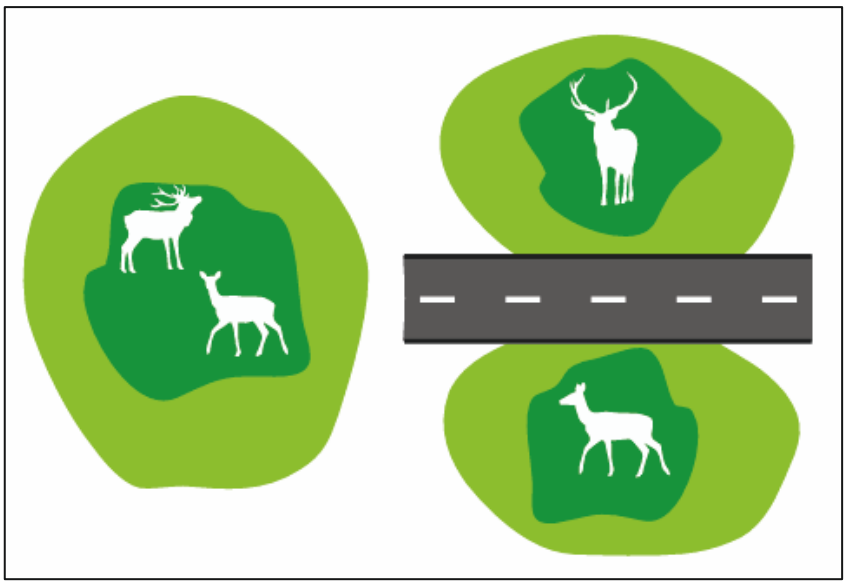


Figure-3: Habitat fragmentation results in far greater reduction in area of available habitat for species in bisected patches.
Source: Rajvanshi etal.2013 in WII Publication.

In addition to the risk of local extinction, fragmentation of habitats can lead to a reduction in genetic diversity (inbreeding) within sub-populations. This can make the whole population susceptible to extinction. If there is to be a mixing of genes and the possibility of recolonizing areas that are locally extinct, then animals have to cross transport corridors.

The '*permeability*' of roads is a measure of the extent to which animals can cross them. A permeable road will constitute a disincentive but may allow some crossing. The highway, through noise and fencing, is a disincentive to travel and forms a natural boundary to the animals' range. Two types of animal movement are important, daily or occasional foraging trips and annual movements made during the mating season and when juveniles leave the family group in search of new habitat. Animals on heat or those who have been driven out of a family group, will overcome natural fears and will attempt movements that they would not consider on a daily basis.

2.2.4 Transformation

Habitat transformation associated with highway and linear infrastructure development extends beyond the physical right-of-way into a broader *edge effect zone*, typically ranging 200–400 m on either side of the carriageway. This zone experiences altered biophysical conditions, including increased temperature, noise, air pollution, modified moisture regimes, and changes in wind exposure. The extent and intensity of these effects are often asymmetrical, influenced by local topography, vegetation structure, and prevailing environmental conditions.

These structural and compositional changes modify microclimatic conditions and habitat suitability, thereby affecting wildlife distribution and behaviour. Species richness in fragmented landscapes may sometimes appear elevated due to the influx of adaptable species, this often masks the loss of native communities and ecological integrity.

Road upgrades such as widening and paving can intensify these transformation effects, further reducing habitat quality and ecological function. Accordingly, ***ecological impact assessments*** must account not only for direct habitat loss within the construction footprint but also for indirect, edge-induced transformations influencing adjacent ecosystems.

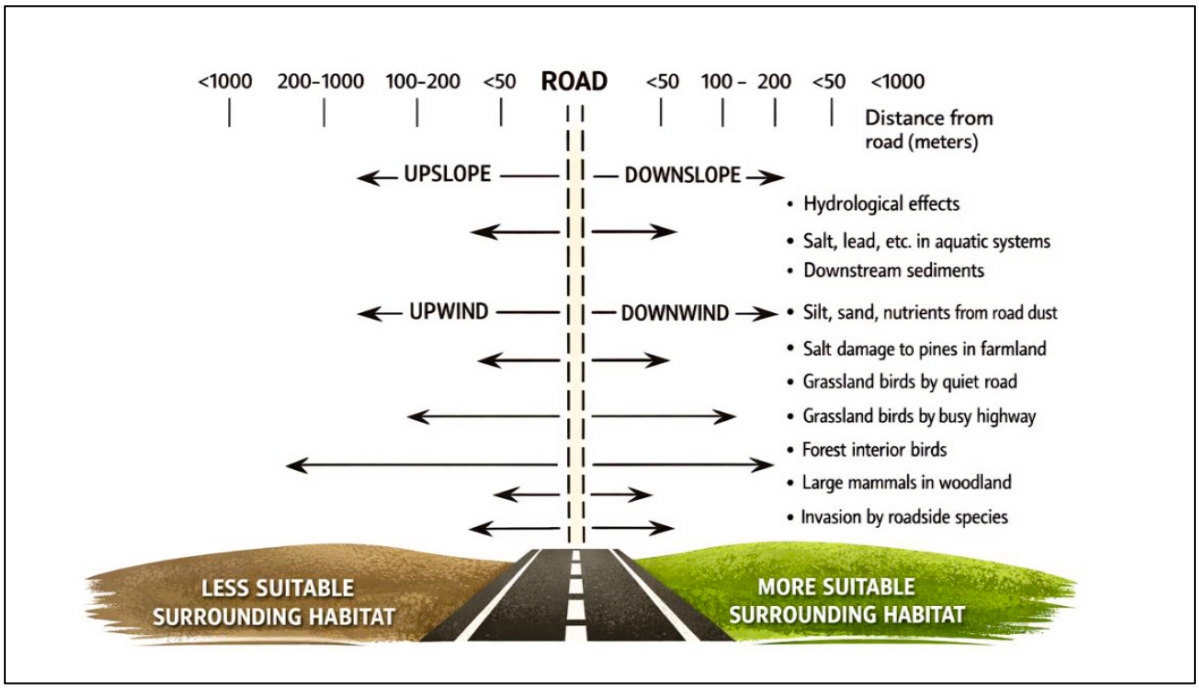


Figure-4: Road Effect Zone - Defined by Ecological Effects Extending Variable Distances from Road Edges (Reproduced from Forman *et al.* 1997).
Source: Roads, Sensitive Habitats and Wildlife by Rajvanshi etal.2001

2.2.5 Isolation

Isolation arises when continuous habitats are subdivided into smaller patches due to linear infrastructure development, potentially influencing ecological connectivity. However, the extent of isolation depends largely on project design, landscape context, and the incorporation of appropriate mitigation measures. With careful alignment planning and integration of wildlife movement structures, functional connectivity between habitat patches can be maintained.

Road networks may increase inter-patch distances and modify land-use patterns; nevertheless, maintaining ecological corridors and minimizing physical barriers can significantly reduce fragmentation effects. Landscape-level assessments, including identification of keystone and

sensitive species, help determine critical movement pathways and inform targeted mitigation strategies.

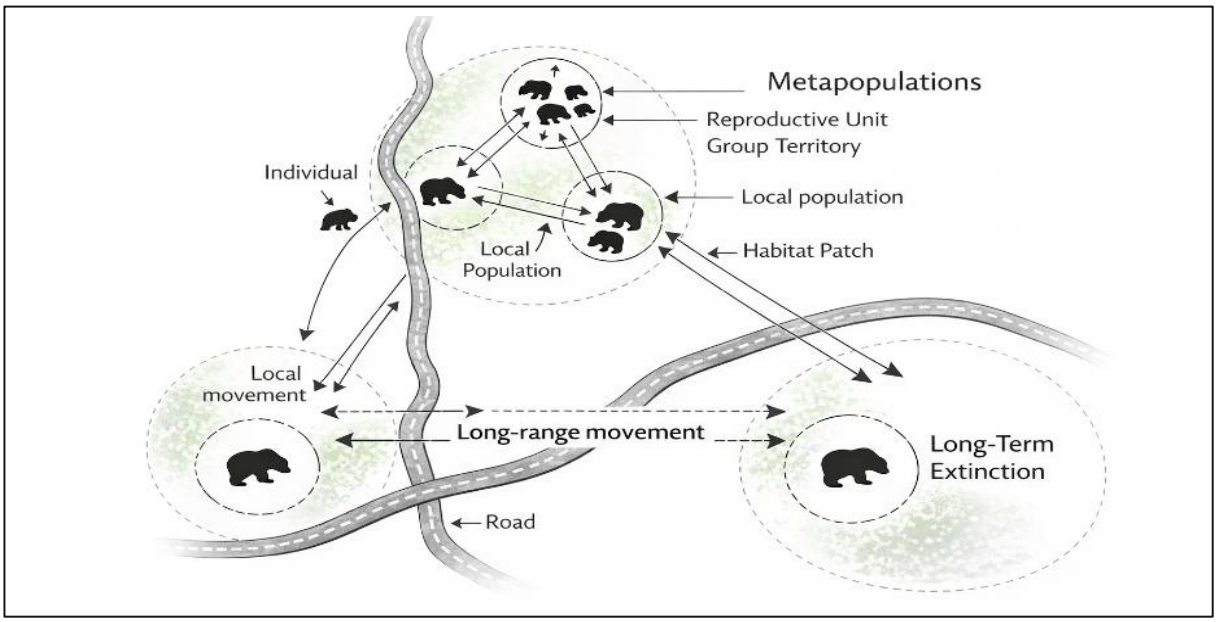


Figure-5: Metapopulations and Roads Source: Roads, Sensitive Habitats and Wildlife by Rajvanshi etal.2001

Where connectivity is sustained, wildlife populations retain the ability to disperse, interact, and maintain genetic exchange. Ensuring that sub-populations remain above minimum viable population thresholds supports long-term ecological stability and resilience. Accordingly, proactive planning and adaptive monitoring are key to managing isolation risks while facilitating infrastructure development.

2.2.6 Headlight glare

Artificial lights may contribute to disturbance of wildlife near roads (Seiler 2001). It may disorient birds (Poot et al. 2008), disturb breeding and foraging behaviour in birds (Hill 1992. It is also thought that a flash of artificial light causes an animal to become momentarily blind, popularly called the "*deer-in-the-headlights*" effect, reducing its chances of avoiding collisions with vehicles.

Headlight glare can interfere with the flights of birds and bats. It can disrupt homing behaviour and mating calls (croaking) of amphibians in wetland habitats, and influence navigational ability and decline in population of reptiles (Beier 2006; Perry & Fisher 2006). For migrating and dispersing animals, highway lights can be disorienting. However, the singular impacts of headlight are of marginal importance unless they contribute to the mortality and barrier effects, multiplying the overall impact (Seiler 2001).

2.2.7 Road avoidance

Repeated disturbances along road corridors may deter animals from using habitats in their vicinity. Avoidance of habitats close to transport corridors may vary diurnally, seasonally and in relation to traffic in these corridors. Some animals avoid habitat in the vicinity of roads because of human activity associated with them. Complete avoidance of habitats traversed by roads can dramatically curtail dispersal, ultimately leading to the isolation and reduced viability of the affected population. The impacts of roads on birds are substantively influenced by behavioural traits such as road surface avoidance, traffic disturbance avoidance, vehicle avoidance and road attraction (by scavenging birds).

2.2.8 Injury and mortality

Animal–vehicle collisions are a major impact of road infrastructure, with a significant number of animals injured or killed by passing vehicles. Upgraded roads that allow higher travel speeds further increase the likelihood and severity of such collisions. Species that are attracted to road surfaces or roadside areas are particularly vulnerable. Reptiles often bask on sun-warmed asphalt, herbivores such as deer graze on roadside vegetation, and predators are drawn to carcasses of previously killed animals, creating a cycle of repeated mortality.

Roadside and Right of Way (RoW) conditions strongly influence collision risks. Vegetation, fruiting shrubs, spilled grains, and grassy edges can attract birds, small mammals, and large herbivores for feeding, resting, or nesting. Post-construction landscaping and plantation choices, therefore, play a critical role in either increasing or reducing wildlife attraction to roads, directly affecting the frequency of animal–vehicle collisions.

Road-induced mortality of animals has always been of concern to biologists (e.g., Stoner 1925; Trombulak & Frissell 2000). Road induced mortality is probably the most acknowledged effect on wildlife- kills ranging from those of snakes to small rodent to deer, to large cats and mega herbivores. The number of casualties would grow constantly as traffic increases and infrastructure expands if adequate mitigation measures are not provided.

The number of kills on most roads is likely to be higher than immediately visible, as many animals that are hit by vehicles die later and elsewhere from injuries or shock. Road deaths in snakes have been attributed to their thermoregulatory needs (Rosen & Lowe 1994; Shine et al. 2004) and seasonal movements; these deaths have been identified as a population-level threat to several species (Clark et al. 2010, Rouse et al. 2011).

2.2.9 Soil Erosion and Sedimentation

Road construction activities can influence soil stability and local hydrological regimes, particularly in hilly and geologically sensitive terrains. Excavation for cuts and fills, embankment formation, removal of slope support, vegetation clearance, inadequate drainage, and vibration from construction activities may increase the susceptibility of slopes to erosion and localized instability. Such risks are accentuated in areas characterized by steep gradients, weathered rock formations, or high rainfall intensity.

Such risks are accentuated in areas characterized by steep gradients, weathered rock formations, or high rainfall intensity.

Alterations to natural drainage patterns through construction of drains, culverts, and channel modifications may further influence surface runoff behavior within and beyond the right-of-way. If not properly designed and managed, eroded material from exposed surfaces can be transported into adjacent streams, wetlands, and low-lying areas, leading to sediment deposition. Elevated sediment loads may affect aquatic habitats, particularly sensitive benthic organisms and fish species, and over time can influence the ecological balance of downstream wetland systems.

Accordingly, careful alignment planning, slope stabilization, preservation of vegetative cover, and adequate drainage design are essential to minimize soil erosion and prevent sedimentation impacts, thereby maintaining both structural stability of the roadway and ecological integrity of surrounding habitats.

2.2.10 Impacts due to Noise Pollution

Noise generated from road infrastructure can significantly influence wildlife behavior and habitat use, particularly in forested and ecologically sensitive areas. Noise from road construction and operation can cause animals to avoid areas near roads. Forman and Alexander (1998) reported that noise significantly decreases bird species richness as one gets closer to the edge of the pavement. Usually impacts are strongly influenced by the type of cover, traffic volume and speed. Continuous traffic noise originating from engines, tire-road interaction, braking, and honking creates a persistent acoustic disturbance that may extend well beyond the physical roadway.

Many wildlife species depend on sound for essential life functions such as mating calls, territorial defense, group coordination, and predator detection. Elevated traffic noise can sometimes mask these acoustic signals, leading to communication disruption and reduced reproductive success. Birds are especially sensitive to such disturbances, and studies have documented reduced species richness and altered singing behavior near busy road corridors. Mammals may respond by avoiding areas adjacent to highways, shifting movement patterns, or becoming more active during quieter periods, such as nighttime.

Chronic noise exposure can also induce physiological stress responses in wildlife, potentially affecting feeding behavior, breeding cycles, and overall fitness. In habitats fragmented by highways, noise may further limit the effective use of available habitat, thereby intensifying edge effects and reducing ecological connectivity.

The magnitude of impact varies depending on traffic volume, vehicle composition, speed, topography, and vegetation cover. Open landscapes and elevated roadways often allow sound to travel farther into natural habitats. Over time, sustained noise disturbance can contribute to habitat degradation and changes in local species composition if not adequately addressed through mitigation and planning measures.

2.2.11 Impacts on Aquatic Ecosystems

Aquatic ecosystems include rivers, lakes and wetlands. Wetlands often support a large number of rare and endangered species, and generally have a high abundance of fish and water birds. Erosion from poorly constructed and inadequately rehabilitated sites can lead to downstream siltation, ruining spawning beds for fish. Constriction of flows at water crossings can make the current too fast for some species. Alteration of flood cycles, tidal flows, and water levels can upset trophic dynamics by affecting the life cycle of plankton, with corresponding effects on the rest of the food chain.

River valleys and their riparian zones, particularly in drier climates, are very sensitive to any development that removes vegetative cover, since such areas are delicately balanced micro-climatic zones, depending on very limited moisture supplies. The wildlife found in these conditions often represent unusual assemblages and need to be protected from unnecessary disturbance. Re-channeling of waterways is sometimes undertaken as part of road construction. This can result in a loss of aquatic habitat diversity and lead to potentially serious and chronic erosion. Finally, streambeds are often used as sources of aggregate material. Serious impacts can occur because of the disruption and outright removal of streambed habitats, and from pollution derived from machinery regularly working in the streambed.

2.2.12 Impacts on watershed due to road infrastructure

Road development across forested and undulating landscapes can modify natural drainage regimes by altering surface runoff patterns and intercepting existing flow paths. Embankments, cut-and-fill sections, and cross-drainage structures, if not properly aligned with natural contours, may obstruct or divert watercourses. Such interventions can lead to upstream water accumulation, downstream flow reduction, or localized erosion, thereby influencing overall watershed balance.

Minor tributaries and seasonal streams are particularly sensitive to these changes. Constriction or inadequate sizing of culverts may disturb natural channel morphology, increase sediment deposition, or accelerate downstream scouring. Over time, these hydrological alterations can reduce water availability, degrade stream habitats, and affect the ecological function of smaller watercourses within the watershed system.

From a wildlife standpoint, minor streams and riparian zones serve as critical resources for drinking, breeding, and foraging. Amphibians, reptiles, small mammals, and aquatic species are especially vulnerable to fluctuations in flow, sediment load, and water quality. Disruption of these hydrological features may fragment microhabitats and weaken ecological connectivity, underscoring the need for drainage planning that maintains natural flow continuity and protects associated wildlife habitats.

2.3 Modelling Barrier Effect on Indian Roads

Road developments become barriers when they are, or are perceived by wildlife to be, impossible or dangerous to cross. The four most important components of road corridors that can act as functional barriers to wildlife movements are:

(i) the road verges (shoulders and ditches);
(ii) the road surface itself;
(iii) poorly-designed crossing structures; and
(iv) traffic

Road Verges:

Road construction alters microclimatic conditions along road edges, affecting temperature, humidity, and evaporation patterns. These *edge effects* create zones that can act as ecological barriers, restricting the movement of various species from insects and amphibians to small mammals and larger wildlife. The modified conditions gradually reduce with distance but can significantly influence species distribution near road corridors.

Road verges often provide limited habitat value due to frequent vegetation clearing, chemical use, and altered plant composition. Such conditions reduce food availability and shelter, discouraging wildlife from crossing or utilizing these areas. Additionally, physical features like wide verges, deep drainage ditches, and steep embankments further intensify the barrier effect, particularly for small terrestrial species, thereby fragmenting habitats and limiting ecological connectivity.

Road Surfaces:

Road surfaces function as strong physical and behavioral barriers to wildlife due to noise, open exposure, artificial substrates, and absence of cover. Many species, particularly those adapted to dense or undisturbed habitats, instinctively avoid crossing such unfamiliar and risky environments. For low-mobility forest-dwelling animals, wide cleared corridors especially those exceeding 100 meters create a stark habitat contrast that significantly restricts movement, thereby contributing to habitat fragmentation and reduced ecological connectivity.

Crossing Structures:

Culverts, underpasses, and bridges can act as barriers to wildlife movement when they are not designed in accordance with species-specific requirements. Their effectiveness depends on structural characteristics such as width, height, length, substrate, approach conditions, and visibility. If these elements do not align with the behavioral patterns and habitat preferences of target species, animals may avoid using them altogether.

A clear understanding of species ecology including movement patterns and habitat use is, therefore, essential for designing functional crossing structures. Inadequately planned structures may restrict terrestrial movement, contribute to habitat fragmentation, and reduce overall landscape connectivity.

Traffic Movement:

Traffic creates a behavioral barrier for wildlife due to continuous noise, vehicle movement, and emissions. Many species, particularly birds, avoid areas near roads, and avoidance distances increase with higher traffic volumes, effectively enlarging the ecological impact zone. Noise disrupts animal communication, especially in birds, while vehicle emissions degrade roadside habitat quality. Species sensitive to pollutants or dependent on smell for survival are especially affected, limiting their movement across road corridors.

Table-3: Barrier Effects of Roads
Source: Roads, Sensitive Habitats and Wildlife by Rajvanshi etal.2001

Phase	Activity	Barrier Effects
Design Period	Alignment of route through contiguous wildlife habitat.	Creation of disjointed habitats split by a physical barrier.
Construction Period	Clearing of vegetation on road verges.	Impaired movement of ground-dwelling and sensorial mammals.
	Removal or thinning of canopy of trees overhanging the carriageway or the RoW.	Transformation of vegetation community to non-native grouping.
		Discontinuity of movement of arboreal mammals (macaques, squirrels, flying foxes).
		Ecological barrier to movement of understorey bird species.
		Physical barrier for movement of small burrowing mammals.
	Movement of workers and machinery on construction sites.	Inhibition of animal movements due to human disturbances.
	Construction of trenches along sides of roads for drainage of water.	Physical barrier for reptiles and small burrowing mammals.
	Land levelling for road surface and development of inclines near verges.	Creation of physical barriers where inclined shoulders inhibit movement of crawling animals.
	Impoundment of water.	Restriction of movement of amphibians.
	Channelization of streams.	Obstruction of movement of aquatic species.
	Construction of overpasses, underpasses, culverts, bridges and causeways.	Restriction of daily and migratory movements.

	Surfacing of carriageway.	Behavioural disorders associated with tunnel syndrome.
		Physical barrier inhibiting diurnal movement and dispersal of animals.
	Movement of traffic.	Collisions with vehicles, leading to injury and mortality.
Operation Period	Traffic noise.	Psychological barrier and disruption of normal activity patterns.
	Headlight glare.	Temporary blinding and risk of collision.
	Emission of products of fuel combustion and spillage of fuels and other material transported by containers.	Impairment of movement of sensitive species in contaminated zones that pose psychological barriers.

There is a difference of opinion between the linear road infra developers and wildlife biologists with regard to the issue that whether widening of the existing highways would have any negative impact on the habitat, especially movement of wild animals. Taking a pro-conservation view point, it would be appropriate to arrange for mitigation measures by accepting that all such upgradations may lead to enhancement of both traffic volumes and velocity and therefore can become a hindrance to animal movement across the highway leading to their avoidance of the highway for crossing over. This phenomenon has been termed as the *'barrier effect'* and it manifests in several forms.



Figure-6: Factors influencing barrier effects of roads. Source: Mathur, V. B., & Rajvanshi, A. (2016).

This *barrier effect* will prevent species from getting on to the road and crossing it. While it may reflect in a decline in their mortality, it would also deprive them from using their entire habitat and may ultimately lead to a decline in their genetic fitness.

2.3.1 Barrier to Movement

Animals move to forage, find mates, seek shelter, reach breeding sites and participate in social interactions. These movements occur on a variety of spatial scales ranging from less than a meter for some invertebrates to hundreds or thousands of kilometers for mammals and migratory birds. Roads are stated to be one of the obstacles to the movement of land vertebrates.

Although roads can serve as a corridor for species moving across landscapes, they may restrict, inhibit or prevent the movement of species. This barrier effect on wildlife results from a combination of factors, from traffic noise, pollution and human activity to physical hindrances and traffic mortality (Trocmé et al. 2003).

A road can act as a strong barrier on a number of counts: the embankment may be too high to climb, constructed of material (e.g., loose gravel or large stones) that cannot be navigated by some species, or present a visual barrier that discourages crossing by species used to long lines of sight. The rate of animal movement through road corridors may be lower than in intact natural habitat. Linear infrastructure thus may act as a filter to movement in that corridor, affecting its so-called *'permeability'*. Roads may reduce access to saltlicks or waterholes by wild animals in general, access to summer and winter ranges by ungulates, to wetland breeding sites by amphibians, and to upland nesting habitat by turtles. Roads may break canopy connectivity, which is essential for the movement of arboreal species.

2.3.2 Disruption of natural processes

Roads aligned through otherwise undisturbed and integrated landscape can affect natural (ecological and evolutionary) processes, which in turn may have long-term implications for wildlife. They have potential to change fire or burning patterns and hydrological regimes (e.g., through alteration in runoff from surfaced areas), introduce and enable the spread of invasive and alien species, and influence genetic drift.

Roads can at times act as a source of ignition of fire in a landscape, or can create firebreaks that prevent the spread of natural fires that may be important in wildlife management. Animal movements among meta-populations are vital for their long-term viability. Roads may block movement of some small animal species and subdivide their populations. Smaller populations are more vulnerable to genetic changes due to genetic drift and inbreeding depression, and to extinction risk.

2.4 Increased human presence

Road corridors may provide access to inaccessible areas, increasing the pressures associated with human presence. Increased access and human pressures are particularly likely during construction and maintenance of roads.

Improved road access can open previously remote natural areas to increased human activity, often leading to expansion of settlements and gradual intensification of land use along transport corridors. Over time, this may contribute to habitat fragmentation, landscape modification, and greater pressure on adjacent forest and protected areas.

Although Protected Areas (PAs) are legally designated to safeguard ecosystems, improved road access can intensify migration and settlement pressures even within or around these zones. In many cases, enforcement capacity and resources are insufficient to counteract the pace of road-induced colonization. Without proactive strengthening of protection measures alongside road development, conservation objectives may be undermined. Therefore, potential colonization and disturbance effects must be carefully considered during the earliest stages of road planning and route selection.

2.4.1 Tourism

Improved Road infrastructure increases visitor access to protected areas, often beyond their carrying capacity, leading to ecological destabilization. Areas directly connected to urban road networks experience sustained habitat and wildlife degradation due to high accessibility and inadequate visitor control. The presence of religious place within protected areas further complicates management efforts to regulate access and maintain secure habitats. Increased access roads intensify these management challenges.

Heavy vehicular movement within protected areas causes noise, pollution, and littering, resulting in disturbance to wildlife, contamination of water bodies, habitat degradation, and disruption of wildlife dynamics such as garbage foraging. The cumulative impact can lead to chronic ecological instability in affected regions. Additionally, tourism-related vehicle movement can introduce exotic plant species, which may threaten native ecosystems and further destabilize ecological balance.

2.4.2 Fire

Improved access and increased population density along roads raise the risk of fires, which can significantly affect wildlife. In tribal areas, at times intentional roadside fires are commonly set to promote new grass growth and clear forest floors for fruit collection. These fires reduce roadside habitat quality and eliminate ecological gains between burns, while also shifting preferred wildlife habitats outside the burned Right of Way (RoW).

In ecosystems where fire plays a stabilizing role, suppressing it can cause degradation. Conversely, roads may sometimes function as fire-prevention belts, helping reduce catastrophic fires. These contrasting impacts highlight the need to involve both scientific experts and local communities in road siting and mitigation planning.

2.4.3 Increased human-wildlife conflict

Roads may disrupt the normal home ranges of elephant families, forcing them to explore new areas for foraging where they may come into conflict with human beings. Human settlement or cultivation of land along road corridors may also increase human-wildlife conflict (HWC) and, occasionally, lead to mortality of wild animals. In case of already fragmented habitats, wild animals are known to use particular corridors to move between various patches. If roads obstruct these corridors, the animals may stray into human localities and feed on crops and livestock, increasing conflict.

2.4.4 Interventions of Invasive Species

Road infrastructure can act as a pathway for the introduction and spread of invasive species, particularly along construction corridors, embankments, and disturbed roadside areas. Movement of construction machinery, transport of soil and materials, and increased vehicular traffic may inadvertently facilitate the dispersal of non-native plant seeds and other invasive organisms. The disturbed and open habitats created during road development often provide favorable conditions for invasive species to establish and proliferate.

The presence of invasive species can alter native vegetation composition, compete with indigenous flora and fauna for resources, and disrupt ecological balance. Over time, this may lead to reduced biodiversity, modification of habitat structure, and degradation of ecosystem functions. In forested or protected landscapes, the spread of invasive species along road edges can extend into adjoining habitats, further intensifying ecological impacts if not appropriately managed.

2.5 Cause and Effect Relationships and Impact Types

Road development can lead to both positive and negative environmental effects. While certain benefits such as improved connectivity and reduced congestion may arise, some impacts may pose challenges that require careful planning and mitigation. These impacts are generally classified into direct, indirect, and cumulative or synergistic categories, based on their nature and the way they influence the surrounding environment and wildlife.

Direct impacts:

Direct impacts are immediate and visible, such as habitat loss from right-of-way clearing, fragmentation of ecosystems, soil erosion affecting habitats, and increased wildlife mortality due to vehicle collisions.

Indirect impacts:

Indirect impacts occur as consequences of direct effects and are often more complex. For example, roads can restrict animal movement (barrier effect), disrupt predator–prey relationships, alter home ranges, and encourage human access leading to habitat encroachment and resource exploitation. These impacts are harder to predict and may have deeper ecological consequences.

Cumulative and Synergistic impacts:

Cumulative and synergistic impacts arise when multiple impacts build up over time or interact. Cumulative effects are additive, where repeated disturbances gradually degrade wildlife habitats. Synergistic effects are multiplicative, where combined impacts—such as erosion, contamination, habitat fragmentation, and human disturbance intensify overall ecological damage beyond individual effects.

Table-4: Potential Impacts of Roads on Wildlife
Source: Roads, Sensitive Habitats and Wildlife by Rajvanshi etal.2001

Project characteristics / activity	Direct impacts	Indirect impacts	Cumulative / synergistic impacts
Clearing of vegetation →	Loss or degradation of habitat →	Reduction in habitat use →	Decline in native population and diversity
Right-of-way clearing →	Fragmentation of habitat →	Reduction in structural diversity, increase in isolation of habitats →	Reduction in population size and integrity
Construction and operation of roads →	Barrier to dispersal →	Disproportionate utilization of habitats →	Competition for resources and/or finding boundaries of home range Increased stress and related health declines
Mowing of roadsides →	Changes in vegetation composition →	Fluctuations in small mammal density due to discontinuity with adjacent wooded habitats →	Alteration of trophic dynamics, ecosystem change

Application of herbicides to control vegetation along roadways	Transportation of chemicals to water bodies	Changes in wetland characteristics	Loss of habitat niche for dependent species; population decline
Road construction in coastal areas	Alteration of tidal flushing cycles in mangroves	Increased or decreased salinity	Changes in habitat quality and species composition
Road construction on unstable land	Soil erosion	Siltation of water bodies	Degradation of aquatic habitat, species decline
Dust raised during operation and construction	Dust deposition on vegetation, interference with photosynthesis	Reduced primary productivity	Reduction of food sources, species decline
Traffic	Disturbance to wildlife species of road verges	Changes in activity patterns leading to habitat use more during night	Competition for resources with nocturnal animals, decline of certain species
		Abandonment of habitat, emigration to others	Overuse of other habitat areas, eventual decline of some species
Increase in traffic volume	Increased road kills	Decline in populations	Change to trophic dynamics and species composition
Channel relocation	Alteration in direction of water flow	Degradation of wetland dependent on flooding	Threats to conservation of some wetland species
		Diminished groundwater recharge	Localized drought, decline in productivity
		Increased flow in receiving streams	Reduced habitat suitability for some species, affecting species composition

Road alignment through wildlife habitat areas →	Increased access to pristine wildlife habitat areas →	Unplanned development →	Decline in habitat quality
		Poaching →	Species decline
Construction activities, blasting and vehicle movement →	Stress on animals →	Changes in behavioural responses and physiological disorders →	Increased mortality
			Reduced fertility
Land taking for road →	Displacement of people →	Colonization pressure in unsettled areas →	Deterioration of previously undisturbed natural areas
Construction of temporary access roads for quarries →	Facilitation of public access →	Eventual acceptance of road as permanent features →	Colonization stimulating road-habitat conversion
Road construction in mountain ecosystems →	Barriers to vertical migration and dispersal of species →	Sub-division of populations in previously connected habitats →	Threat to endemic character of the mountain ecosystem



Chapter 3: Statutory Framework Requirements for NHAI

This chapter outlines the key statutory provisions and regulatory requirements governing the implementation of wildlife mitigation measures for the project. It highlights the applicable environmental, forest and wildlife-related legislations, guidelines, and clearance processes that must be complied with during project planning and execution. It also to some extent describes the roles of relevant authorities and regulatory bodies involved in granting approvals and ensuring environmental compliance.

There are adequate provisions under the existing statutes to safeguard the protection of faunal and floral bio-diversity in our country. For the purposes of undertaking developing endeavours, the Wildlife Mitigation Plans are prepared in alignment with:

- Environmental Clearance requirements under the Environment (Protection) Act, 1986.
- Wildlife habitat protection provisions under the Wildlife (Protection) Act, 1972.
- Forest land diversion safeguards under the Van (Sanrakshan Evam Samvardhan) Adhiniyam, 1980.

3.1 Environment (Protection) Act, 1986

The Environment (Protection) Act, 1986 (EPA) serves as the umbrella legislation for environmental protection in India. An Act to provide for the protection and improvement of environment and for matters connected there with. Although there are existing laws dealing directly or indirectly with several environmental matters, government felt it is necessary to have an umbrella legislation for environmental protection.

While several statutes address environmental concerns either directly or indirectly, many of these frameworks are sector-specific and focus primarily on particular forms of pollution. As a result, certain environmental risks—especially those arising from cumulative impacts—require a more integrated and comprehensive regulatory approach. Fragmented oversight across multiple regulatory bodies can also create coordination challenges.

In this context, the need arose for an overarching environmental legislation that provides a unified framework for environmental protection. Such a framework enables effective coordination among regulatory agencies, establishes empowered authorities to oversee environmental safeguards etc. A comprehensive legislative mechanism further strengthens accountability by prescribing appropriate enforcement measures to safeguard human health, ecological integrity, and long-term environmental sustainability.

The Environment Impact Assessment (EIA) Notification, 2006 (as amended), issued under this Act, mandates prior Environmental Clearance (EC) for specified highway projects. This requirement ensures that environmental impacts, including those on wildlife and biodiversity, are scientifically evaluated by EIA process before the project approval.

As part of the EIA process, projects are required to assess impacts on ecological receptors, including flora, fauna, wildlife habitats, and corridors. Where significant ecological sensitivities are identified, mitigation measures must be incorporated into the Environmental Management Plan (EMP). The conditions stipulated in the Environment Clearance (EC) make these measures obligatory, ensuring systematic implementation and monitoring throughout the project lifecycle.

3.1.1 EIA Notification, 2006 and its amendment on 22nd August, 2013

Based on the consolidated amendment document, as per the EIA Notification, 2006 and its subsequent amendments issued till January 2026, as per *entry 7 (f)* under the category *'Highways'* – all New National Highways fall under *category A* projects, wherein Environment Clearance is mandatory irrespective of length, meaning thereby that all the *Greenfield projects* are covered under the environment clearance regime.

It also states *Expansion of National Highways greater than 100 Km involving additional right of way or land acquisition greater than 40 m on existing alignments and 60 m on re-alignments or by-passes* requires environment clearance, meaning thereby that the brownfield projects falling in the above threshold are covered for seeking environment clearance.

Further, the report of the Expert Committee Constituted by the Ministry of Environment, Forest and Climate Change (MoEFCC), Govt. of India in compliance to the Order of Hon'ble Supreme Court dated 19.01.2021 in the matter SLP (C) No. 8665 - 8667 of 2020 titled as "The National Highways Authority of India Vs. Pandarinathan Govindarajulu & Others, to ascertain *"whether segmentation is permissible for National Highway Project beyond a distance of 100 Kms, and if permissible, under what circumstances"* has been submitted.

Accordingly, NHAI is complying its recommendation so that environmental concerns are suitably addressed in all its developmental initiatives including *Brownfield* projects.

3.1.2 Implementation of EIA & EMP

For National Highway projects, preparation of EIA and EMP is governed by EIA Notification, 2006 under the Environment (Protection) Act, 1986 by MoEFCC varies depending on whether the project is a *Greenfield (new alignment)* or a *Brownfield (expansion/upgrade of existing road)* development, though the overall regulatory framework remains the same under the EIA Notification, 2006.

In the case of *Greenfield projects,* since the alignment passes through previously undisturbed areas, a comprehensive EIA is required. The process begins with scoping and issuance of ToR, followed by detailed baseline environmental studies covering:

i) Physical Environment:

a) **Land Environment:** It includes PAs, wetlands, forests, water bodies, populated zones, sensitive land uses, natural hazard zones, resource-rich areas, soil characteristics, geology.
b) **Water Environment:** It covers surface and ground water quality.
c) **Air Environment:** Includes meteorology, ambient air quality.
d) **Noise Environment:** Noise levels.

ii) Biological Environment:

It covers forest areas, vegetation types, floral diversity, faunal inventory, wildlife habitats and corridors, aquatic ecology, presence of protected or endangered species, and sanctuaries, national park, protected reserve areas around the project site;

iii) Socio Economic and Health Environment:

It includes human Settlements, health status of the communities, community infrastructure, present employment, livelihood, and awareness of population about the projects.

Based on this baseline, potential direct, indirect, and cumulative impacts for each environment during construction and operation phases are identified and assessed, and alignment alternatives are analysed to minimize ecological and social impacts. A cost–benefit analysis is also undertaken, wherein environmental and social costs such as loss of vegetation, ecosystem services, pollution impacts, and mitigation expenses are evaluated alongside projected economic and connectivity benefits of the project. This analysis supports informed decision-making and ensures that environmental safeguards are proportionately integrated into project planning. Based on the impact assessment, a detailed Environmental Management Plan (EMP) is prepared.

The EMP specifies following mitigation measures for:

- **Physical Environment:**
  Land, air, noise, water, and soil.
- **Biological Environment:**
  Wildlife protection measures such as crossing structures and habitat restoration where required; compensatory afforestation and greenbelt development; slope stabilization and erosion control; drainage and sediment management; waste management (including hazardous waste); traffic and safety management during construction; and site restoration measures.
- **Socio-Economic Environment:**
  Rehabilitation plan, training to local people, etc.

The EMP also includes a structured environmental monitoring plan, detailing parameters to be monitored (air, water, noise, soil, and ecological indicators), monitoring locations, frequency,

reporting formats, and compliance mechanisms. Importantly, the EMP provides budgetary allocation for implementation of mitigation measures and for periodic environmental monitoring throughout construction and operation phases, ensuring financial provisioning for effective compliance.

In environmentally sensitive stretches, the EMP additionally provides for preparation and implementation of a *Wildlife Passage Plan and Soil & Moisture Conservation Plan (SMCP)* to ensure habitat connectivity and long-term species protection.

NHAI undertakes EIA studies for brownfield projects as well. In the case of brownfield National Highway projects—such as widening or upgradation of existing roads—the environmental assessment focuses on incremental and cumulative impacts within the existing corridor. Baseline studies evaluate additional land requirements, tree felling, impacts on roadside vegetation, drainage changes and slope protection, increased air and noise pollution, nearby settlements, protection of water bodies, any forest or wildlife-sensitive stretches and site-specific wildlife mitigation where required. Direct, indirect, and cumulative impacts arising from increased traffic and capacity are assessed as per the MoEF&CC guidelines. It also includes environmental monitoring, defined institutional responsibilities, compliance reporting, and dedicated budgetary provisions. Public consultation is conducted where applicable, and the final EIA/EMP incorporates stakeholder inputs before grant of Environmental Clearance.

In both *greenfield* and *brownfield* projects, the EIA serves to systematically identify and evaluate environmental risks, while the EMP translates these findings into actionable mitigation, monitoring, and management measures integrated into project design, tender documents, and construction contracts, thereby ensuring compliance with MoEF&CC guidelines and environmentally responsible highway development.

3.2 Wildlife (Protection) Act, 1972

The Wildlife (Protection) Act, 1972 (as amended) *"An Act to provide for the protection of wild animals, birds and plants and for matters connected therewith or ancillary or incidental thereto with a view to ensuring the ecological and environmental security of the country."*

Procedure for Seeking Recommendation or Approval of the National Board for Wildlife

As per Wildlife (Protection) Act, 1972, and as per amendments the Wild Life (Protection) Amendment Act, 2022, in force since April 1, 2023, any diversion or modification of wildlife habitat within Protected Areas (PAs) requires prior approval of the National Board for Wildlife (NBWL). Accordingly, the opinion of the Standing Committee of NBWL (SC-NBWL) is a prerequisite for projects involving the use of forest land within PAs such as National Parks, Wildlife Sanctuaries, and Conservation Reserves. Linear infrastructure projects like roads,

railways, and pipelines passing through these areas also require prior consultation with the SC-NBWL even when diversion of forest land is not involved.
Additionally, projects located within Eco-Sensitive Zones (ESZ) or those likely to impact wildlife corridors connected to PAs may also require appraisal by the SC-NBWL. In cases where diversion of forest land is involved within a PA, the proposal for wildlife clearance and forest clearance is processed simultaneously through the prescribed procedure.

The Wildlife Mitigation Plan plays a critical role in facilitating statutory compliance by systematically addressing key ecological considerations. This includes:

a) Evaluation of wildlife movement patterns and corridor connectivity within the project landscape,
b) Assessment of faunal sensitivity across the project influence zone,
c) Formulation of scientifically informed and site-specific mitigation measures,
d) Ensuring minimal disruption to habitat continuity and free movement of species.

If any projects, proposed within tiger reserves are also needed to be referred to NBWL (SC-NBWL) through National Tiger Conservation Authority (NTCA) for approval under different sections of Wildlife (Protection) Act, 1972.

3.2.1 Components of Wildlife Mitigation Plan

A Wildlife Mitigation Plan provides a systematic approach to assess and minimize the impacts of infrastructure development on wildlife and their habitats. It begins with an *introduction* outlining the importance of wildlife conservation, the project background, details of the project proponent, and the need for the mitigation plan. This is followed by a *description of the project,* including traffic survey and analysis, proposed improvements, and expected benefits. The plan also presents the *environmental setting of the study area,* covering aspects such as topography and geology, seismicity, drainage, land use, soil quality, agriculture, water resources (ground and surface), and the biological environment including flora, fauna, and nearby protected areas. Based on this baseline, potential *impacts on ecology*—particularly on flora and fauna—are identified.

The mitigation plan then outlines objectives, approaches, and both structural and non-structural measures to reduce these impacts, along with an implementation timeframe and a *cost estimate* for executing the proposed measures.

3.2.2 Components of Soil & Moisture Conservation Plan

The **Soil and Moisture Conservation Plan (SCMP)** aims to protect soil resources and maintain moisture balance in the project area. It begins with an *introduction and objectives*, followed by an *analysis of problems* such as soil erosion, loss of topsoil, waterlogging, and sedimentation. Based on this analysis, suitable *treatment measures* are proposed, including *biological measures* like vegetation and afforestation, and *engineering measures* such as contour bunds, check dams,

and drainage systems. The plan also considers the *land use and land cover* of the area and outlines an *implementation plan* for the pre-construction, construction, and post-construction phases to ensure effective soil and water conservation. Finally, the cost *summary* is given.

3.3 Van (Sanrakshan Evam Samvardhan) Adhiniyam, 1980

The Van (Sanrakshan Evam Samvardhan) Adhiniyam, 1980 "*An Act to provide for the conservation of forests and for matters connected therewith or ancillary or incidental thereto.*"

It was enacted to provide for the conservation of forests and to regulate the diversion of forest land for non-forest purposes. Prior approval of the Central Government is mandatory for such diversion.

According to the *Consolidated Guidelines & Clarifications* issued under Van (Sanrakshan Evam Samvardhan) Adhiniyam, 1980 and Van (Sanrakshan Evam Samvardhan) Rules, 2023 issued by MoEFCC, Govt. of India that every project requiring diversion of designated forest land for non-forestry purposes requires clearance from MoEFCC. The Rules notified under the Van (Sanrakshan Evam Samvardhan) Adhiniyam, 1980 provides the procedure to obtain prior approval of Central Government under section 2 of the Van (Sanrakshan Evam Samvardhan) Adhiniyam, 1980 with an objective to prevent indiscriminate diversion of forest lands, to conserve forest cover and maintain ecological balance, to ensure compensatory afforestation and restoration measures and to subject forest diversion proposals to Central Government approval.

Where forest land forms part of wildlife habitat or movement routes, Forest Clearance conditions often include site-specific mitigation measures to reduce ecological impacts. The proposed mitigation interventions outlined in this report are aligned with typical Forest Clearance conditions related to habitat conservation and connectivity.

The perusal of the notification of MoEF&CC dated, 08.07.2024, states the following:

1. The proposal involving entire forest land located in one or more PAs would be considered for grant of *'In-Principle'* approval under the Van (Sanrakshan Evam Samvardhan) Adhiniyam, 1980, only after obtaining recommendation of SC-NBWL, permitting use of forest land for non-forestry purpose, has been obtained.
2. The proposal where in forest land is located both within and outside PA, the *'In-Principle'* approval can be granted for the portion *outside* the PA provided that Stage-II in such proposal will be given after the recommendation of SC-NBWL. *No working permission after Stage-I will be admissible in such cases to avoid fait accompli situation.*
3. The proposals located in ESZ, requiring approval in Van (Sanrakshan Evam Samvardhan) Adhiniyam, 1980 and Wild Life Protection Act will be processed simultaneously.

This sequenced approach although undertaken in parallel integrates environmental, forest, and wildlife safeguards with project development timelines, thereby strengthening regulatory compliance and reducing post-award implementation risks.

3.4 PARIVESH

To streamline and enhance transparency in the environmental clearance process, MoEF&CC has developed an online portal known as ***PARIVESH (Pro-Active and Responsive facilitation by Interactive, Virtuous and Environmental Single-window Hub)***. The portal serves as an integrated digital platform for submission, processing, and monitoring of proposals related to environmental, forest, wildlife, and coastal regulation clearances.

About PARIVESH

PARIVESH is a Single-Window Integrated Environmental Management portal, developed in pursuance of the spirit of '*Digital India*' and capturing the essence of *Minimum Government and Maximum Governance*. To provide a seamless experience across all major clearance, the *New Version- PARIVESH 2.0* has been completely automated with modern technologies to further increase its efficiency and decision making without compromising on the environmental rigors.

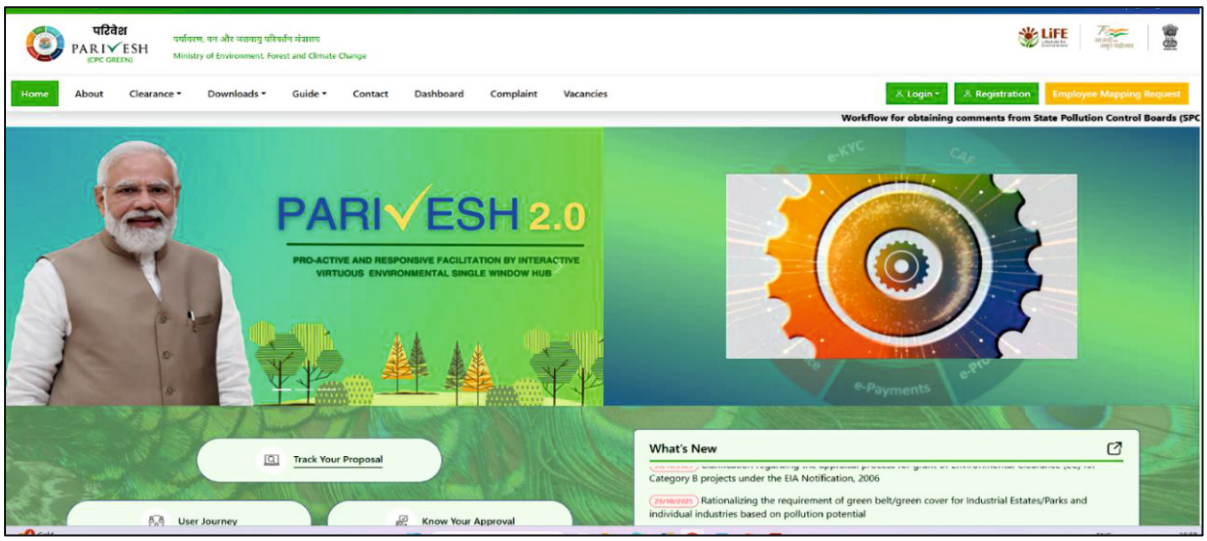
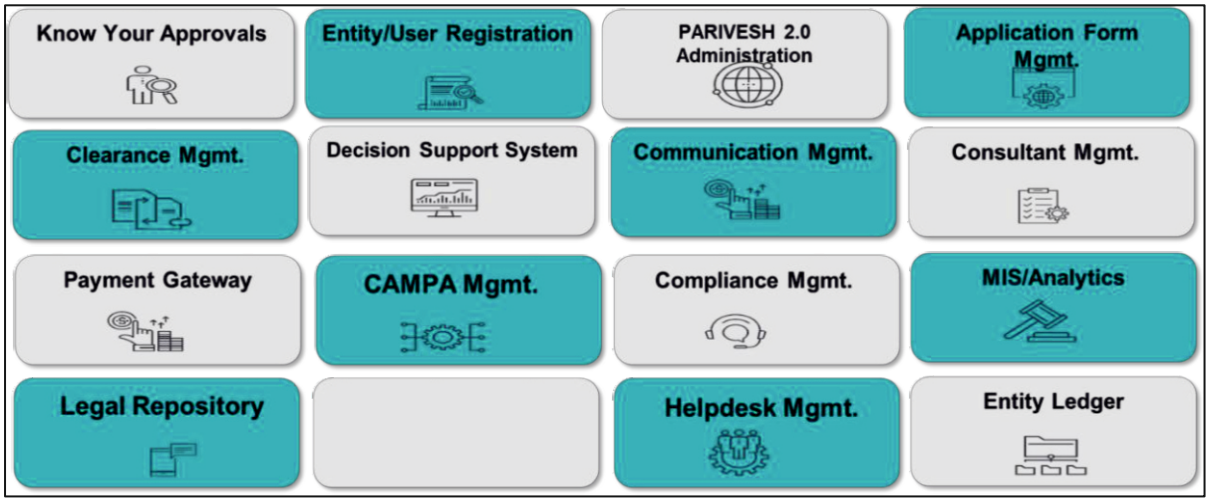


Figure-7: PARIVESH 2.0 Home Page

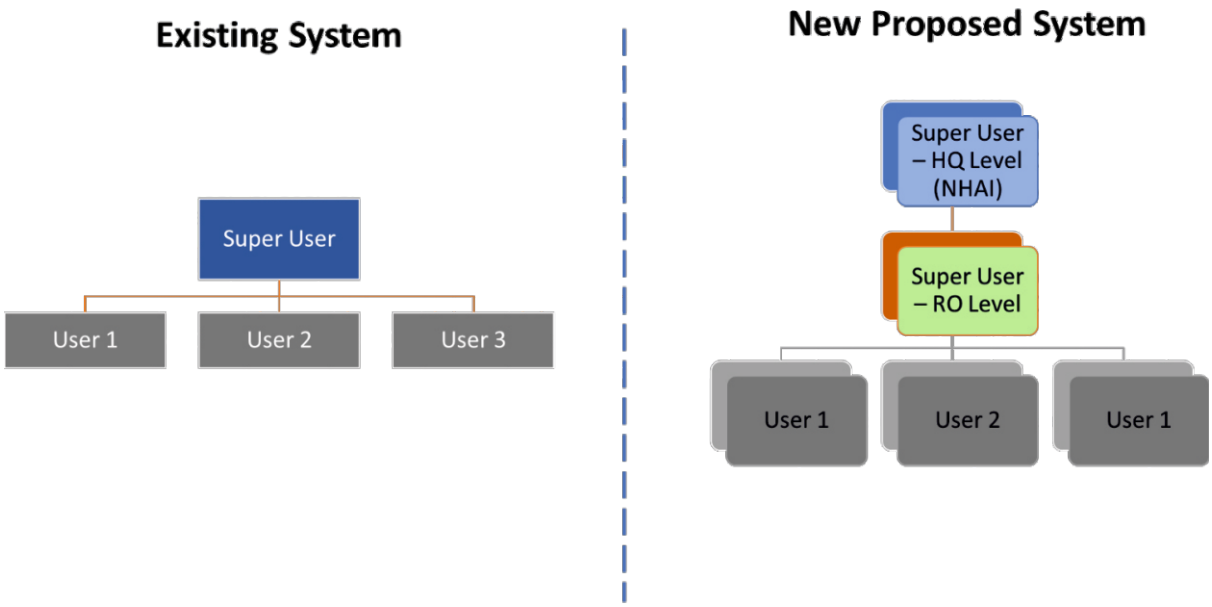
Encouraged by the success of the existing PARIVESH its scope has been further onboarded with a technology-driven and professionally run institutional mechanism, to provide a comprehensive single window solution for the administration of all green clearances and monitor their subsequent compliance across the nation. Process transformation, technology transformation, and domain knowledge intervention were the key drivers behind the framework of the new PARIVESH 2.0.

Key Modules in PARIVESH 2.0



3.4.1 Enhanced PARIVESH Set-up for User Management customized for NHAI

The User Management System has especially been customized for NHAI wherein a 3-tier Essential Details Sought (EDS) Management System has been provided by NIC, MoEF&CC. This has facilitated effective supervision by the Apex Level Users and Super Users with regard to EDS management and timely replies.



All these statutory provisions have integrated the wildlife mitigation measures and structures in the developmental planning and execution of linear road infra projects and especially that of NHAI in the country.

Chapter 4: Relevance of Mainstreaming Biodiversity Conservation in Road Infrastructure Development

4.1 Wildlife Conservation: Approaches and Practice

'Wildlife' encompasses both wild animals and plants. Wildlife conservation is not just a strategy aimed at protection of rare, threatened and endemic biodiversity but is a well-recognized means of achieving ecological security, human well-being and sustainable development of any country. Establishment of Protected Areas (PAs) is a globally-accepted planning approach for the protection of wildlife, and conservation of biodiversity and valued ecosystem services. Fifty years ago, PAs were managed as natural 'islands' that remained largely untouched by human influence. Today, it is recognized that conservation cannot succeed by managing discrete PAs alone: these areas are part of a global matrix and their survival—and the persistence of biodiversity— depends upon a wide variety of human and natural factors that operate at different scales. For this reason, PAs need to be managed as a network of interacting and interdependent areas, to safeguard their biodiversity values and ecosystem functioning in the long term.

The forest cover in India is 21.76% of the total geographical area of the country, out of which the PA network covers about 5.69% presently comprising 106 national parks, 573 wildlife sanctuaries, 145 conservation reserves and 309 community reserves (India State of Forest Report (ISFR) 2023 – Forest Survey of India and http://www.wii.gov.in/national_wildlife_database).

This network's core land use and purpose are biodiversity conservation. The average size of PAs in India is, however, small and a significant proportion of wildlife populations exists outside the PA network. To manage this situation, the concept of PA management has gradually expanded to landscape conservation, where areas adjoining as well as outside the PAs have a significant role to play in supporting wildlife. Tiger reserves have, in fact, legalized their management on the basis of a landscape approach that involves designation of core and buffer areas, and areas that provide important connecting corridors.

There is a likelihood that in these PAs and protected landscapes, linear developments such as roads, railway lines, power-lines and canals etc. sometimes can be in conflict with the objectives of wildlife conservation if not properly addressed through adequate mitigation.

4.2 Challenges of Managing Road Developments

Within many of India's PAs, linear projects have a potential to cut across the landscape and fragment wild habitats which may result in mortality of animals, further endangering many of the species that have already been severely affected by development. Major roads including national highways, state highways and roads of the Public Works Department traverse—for varying distances—through PAs in the country.

Wide-ranging species require contiguity of their habitats across landscapes. The increase in extent of linear road developments in most landscapes even outside PAs thus can present a major challenge for wildlife management and conservation. These linear road developments can create barriers or breaks in the landscape, which may prove detrimental to the long-term conservation of species and ecosystems. There is a pressing need for conservation and development to go hand in hand, complementing rather than conflicting with each other.

Any road works such as repair, widening, or strengthening of roads and shoulders within Wildlife Protected Areas or other forest areas, therefore, shall be undertaken only after

- Obtaining approval from the Standing Committee of the National Board for Wildlife or the Forest Advisory Committee, as applicable,
- A site assessment is carried out by the concerned authorities or independent experts,
- Evaluation of possible realignments to avoid Protected Area or forest and
- Identification and inclusion of appropriate mitigation measures such as wildlife crossings, speed control, and slope stabilization in the road budget and their implementation and monitoring.

4.3 Mainstreaming Biodiversity in Road Developments

Harmonizing biodiversity conservation and road development will require the twin actions of i) creating and strengthening protected areas; and ii) mainstreaming biodiversity conservation in road developments.

The general concept of working to embed conservation values in development has been pursued for many years under many names; 'mainstreaming' is one such name. 'Mainstreaming' biodiversity has no single agreed-upon definition. According to the Merriam-Webster Dictionary, 'mainstreaming' refers to 'integrating' biodiversity into development.

According to Kosmus et al, (2012), the overall goal of biodiversity mainstreaming is to have biodiversity principles included at every stage of the policies, plans, programmes and project cycles, regardless of who leads the process. A recent definition (Huntley & Redford 2014) describes 'biodiversity mainstreaming' as 'the process of embedding biodiversity considerations into policies, strategies and practices of key public and private actors that impact or rely on biodiversity, so that biodiversity is conserved, and sustainably used, both locally and globally'.

All these definitions reflect the view that biodiversity conservation goals are not seen as distinct from, or contradictory to, the goals of development and economic growth. Rather, the approach is intended to shift the focus of development policies and interventions towards better incorporation of the values of biodiversity. Integration of biodiversity considerations into the location, design and operation of infrastructure projects would not only have the advantage of reducing the environmental, social and economic costs, but of creating 'win-win' results for biodiversity conservation and human safety which lie at the core of all development initiatives.

Mainstreaming Approaches:

Mainstreaming can best be understood as an attempt to influence landscape- level plans and strategies by incorporating clear biodiversity goals. It would, for example, mean having to ensure that road infrastructure development would be 'animal friendly' by providing pathways for movement of species. In addition, road infrastructure would need to be 'green' to mitigate any negative impacts on sensitive habitats. Importantly, designing 'green' infrastructure can encourage community support for—and reduce opposition to—economic development.

4.4 'Smart and Green' Infrastructure

Green infrastructure may sound like a new or an uncommon term, but it is certainly not a new concept. It has its roots in the founding principle of conservation planning that emphasizes preserving and linking natural areas to benefit biodiversity. This approach helps to counter the likely negative impacts of habitat fragmentation.

Green Infrastructure thus be understood simply as a 'design and develop with nature' concept: it looks at conservation values and actions in concert with land development, growth management and built infrastructure planning (Benedict 2000). It aims to respect and navigate important biodiversity and sensitive habitats, including natural corridors across the landscape. It also aims to maintain, strengthen and restore ecosystems at all spatial scales, thereby ensuring sustained benefits to people from the goods and services they provide. Green infrastructure helps to build robust healthy and enduring landscapes which enable species and their communities to move and adapt (Lucius et al. 2011).

In addition to ecological issues, green infrastructure has to take into account a number of human dimensions such as safety and economic considerations, and ways to utilize the landscape in an optimum way. Human safety is particularly relevant in the planning of roads: wild animal-vehicle collisions have a significant cost for both human and animal populations. Green infrastructure offers a blueprint for 'smart conservation' (Benedict & McMahon 2002) in the same way that engineering plans provide a blueprint for future roads. It can create a sound framework for future growth while making sure that significant natural resources will be conserved for future generations.

Green Infrastructure Principles

Large to local scale	• Understands the wider landscape and the development context
Proactive	• Identifies and avoids areas that are significant for biodiversity • Identifies and protects natural processes and resources of value or benefit to people • Identifies, protects and/or restores natural corridors and networks
Harmonising	• Considers the human dimensions (safety and economy) • Seeks to integrate human and ecological values and goals • Provides a framework for sustainable development
Rigorous	• Applies good science, land use theory and practice

Source: Mathur, V. B., & Rajvanshi, A. (2016) in WII Publication

4.5 Progressive Trends in Linear Road Development Sectors in India

Roadways, railways and power-lines constitute the predominant linear infrastructure in India, with plans for substantial expansion. They therefore can pose the threat of harmful impacts on wildlife if not attended properly.

An understanding of the scale and type of linear development is essential if ecological concerns are to be mainstreamed in all new initiatives of the transportation sectors. This factor becomes even more pertinent for a country the size of India, where road, rail and power infrastructure are becoming the most pervasive form of linear features that traverse the entire length and breadth of the country. These linear structures are essential links for transporting people, transmitting energy and improving access for rapid economic development. The expansion of the road and rail networks, upgrading of existing roads and railway lines, and planning of superior and more sophisticated surface transportation options such as expressways and metro rails have thus become priorities.

Other factors that are strongly contributing to growth in transportation infrastructure are growth of freight traffic due to industrialization, increase in urban conglomerations and rising demand for urban mass transportation, increasing requirements of safety and modernization, and increasing participation of the private sector.

4.6 Road Network in India

India possesses one of the largest road networks in the world, serving as a critical backbone for economic growth and connectivity across diverse regions. National Highways, though a smaller proportion in length, carry a significant share of traffic and play a vital role in long-distance connectivity. As of March 31, 2025, the country's road network extends over 63 lakh km, comprising National Highways, State Highways, and an extensive network of other roads:

- NATIONAL HIGHWAYS - 1,46,204 km
- STATE HIGHWAYS - 1,79,535 km
- OTHER ROADS - 60,19,723 km

(Ref:https://www.pib.gov.in/PressNoteDetails.aspx?NoteId=154624&ModuleId=3&reg=3&lang=1)

4.7 Mitigation Principles

In the context of developing linear infrastructure (roads), the purpose of mitigation is to identify strategies and measures that will address the conservation concerns likely to be associated with the development proposals. In order to deliver the potential benefits of green infrastructure development, these strategies and measures must follow a set of key mitigation principles, as set out below:

Mitigation should be Goal Oriented:

Mitigation should be focused on achieving explicit conservation goals within clear timeframes, to be integrated in the broader 'green infrastructure development' approach. These goals should be guided by the significance of affected biodiversity, priority of conservation goals and the values of natural systems to affected communities.

Use of the SMART approach is recommended to evaluate the likely effectiveness of alternative mitigation strategies or measures: 'SMART' refers to measures that are specific, measurable, achievable, realistic and timely. Mitigation should aim to address not only direct footprint' impacts on natural systems, but also ecological effects caused by the development of linear infrastructure which may only be manifest in decades to come (Forman et. al. 2003), affecting regional populations of wild animals.

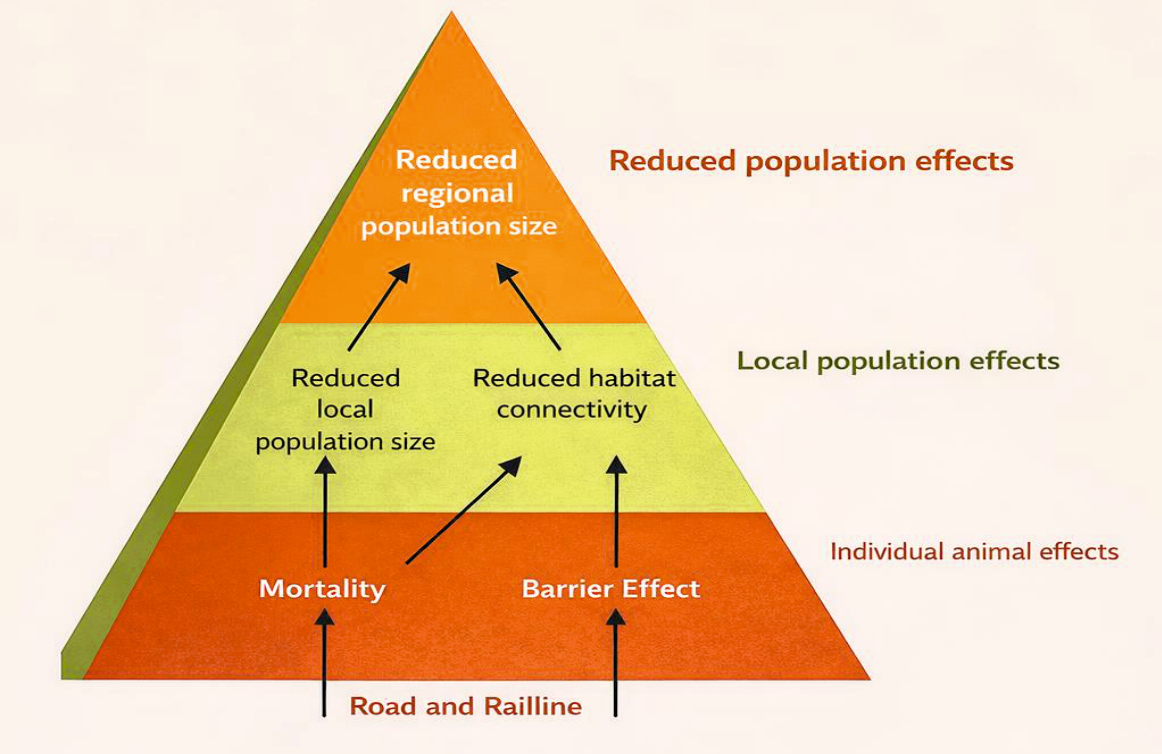


Figure-8: Effects of Roads and Rail Tracks on Individual Animals and Wildlife Populations
Source: Adapted from Forman et al. 2003

Mitigation as an Integral Part of Project Planning & Implementation:

Mitigation strategies should be considered and applied early in the planning stages of the project cycle. Mitigation measures for impacts of each linear development proposal need to consider the combined (cumulative) effects of existing projects on biodiversity, as well as the anticipated impacts of infrastructure foreseen to be developed over the next 10-20 years: conservation values are eroded by multiple developments in a given landscape. These measures should be reviewed and adapted over the long term, based on an improved understanding of these combined impacts.

Mitigation must address impacts not only at project site level, but at the level of the wider living landscape, respecting the need to maintain corridors and networks of natural habitat: linear infrastructure development has impacts across multiple habitats, species ranges, watersheds and land-use zoning.

The design of mitigation measures must consider that each species is unique, with different ecological requirements, capacities, behavioural patterns and responses to linear infrastructure. Competent wildlife ecologists should be engaged at the planning stage to identify impacts and develop optimum mitigation measures: this approach would save lot of time and resources, and be beneficial for society and for conservation in the long term. Further, mitigation measures should be incorporated in the tender and contract documents for implementation during the construction and operational phases.

Mitigation measures need to target significant impacts:

Mitigation must focus on the most extinction-prone taxa and habitats in the landscape under consideration, as well as those species that are most sensitive to the specific development impacts. Mitigation needs to include measures to sustain prey populations and other elements of the ecosystem that support conservation of charismatic or umbrella species (e.g., the tiger) which command high conservation significance.

Mitigation should first consider avoidance of development ('no go' option) in source areas of threatened taxa. If avoidance is not possible, stringent measures need to be stipulated in areas representing specialized habitats, the habitat ranges of protected species, migratory routes and bottlenecks in ecological corridors that are crucial to effective conservation in the long term. The mitigation plan should include implementation schedule, clear institutional responsibilities for implementation of measures and the cost estimates for mitigation action.

4.8 Mitigation of Impacts of Roads

Ideally, the alignment of roads in the landscape should be planned at a strategic landscape level, in such a way that they are located and concentrated in areas of little importance to wildlife and would not bisect or fragment their habitats. While there is thus a need in the longer term to encourage a more strategic, landscape-scale approach, there is an urgent need to improve the design and uptake of appropriate wildlife-friendly technology in existing infrastructure and in projects that have been authorized.

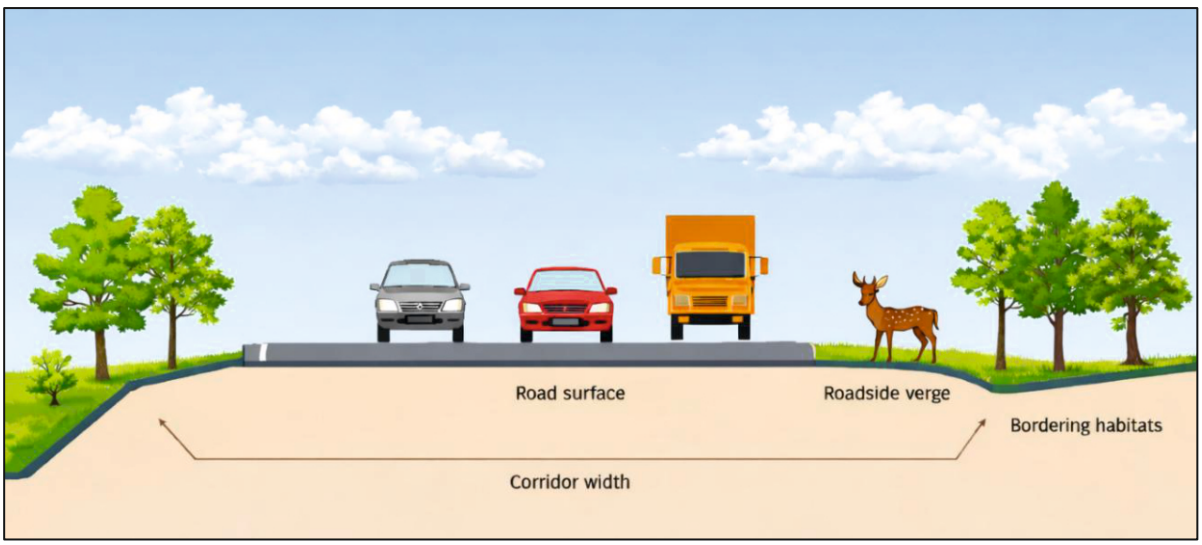


Figure-9: Components of a Road Transportation Corridor Source: Illustration by N. S. Bist

4.8.1 Measures taken for Speed Control in Road Infrastructure

Effective speed management is a critical component of road infrastructure planning, contributing to both user safety and environmental protection. Various engineering, regulatory, and traffic management measures are incorporated to regulate vehicular speed, particularly in sensitive zones such as wildlife corridors, settlements, accident-prone stretches, and construction areas.

As per the Guidelines for *Linear Infrastructure Intrusions in Natural Areas* by NBWL, speed limits shall be defined and enforced within all roads passing through natural areas described in earlier sections with the following conditions:

- Vehicle speeds in excess of 30 kmph shall not be permitted in those stretches of road that pass through any natural area and
- Speed limit monitoring and imposition and collection of fines shall be the prerogative of State Forest Departments as well as highways and traffic police authorities.

Engineering measures include the installation of speed calming devices such as rumble strips, transverse bar markings, speed breakers (where appropriate), *red table-top markings* and optical speed bars to alert drivers and encourage gradual deceleration, hence, provisioning of speed breakers at every 400 m of roads passing through natural areas such that the speed is regulated so as to avoid accidental death of wild animals.

Proper road signage, including cautionary, regulatory, and warning signs, is strategically placed to inform drivers of speed limits and sensitive zones ahead at entry and exit points and all other relevant locations. In wildlife-prone areas, signboards highlighting animal crossing zones are installed to enhance driver awareness needs to be placed at every 500 m using good material and having proper font size and pictures.

Geometric design interventions such as narrowing of carriageways at specific locations, provision of median islands, and curvature adjustments may also contribute to moderated speeds subject to road safety aspects. Additionally, enforcement mechanisms, including speed monitoring systems and coordination with traffic authorities, support compliance with prescribed limits. Collectively, these measures aim to enhance road safety, reduce accident risks, and minimize disturbances in environmentally sensitive stretches while ensuring smooth and regulated traffic flow.

4.9 General Guidelines for Mitigating Impacts on Wildlife

Transportation planners know that highway systems must accommodate other elements of human infrastructure (e.g., water supply systems, sewer systems, electric and gas utilities). Biologists and natural resource planners can define networks of core conservation areas and connectivity zones, effectively defining the *ecological infrastructure* for a region. They can then work with transportation agencies to ensure that transportation systems are designed to accommodate this *ecological infrastructure.*

Traditionally, highway impacts on wildlife have been viewed in terms of road mortality and threats to selected populations of animals. Viewing this issue from a wider perspective, however, it is clear that highways have the potential to undermine ecological processes at a landscape scale through the fragmentation of wildlife populations, restriction of wildlife movements, and the disruption of gene flow and meta-population dynamics. ***'Smart'*** or ***'green'*** linear infrastructure must aim to reduce mortality and make linear structures conducive to safe movement of animals across the landscape.

Many questions remain about how to design roads, highways, and passage structures for wild animals that will effectively mitigate the impact of roadways on animal movements and wildlife populations. Based on learning from projects, current approaches to mitigation should aim to achieve at least two important and measurable conservation outcomes that should prevent decline in wild animal populations in the long term, namely:

- increased population viability and
- a significant reduction in infrastructure-induced mortality of animals.

Mitigation measures essentially fall into two categories, for roads:

- regulatory or prescriptive measures that are intended to alter human behaviour, and
- measures to manage habitat on or near the site that are intended to influence animal responses.

To reduce these impacts, these mitigation strategies are applied within road corridors focusing on managing both traffic-related activities and the surrounding habitat conditions. Accordingly, the measures can be grouped based on whether they regulate human behaviour or modify site conditions to guide wildlife movement. The key measures under these two categories are presented in the table below:

Table-5: Transportation induced impacts
Source: Mathur, V. B., & Rajvanshi, A. (2016) in WII Publication.

S. No.	Measures to alter human behaviour	Measures to alter animal responses
	Regulatory or prescriptive measures	**On-site construction and habitat**
1	Speed control.	Clearing vegetation for improving visibility along road.
2	Temporary road closure.	Erection of animal-proof fencing to prevent animals entering road.
3	Control on feeding of wild animals on the road.	Installation of wildlife detection systems.
4	Regulatory guidelines for laying/upgrading sensitive habitats and wilderness.	Increasing permeability of a road corridor by facilitating movement through construction of appropriately designed and positioned culverts or underpasses.

5	Prescriptions for width of verge to be retained in different landscapes and habitats.	Retrofitting existing drainage culverts to facilitate wildlife crossing.
6	Restrictions on stopping/parking segments passing through sensitive.	Maintenance of hedgerows along the road to serve as movement corridors.

Factors for enhancing permeability of crossing structures:

The design and number of structures to improve the permeability of road corridors must facilitate animal movement across these corridors and maintain habitat connectivity across the landscape. The siting and design of animal passages must consider the specific requirements and behaviour of target species; where communities of animals may be affected, passages will need to be designed and managed to accommodate multiple species with different needs. The siting and design must also consider site-specific variables such as vegetation, topography and hydrology. The types and levels of disturbance must be taken into account too: traffic (vehicles, trains) noise and vibrations may discourage wild animals from using crossing structures.



Table-6: 'Good Practice' Guidance in the form of Do's and Don'ts for Avoiding and Regulating the Impacts of Linear Infrastructure Projects. Source: Mathur, V. B., & Rajvanshi, A. (2016).

Project Phase	Do's	Don'ts
Planning & Design Phase	• Organise a good team of professionals to review technical, financial and ecological aspects of the project. • Include an ecologist/wildlife expert on the team if the linear development would be routed through forested sections and natural landscapes. • Avoid aligning roads and railway line along or through sensitive habitats (wildlife movement corridors, flight paths of birds, areas of high biodiversity values, specialised habitats e.g. pools, dens, roosting sites, caves etc.). • Identify feasible alternatives of alignment to review the merits of different sites to arrive at the 'least impact' options. • Conduct a rigorous assessment of impacts on key wild species of animals and plants and habitats to integrate any special considerations in design features and structures. • Plan appropriate designs that facilitate animal movements. • Include estimates of costs for constructing mitigation structures in the financial proposal to avoid cost overrun. • Prepare a schedule for implementation of mitigation measures, and institutional responsibilities for mitigation measures.	• Do not undermine the importance of inter-agency coordination. • Do not avoid consultation with wildlife experts and conservation agencies to understand challenges for wildlife that may come in the way of environmental decision-making. • Do not avoid field-based surveys for generating primary information for impact assessment reports as a weak EIA would lead to subsequent delays in the implementation of the project. • Do not split sections of the same road, rail or pipeline passing through different land use or states as separate projects for ease of implementation as this may pose difficulties in assessing the landscape level impacts on wildlife habitats and species with large home ranges. • Do not plan mitigation structures and actions in a single site but around all species of conservation importance in a landscape. • Do not suggest mitigation measures without considering local ecology. Measures suitable for implementation in one landscape may not work in another site with different ecological conditions.

Construction Phase	• Recommend construction schedule to avoid breeding/migration season of important species. • Take care to avoid direct impacts to land, water and habitats of wild animals due to labour camps, storage sheds and parking lots. • Initiate construction of mitigation structures along with road/rail upgradation projects so that damages during this phase are minimised. Install sufficient drainage works under all access roads to avoid flooding land and damaging streams. • Protect top soil and implement measures to control soil erosion. • Avoid/minimise removal of natural vegetation. • Take measures to prevent animal injuries and mortality during earthworks, clearing of vegetation, and managing pools and streams. • Enforce good behaviour by construction workers to prevent illegal hunting, fishing and pillage of resources.8. Restore cleared areas wherever possible.	• Do not add to direct and physical impacts by careless material management and inducing avoidable disturbance. • Do not violate conditions and specifications agreed upon as part of mitigation. • Do not dump/stack construction material inside sensitive habitats. • Do not dispose debris and other excavated material near water bodies and valley bottoms. • Do not wash vehicles or change lubricants in waterways or wetlands.
Operation & Monitoring Phase	• Conduct independent regular site inspections to ensure compliance with all EMP provisions, particularly in sensitive areas. • Implement an evidence-based system of data collection, collation and analysis of data to assess efficacy of mitigation measures. Use audio-visual tools for generating more convincing evidence.	• Do not forget to draw a schedule for maintenance of crossing structures such as drains and culverts to ensure their functionality. • Do not justify lack of manpower and financial resources to neglect/avoid monitoring.

Chapter 5: Wildlife Mitigation Planning at NHAI

5.1 Mitigation Planning

The environmental safeguard measures of a National Highway project are consolidated under the overarching framework of the Environmental Management Plan (EMP). These include Wildlife Mitigation Strategies and Measures, Environmental Impact Assessment (EIA), Soil and Moisture Conservation Plans (SMCPs), and other statutory compliance requirements. Wildlife Mitigation Planning is an integral component of sustainable highway development under NHAI, particularly for projects traversing ecologically sensitive landscapes. This is undertaken in accordance with established guidance for linear infrastructure projects issued by the Wildlife Institute of India, Dehradun. It emphasizes avoidance, minimization and mitigation of impacts on wildlife movement and habitat connectivity.

The *Wildlife Mitigation Plan (WMP)* is formulated as a project-specific instrument to address potential ecological impacts arising from highway development and to integrate wildlife protection measures into the planning, design, construction and operation stages of the project. The primary objective of wildlife mitigation planning is to minimize adverse impacts on fauna by maintaining ecological connectivity across the project corridor. The *Wildlife Passage Plan (WPP)* forms a core component of the WMP and provides for location-specific *structural* and *non-structural* interventions.

Structural interventions, such as wildlife underpasses, overpasses, modified culverts, bridges, noise barrier, reptile crossings, canopy bridges are planned at locations where animal movement is frequent or ecologically significant. The selection, placement and design of these measures are guided by site conditions, anticipated wildlife movement patterns and engineering feasibility, and are aligned with eco-friendly highway practices adopted by NHAI. Fencing and canalization structures are provided in vulnerable stretches to guide animals safely toward designated crossing points and to prevent accidental entry onto the carriageway. Similarly, *non-structural measures* complement the engineering interventions and include installation of wildlife crossing signages, speed-calming measures, salt licks, monkey canopy bridge and regulated lighting in forest and wildlife-sensitive stretches.

In addition, a *Soil and Moisture Conservation Plan (SCMP)* is prepared as part of statutory compliance requirements for forest land diversion cases. The SCMP addresses soil stabilization, erosion control and moisture retention in areas disturbed during construction, thereby contributing to slope stability, habitat integrity and the overall effectiveness of wildlife mitigation measures.

Pro-active coordination with the State Forest Departments and compliance with statutory environmental and wildlife clearance conditions form a critical part of the mitigation framework. Wildlife mitigation planning under NHAI projects, thus, reflect a balanced approach, integrating infrastructure development with environmental responsibility, and contributes to long-term ecological sustainability while enhancing road safety.

The impact indicators align primarily with the ***Baseline Data Collection*** and ***Impact Prediction & Significance Assessment*** stages of the Environmental Assessment (EA) flow process. During baseline studies, these parameters help establish existing environmental and ecological conditions across geology, soil, water, air, and biodiversity components. In the impact assessment stage, the same indicators are used to evaluate the magnitude, extent, and significance of potential project-related impacts. They further guide the formulation of appropriate mitigation measures and monitoring strategies within the EIA framework.

Geology & Landscape	Soil	Water	Air	Wildlife Habitat	Fauna & Flora
•Change in unique features. •Landform sensitivity. •Rock characteristics (sedimentary / metamorphic). •Slope stability. •Visual quality. •Weathering.	•Erosion properties. •Fertility. •Nutrient cycling. •Sedimentation. •Soil microfauna. •Soil microflora.	•Groundwater quantity & quality. •Surface water quantity & quality. •Nutrient cycling.	•Ambient air quality (SO_2, NO_x, CO, THC, RPM_{10}). •Odor levels. •Climate variability. •Microclimate changes.	•Vegetation cover & density. •Habitat alteration / degradation. •Bank vegetation. •Habitat fragmentation. •Habitat size & quality. •Ecotone pressure. •Shoreline drying / Mudflat area. •Ecological corridors.	•Breeding biology & sites. •Dispersal / Migration. •Immigration / Emigration. •Endemism / Rarity. •Faunal & Floral diversity. •Home range & Territory size. •Population mortality & natality. •Resource competition. •Endangered / Vulnerable species. •Local extinction risk. •Resilience & Redundancy.

Source: Roads, Sensitive Habitats and Wildlife by Rajvanshi etal.2001.

The impact indicators outlined in Table identify the key ecological parameters such as habitat fragmentation, vegetation cover, wildlife corridors, breeding sites, dispersal, migration patterns, and population dynamics. These indicators help determine ecologically sensitive stretches requiring structural measures like underpasses, overpasses, fencing, and canopy bridges to maintain habitat connectivity. Additionally, parameters related to soil erosion, slope stability, hydrology, and microclimate guide complementary measures under the EMP and SCMP, ensuring that mitigation strategies effectively address both habitat integrity and long-term ecological sustainability.

5.2 Mitigative Measures

An environmentally acceptable road project should allocate adequate funds for mitigating road-induced impacts and, where impacts are unavoidable, for compensating associated losses. Through proactive planning and environmentally sensitive design supported by NHAI many adverse effects are avoided or minimized within the road corridor using technological and ecological improvements.

Mitigation measures aim to reduce or prevent ecological disturbances, while compensation measures address unavoidable damage by restoring affected areas, creating or replacing damaged natural features elsewhere.

5.2.1 Mitigating Fragmentation & Isolation

Fragmentation and isolation can be reduced by developing engineered and ecological landscape connectors. Designing these connectors requires understanding the ecological processes that regulate ecosystem functioning and maintain the stability of plant and animal communities. Properly designed connectors enable movement across landscapes, including animal dispersal and migration, pollination and seed dispersal, as well as the crossing of ground and surface water flows.

Engineered or Engineering Structures:

Well-designed culverts, underpasses, and overpasses can reduce fragmentation by allowing wildlife movement despite the presence of roads. For these structures to be effective, their width, height, length, approach areas, and visibility must suit the requirements of the target species. For example, elephants need adequate headroom, prey species avoid structures with restricted escape routes, and the configuration and placement of aquatic crossings determine whether aquatic species can pass. Wildlife experts must, therefore, be involved in the design process. The NHAI is implementing such engineered structures in road projects to facilitate safe wildlife movement in collaboration with WII, Dehradun and other institutes of repute.

In mountainous areas, constructing road or tunnels beneath sensitive wildlife zones can prevent disruption of surface ecosystems and maintain ecological integrity. However, tunneling must be carefully managed to avoid additional ecological impacts, such as improper disposal of muck/debris that can lead to long-term habitat loss.

Conservation of Buffer Zone:

Buffer zones surround the core of Protected Areas (PAs), permitting limited human activities while protecting the core from negative impacts and maintaining ecological linkages with less disturbed habitats. By retaining features such as riparian forests, wide hedge-rows, and connected production forests, they facilitate wildlife movement between core areas and help reduce habitat isolation.

In road planning near PAs, it is therefore important to adjust route alignments, maintain adequate distance from protected area boundaries, and incorporate appropriate crossing structures so that the functional role of buffer zones is not compromised. Buffer zones also help minimize edge effects by maintaining forest cover near boundaries, reducing micro-climatic changes, and discouraging invasive species.

Since the effectiveness of buffer zones depends on the habitat needs of specific wildlife species, expert involvement from the early planning stage is essential. NHAI through the *Alignment Approval Committee* at MoRTH which has a WII representative, integrates these considerations into the planning and design of road projects passing near PAs to ensure ecological sensitivity.

Ecological Networks:

Ecological networking is based on four key concepts:

- conservation of core habitat areas,
- creation of green corridors to enable species dispersal and migration between core areas,
- restoration of areas to increase habitat availability, and
- delineation of buffer zones to protect the network from damaging external influences such as roads.

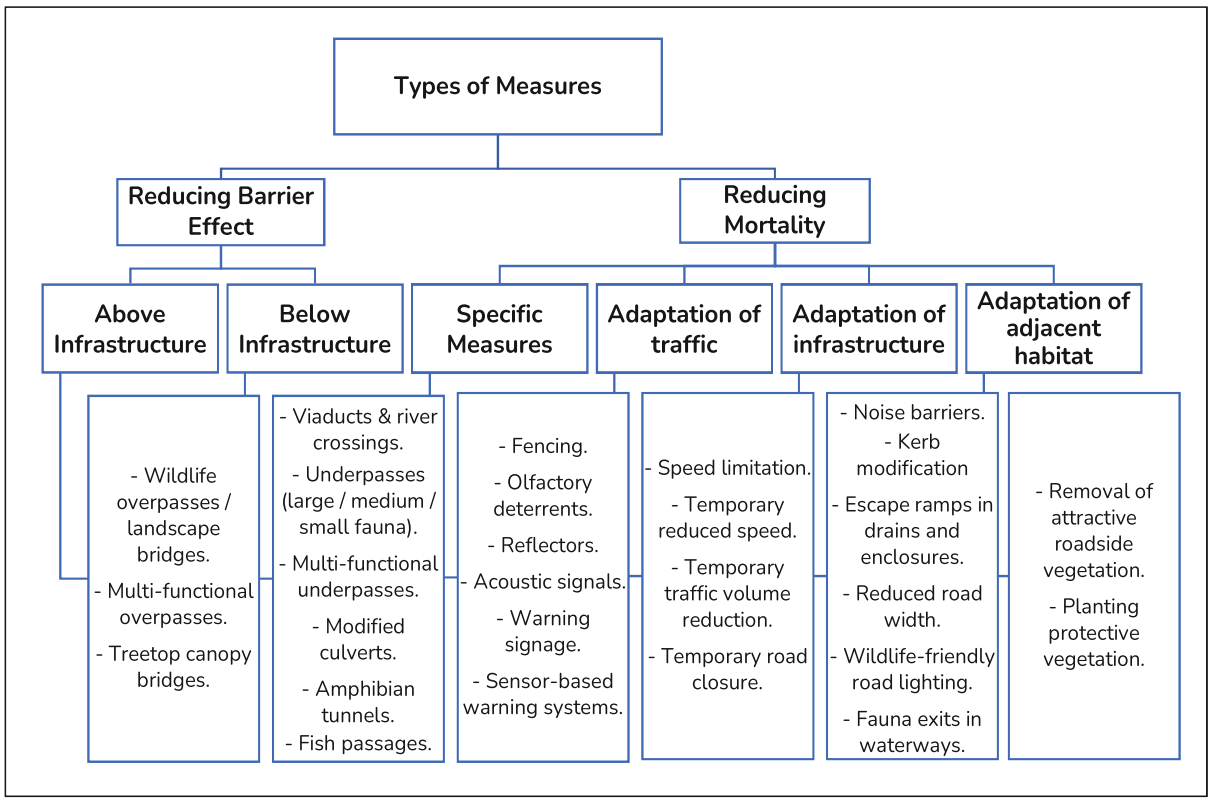
This approach shifts the focus from protecting isolated valuable sites or endangered species to managing wildlife conservation at the scale of an entire landscape, while also considering human and developmental needs. NHAI is incorporating these principles by integrating corridor connectivity, habitat restoration measures, and buffer zone planning into road alignment and project design, so that infrastructure development supports rather than disrupts ecological networks. By maintaining green corridors without excluding human activities, ecological networks help ensure connectivity between *natural areas.*

Compensation for Habitat Fragmentation or Loss:

Mitigative measures cannot always reduce ecological impacts to acceptable levels; where impacts are unavoidable, compensation must be undertaken. Options include re-establishment and restoration of habitats, creation of new habitat areas, upgrading suitable habitats to protected status, and relocation of displaced wildlife species. The choice depends on the habitat's uniqueness, conservation significance, extent of impact, availability of alternatives, and funding.

In this regard, the NHAI is taking initiatives by incorporating habitat restoration, compensatory afforestation, designation support for protected areas, and species management measures within project planning, in coordination with ecological experts and relevant authorities.

Effective compensation requires specialist input, close coordination between ecologists and engineers, and involvement of local communities. Such measures are clearly defined within projects, with costs explicitly included in the overall budget, making mitigation and compensation integral components rather than afterthoughts.



Source: The Ecology of Transportation: Managing Mobility for the Environment by Davenport, J., & Davenport, J.L. (Eds), 2006

5.2.2 Mitigating the Barrier Effect

Barrier effects caused by roads can be reduced through integrated planning, engineered structures, and habitat management. NHAI incorporates wildlife-sensitive alignment planning and ecological design measures in highway projects to maintain habitat connectivity.

Preventive measures during the planning stage:

Route selection avoids critical habitats of rare and threatened species and areas of high biological diversity. Where feasible, widening, resurfacing, or realigning existing roads is preferred over constructing new roads near protected areas. Tunnels, bridges, culverts, and other crossing structures are designed to serve both transportation and wildlife movement needs, ensuring adequate dimensions and suitability for large animals and riparian species.

Wildlife crossing structures:

Crossing structures such as wide bridges for large animals (e.g., 50 m for elephants with railings and vegetation cover), appropriately designed overpasses and underpasses (e.g., 4 m × 4 m for deer species), and biodiversity-sensitive road tunnels in mountainous regions can reduce barrier effects. Light-colored or naturally designed tunnel entrances can improve wildlife usage, while feeding or watering areas near entrances must be carefully evaluated due to potential poaching risks.

Manipulating roadside habitat:

Altering roadside habitat by reducing vegetation cover and food sources can discourage unsafe wildlife crossings, while maintaining canopy connectivity above roads supports movement of arboreal mammals, birds, and reptiles, thereby help sustain ecological linkages across road corridors.

5.2.3 Preventing Vehicle–Wildlife Collisions

Wildlife frequently cross roads due to daily and seasonal movements, feeding activity, and territorial behavior, often resulting in vehicle- wildlife collisions. Such incidents can be reduced through careful alignment planning and appropriate roadside planting to discourage animals from entering the roadway. NHAI is incorporating wildlife-sensitive planning, traffic management strategies, and protective infrastructure in identified conflict zones to minimize collision risks.
Some of such strategies are:

i) Flash mirrors or game reflectors can be installed on roads with moderate traffic; these are particularly effective for larger ungulates such as deer.
ii) Warning signs should be placed in areas with known high-use crossing points or wildlife corridors to alert drivers to slow down.
iii) Regulating traffic, especially during peak wildlife activity periods such as night-time, can significantly reduce collision risks.
iv) High fencing (over 3 m) in areas heavily used by large ungulates such as chital, sambar, nilgai, and black buck can deter crossings, though not act as absolute barriers. Their effectiveness improves when alternate crossing provisions are included, and fencing design must be undertaken in close consultation with wildlife experts to prevent creating additional ecological barriers.

5.2.4 Mitigating Human Use Impacts

Human use impacts such as urbanization in wildlife-rich areas must be addressed from the planning stage of road projects. While comparing alternative alignments, habitat types should be carefully assessed to avoid biologically rich areas such as nesting or rearing zones, even if the shortest route is not selected. Controlling road width within forest and wildlife habitats can help reduce habitat loss and intrusion while maintaining necessary traffic flow. In this direction, NHAI integrates environmental safeguards into project design by optimizing alignments, restricting excessive widening in sensitive stretches, and embedding protective provisions within contract and management frameworks to limit secondary human pressures.

During the operational phase, further measures strengthen wildlife protection. These include promoting environmental awareness, engaging local communities in conservation-linked activities, incorporating environmental conditions in maintenance contracts, and ensuring that road verges remain as undisturbed as possible to facilitate animal movement. The choice of measures depends on species behavior, scale of impact, and available expertise, with specialist inputs guiding effective implementation.

5.2.5 Mitigating Erosion

Erosion control in road projects is essential to prevent habitat degradation, siltation of streams, and damage to riparian corridors that support wildlife movement and aquatic species. Measures such as erosion hazard mapping, contour-based alignment, maintaining distance from water bodies, slope stabilization, revegetation with bioengineering techniques, controlled drainage, and protection of riparian buffer zones help reduce sediment flow into sensitive ecosystems.

NHAI integrates erosion and slope stabilization measures, bio-engineering practices, regulated drainage systems, and contractual safeguards against activities like indiscriminate aggregate extraction to ensure that soil conservation efforts directly support wildlife mitigation objectives. By protecting aquatic habitats, maintaining riparian vegetation, and preventing sedimentation, these initiatives align erosion control with broader wildlife conservation and habitat connectivity goals within highway development.

5.2.6 Integrating Climate Resilience in Wildlife Mitigation

NHAI is also exploring ways to make highway infrastructure more climate-resilient by considering the impacts of floods, droughts, and extreme weather events on roads and bridges. This involves upgrading the design of highways and bridges to withstand changing climate conditions.

In ecologically sensitive landscapes, NHAI adopts a structured approach that aligns highway engineering with emerging climate realities and ecological considerations. During project planning and Detailed Project Report (DPR) preparation, detailed assessments are undertaken to understand terrain characteristics, watershed behavior, wildlife corridors, and habitat linkages.

These baseline studies are examined alongside climate projections relating to rainfall intensity, flood recurrence, temperature variability, and extreme weather events. Such integration enables informed recalibration of hydrological design parameters, ensuring that cross-drainage structures, culverts, and bridges are capable of accommodating projected peak flows without disrupting natural watercourses that sustain surrounding habitats.

The engineering response also extends to slope stabilization and embankment protection in areas vulnerable to erosion or landslides. Structural measures are complemented with bio-engineering techniques that utilize locally suitable vegetation to enhance soil binding, reduce sediment transport, and maintain ecological compatibility. This approach is particularly relevant in forested and riparian stretches where excessive sedimentation or altered runoff patterns could affect minor tributaries and dependent wildlife species. By preserving natural drainage continuity and minimizing disturbance to micro-habitats, the design framework supports both infrastructure durability and ecological stability.

Furthermore, the planning process emphasizes avoidance and minimization strategies wherever feasible, including alignment optimization to reduce intrusion into critical habitats and retention of natural vegetation buffers along water bodies. Consideration of seasonal wildlife movement, availability of water resources during dry periods, and protection of riparian zones ensures that infrastructure interventions do not exacerbate climate-induced stress on fauna. Through such calibrated and evidence-based design integration, NHAI seeks to create highway corridors that are resilient to climatic variability while maintaining the functional integrity of wildlife habitats and associated ecosystems.

5.3 Wildlife Mitigation Structures

Mitigation measures to reduce deaths due to transportation infrastructure involve a combination of approaches: erecting fences and walls to exclude wild animals, constructing structures such as overpasses and underpasses to allow animals to cross a road corridor safely, and erecting signage and warning systems for road users. The integration of such features in road projects can be effective for a variety of wildlife, provided that the specific requirements of all the different taxa at risk are considered in their design.

The location and design of safe crossings for terrestrial mammals is an important way of reducing their mortality on roads. Some studies have reported movement rates as the single greatest factor influencing the risk of road mortality. Birds that typically fly short distances (e.g., from one tree to the next) may struggle to fly across a large open space, making them vulnerable to collision. Reptiles which sometimes bask on the warm asphalt of the road to regulate their body temperatures, are at greater risk of being run over by speeding traffic.

Measures specifically to address habitat fragmentation effects of transportation infrastructure fall into two broad categories:

- Engineering (structural) options and
- Non-structural options.

5.3.1 Engineering Options

There are several types of crossing structures that are used to mitigate impacts of highway corridors on animal movement and safety, each with different levels of effectiveness and cost. Fundamentally, these structures are designed either to allow animals to travel below the infrastructure (underpasses) or over it (overpasses). The crossing structures are primarily about maintaining connectivity and animal movement, and less about reducing animal mortality.

Viaduct:

Viaducts are adopted as an effective wildlife mitigation solution in ecologically sensitive areas where continuous ground-level movement of animals needs to be maintained across the highway alignment. Unlike conventional embankment roads, viaducts elevate the carriageway on piers, allowing wildlife to move freely beneath the structure across a broad, open stretch rather than being funneled through confined passages. This type of structure maintains or elevates the grade of the road, allowing for the passage of fauna below. There may be seasonal drainage associated with the viaduct. Viaducts are useful near valley bottoms to lead roads across the valley.



Figure-10: Viaduct in Ganeshpur- Dehradun Project of NH 72 A (Pkg.2)

Viaducts have proven particularly useful in forest landscapes, floodplains, river crossings, and areas with mixed wildlife movement, where multiple species use the same terrain for daily or seasonal movement. From an on-ground perspective, viaducts reduce habitat fragmentation, preserve natural drainage patterns, and minimize disturbance caused by extensive filling and cutting during construction. Over time, natural vegetation regenerates beneath viaducts, further improving their acceptance by wildlife.

Animal Underpass:

Animal underpasses are one of the most commonly implemented wildlife mitigation measures on highway projects, particularly in forested, rural, and agricultural landscapes where animals naturally prefer to move below road level.

It is defined as a specifically designed structure, often bridge-like or cave-like, constructed beneath linear infrastructure (roads or railways) to allow for the safe passage of wild animals, thereby maintaining habitat connectivity and reducing wildlife-vehicle collisions.



Figure-11: Animal Underpass in Four laning of Mancherial to Repallewada section of NH-363 Telangana

These structures often take the form of dedicated modified box culverts and bridge spans, designed with adequate height and width to suit the target species and to avoid a confined or tunnel-like effect. Natural earthen flooring, gentle approach slopes, proper drainage, and unobstructed entry and exit points are critical design features that significantly influence animal usage. Highway projects shows that animals are more likely to use underpasses that remain dry, free from debris, and minimally disturbed by human activity. To improve effectiveness, animal underpasses are typically integrated with fencing or canalization measures that guide wildlife toward designated crossing points and prevent accidental access to the carriageway. Over time, vegetation growth near the openings further improves acceptance by wildlife.

WII monitoring studies on operational highways have demonstrated regular usage of such underpasses by a wide range of species, confirming their role in maintaining habitat connectivity, reducing wildlife mortality, and enhancing road safety when properly designed, located, and maintained.

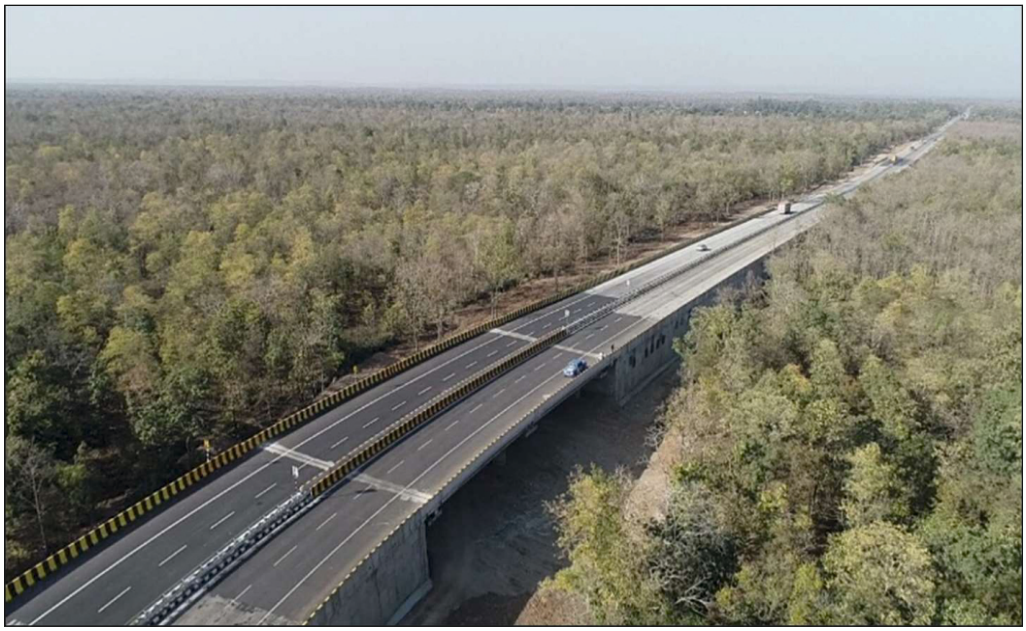


Figure-12: Underpass around Pench National Park, Maharashtra



Figure-13: Underpass in Pench National Park, Madhya Pradesh



Figure-14: Underpass around Pench National Park, Madhya Pradesh

Animal Overpass:

Animal overpasses also known as eco-ducts or green bridges are specialized structures covered with soil and vegetation that allow wildlife to safely cross human-made barriers like highways. These are built structures that go above the linear intrusion to provide a passage or movement route for wildlife can be considered for roads disrupting movement routes of animals such as some ungulates, small mammals, and arboreal mammals. These bridges combat habitat fragmentation, allowing animals to move between habitats, while reducing vehicle-animal collisions and enhancing safety for drivers.



Figure-15: Animal Overpass in Six lane Sargi-Basanwahi section of NH-130CD under Raipur-Visakhapatnam Economics Corridor in Chhattisgarh



Figure-16: Animal Over Pass-6L Greenfield Badakumari to Karki section of NH-130CD Road under Raipur-Visakhapatnam Economic Corridor, Odisha

They are often paired with fencing to guide animals to the crossing. Animal overpasses are provided in highway sections where wildlife movement occurs at surface level and where at-grade crossings pose a high risk of wildlife–vehicle collisions, particularly near forests, protected areas, and identified wildlife corridors.

In highway projects, the planning of animal overpasses is largely driven by field-based evidence such as animal trails, camera-trap records, inputs from the State Forest Department, and local knowledge of habitual crossing locations.

These structures are typically designed as wide, earth-covered crossings with natural soil and vegetation, allowing animals to perceive them as a continuation of the surrounding landscape. On the ground, features such as boundary walls, guide fencing, plantation, and noise-buffering elements are used to channel animals toward the overpass and reduce disturbance from fast-moving traffic below.



Figure-17: Animal Overpass constructed across NH 363 in the Mancherial–Repallewada section in Telangana

Designed to facilitate safe movement of wildlife across the highway corridor while maintaining ecological connectivity between adjoining forest habitats. Such **wildlife crossing structures**, along with guiding fencing visible along the road, help channel animals toward the designated crossing point, thereby **reducing wildlife–vehicle collisions and minimizing habitat fragmentation** in forested landscapes. **Guide fencing installed along the highway** directs animals toward the designated overpass, preventing direct access to the road surface and thereby reducing the risk of wildlife–vehicle collisions. The implementation of these measures reflects the **adoption of environmentally responsible highway planning**, where transportation development is aligned with biodiversity conservation and sustainable infrastructure practices.

Land Bridge:

It is also known as an eco-duct or a wildlife bridge, it is a 30-70 m wide bridge that extends above roads or railway lines. The bridge is typically enhanced with habitat features such as native vegetation, rocks and logs. These structures allow for natural movement of wild animals as they are less confining, quieter, have ambient natural conditions of rainfall, light and temperature, and can be used by a wide range of fauna.

Design considerations:

The bridge may be rectangular or hour-glass shaped. Human activities and disturbance (noise and artificial light) should be minimized. Fencing should be used to funnel the animals towards the structures and away from the road or rail. Acceptability to wild animals should be achieved by planting and maintaining native vegetation.

In the Indian context, these structures are planned where maintaining landscape-level connectivity is critical, such as near protected areas, forest corridors, and habitats used by wide-ranging species. Land bridges are constructed as wide-span structures covered with natural soil and native vegetation, allowing animals to cross the highway without visual or sensory exposure to traffic below.

Fencing and plantation are used to guide animals toward the bridge and to reduce noise and light disturbance from vehicles. Over time, as vegetation matures, land bridges function as extensions of the natural habitat, supporting movement of large mammals, smaller fauna, and even plant dispersal, thereby significantly reducing habitat fragmentation. When properly designed and maintained, eco-ducts have proven to be one of the most effective long-term mitigation measures for sustaining ecological connectivity across high-speed highway corridors in India.

Tunnels:

Tunnels are provided in ecologically sensitive areas where surface-level construction would result in significant habitat fragmentation or disruption to wildlife movement. By routing the highway underground, tunnels maintain above-ground habitat continuity, preserve vegetation cover, and allow natural wildlife movement, minimizing noise, light, and human disturbance.



Figure-18: Tunnel in Ganeshpur- Dehradun Project of NH 72 A (Pkg.2)

The location and design of tunnels are based on field assessments, wildlife movement patterns, and ecological sensitivity of the area. Controlled construction practices, careful muck management, and restricted working periods reduce disturbance during implementation. Properly executed tunnels provide a long-term mitigation solution, maintaining connectivity while allowing sustainable highway operation.



Figure-19: Tunnel: Chenani - Nashri Section in Jammu and Kashmir

Box Culvert:

Wildlife-friendly box culverts are provided at locations where the highway intersects natural drainage channels, seasonal nalas, or terrain features regularly used by small and medium-sized fauna. In addition to serving hydraulic requirements, these culverts offer a defined passage beneath the road, particularly for species that follow ground contours and moisture gradients. These are typically square or rectangular structures built under the linear infrastructure for passage of fauna (including aquatic species) and/or water. Box culverts with rectangular profiles, flat bases, and adequate openness are more readily used by animals, especially when the floor is left unpaved or covered with natural soil and leaf litter. Integration with guiding fencing, vegetation buffers, and absence of sudden drops or obstructions at entry and exit points improves usability. Periodic maintenance to prevent siltation, debris accumulation, or water stagnation is essential to retain their effectiveness as functional wildlife crossings.

Design considerations:

- Culverts may be of different types depending on their shape and size, and the need to cater for natural drainage.
- Adding ledges or planks above the water level in culverts has been shown to encourage many terrestrial species to use the structures.
- The type of materials and substrate used in the structure, and the establishment of native vegetation at each end of the underpass for cover, are other factors that affect use of underpasses by animals.



Figure-20: Box Culvert- 4 laning of Sangareddy- Nanded- Akola of NH-161 Section – Hyderabad-Telangan

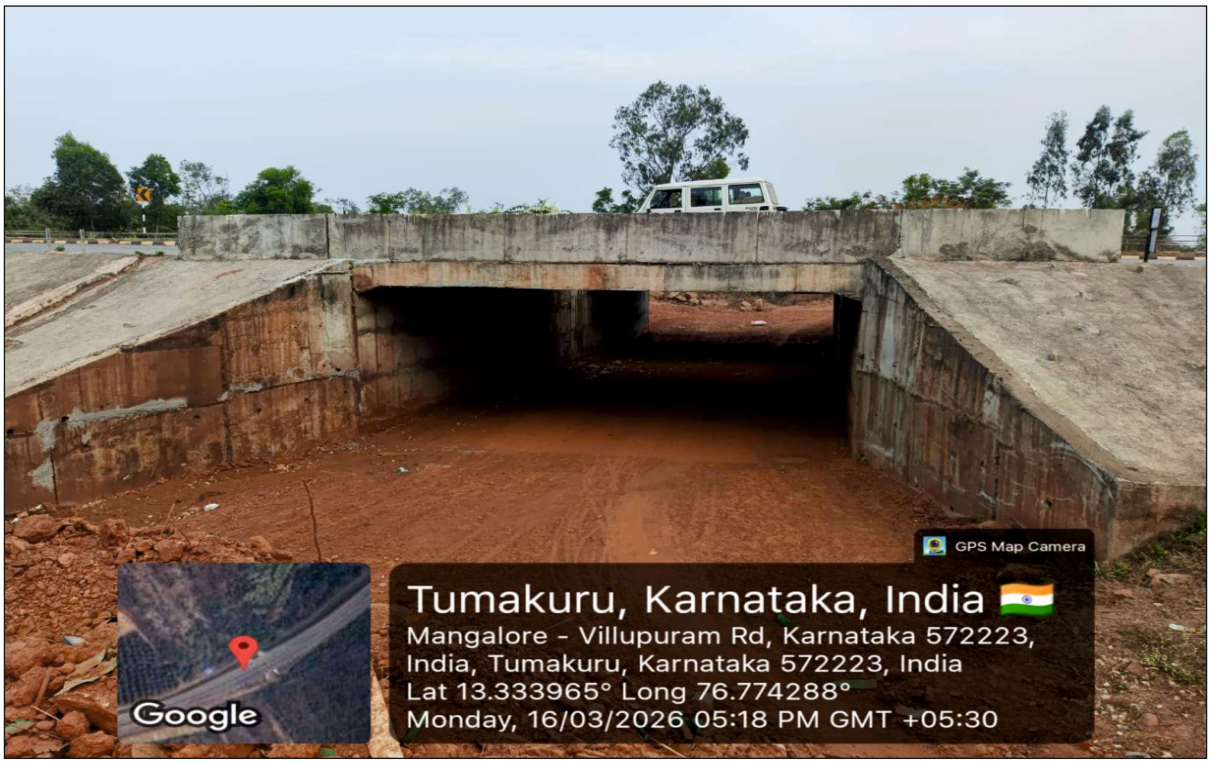


Figure-21: Box Culvert in Four laning of Mallasandra to Karadi Section of NH 206 (Pkg. – 1)

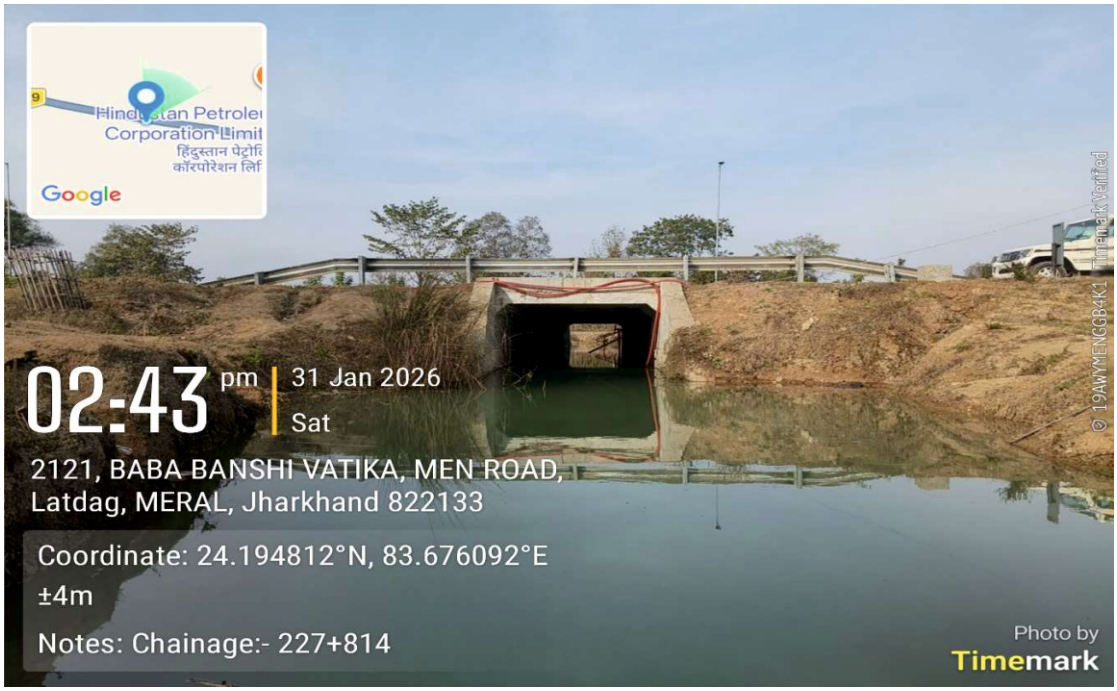


Figure-22: Culvert structure constructed along the four-laning project of NH 75 near Meral, Jharkhand.

This structure has been designed primarily to maintain **natural drainage connectivity** by allowing water flow beneath the highway embankment, thereby preventing waterlogging and maintaining the hydrological balance of the surrounding area.

The presence of a water channel through the culvert indicates that the structure supports **surface runoff and local stream movement**, which is particularly important in areas with seasonal rainfall. Such drainage structures are essential components of highway infrastructure, ensuring that the road embankment does not obstruct natural watercourses or alter existing drainage patterns.

In addition to its drainage function, the culvert can also serve as a **secondary passage for small wildlife species**, including reptiles, amphibians, and small mammals. By allowing animals to move beneath the roadway, the structure contributes to **maintaining habitat connectivity and reducing potential wildlife–vehicle conflicts** along the highway corridor. This approach aligns with environmentally sensitive highway design practices where infrastructure elements are planned to support both **engineering requirements and ecological considerations**.

Pipe Culvert:

These are typically round pipes of relatively small diameter (1.5 m) made of smooth steel, corrugated metal, or concrete. Although their primary purpose is of convey water under roads, a variety of wild animals has been observed using them as passageways: they are often used by small mammals, reptiles and amphibians. They have also been used as fish passages.

Design considerations:

- Single or multiple pipes should be placed at an appropriate spot.
- Native vegetation should be established on both sides of the culvert to provide cover.

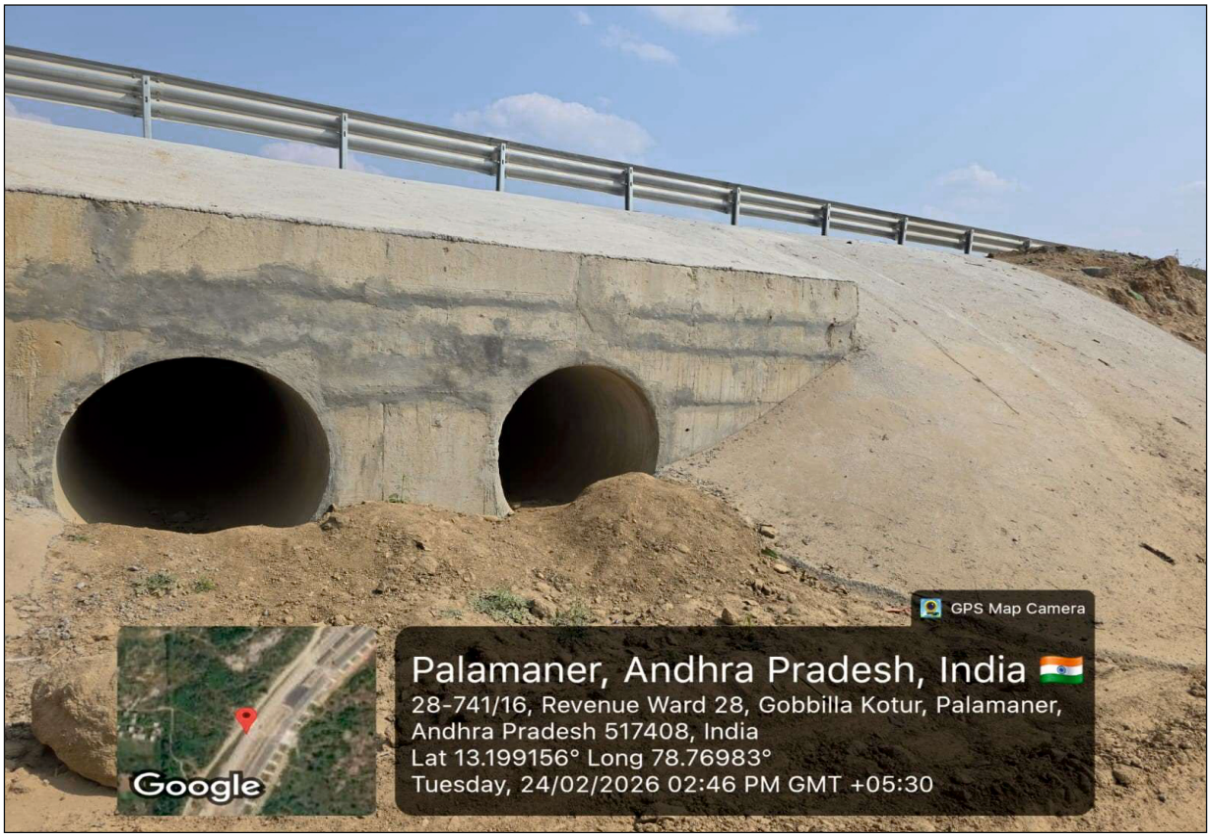


Figure-23: Pipe Culvert- 4L Bangalore-Chennai Expressway from Baireddypalle to Bangarupalem Section of NE-7 in Andhra Pradesh under Bharatmala Pariyojana

Pipe culverts are primarily installed for drainage and water conveyance; however, these can support movement of certain small-bodied fauna when appropriately designed and located. These structures are most effective for reptiles, amphibians, and small mammals that utilize narrow, shaded, and moist pathways. Pipe culverts located along existing animal trails or natural drainage lines, with gentle slopes and clear openings, are more likely to be used. Ensuring partial dry passage during non-monsoon periods and avoiding sharp bends or steep gradients enhances their usability. While pipe culverts are not suitable for larger species, their cumulative presence along the highway contributes to micro-level connectivity and reduces mortality of smaller fauna in fragmented landscapes.

Fencing:

Fences are best used in combination with properly placed wildlife crossing structures; they direct animals away from roads or railways and towards these structures. Fencing has been clearly demonstrated to make crossing structures much more efficient and effective. Different fence designs can be used for small or large mammals, amphibians and reptiles.

Design considerations:

- Fencing may be erected along the entire length of the linear Infrastructure or only along sections known to present a risk to wild animals or livestock. Decisions on continuous or partial fencing will depend on land-use patterns (e.g., private land, forest land).
- Both sides of the road should be fenced. Fences should be symmetrical and not staggered.
- Breaks in the fences should have wildlife warning systems, warning signs or cattle guards/gates to avoid animal mortality.
- The height, material and mesh size of the fence should be decided based on the target species.



Figure-24: Chain Link Fencing - Four Laning of Natham-Thuvarankurichi of NH-785 E in Madurai, Tamil Nadu

Wildlife fencing is provided along identified highway stretches to restrict animal access to the carriageway and to guide wildlife movement toward designated mitigation structures such as animal underpasses, bridge-cum-underpasses, culverts, and canopy bridges. The fencing design considers local species movement patterns, terrain, and habitat characteristics, with appropriate height, mesh configuration, and strength to ensure effectiveness without causing injury.

Fencing is aligned continuously along the right-of-way and is integrated with the approaches of crossing structures to create a guided and predictable movement pathway for fauna. Provisions such as escape ramps and appropriate end treatments are incorporated to prevent entrapment and allow safe exit in case of accidental entry. Proper installation and periodic maintenance of fencing enhance the functionality of wildlife crossings, reduce wildlife–vehicle collision risk, and support overall ecological connectivity along the highway corridor.

Minor Bridge cum AUP:

Minor bridges integrated with animal underpasses are provided at locations where small watercourses, streams, or low-lying terrain intersect wildlife movement corridors. These structures serve a dual function by maintaining natural drainage while facilitating safe passage of terrestrial fauna beneath the highway. On ground, the underpass portion is designed with sufficient width and height for regular animal movement, natural flooring, and gentle approaches to ensure usability by a variety of species, including small and medium-sized mammals. Guiding barriers, fencing, and vegetation are implemented to channel wildlife toward the crossing and prevent access to the road surface.

Minor bridge cum AUPs is particularly effective in agricultural and fragmented forest landscapes, providing a cost-effective solution that maintains habitat connectivity, reduces wildlife mortality, and ensures continuity of ecological functions along the highway corridor.



Figure-25: Minor Bridge cum AUP 4L in Bangalore-Chennai Expressway from Baireddypalle to Bangarupalem Section of NE-7 in Andhra Pradesh (Phase II /Package-II)

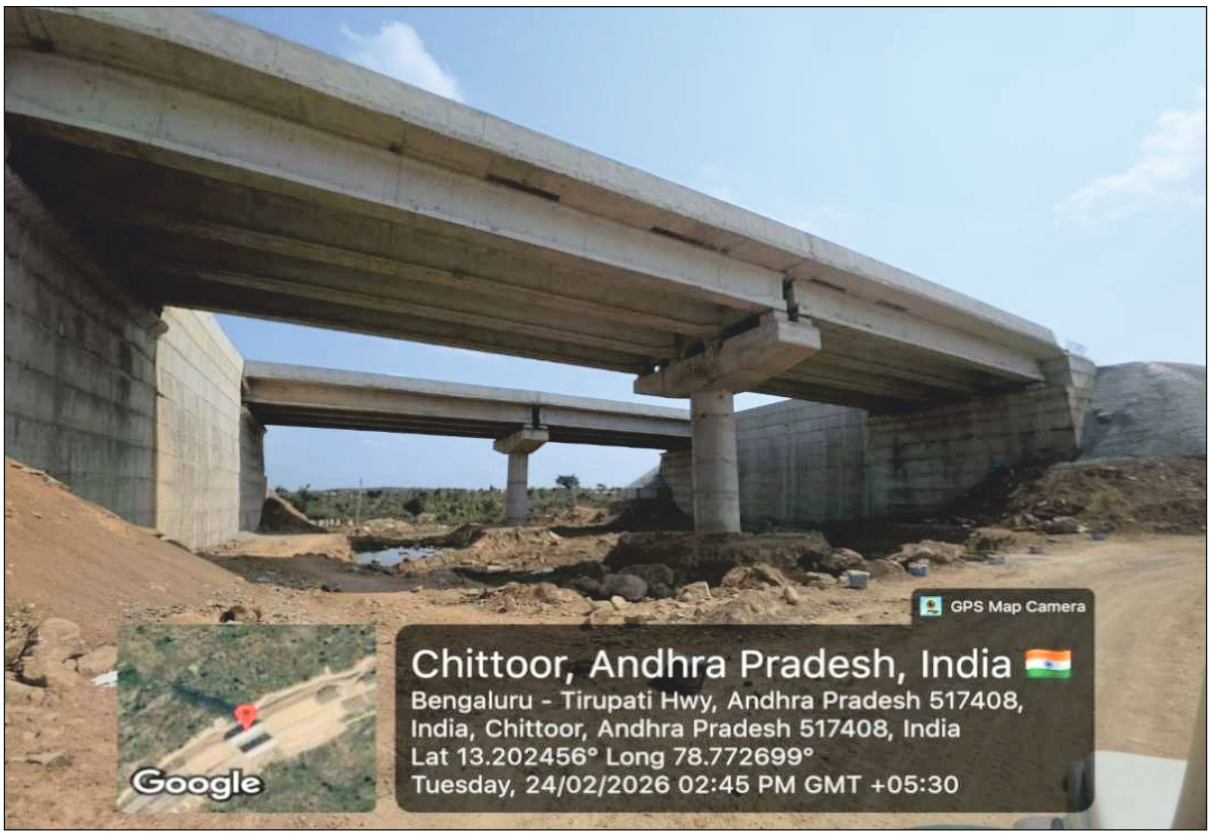


Figure-26: Minor Bridge cum AUP- 4L Bangalore-Chennai Expressway of Baireddypalle to Bangarupalem Section of NE-7 in Andhra Pradesh

Major Bridge cum AUP:

Major Bridge-cum-Animal Underpasses are proposed along highway stretches where the alignment traverse major rivers, wide floodplains, or ecologically sensitive areas that also serve as important wildlife movement corridors. These structures are designed to ensure uninterrupted hydrological flow while facilitating safe and unobstructed movement of terrestrial fauna beneath the highway. The underpass portion is provided with adequate horizontal and vertical clearance, open sightlines, gentle approach gradients, and natural earthen or sandy flooring to promote regular use by large mammals and herd-forming species. The open-span configuration minimizes confinement and reduces disturbance from traffic, noise, and artificial lighting.

Guiding measures, including fencing, earth bunds, and appropriate plantation, are integrated to direct wildlife toward the crossing and restrict access to the carriageway. When implemented along identified animal movement paths, Major Bridge cum AUPs contribute effectively to maintaining ecological connectivity, reducing wildlife–vehicle collision risk, and mitigating long-term impacts of linear infrastructure on wildlife habitats.



Figure-27: Elevated Corridor around Pench National Park, Maharashtra



Figure-28: Elevated Corridor Pench National Park, Maharashtra



Figure-29: Elevated Corridor in Pench National Park, Madhya Pradesh



Figure-30: Group of Spotted Deer (*Chital*) utilizing an Animal Underpass (AUP)- NH 74 **under the Ganeshpur–Dehradun (DDN) Highway Project in** Uttarakhand

The structure facilitates safe wildlife movement beneath the highway while maintaining habitat connectivity across the surrounding forest landscape. The observed use of the underpass by wildlife demonstrates the **functional effectiveness of dedicated crossing structures**, confirming that such mitigation measures are actively used by animals and contribute to reducing habitat fragmentation.

The underpass also serves as an **important ecological linkage** between habitat patches located on either side of the highway, enabling wildlife to continue their natural movement patterns related to foraging, breeding, and seasonal dispersal. By allowing animals to move below the roadway rather than across it, the structure **significantly lowers the likelihood of wildlife–vehicle collisions**, thereby improving both wildlife safety and road user safety.

The successful utilization of the AUP highlights the importance of **integrating wildlife-sensitive design features into highway infrastructure**, demonstrating how transportation development can coexist with biodiversity conservation objectives.

Canopy bridge/ Monkey ladder:

This is a rope, pole or wooden ladder or walkway suspended above the road or railway, either from vertical poles or trees, and installed for tree-dwelling species.

Design considerations:

- The bridge should be located in areas having important populations of arboreal species with a high risk of mortality.
- Structures should be taut and wide enough for animals to walk on.
- Each end of the bridge should be connected to trees or bushes for cover.
- A thin rope above the bridge can prevent predation small arboreal mammals by birds.

Canopy bridges are proposed at locations where highway alignments intersect arboreal wildlife movement routes, particularly in forested stretches supporting primates and other tree-dwelling species. These structures are designed to restore canopy continuity disrupted by road construction and to facilitate safe, uninterrupted movement of arboreal fauna above the carriageway. On ground, canopy bridges are constructed using durable ropes, cables, or modular platforms installed at appropriate heights consistent with adjoining tree canopies, ensuring natural access and ease of movement. The placement of canopy bridges is guided by field observations of arboreal activity and connectivity requirements between forest patches.

Supporting plantation and canopy restoration on either side of the structure are undertaken to enhance long-term functionality. When appropriately located and maintained, canopy bridges reduce wildlife–vehicle interaction, prevent accidental road crossings by arboreal species, and contribute to the preservation of ecological connectivity along the highway corridor.



Figure-31: Canopy Bridge-Six lane Sargi-Basanwahi section of NH-130CD under Raipur-Visakhapatnam Economics Corridor in Chhattisgarh (Package-CG-2)

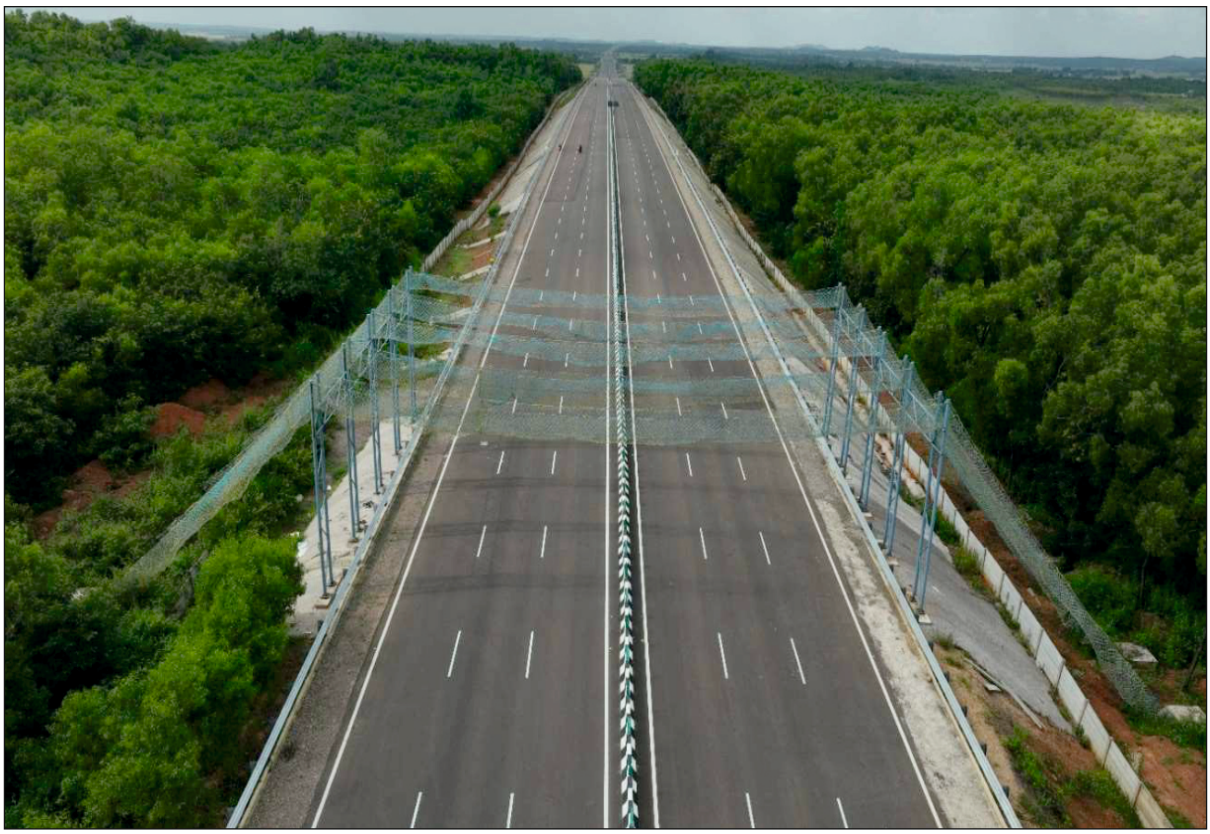


Figure-32: Canopy Bridge-6L Greenfield Karki to Kaligura section of NH-130CD Road (Package - OD-4)

Noise Barrier:

Noise barriers are provided along identified highway stretches adjoining ecologically sensitive areas, wildlife habitats, and movement corridors to reduce the impact of traffic noise on fauna. These barriers are designed to attenuate vehicular noise and visual disturbance, particularly in areas supporting noise-sensitive species and near wildlife crossing structures.

Noise barriers are strategically located in proximity to animal underpasses, overpasses, bridge-cum-underpasses, and canopy bridges to create a quieter and less disturbed environment, thereby improving the effectiveness of mitigation measures. Barrier design considers height, material, and continuity to ensure functional noise reduction while maintaining landscape compatibility. Proper installation and maintenance of noise barriers contribute to minimizing behavioral disturbance to wildlife, supporting regular use of crossing structures, and enhancing overall ecological performance of the highway corridor.



Figure-33: Noise Barrier-Four laning of existing 2-lane stretch from Govindpur MHTG Border to Rajura section of NH-353B in Maharashtra



Figure-34: Sound and Noise barrier on animal crossing in Pench National Park, Madhya Pradesh



Figure-35: Sound and Noise barrier on animal crossing in Pench National Park, Madhya Pradesh

Reptile Crossing:

Reptile crossings are provided along highway stretches intersecting habitats and movement paths of reptiles, particularly in areas with rocky terrain, forest edges, wetlands, and seasonal drainage lines. These crossings are designed to facilitate safe movement of reptiles beneath the highway and reduce mortality due to vehicular traffic. Reptile crossings are typically integrated with box culverts, pipe culverts, or purpose-designed low-profile passages, ensuring suitable microclimatic conditions such as shade, moisture retention, and natural substrates.

Guiding features such as low kerb walls, drift fencing, or surface contours are incorporated to direct reptiles toward the crossing openings and prevent access to the carriageway. Proper placement, design, and maintenance of reptile crossings contribute to minimizing roadkill, maintaining local population connectivity, and enhancing the overall effectiveness of wildlife mitigation measures along the highway corridor.

Watch Towers:

Watch towers are provided at selected locations along the highway corridor to facilitate monitoring of wildlife movement, effectiveness of mitigation measures, and potential conflict zones. These structures support surveillance and patrolling activities by authorized personnel, particularly in ecologically sensitive stretches and near wildlife crossing structures. Watch towers are strategically located to offer clear visibility of adjoining habitats, underpasses, overpasses, and fence lines, enabling timely detection of animal presence or breaches. Their placement and design are aligned with operational and safety requirements while minimizing disturbance to wildlife. Watch towers contribute to effective implementation, monitoring, and adaptive management of wildlife mitigation measures, supporting long-term ecological safety along the highway corridor.

5.3.2 Non-Structural Options

The following non-structural approaches provide additional measures for restoring wildlife Connectivity across linear— infrastructure and helping to improve the permeability of affected habitat.

Salt Licks:

Salt licks are provided at selected locations within forest areas to supplement essential minerals for herbivorous wildlife and to support natural foraging behaviour away from the highway corridor.

These are strategically located based on habitat use patterns to avoid attracting animals toward the carriageway or crossing structures. Salt licks are established in suitable forest patches at safe distances from the road, water bodies, and human activity zones. Their placement is coordinated with fencing and other mitigation measures to discourage wildlife congregation near traffic-prone areas.

Periodic monitoring and controlled replenishment of salt licks support their effective functioning as a non-structural mitigation measure, contributing to reduced wildlife–vehicle interaction and improved habitat management along the highway corridor.

Water Holes:

Water holes are developed or augmented at selected locations within forest areas to ensure reliable water availability for wildlife and to support natural movement patterns away from the highway corridor.

These are strategically located based on habitat conditions and seasonal water scarcity, ensuring that wildlife is not drawn toward the road or mitigation structures. On ground, water holes are designed considering local terrain, soil conditions, and drainage characteristics to allow safe access for multiple species while minimizing erosion or stagnation.

Their placement is coordinated with fencing and other mitigation measures to discourage wildlife congregation near traffic-prone areas. Regular maintenance and monitoring of water holes contribute to effective habitat management, reduce the need for animals to approach the highway for water, and support overall ecological stability along the corridor.



Figure-36: Water holes in Sanamavu Reserve Forest along Thorapalli Agraharam–Jittandahalli section of NH 844

A **rainwater harvesting (RWH)–based water hole** has been developed to support wildlife conservation in the surrounding forest landscape. The water hole serves as a **supplementary water source for wild animals**, particularly during dry periods, thereby reducing their need to move towards nearby highways or human habitations in search of water. Such nature-based mitigation measures help **improve habitat conditions, minimize wildlife–vehicle interactions, and strengthen ecological resilience along highway corridors**. The image also reflects active wildlife usage of the structure, demonstrating its effectiveness as a habitat-supporting intervention.

5.4 Mitigation Measures for Connecting Landscapes & Species

Landscape connectivity is the degree to which habitats across the landscape are connected, facilitating wildlife movement and other ecological flows. Besides landscape related mitigation measures, species specific measures are equally important.

5.4.1 Landscape- Specific Measures

The following aspects and concepts need to be considered when locating and designing linear infrastructure and deciding on appropriate measures to mitigate impacts:

- The concept of minimum viable population', which sets and respects — a lower limit on the population size or numbers of individuals of a species (including their genetic diversity) to make sure that species will survive in the long term.
- Source-sink dynamics of the landscape, which identifies the critical elements and quality of different ecosystems and habitats on which the persistence of wildlife depends, and describes how variation in habitat quality may affect the population growth and decline of organisms.

- Metapopulation structure, which considers the geography of, and relationship between, different populations of the same species, to ensure the persistence of that species.
- The **'Allee effect'** with respect to the behavioural ecology of the species, habitat matrix and its porosity to the taxa (corridors for movement). This effect considers the correlation between population size or density, and the mean fitness of individual animals of a population or species, recognizing that fitness tends to decline in smaller populations.

Mitigation measures should be designed and implemented to meet the collective needs of all target taxa and biodiversity values of the landscape; designing for the biggest or most demanding species will often ensure that the needs of other species would simultaneously be met.

However, in certain cases, additional measures may be required for particular taxa or functional groups to provide for specific needs: e.g., structures designed for elephants will serve the purpose for most terrestrial mammalian species but may not be effective for strictly arboreal taxa, or for reptiles and amphibians; special mitigation measures will still be needed for them.

General rules for maintaining habitat connectivity across the landscape:

The general guidelines set out below to maintain connectivity across an identified species corridor are based on species ecology, such as home range and habitat use pattern, species communities across different landscapes and other ecological information.

- If the width of the corridor through forest habitat is 1 km or less, the construction of flyovers should be undertaken in such a way that the entire stretch of forest remains connected.
- If the width of the corridor is 1-2 km, one underpass of 750 m should be provided across the landscape. The exact location of the underpass should be based on topographic features of the area and information about customary animal crossing zones. This 750 m stretch of elevated road could also be divided into two parts of minimum 300 m each, located within that corridor. Their location would depend upon the terrain, characteristics of the particular species and its movement patterns.
- If the width of the corridor is 3 km or more, or if the forest landscape is to be dissected by either a new road or the upgrading of an existing road, 300 m underpasses are suggested within every km stretch of the road. The exact location of the underpass should be based on topographic features, crossing zones, and the particular ecological requirements of the affected species.
- Other than maintaining connectivity for larger mammalian species, for amphibians or reptiles across the landscape, small pipe culverts or bridges should be constructed in every 100 m stretch of road.

Table-7: Placement of Crossing Structures Across Animal Movement Corridors

Landscape characteristic	Design measures for maintaining connectivity
Connectivity across 1 km species corridor	Entire 1 km stretch to be connected
Connectivity across 1-2 km species corridor	750 m underpass either as one structure or two 300 m each depending upon terrain and other conditions
Connectivity across 3 km species corridor or across the forest landscape to be divided by either 2 new road or upgrading of existing road	300 m underpasses are suggested at every km of the road
For smaller species such as amphibians and reptiles	Small pipe culverts or bridges at every 100 m stretch of the road.

Source: Mathur, V. B., & Rajvanshi, A. (2016) in WII Publication.

5.4.2 Species- Specific Measures

It is important to consider, and design wildlife crossings and animal passages to cater for, all of the species using the area affected by linear infrastructure, to improve the efficiency and effectiveness of mitigation solutions. The following paras focuses on the use of underpasses as a principal measure to mitigate negative impacts of roads on terrestrial mammals. However, it is useful to note that these underpasses would also be used by other animal taxa.

Underpasses for Terrestrial mammals:

The following minimum design requirements of underpasses for specific terrestrial mammal species are based on the effectiveness of underpasses for mule deer, which have a shoulder height of 106 cm (Reed et al. 1975; Reed et al. 1979; Reed 1981; Ward 1982; Olbrich 1984; Reed & Ward 1987; Foster & Humphrey 1995; Putnam 1997).

- For chital, with a shoulder height of up to 75 cm, an openness index of 0.52 (metric) is needed.
- For sambar, with a shoulder height up to 160 cm, an openness index of 1.12 (metric) is needed.
- For gaur, shoulder height up to 175 cm, an openness index of 1.22 (metric) is needed.

In landscapes where sambar, gaur and tiger are the largest animals present, a minimum underpass height of 5 m would be acceptable if the viaduct were 300 m long and the span of the underpass were 28-30 m. For any other underpass with a viaduct of less than 300 m, and in landscapes where elephant and rhino are the largest animals in the community, the minimum height of the underpass should be 6-8 m to provide an openness ratio that could provide an optimum passage for these animals. While approaching the underpass, the animal should preferably be able to view the horizon across the underpass in order to perceive any risks and opportunities on that side. Although a structure 5 m high and passage with a viaduct length of 300 m should be able to provide this view, a 7 m high a passage would provide a more Liberal view created by higher openness ratio.

The design of the walls and the piers of an underpass can significantly improve the acceptability of passage structure by animals. Isolated piers are more favourable than wall-type piers: wall-type piers reduce lateral visibility and increase tunnel effects, especially for species that move in groups, such as chital. The inclusion of a cross beam at the top of isolated piers further improves their acceptability.

5.5 Mitigation Measures for Different Landscapes

There are specific mitigation measures for different landscapes viz. Tiger Landscapes, Elephant Landscapes.

5.5.1 Tiger Landscapes

Both underpasses and overpasses (passageways) are potential engineering solutions for mitigating the impacts of linear infrastructure in tiger landscapes. The following designs and norms for these structures should serve as the minimum requirements for mitigation in such landscapes where elephants do not occur. In landscapes where elephants are present, the design of mitigation structures would generally also meet the needs of tigers and most other biota.

Tiger Underpass:

A minimum span of 30 m with a height of 5 m and width of 5-8 m would work for most species in tiger landscapes. The 30 m span refers to clear open passageways — often these underpasses would have support pillars for the infrastructure and they should be excluded from the span measurement. In critical tiger corridors as well as core areas of tiger reserves— if linear infrastructure is permitted at all— mitigation measures need to be especially stringent: the span needs to be a minimum of 50 m with the same dimensions of height (5 m) and width (5-8 m).

Tiger underpasses are specialized wildlife crossing structures provided along highway stretches passing through or near tiger habitats and identified movement corridors, where safe and uninterrupted movement of large carnivores is critical. Their locations are finalized based on field evidence such as camera-trap data, pugmark records, and inputs from the Forest Department and wildlife experts. These underpasses are designed with larger width and height than standard animal underpasses to avoid a tunnel effect and to suit tiger movement behavior, with natural earthen flooring, gentle approach slopes, and clear visibility. Continuous fencing is provided to guide animals toward the crossing and prevent access to the carriageway.

Tiger Overpass:

After accounting for structural construction requirements, the minimum passage width of an overpass needs to exceed 30 m. The overpass should not have a steep incline to the infrastructure crossing: slopes over 25 degrees should be avoided. Thus, the length of the overpass is site specific and needs to be adjusted according to the lay of the land.

Tiger overpasses are dedicated wildlife crossing structures provided on highway stretches passing through or adjoining tiger habitats and identified movement corridors, where surface-level crossings pose a high risk to both wildlife and road users. Tiger overpasses are designed as wide, soil-covered structures with natural vegetation, allowing tigers to cross the highway without visual or sensory exposure to traffic below. Fencing and plantation are used to guide animal movement toward the overpass and minimize disturbance from noise and lighting.

Density of mitigation structures:

Besides the dimensions of the underpasses and overpasses, the density or numbers of such structures per unit length of the infrastructure is a crucial consideration for mitigating impacts. A passageway of over 50 m per 1 km length of infrastructure in forested habitats and over 100 m per 1 km length of infrastructure in critical tiger corridors would ensure that habitat connectivity is maintained and fragmentation is avoided.

It is important that wild animal movement is channeled to the passageway for crossing the infrastructure by using appropriate funneling structures, either natural or artificial. At times it may be necessary, except at the underpasses and overpasses, to fence off the road when passing through wildlife habitat. This fence may be essential to avoid mortality of wildlife, prevent accidents and ensure the safety of humans. Where fences are not required or are not feasible along the entire length of the infrastructure corridor, specific mitigation measures will still be required in the vicinity of topographic features that are known to trap wildlife on roads.

Visual barriers:

Visual barriers along the sides of the infrastructure need to be installed in such a manner that the traffic (vehicles) is not visible from a distance or up close from the wild animal crossings. Care should be taken that vehicular lights do not escape the visual barrier at night as these visual clues could deter nocturnal species from using the underpass. Visual barriers can be camouflaged and enhanced by planting tall vegetation along the edges of the engineered structure.

Sound barriers:

Both underpasses and overpasses need to be fortified with sound barriers to prevent any disturbance to wildlife that could potentially use these structures for passage across the infrastructure. The installation of appropriate sound and visual barriers cannot be over emphasized: without them, investments in constructing underpasses and overpasses can go to waste, as wildlife may never use them.

Olfaction and other sensory enhancers:

Target wild animals can be encouraged to use the overpass or underpass by enhancing its porosity to wildlife through enrichment. These enrichments consist of

a) use of appropriate substrate like soil, leaf litter, gravel, herbaceous vegetation

b) attractants like food plants, carrion, pheromones, dung of conspecifics and scats in the case of carnivores like tigers.

These enrichments require inputs from professional wildlife biologists and, if not appropriately used, can also act as deterrents to wildlife passage. Use of these enrichment approaches must be accompanied by rigorous evaluation and testing.

5.5.2 Elephant Landscapes

Roadways impact elephants in multiple ways. Loss and fragmentation of elephant habitat is the most severe problem arising from linear infrastructure development: it alters the elephant's home range and, consequently, may lead to an escalation of human-elephant conflict where these animals are forced into new areas. In addition, it may lead to elephant populations becoming isolated, resulting in a loss of their genetic diversity. To aggravate these impacts, elephants trapped in isolated areas rapidly destroy their own habitats.

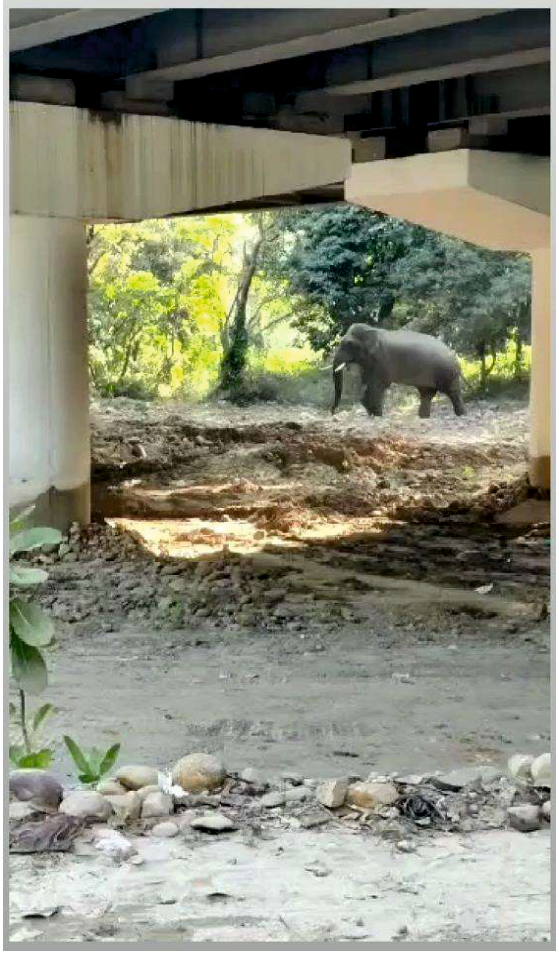
Poorly planned roadways in elephant landscapes result in loss of both elephant and human life due to accidents. However, these critical problems can be addressed by appropriate mitigation measures. The principal mitigation measures proposed to minimize the impact of linear infrastructure in elephant landscapes are set out below.

Elevated linear infrastructure:

Raising the linear infrastructure (road) on pillars above the ground is the best solution in elephant landscapes. A major consideration while elevating the linear infrastructure is height: the height of the pillars should be at minimum 8-10 m (thrice the height of an adult bull elephant) above ground, so as to provide safe passage for elephants. In the event that the costs of elevating infrastructure would be prohibitively expensive, other measures covered below should be considered.

Elephant Underpass:

The height of the underpass, to allow elephant movement, should be the major consideration. A minimum span of 50 m with a height of 6-8 m and a width of 10-12 m is desirable for movement of elephants.



The selection of sites for elephant underpasses should be carefully planned before road design is finalized. Elephants tend to use fairly regular paths/trails and drainage lines in the forest. Such trails and drainage lines need to be identified by specialists trained specifically for this task (i.e., not untrained staff), following a thorough survey of the area. Underpasses should be located where the linear infrastructure corridor intersects with these paths/trails and drainage lines. Girder bridges are one of the best forms of underpass that can be provided for elephants' passage. Physical barriers should be erected along the remaining length of roads or railways in order to funnel elephant movement through these underpasses.

Figure-37: Combined Structure for Elephant at Chila Motichur in RNP, NH-58, Haridwar-Dehradun-Section

Elephant underpasses are provided along highway stretches intersecting identified elephant movement routes, migratory paths, and access corridors to water and forage areas. These structures are designed with large clear spans and high vertical and horizontal clearance to facilitate safe passage of elephant herds, including calves, without causing stress or obstruction. Elephant underpasses incorporate wide openings, open sightlines, gentle approach gradients, and natural earthen flooring that closely resembles the surrounding habitat, encouraging regular use. Guiding measures such as robust fencing, earth bunds, and plantation are provided to channel elephant movement toward the underpass and prevent access to the carriageway. When strategically located along established movement paths, elephant underpasses effectively maintain habitat connectivity, reduce human–elephant conflict and wildlife–vehicle collisions, and support long-term ecological sustainability of highway corridors.

Elephant Overpass:

Construction of overpasses in flat terrain is not desirable in elephant landscapes. Overpasses can be considered as a mitigation measure only when the linear infrastructure passes through a stretch with steep terrain on both sides: the steep terrain on both sides of the road can be connected with an overpass of at least 10-12 m in width.

Elephant overpasses are proposed in ecologically sensitive stretches where surface-level connectivity for elephant movement is essential and where underpass solutions are not feasible due to site constraints. These structures are planned as wide, land-like crossings with adequate soil depth and native vegetation cover, allowing elephants to traverse the highway in a manner consistent with natural movement behavior. The siting and design of elephant overpasses are finalized in consultation with the Forest Department and wildlife experts, based on corridor mapping and movement evidence. Measures such as earthen bunds, plantation, fencing, and visual barriers are incorporated to guide elephant movement toward the overpass and to minimize disturbance from traffic noise and lighting. Properly designed elephant overpasses function as long-term mitigation structures that ensure landscape-level connectivity, comply with wildlife conservation objectives, and enhance safety for both wildlife and highway users, consistent with NBWL and environmental clearance requirements.

Density of mitigation structures:

The density and numbers of mitigation structures is an important consideration for addressing the impacts of linear infrastructure in elephant landscapes. If elevating the linear infrastructure above the ground on pillars is not possible due to prohibitive costs, at least 100 m of passageways per 1 km length of linear infrastructure in elephant landscapes would ensure habitat connectivity.

Visual barriers:

Visual barriers as proposed in tiger landscapes are applicable for elephant landscapes.

Sound barriers:

Since elephants are sensitive to sound, all mitigation measures such as elevated structures, underpasses and overpasses need to be fortified with sound barriers.

5.6 Measures for Reducing Bird Hits

The adverse impact roads and associated vehicular traffic on birds can be minimized through their careful design, controlling the disturbance they cause, and reducing the availability of resources that attract birds next to roads.

Planning the timing of road construction and maintenance:

Vehicle collisions with birds are likely to be more pronounced during the breeding season and migration period. They can be minimized by avoiding undertaking road construction and maintenance activities during these time periods: the breeding season for most birds generally starts in early spring in lower altitudes and may continue until late in the rainy season in some areas and for particular species.

Avoidance of impacts on important bird habitats:

Roads should be located away from water bodies, rivers and streams, to avoid or minimize the risks of vehicular collision and mortality to rare, threatened and migratory species of birds using these habitats.

Flight diversion:

Birds with rapid and direct flight can be diverted to fly high over the traffic zone by erecting suitable roadside structures: fences, poles, soil berms above road level and solid walls with suitable improvisation, can help divert birds away from a roadway. Careful planning is needed before deciding on the most appropriate structure to use: particular structures may not be effective for all bird species and may pose a risk of collision for some species.

Managing roadside habitat to reduce its attractiveness for birds:

Creating and maintaining vegetation should be a standard part of the prescription for roadside management: a 5 m-wide 'clear zone', with a 3 m-high clearance, devoid of trees and shrubs, is necessary to prevent reptiles and rodents become prey for birds patrolling for food. Planting of trees with non-edible fruits, and species that inhibit undergrowth along the roadside would be effective in reducing the use of roadside habitat and verges by most birds. To reduce mortality in canopy-dwelling birds, it may be helpful to plant tree species next to roads that tend to grow tall and have dense foliage. Plant species providing food and nesting opportunities for birds should be avoided along roadsides.

Wildlife crossing structures:

Bridges, underpasses and overpasses, designed as passageways for other wild animals, can be used by some short-flighted birds (e.g., peafowl, quails, partridges and francolins, which cannot cross over roads in a single flight or avoid crossing traffic corridors), provided that these structures are sufficiently large and use suitable substrate.

Making roads less attractive to birds:

Road surfaces and roadside habitats are an attractive source of food for birds, offering, e.g., spilled grains, road kills, seeds and fruit. Careful planning and management of roadsides can reduce their attractiveness to granivorous birds such as sparrows, munias, finches and doves, and scavenging birds such as black kite, vultures and crows.

Carcasses of road kills should be removed as soon as detected. Lighting along roads may attract insects, which in turn attract birds like owls and nightjars. Use of appropriate lighting systems for illumination of roadways can reduce attraction for birds: artificial lights should generally be discouraged; and reflective posts should be used instead.

5.7 Mitigation Measures Specific to Reptiles and Amphibians

Herpeto-faunal (reptile and amphibian) road kill is often a function of species-specific ecological and life-history traits, behaviour, and movement patterns (Forman et al. 2003; Andrews & Gibbons 2005). The dispersing and migratory behaviour of herpeto-fauna makes them particularly vulnerable to the impacts associated with roads. They move between spatially separated breeding and foraging sites, and often need to cross landscapes that are fragmented by roads (Andrews et al. 2008). Their vulnerability is further increased by their relatively slow movement rates (Hels & Buchwald 2001) and by the fact that many species become immobile in response to approaching vehicles (Mazerolle et al. 2005).

Seasonal amphibian movement also makes them particularly susceptible to road mortality. Their life stages comprise juvenile dispersal and adult migration (Pittman et al. 2014), a decline in amphibian populations can also result when their breeding sites and land habitats are interrupted or fragmented by roads. Daily cycles in the thermal profiles of highways suggest that snakes that are active at night may be at particular risk, because the road is warmer than the surrounding grassland early in the evening (Shine et al. 2004) and thus may be thermally attractive to snakes at this time. Basking or thermoregulatory behaviour thus prolongs their exposure to traffic and increases the likelihood of collisions (Rosen & Lowe 1994). Turtles are known to cover long distances seasonally, and persistent road mortality may cause a serious bottleneck in the affected population: adult turtles need considerable time to mature.

Mitigation:

Roads are built to be long-lasting structures; mitigation measures should also be durable and long lasting. Wetlands, forests and rocky habitats on either side of road are likely to be key areas in which mitigation measures for impacts on herpetofauna are required. In order to design appropriate and species-specific mitigation measures, it is necessary to determine which species are at risk: an assessment of species composition (threatened species if any), relative abundance and habitat association along the road stretch must be made.

Visual encounter survey, road cruising (night driving method), tracking animal trail or signs (such as python drag marks), radio telemetry, mark-recapture studies using VIE (Visible Implant Elastomer) or PIT (Passive Integrated Transponder) tags (Heyer et al. 1994) are the most common methods to identify zones of animal activity. It is important to determine and map the ***'fatality hotspot'*** zones of movement along road stretches, to pinpoint optimum locations for mounting mitigation structures:

detailed monitoring of amphibian road kill for at least three years has been suggested as an appropriate time interval in this respect (Grossi et al. 2001). Effective mitigation measures must focus on strategies to reduce the use of roads, by providing connectivity corridors.

The following are the principal measures for reducing road-induced mortality of reptiles and amphibians.

Providing passages to retain habitat connectivity:

Movement of herpeto-fauna across linear infrastructure is often facilitated by drainage pipes, box culverts and minor bridges which often act as drainage structures associated with road construction. These ***'non-wildlife engineered'*** passages (Forman et al. 2003) exist by default, and are not constructed with the objective of facilitating wildlife movement. However, they can provide crucial connectivity to maintain the meta-population dynamics if their location corresponds with locations suitable for animal movement.

For passages to be functional and optimally used, they must be placed within the natural migration and dispersal routes of target amphibian or reptile species. Drift fencing or cemented crash barriers may be used to prevent animals from reaching the road and direct amphibians or reptiles to a safe passageway (e.g., turtles to a tunnel entrance).

Small passages of 20-25 m in length should have a diameter of at least 100 cm. Tunnels of 50 m length need to have a diameter of at least 200 cm (also see Forman et al. 2003). Reptiles particularly cross more frequently through circular structures, while rectangular or square-shaped structures are preferred by amphibians. Frogs often prefer square-shaped tunnels that are buried close to the ground surface. Box culverts of dimension 2x2 m or 2x3 m are widely used above waterways in highway construction in India. These structures can provide passageways for reptiles and frogs connecting their habitat. However, they should be designed with risen '*dry ledges*' of at least 50 cm width on each side of the central watercourse to facilitate animal movement. If roads bisect amphibian habitat and migration routes, specially designed underpasses need to be provided.

Traditional culverts and minor bridges (built on ditches, streams and rivers) can be modified to facilitate safe movement of amphibians under the highway. The position and size (length and diameter) of these structures, and the angle that they are approached by amphibians, are critical factors determining their success. If placed across peak activity zones, these passageways can help reduce impacts on habitat fragmentation significantly. Lack of light within tunnels may deter usage by amphibians (Jackson & Tyning 1989; Krikowski 1989). For this reason, larger tunnels should be designed to provide sufficient light to encourage their use (Puky 2003) by maximizing the diameter-to-length ratio of passageways to maximize light penetration and airflow. Tunnels fitted with metal grates on the top (i.e., on road surface) may act as effective small passages for amphibians. Metal grates may be installed to facilitate light and air penetration; gaps on the metal grates would help amphibians to drop down into the passage.

In dry areas, an engineering solution to maintain moisture levels in the passageways needs to be found. Where an underpass falls on a waterway or wetland, provision should be made to fence the sides of the water channel to direct animals to the safe passage.

Passageways should be designed to minimize environmental gradients. Amphibians are particularly sensitive to moisture condition and thus cement flooring of a passage may deter amphibian movement. Cement flooring is also likely to limit natural vegetation growth and may be unsuitable for cryptic animals. Passageways must provide an unbroken connection between the linked habitats: there should not be gaps in the fencing of passages, and fencing or barriers should be made of durable material.

Fencing to guide movement of amphibians:

The aim of fencing is to prevent mortality and deter herpeto-faunal movement on to roads by directing them to safe crossing points or passageways. If fencing can be erected along sufficient road lengths along *'fatality hotspots'* and is properly designed, installed and maintained, it can significantly reduce road mortality (Malt 2012).

Fencing should cover all areas where the road intersects amphibian habitat and movement routes. It should ideally be located between two underpasses so as to guide animals to safe passageways. The angle of fencing is an important aspect: if installed parallel to the road, a fence may exclude animals from the road but not direct them effectively towards passageways. An ideal design may be a zig-zag pattern, as described by Jackson and Tyning (1989). This design is likely to direct animals towards passageways at all points of contact, while simultaneously excluding animals. It is important to check if there are any holes or gaps remaining along the fence, particularly at culvert-fencing junctions, as this may reduce the effectiveness the fencing.

A 1 m-high reinforced cement concrete (RCC) wall, having an outward lip of at least 50 cm, may be constructed along two sides of the road to prevent animals from accessing it and direct them to use passageways. This RCC structure may also act as crash barrier for vehicles and would help prevent pollutants and litter from entering adjacent natural habitat (e.g., forests and streams of protected areas). If the road is built in a high-rainfall area, a small opening at the base of such structure covered with iron mesh should be provided every 10-20 m along the road to permit drainage.

Most fences act as a one-way barrier: the movement of amphibians is only prohibited in a single direction. The top of the fence should thus curve away from the highway, in order to prevent tree frogs from climbing over (Puky 2003). Fences should be at least 50 cm high. However, in case of fencing for both reptiles and amphibians it needs to be at least 80 cm high above ground and 20 cm below ground.

Measures to reduce impacts on breeding success of amphibians:

Protection of breeding sites of amphibians is of the utmost importance in the planning of linear developments, especially transportation corridors. Specific measures of protect the breeding sites of amphibians that fall within highway corridors are given below:

- The availability of amphibian breeding areas (e.g., streams, ponds, lakes, wetlands) along the proposed corridor must be mapped using GIS.
- Roads should be located at a distance of at least 1 km away from amphibian breeding sites: although limited data is available on amphibian movement, most native species are likely to move less than a kilometre during dispersal or migration.
- Construction of new amphibian breeding sites or ponds, or restoration of habitat in previously used but degraded breeding sites, could be valuable mitigation measures which help to link populations.
- Pond design should take into account measures to assist in the long-term management of amphibians. Studies should be undertaken to determine the number, size and type of breeding sites that will be needed to provide effective mitigation.
- The design of breeding pond may vary according to the particular biological requirements of targeted species or amphibian assemblages. The exact size and shape of breeding ponds should be designed in consultation with amphibian experts.
- If new breeding ponds are located close to the road, care should be taken to separate their catchment from the road drainage system, to avoid pollution.
- Management of breeding ponds may include the removal of extensive growths of aquatic vegetation and the removal of predatory fish.

Traffic noise is known to interfere with noise perception in amphibians (Parris et al. 2009). If a road is planned to pass through a forest, mitigation measures should include the construction of noise barriers along the length of forested sections of road. The barriers should be made of synthetic fibre (A) of height 1.5 m, and may also be constructed on the rigid crash barrier on either side of the highway.

Measures to reduce use of road surfaces by snakes for thermoregulation:

Thermoregulation has been found to be the primary factor influencing the number of snakes on roads or the time spent on the road surface (Brattstrom 1965; Moore 1978; Sullivan 1981; Bemardino & Dalrymple 1992; Ashley & Robinson 1996). Pragatheesh and Rajvanshi (2013) thus recommend placing strips of different surfaces that may be attractive to thermoregulating snakes next to the road in areas known to have high mortality, and testing their effectiveness in diverting snakes from the road surface. Results and practical application of these trials should significantly reduce the mortality of snakes of high conservation importance, including the Indian rock python and Russell's viper.

Measures to facilitate turtle movement across roads:

Turtles exemplify the types of species least able to disperse across roads. Breeding female turtles are the most likely portion of the population to be killed by turtle-vehicle collisions (Langen 2011). These deaths are extremely detrimental to turtle populations and can, in some cases, cause a total collapse of a given population due to the loss of breeding-aged females and lack of recruitment. Installation of temporary exclusion fencing to direct turtles and other small animals to an existing culvert can be an effective measure to prevent turtle mortality and facilitate their safe passage across roads to seasonally available habitat. Fencing should be carefully designed, located, installed, and maintained to reduce turtle mortality rates.

5.8 Retrofitting of Existing Structures to Function as Wildlife Crossing Structures

Existing structures such as bridges, culverts and other drainage structures can modified to enable animals to use them for passage across highways. This modification is a cost-effective measure for mitigating impacts of highways where no new mitigation structures are proposed.

The following points should be kept in mind while retrofitting existing structures:

- Animals' responses to retrofitted structures may vary; some animals/taxa, for example elephants, may have special requirements that may not be fulfilled through retrofitting.
- For drainage structures that are inundated seasonally or perennially, shelves made of wood or boulders can be installed to allow movement of animals
- If a structure is not already being used, the approach to the structure and nearby vegetation may be altered, and human-related disturbance may be reduced, to attract animals to it and encourage its use.
- Structures that are too old, long or curved, or have other negative issues such as too much disturbance or land ownership conflict, may not be considered suitable for retrofitting.
- Wildlife fencing could be installed near these structures to funnel animals towards these passages.
- Placement of natural elements such as boulders and logs would make the structure appear more natural to the target animals.

5.9 Implementation and Follow-up of Measures

Rigorous and timely implementation of the mitigation measures described in previous sections, giving due consideration to the design specifications and particular features required, is crucial for minimizing the impacts of roads and railways on wildlife. Scientists, wildlife managers and engineers should all be involved in supervising the execution of mitigation measures during construction, to ensure that the design and structures proposed in the plan are faithfully implemented.

Gilbert et al. (2015) underlines the importance of assessing the effectiveness of mitigation measures that have been implemented, and adjusting them to improve their performance and/or replicating effective measure in other areas to minimize animal mortality.

Four follow-up methods are commonly used:

- *'Before and after impact control'* studies to examine change in animal abundance on roads.
- Use of radio telemetry to examine animal movements around roads.
- Evaluation of the willingness of animals to utilize passageways.
- Monitoring of passages using remote cameras and mark-recapture studies. Camera traps may also be used to check the utilization of passageways by wild animals during the operational phase of a project.

Mitigation measures found to be effective in reducing animal mortality may be replicated in other areas to minimize the impact of vehicular on wildlife.

5.10 Non-Structural Measures for Reducing Mortality: Signage and Warning Systems

The purpose of animal warning signs and detection systems is to prevent or reduce the number of Animal-Vehicle Collisions (AVCs). Animal Detection Systems (ADS) detect large animals before they enter the road or rail corridor to alert drivers of their presence and warn drivers of collision risk.

5.10.1 Signage

Signs warning of wildlife are put up a long stretch of roads where animals are known to occur or use local habitat, to caution drivers about the potential presence of animals. All warning signs can be grouped into the following five categories (Mastro et al. 2008):

1. Caution Sign: Simple caution signs are commonly used to alert drivers to the presence of wildlife crossing zones. In India, the most common caution signs are simple warning signs with silhouettes of the animal that may be using the crossing, sometimes together with a prescribed speed limit or written message.

2. Enhanced Caution Signs: Many caution signs are enhanced by adding words like ***'Deer Xing'*** or illuminated with reflective tape, in addition to silhouettes of animals. Although multiple studies have noted that caution signs and enhanced caution signs are 50 common that motorists tend to ignore them, surveys also show that most motorists (76%) said that caution signs increased their alertness (Stout et al. 1993).

3. Temporary wildlife signs: These signs may be put up to warn drivers of wildlife presence during specific times of the day or year: e.g., during animal migration or active and/or breeding periods of amphibians and reptiles.

4. Dynamic message signs: These electronic signs can be used to alert motorists of the presence of wild animals, or in areas of high AVCs. These signs are most effective at night when most AVCs occur.



Figure-38: Red table-top markings in Balance 11.96 Km. stretch (New NH-45) in Nauradehi Wildlife Sanctuary area, Hiran River to Sindooer River section, in Madhya Pradesh.

Red **speed-calming pavement markings** have been introduced along the **balance stretch on New NH-45** passing through the **Nauradehi Wildlife Sanctuary**, particularly in the section between the **Hiran River** and **Sindoor River** in **Madhya Pradesh**.

The **distinct red markings on the carriageway act as visual traffic-calming measures**, alerting motorists that they are entering an ecologically sensitive wildlife zone. This intervention is intended to **encourage speed reduction, enhance driver attentiveness, and minimize the risk of wildlife–vehicle collisions**, thereby supporting safer passage for wildlife while maintaining road safety along the corridor.



Figure-39: Signage- Four laning of the Mancherial to Repallewada section of NH-363 in Telangana

5. Posters and billboards: Posters and roadside billboards are put up on highways as part of programmes and campaigns to reduce animal mortalities due to collisions with vehicles. They also help to generate awareness of this issue among the public.

Factors influencing the effectiveness of these signs are listed below:

- Animal detection systems are best installed at locations that have a history of AVCs, especially involving large mammals such as elephant, rhinoceros or gaur and where animals are known to pass frequently: daily or seasonally.
- The distance between signs and the frequency of these signs should be decided according to the occurrence of AVCs in particular stretches of roads: the higher the incidence of AVCs, the greater the signage.
- Roadside vegetation should be cleared, especially near curves and embankments, to make the signs visible to motorists and train drivers.
- The size, shape, colour and material (reflective, non-reflective) of signs should be chosen to make the signs most effective.
- Signs that highlight the conservation importance of the site through which the transportation corridor passes, such as World Heritage Site or National Park can help garner support for reducing traffic speed and increased awareness of drivers, thereby helping to protect several threatened species.

5.10.2 Warning Systems

Animal Detection Systems (ADS) are roadside wildlife detection systems that use radar and lasers to flash warning signs to alert motorists, preventing collisions between wild animals and motorists. They may be of different types, as described below:

1. Area Cover Systems: Detect large animals within a certain range of a sensor

- **Active Systems:** Detect animals by measuring reflected signals (e.g., microwave radar)
- **Passive Systems:** Detect animals only by receiving signals (e.g., passive infra-red & video detection)

2. Break the Beam Systems: Detect large animals when their bodies block or reduce a beam of radio signals from transmitter to receiver.

3. Other Systems: Systems dependent on radio-collared animals, receivers placed in Right of Way, seismic sensors for large animals.

Multiple factors influencing the effectiveness of ADSs:

- Road characteristics: ADSs are usually not effective on wide roads or on roads with roadside vegetation that impedes operation of the sensors. They are also not effective on high-speed roads as well as high-traffic roads.
- **Siting and spacing of the ADS:** The ADS should be located at a site where a relatively large number of AVCs have taken place in the past, or at locations where animals are known to cross a road or railway line (for daily movement or seasonal migration). The gap between two adjacent sensors should be determined according to the range of the sensors, location of wildlife fences and local conditions.
- The ADS site should allow for solar power or connection to a power source, and should have low risk of theft and vandalism.
- ADS systems are known to give *'false positives'* or exaggerated signals: sensors may be triggered by falling leaves or by each and every individual of a herd of animals. Clearing all vegetation from the site of ADS installation would avoid 'false positives' caused by moving leaves.
- ADS sensors should not be placed on ***'blind spots'*** such as near or on curves, or slopes.

5.11 Measures for Noise Attenuation

Wild animals rely on sound for effective navigation, intra- and inter-specific communication, avoiding danger and finding food for survival. Excessive noise caused by engines and emission of exhaust, aerodynamic sources, and tyre/pavement interactions have multiple effects on ecosystems. Roads and traffic alter the physical and acoustic environment of species and ecological communities, both during construction and when a road is open to traffic. While the construction-related noise produced during earthworks, pile driving and road surfacing is usually of limited duration, the traffic-induced noise persists over time.

Noise may interfere with the acoustic signals that are used by various species for navigation, maintaining or establishing contact with members of a family or larger social group. Signals convey many types of messages, including distress or danger, the presence of food, and extent of territory (Fletcher & Busnel 1978). Noise may harm not only individual species, but it may also alter species' relationships, as in the case of song birds that depend on acoustics for defending territories, attracting mates, begging for food (by fledglings in a nest), and alarm calling (Slabbekoorn & Halfwerk 2009). Anthropogenic noise pollution is one of many factors contributing to the depletion of wildlife populations. Limited studies in India indicate a lower abundance and variability of birds in forests affected by air and noise pollution than in non- polluted forest in the same bio-geographic zone (Saha & Padhy 2011).

Laboratory experiments and field studies have suggested that wildlife is adversely impacted by noise pollution in the following four ways:

- Hearing loss, resulting from noise levels of 85 decibels dB(A) or greater.
- *'Masking'*, which is the inability to hear important environmental cues and animal signals because of other background noise (Warren et al. 2006).
- Non-auditory physiological effects, such as increased heart rate and respiration, and general stress reaction (Francis et.al. 2009).
- Behavioural effects, which vary greatly between species and according to the characteristics of the noise, resulting in, for example, abandonment of territory and failed reproduction (Barber et.al. 2009).

Although the generally accepted definition of *'excessive noise'* is an increase of 10 dB(A) or greater, the sensitivity of different groups of wildlife varies. According to the US Department of Transportation, Federal Highway Administration (https://www.fhwa.dot.gov/), they can be summarized as:

- Mammals: < 10 Hz to 150 kHz; sensitivity to -20 dB(A).
- Birds (more uniform than mammals): 100 Hz to 8-10 kHz; sensitivity at 0-10 dB(A).
- Reptiles (poorer than birds): 50 Hz to 2 kHz; sensitivity at 40-50 dB(A).
- Amphibians: 100 Hz to 2 kHz; sensitivity from 10-60 dB(A).

The Government of India, through the Noise Pollution Regulation and Control Rules (2000), prescribes ambient air quality standards. It directs State Governments to categorize areas into *'industrial', 'commercial', 'residential'* or *'silence'* areas or zones for the purpose of implementing noise standards for different areas.

Table-8: Ambient Noise Standards

Area Code	Category of area zone	Limits in dB(A)	
		Day time	Night time
(A)	Industrial area	75	70
(B)	Commercial area	65	55
(C)	Residential area	55	45
(D)	Silence zone	50	40

Source: (ref: S.0.123 (E), [14/2/2000] - Noise Pollution (Regulation and Control) Rules, 2000; website: 'http:/www.moef nic.in/noise pollution)

Noise pollution control and abatement is, therefore, a mandatory activity, especially when designing and planning a roadway project. Attenuation or reduction in noise due to vehicular traffic can be achieved by the use of noise barriers, limitation of vehicle speeds, alteration of roadway surface texture, limitation of heavy vehicles, use of traffic controls that smooth vehicle flow to reduce braking and acceleration, and tyre design. Costs of incorporating mitigation measures can be significantly reduced if the solutions are planned in the early scoping or planning stages of a roadway project.

Noise may reduce the effectiveness of mitigation measures installed on roads to reduce the fragmentation and isolation of wildlife populations. It is therefore important to implement measures to reduce noise that has the potential to disturb human beings and wild animals.

Noise Attenuation Structures or Noise Barriers:

Noise barriers are the most commonly used form of noise abatement. On roads and highways, noise barriers (sometimes referred to as noise walls or sound walls) are intended to block or reduce highway noise from reaching and affecting activities near the highway. They do this primarily by blocking the direct path that sound must travel between the source of sound on the highway and the receiver exposed to the sound. Effective noise barriers can reduce noise levels by 10 dB(A), cutting the loudness of traffic noise by half.

Factors Influencing Design of Noise barriers:

Design of a noise barrier begins with the determination of its height and location relative to the roadway. These parameters are dictated by acoustical requirements, and are determined by the environmental engineer. Once these parameters have been determined, the structural design of the sound wall can proceed. The structural design of sound walls was principally controlled by the following factors: aesthetics, cost, maintenance, local influences, and structural constraints. In addition to the structural factors mentioned above, several other factors influence the final design of sound walls. These include drainage, landscape, road access, vehicular impact, foundations, environmental impact, community impact, sight distance, right-of-way width, and soil conditions.

Table-9: Types of Noise Barriers commonly used in Road Projects

Type	Construction details	Aesthetics	Drainage, Utility and Safety	Cost and Maintenance
Ground mounted noise walls				
1.Noise berm	Constructed from natural earth materials such as soil, stone, rock, rubble, etc. in a natural, unsupported condition.	High appeal and natural.	May obstruct natural drainage channels and cause localized flooding. Safe, although occupies more space than a wall-type barrier. Height may be a consideration in significantly reducing the noise levels.	Low costs, if raw material is available on site for construction and repairs.
2. Post and panel noise wall	Consists of noise barrier panels mounted between foundation-supported posts.	Colour and material for the pre-fabricated structures may be chosen to blend with the surrounding landscape.	Side drains are usually provided. May have weight and size limitations.	Installation costs are higher than overall maintenance costs. Replacement of barrier elements may be required throughout the life of the noise barrier; availability of replacement parts becomes a critical issue.
3. Free-standing noise wall	Includes barriers which support themselves using *'zig-zag'* configuration or compacted soil and a well-drained stone base, a plain cement-concrete levelling pad,	Wider aesthetic appeal and variability, as can be adapted to suit various soil types and landscapes.	Side drains are usually provided.	High installation costs.

	or a continuous reinforced concrete footing. Includes three types: precast concrete, planted or *'bin'* types, and stone crib.			
4. Direct burial panel	Involves burying a portion of one end of the panel (either precast concrete or wood) directly into the ground with no other means of foundation support.	A is unique architectural design obtained due to the 'tongue and groove' design	Differential settlement may not be of even throughout the length each panel, thus causing tilting and separating of the panels.	High installation costs
5. Cast-in-place concrete noise walls	Constructed at the project site, includes excavating for the footing, erecting form work, setting reinforcement steel, pouring concrete, surface finishing, & curing.	Less appealing as Surface textures obtained through raking, brushing, or stamping of concrete are not possible	Higher safety standards are achieved	High installation costs
6. Combination noise berm and noise wall systems.	Consist of a portion of the barrier height obtained through use of an earth berm with the remainder of the required height achieved by placing a noise wall on top of the berm. The foundation, post, and panel considerations for these wall portions are similar to those of original structures.	Limited aesthetic appeal	May obstruct natural drainage channels and cause localized flooding. Safe, although occupies more space than a wall-type barrier. Height may be a consideration in significantly reducing the noise levels.	High installation costs

Structure-mounted noise walls				
7. Structure-mounted noise walls	Noise walls used on structures, especially on bridges and retaining walls.	May block the 'view' although may be useful for privacy to settlement areas.	Normal safety standards are achieved if maintained properly.	Require additional costs of structural modifications on existing bridges and retaining walls. Overall considerations include maintenance, protection of traffic (both on and beneath bridge), accessibility to areas require modifications, bridge vibrations due to existing traffic, from construction operations, and potential environmental mitigation measures (e.g., related to painting beams or working over waterways or wetland areas).

Source: Mathur, V. B., & Rajvanshi, A. (2016) in WII Publication.

Other Considerations:

i) Material types in noise barriers:

Highway agencies like NHAI normally make this selection based on a number of factors such as aesthetics, durability, maintenance requirements, cost, public views, etc. The material chosen should be rigid and of sufficient density (approximately 1.8 kg/0.1 m3 minimum) to provide a loss of 20 dB(A) greater than the expected reduction in the noise diffracted aver the top of the barrier (Anon. 2011).

ii) Use of vegetation as a noise barrier:

Vegetation, if it is high enough, wide enough, dense enough and opaque, may reduce highway traffic noise. Approximately 60 m width of dense vegetation can reduce noise by 10 dB(A); it is usually impossible, however, to plant enough vegetation along a road to achieve such reductions. It would be ideal to create noise buffers using a diversity of tree species, with a range of foliage shapes and sizes: a combination of shrubs and trees may be necessary to achieve this effect. Evergreen species that could provide a year-round buffer would be desirable.

iii) Height of a noise barrier:

To produce at least 5 dB(A) reduction, a barrier must be tall enough (and long enough) to block the line of sight between a source and a receiver. If a barrier is too short, or if there are gaps between barriers, the noise can travel around the end of the barrier wall, reducing its effectiveness. Provided that sufficient barrier segments are installed, the noise barrier can achieve 2 5 dB(A) reduction, even with gaps between segments. Computer-generated models should preferably be used to determine the optimum overall barrier dimensions.

iv) Noise barriers and neighbourhood planning:

Project design engineers should be involved in decisions on the optimum locations of noise barriers: they should be asked for input regarding sight distance requirements, right-of-way issues, utility easements, and foundation requirements. Noise barriers should not cause any displacement or relocation of receivers. It is normally not cost- effective to build a noise barrier for a single receiver. Large gaps for driveways and alleys entering onto a roadway greatly reduce the effectiveness of a barrier. Access streets should not be closed to eliminate large gaps in a noise barrier and thereby enhance its effectiveness, unless requested and approved by local government officials.

v) Noise barriers on hilly, elevated, or depressed sites:

Noise barriers are normally not effective for receivers on a hillside, overlooking the highway, or for receivers at heights above the top of the noise barrier. Depressed and elevated roadways normally result in somewhat lower noise levels (3—5 dB(A)), potentially eliminating the need for a noise barrier or requiring a lower barrier than would otherwise be the case.

vi) Effects of holes and surface texture:

Small gaps and drainage holes (less than 3% of the total surface area) do not significantly reduce a noise barrier's overall acoustical effectiveness. The surface roughness of a barrier matters only if it is of the same order of magnitude as the wavelength of sound that the barrier is intended to attenuate. Because the wavelength of 100 Hz sound is around 3 m, ordinary surface roughness has little effect.

vii) Multiple-reflection issues:

Multiple reflections of traffic noise between two parallel plane surfaces, such as noise barriers or retaining walls on both sides of a highway, can theoretically reduce the effectiveness of individual barriers and contribute to overall noise levels. During the preliminary design of noise barriers, the possible influence of parallel reflections should be checked.

viii) Effects of absorptive materials:

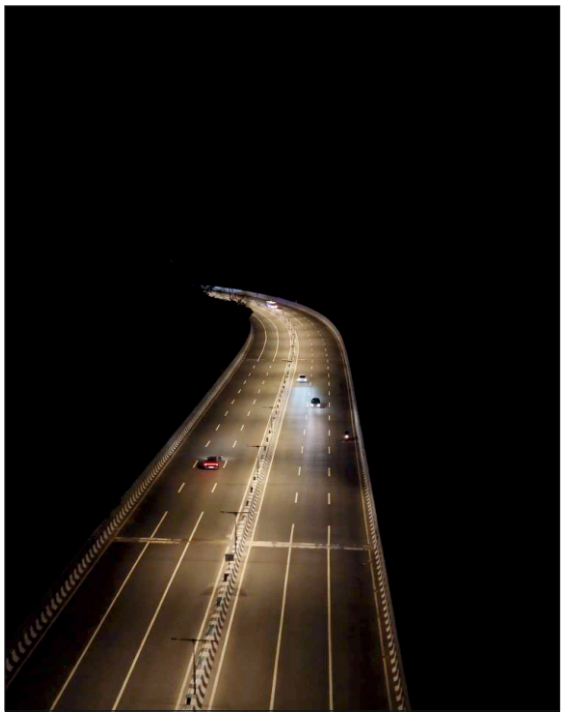
Constructing barriers using sound-absorptive materials significantly reduces the noise level experienced by drivers on the roadway. It does not significantly reduce the noise level away from the highway, except when the highway has barriers on both sides.








AUGUST
2020



Chapter 6: NHAI's Wildlife Mitigation Initiatives

NHAI through meticulous planning integrates wildlife mitigation structures and measures while undertaking construction of highway projects to ensure that infrastructure development proceeds in harmony with ecological conservation and statutory requirements. As the national highways at times traverse forest areas, protected landscapes, and identified wildlife corridors, this has a potential to fragment habitats, disrupt animal movement, and increase wildlife–vehicle collisions, posing risks to both biodiversity and public safety.

In compliance with the Wildlife (Protection) Act, 1972, Van (Sanrakshan Evam Samvardhan Adhiniyam), 1980, and Environmental Impact Assessment (EIA) framework, under Environment (Protection) Act, 1986 NHAI incorporates scientifically designed mitigation measures such as viaducts, animal underpasses, box culverts, fencing, reptile crossings to guide animal movement, and traffic calming mechanisms in sensitive stretches. These interventions are planned at the DPR stage in consultation with expert institutions like WII, ZSI and the Wildlife Wing of the State Forest Departments. By adopting such measures, NHAI not only fulfills regulatory mandates but also promotes sustainable, environmentally responsible, and safety-oriented highway development aligned with national conservation goals.

The wildlife mitigation measures proposed for the project comprise a combination of structural and non-structural interventions designed to address site-specific ecological sensitivities and movement requirements of fauna. These measures are intended to ensure functional connectivity across the highway corridor while minimizing wildlife–vehicle interactions and associated risks. The key components of the mitigation measures are summarized in the table below:

Table-10: Components of Wildlife Mitigation Measures and Structures

Category	Mitigation Measure
Structural measures	Viaduct
	Animal Underpass
	Elephant Underpass
	Tiger Underpass
	Box Culvert
	Pipe Culvert
	Slab Culvert
	Animal Overpass
	Elephant Overpass
	Tiger Overpass

	Eco-Duct/ Land Bridge
	Tunnel
	Minor Bridge cum AUP
	Major Bridge cum AUP
	Canopy Bridge/ Monkey Ladder
Category	**Mitigation Measure**
Non-Structural measures	Noise Barrier/ Fencing
	Reptile Crossing
	Watch Tower
	Salt Licks
	Water Holes
	Signage and Warning Signs
	Plantation

Regional Office Bengaluru

During the past five years, RO Bengaluru has implemented/implementing wildlife mitigation measures across '11' National Highway projects passing through forest and protected areas in Karnataka. These projects incorporate structures such as viaducts, animal underpasses, and overpasses, along with provisions aligned with statutory approvals and Environmental Management Plans. These measures aim to facilitate safe animal movement and minimize wildlife–vehicle conflicts.

Table-11: RO Bengaluru - Number of Structures and Expenditure incurred on Mitigation

S. No	Name of the item	No. of Structures	Expenditure (in Crore)
1.	Viaduct	1	894
2.	Animal Under Pass	385	277.43
3.	Animal Over Pass	9	69.38
4.	Minor bridge cum AUP	32	30.96
5.	Major bridge cum AUP	2	0.65
6.	Noise barrier/ fencing (km)	13.02	8.64
7.	Monkey Ladder	9	0.18
8.	Any other Structures and measures	9	4.05
Total (in Crore)			**1285.29**

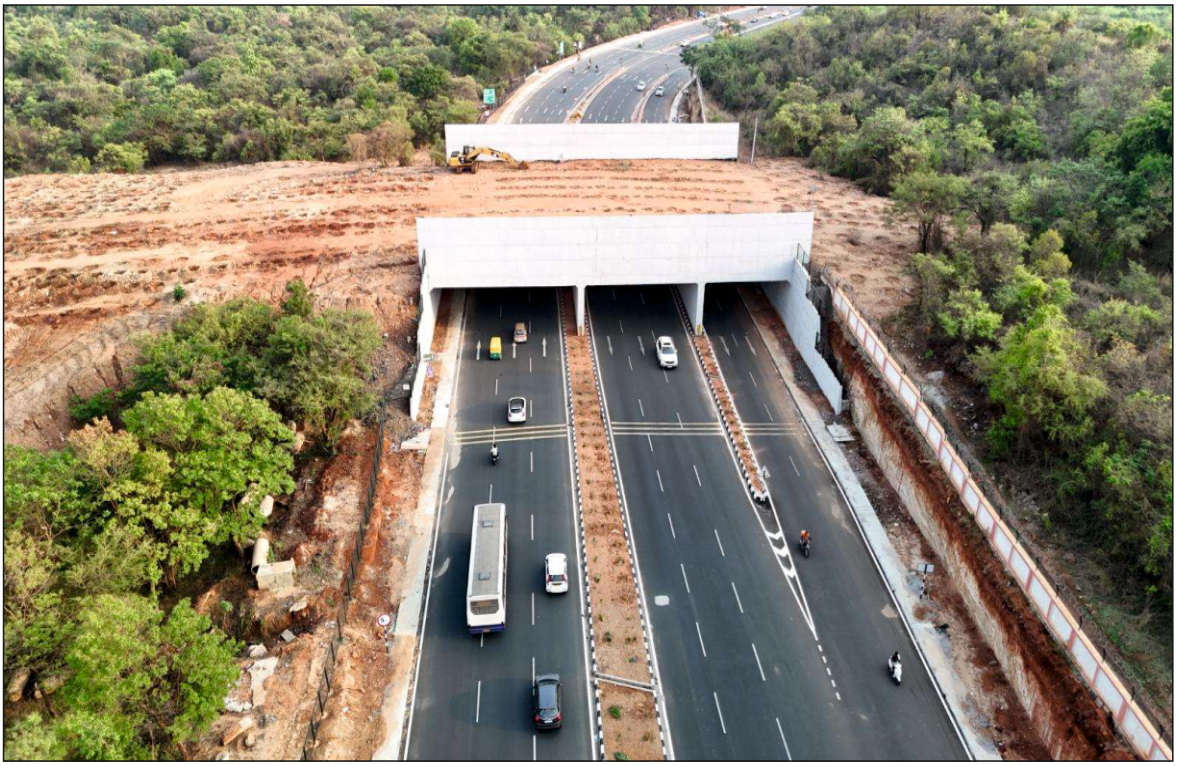


Figure-40: Elephant Overpass in Rectification of black spot near Agara-Tataguni cross of NH-209 including EOP.

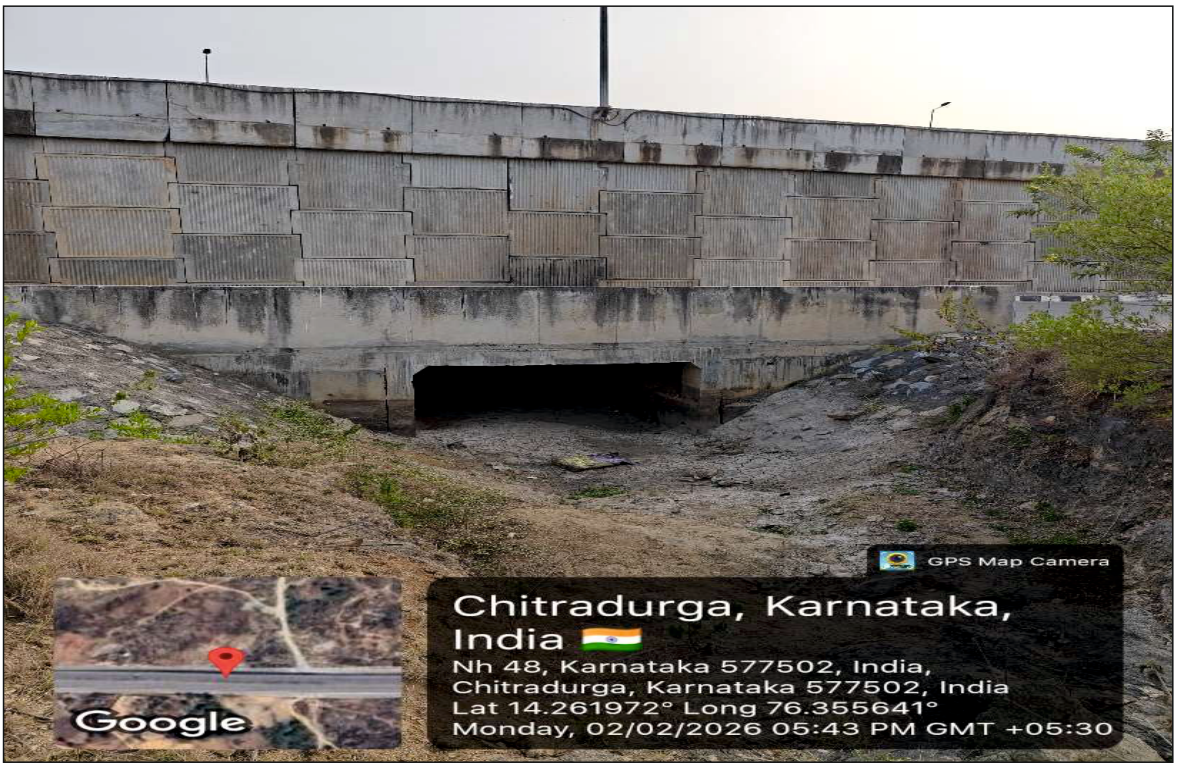


Figure-41: Box Culvert in Chitradurga to Davanagere (CHPL) NH-48.

Regional Office Bhopal

RO Bhopal has undertaken/undertaking wildlife mitigation initiatives across 09 National Highway projects passing through forested and ecologically sensitive regions of Madhya Pradesh over the last five years. The projects incorporate measures such as wildlife underpasses, channelizing fencing, and bridges, designed in compliance with clearance conditions to facilitate safe animal movement and reduce habitat fragmentation.

Table-12: RO Bhopal - Number of Structures and Expenditure incurred on Mitigation

S. No	Name of the item	No. of Structures	Expenditure (in Crore)
1.	Animal Under Pass	195	860.54
2.	Animal Over Pass	5	16.83
3.	Minor bridge cum AUP	6	0.83
4.	Major bridge cum AUP	8	1076.03
5.	Noise barrier/ fencing (km)	55.264	46.09
Total (in Crore)			**2000.32**



Figure-42: AUP at Four laning of Ratapani stretch of Obedullaganj-Itarsi section of NH-46 in M.P.



Figure-43: Animal Overpass in Temagaon-Chhicholi, PKg-2 (Harda-Betul, NH-47)



Figure-44: AUP in Delinked Stretch of Seoni - MP/MH Border (MP 3) 6101/ 4 Laning of Seoni - MP/MH Border of NH-7 in MP

Regional Office Bhubaneswar

Over the past five years, RO Bhubaneswar has implemented/implementing wildlife mitigation measures in 13 National Highway projects passing through forested and environmentally sensitive areas of Odisha. The initiatives include the construction of viaducts and tunnels to reduce surface disturbance, development of animal underpasses and overpasses to maintain habitat connectivity, installation of noise barriers and continuous fencing to guide and safeguard wildlife, and provision of monkey canopy crossings to support arboreal movement, in accordance with statutory requirements.

Table-13: RO Bhubaneswar - Number of Structures and Expenditure incurred on Mitigation

S. No	Name of the item	No. of Structures	Expenditure (in Crore)
1.	Viaduct	27	976.97
2.	Animal Under Pass	488	1262.51
3.	Animal Over Pass	4	17.20
4.	Tunnel	2	1139.51
5.	Minor bridge cum AUP	81	393.91
6.	Major bridge cum AUP	21	273.48
7.	Noise barrier/ fencing (km)	21.52	22.76
8.	Monkey Canopy	22	8.01
Total (in Crore)			**4094.35**



Figure-45: AUP in 6L Greenfield Badakumari to Karki section of NH-130CD Road under Raipur-Visakhapatnam Economic Corridor in Odisha (Package OD-3)



Figure-46: Monkey Canopy in 6L Greenfield Badakumari to Karki section of NH-130CD Road under Raipur-Visakhapatnam Economic Corridor in Odisha (Package OD-3)

Regional Office Chandigarh (PB)

In the recent five-year period, RO Chandigarh (Punjab) has focused on embedding wildlife protection components within 03 National Highway projects of the State. RO has facilitated the incorporation of animal underpasses, bridge-cum-wildlife crossings etc., as part of project execution. These interventions have been undertaken in adherence to clearance stipulations and in coordination with the State Forest Department to preserve ecological continuity and reduce potential wildlife–vehicle collision along highway corridors.

Table-14: RO Chandigarh (PB) - Number of Structures and Expenditure incurred on Mitigation

S. No	Name of the item	No. of Structures	Expenditure (in Crore)
1.	Animal Under Pass	1	0.96
2.	Minor bridge cum AUP	1	1.8
3.	Major bridge cum AUP	5	866.17
4.	Any other Structures and measures		16.18
Total (in Crore)			**885.11**



Figure-47: Animal Under Pass- Four laning from Malout via Abohar to Sadhuwali of NH-62) in Punjab

Regional Office Chandigarh (HR)

RO Chandigarh (HR) incorporated a dedicated wildlife mitigation intervention in 01 National Highway project during the FY 2019-20 through the construction of an Animal Underpass (AUP) along a forest-influenced stretch. The structure was integrated into the project framework as part of environmental management provisions to reduce the risk of wildlife and to support compliance with stipulated environmental and forest clearance conditions.

Table-15: RO Chandigarh (HR) - Number of Structures and Expenditure incurred on Mitigation

S. No	Name of the item	No. of Structures	Expenditure (in Crore)
1.	Animal Over Pass	2	1.32
Total (in Crore)			**1.32**



Figure-48: Animal Overpass- 4L Yamunanagar Panchkula PKG 3 section of NH-07

Regional Office Chennai

Over the past five years, RO Chennai has incorporated/incorporating wildlife mitigation measures in 05 National Highway projects traversing forest stretches and eco-sensitive areas of Tamil Nadu. The interventions include provision of animal underpasses, watch tower, RWH cum water holes etc., these measures have been integrated into project planning and implementation to address site-specific ecological sensitivities and to ensure adherence to approved Environmental Management Plans.

Table-16: RO Chennai - Number of Structures and Expenditure incurred on Mitigation

S. No	Name of the item	No. of Structures	Expenditure (in Crore)
1.	Animal Under Pass	2	69.52
2.	Animal Over Pass	1	8.83
3.	Watch Tower	3	0.27
4.	RWH cum water holes	45	3.01
5.	Any other Structures and measures		12.01
Total (in Crore)			**93.64**



Figure-49: Steel Wire Rope Fence in Sanamavu in Thorapalli Agraharam - Jittandahalli Section of NH-844



Figure-50: Steel Wire Rope Fence in Sanamavu in Thorapalli Agraharam - Jittandahalli Section of NH-844



Figure-51: Wildlife Signage Board- Improving the Alignment of Thoppur Ghat Section in Dharmapuri - Salem Section of NH-44



Figure-52: Animal Over Pass in Bengaluru Chennai Expressway



Figure-53: Hanging Solar Fence in Sanamavu RF-Thorapalli Agraharam - Jittandahalli section of NH-844.

Regional Office Dehradun

Over the past five years, RO Dehradun has integrated wildlife considerations into 8 National Highway projects situated in the forested and hilly regions of Uttarakhand. Of these, 4 projects have been completed, while the remaining 4 are under construction. The initiatives include the development of animal underpasses and bridge-integrated crossings, along with the installation of protective fencing and monkey canopy crossings. These measures have been incorporated in line with site-specific environmental requirements and statutory approvals, ensuring that project implementation remains consistent with ecological safeguards for sensitive Himalayan corridors.

Table-17: RO Dehradun - Number of Structures and Expenditure incurred on Mitigation

S. No	Name of the item	No. of Structures	Expenditure (in Crore)
1.	Viaduct	3	1193.11
2.	Animal Under Pass	14	202.55
3.	Tunnel	1	65.24
4.	Minor bridge cum AUP	19	17.97
5.	Major bridge cum AUP	6	77.82
6.	Noise barrier/ fencing (km)	49.566	16.75
7.	Reptile Crossing	22	25.96
8.	Watch Tower	7	0.55
9.	Salt Licks	17	0.55
10.	Monkey Canopy	28	2.71
Total (in Crore)			**1603.21**



Figure-54: Noise Barrier in Ganeshpur DDN Project-Pkg.1



Figure-55: Elephant Underpass in Balance work of 4-laning of Haridwar – Dehradun Section of NH-72

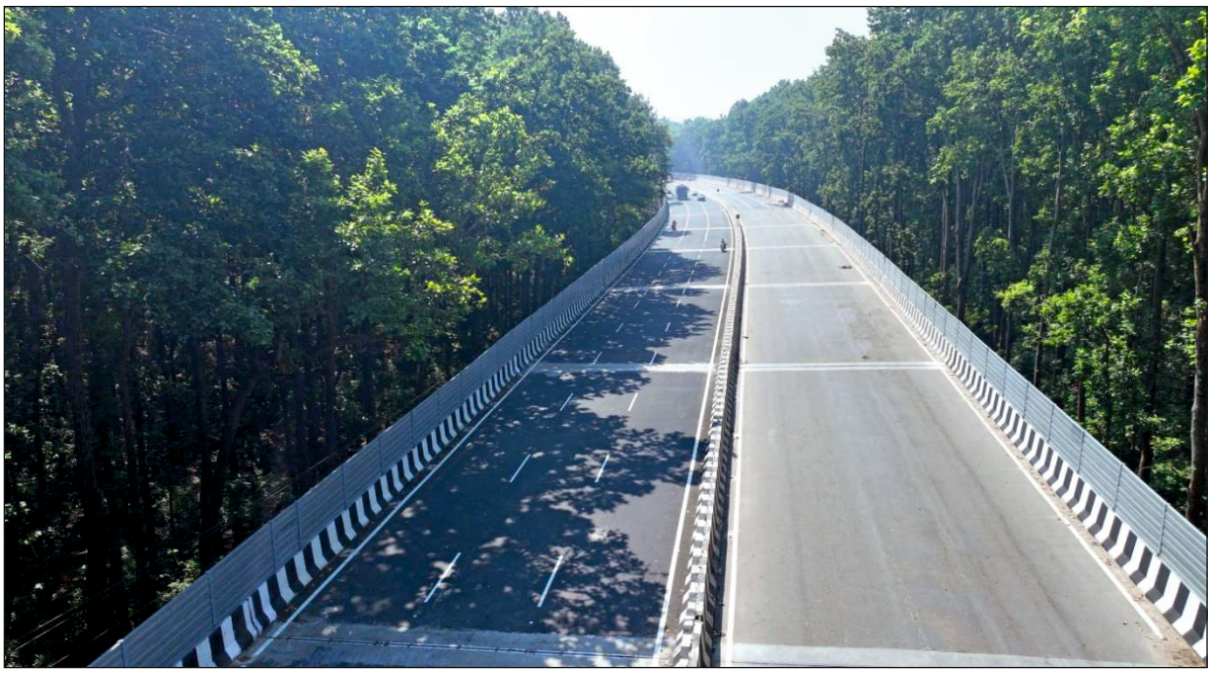


Figure-56: EUP cum Noise Barrier in Ganeshpur DDN Project-Pkg.3

Regional Office Delhi

RO Delhi is implementing wildlife mitigation measures in one National Highway project, which is currently under construction. The project incorporates structures such as a viaduct, animal underpass, and noise barriers to address environmental sensitivities along the corridor. These provisions are being integrated as part of the approved environmental safeguards to facilitate safe wildlife movement, minimize disturbance, and ensure compliance with stipulated clearance conditions.

Table-18: RO Delhi - Number of Structures and Expenditure incurred on Mitigation

S. No	Name of the item	No. of Structures	Expenditure (in Crore)
1.	Viaduct	1	3.55
2.	Animal Under Pass	2	1.42
3.	Noise barrier/ fencing (km)	1.4	0.45
Total (in Crore)			**5.42**

Regional Office Gandhinagar

Under RO Gandhinagar, one National Highway project is incorporating wildlife-oriented interventions such as an Animal Underpass (AUP) and Rainwater Harvesting (RWH) structures integrated with water holes to support ecological sustainability along the project corridor, which is currently under construction. These measures are being embedded into the project design to facilitate safe faunal movement and enhance water availability for wildlife, while ensuring adherence to applicable environmental clearance conditions and management provisions.

Table-19: RO Gandhinagar - Number of Structures and Expenditure incurred on Mitigation

S. No	Name of the item	No. of Structures	Expenditure (in Crore)
1.	Animal Under Pass	23	23.48
2.	RWH cum water holes		0.57
3.	Any other Structures and measures		3.77
Total (in Crore)			**27.82**

Regional Office Guwahati

RO Guwahati is incorporating wildlife mitigation provisions in 02 National Highway projects traversing ecologically sensitive and forested corridors of the North-Eastern region, wherein 1 project is under construction and 1 project is currently in the initial proposal phase. The measures include construction of animal underpasses, integration of wildlife-friendly bridge structures. These interventions are being embedded at the planning stage to address regional biodiversity concerns and ensure adherence to prescribed environmental safeguards.

Table-20: RO Guwahati - Number of Structures and Expenditure incurred on Mitigation

S. No	Name of the item	No. of Structures	Expenditure (in Crore)
1.	Viaduct	1	3218.09
2.	Animal Under Pass	6	7.0
3.	Major bridge cum AUP	2	118.00
Total (in Crore)			**3343.09**

Regional Office Hyderabad

Over the past five years, RO Hyderabad has undertaken wildlife mitigation interventions across 4 National Highway projects. Of these, 2 projects have been completed and the remaining 2 are under construction. The projects align design and execution with statutory environmental provisions through the inclusion of designated wildlife crossing structures and protective fencing to address biodiversity considerations within project influence zones.

Table-21: RO Hyderabad - Number of Structures and Expenditure incurred on Mitigation

S. No	Name of the item	No. of Structures	Expenditure (in Crore)
1.	Animal Under Pass	5	25.26
2.	Animal Over Pass	1	23.80
3.	Minor bridge cum AUP	6	1.75
4.	Noise barrier/ fencing (km)	8.842	1.87
Total (in Crore)			**52.68**



Figure-57: Animal Overpass in Four Laning of NH-363 from Repallewada to TS/ MH Border in Telangana



Figure-58: AUP in Four Laning of NH-363 from Repallewada to TS/ MH Border in Telangana



Figure-59: Box Culvert in 4 Laning of Sangareddy- Nanded- Akola of NH-161 Section



Figure-60: Box Culvert in 4 Laning of Sangareddy- Nanded- Akola of NH-161 Section

Regional Office Jaipur

Recognizing the ecological sensitivity of certain corridors, RO Jaipur has adopted wildlife-friendly engineering solutions in 3 National Highway projects. Among these, 2 projects have been completed and 1 is under construction. The initiatives include the incorporation of structured crossing provisions and impact mitigation features to balance infrastructure expansion with conservation priorities.

Table-22: RO Jaipur - Number of Structures and Expenditure incurred on Mitigation

S. No	Name of the item	No. of Structures	Expenditure (in Crore)
1.	Viaduct	2	160.18
2.	Animal Under Pass	2	212.79
3.	Animal Over Pass	5	426.85
4.	Tunnel	1	891.87
5.	Noise barrier/ fencing (km)	8.27	50.80
Total (in Crore)			**1742.49**



Figure-61: AOP in Delhi-Vadodara Expressway (Pkg.11)



Figure-62: AUP in Delhi-Vadodara Expressway (Pkg.11)

Regional Office Jammu

RO Jammu is integrating wildlife mitigation measures in 02 National Highway projects across forested and ecologically sensitive Himalayan stretches, both of which are currently under construction. The interventions include animal underpasses, bridge-cum-wildlife crossings, along with terrain-responsive design measures to minimize disturbance to natural habitats and drainage patterns. These provisions are being incorporated in coordination with the concerned Forest authorities to ensure compliance with necessary clearances and to address region-specific ecological sensitivities.

Table-23: RO Jammu - Number of Structures and Expenditure incurred on Mitigation

S. No	Name of the item	No. of Structures	Expenditure (in Crore)
1.	Viaduct	4	132.61
2.	Animal Under Pass	13	10.37
3.	Minor bridge cum AUP	7	38.66
4.	Major bridge cum AUP	2	66.86
Total (in Crore)			**248.50**

Regional Office Kolkata

Balancing infrastructure expansion with environmental responsibility, RO Kolkata is implementing wildlife mitigation interventions in 02 National Highway projects. These projects are currently under construction, with provisions ensuring that highway development in forest-influenced and eco-sensitive zones is supported by appropriate wildlife crossing structures and impact-reduction measures.

Table-24: RO Kolkata - Number of Structures and Expenditure incurred on Mitigation

S. No	Name of the item	No. of Structures	Expenditure (in Crore)
1.	Viaduct	1	297.00
2.	Animal Under Pass	1	28.00
Total (in Crore)			**325.00**

Regional Office Madurai

RO Madurai has incorporated wildlife mitigation measures in 03 National Highway projects. Of these, 2 projects have been completed and 1 is under construction. The projects ensure the inclusion of structural interventions such as designated wildlife crossings and noise barriers where mandated. These measures have been integrated into project execution in compliance with mandatory statutory requirements.

Table-25: RO Madurai - Number of Structures and Expenditure incurred on Mitigation

S. No	Name of the item	No. of Structures	Expenditure (in Crore)
1.	Animal Under Pass	1	4.21
2.	Animal Over Pass	1	7.75
3.	Noise barrier/ fencing (km)	3.5	0.54
4.	Any other Structures and measures	2	2.89
Total (in Crore)			**15.39**



Figure-63: Animal Overpass with Noise Barrier in Four Lane divided Carriageway from Vadipatti to Thamaraipatti stretch of Madurai Ring Road section of NH-744 A



Figure-64: Check Dam in Four Laning of Natham-Thuvarankurichi section of NH-785 E



Figure-65: Animal Underpass in Four Laning of Chettikulam-Natham Section of NH-785

Regional Office Mumbai

Operating within a region characterized by urban expansion along with protected forests and coastal ecosystems, RO Mumbai has incorporated wildlife-responsive planning in 03 National Highway projects. Among these, 1 project has been completed and 2 are under construction. The mitigation approach emphasizes minimizing edge effects and disturbance in urban–forest interface zones through the provision of animal underpasses and overpasses. These measures are designed to harmonize high-traffic corridors with surrounding ecological pockets while maintaining functional connectivity across fragmented landscapes.

Table-26: RO Mumbai - Number of Structures and Expenditure incurred on Mitigation

S. No	Name of the item	No. of Structures	Expenditure (in Crore)
1.	Animal Under Pass	16	61.5
2.	Animal Over Pass	4	11.12
Total (in Crore)			**72.62**



Figure-66: Animal Underpass in Solapur to Vjiayapur section of NH-13

Regional Office Nagpur

Located within central India's forested and tiger corridor landscape, RO Nagpur has integrated wildlife mitigation components in 08 National Highway projects, wherein 3 projects have been completed and other 5 projects are presently under construction. The measures comprise wildlife underpasses, bridge-cum-animal crossings, and guidance fencing designed to sustain habitat connectivity across notified corridors. This corridor-focused approach supports ecological continuity while advancing infrastructure development in biodiversity-rich regions.

Table-27: RO Nagpur - Number of Structures and Expenditure incurred on Mitigation

S. No	Name of the item	No. of Structures	Expenditure (in Crore)
1.	Viaduct	1	4.2
2.	Animal Under Pass	72	417.14
3.	Minor bridge cum AUP	17	25.44
4.	Noise barrier/ fencing (km)	88.766	22.41
5.	Monkey Ladder	6	0.97
Total (in Crore)			**470.16**



Figure-67: SASEKARAN GAT- Animal Underpass in Construction of Mitigation measure structures on CH/MH Border to Wainganga Section of NH-6 (New NH-53) in Maharashtra



Figure-68: MARAMJOB- Animal Underpass in Construction of Mitigation measure structures on CH/MH Border to Wainganga Section of NH-6 (New NH-53) in Maharashtra

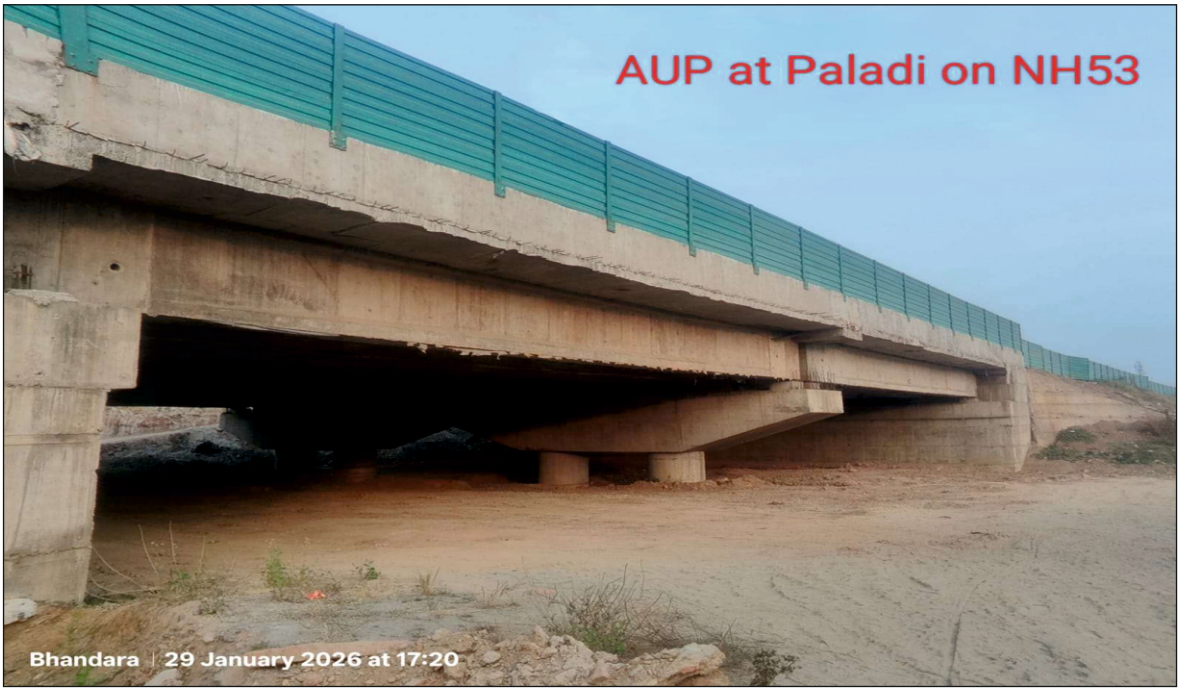


Figure-69: AUP in Construction of Six Lane Bhandara Bypass section of NH-53(Old NH-06) in Maharashtra



Figure-70: Signage Board in Four laning of Mahagaon to Yavatmal section of NH 361 in of Maharashtra

Regional Office Patna

RO Patna has incorporated wildlife mitigation provisions in 02 National Highway projects across Bihar, and the projects are presently under construction. It has been planned to integrate elephant underpasses, viaduct within the project design framework. These measures have been included to address localized ecological sensitivities and to ensure compliance with applicable clearance conditions during project execution.

Table-28: RO Patna - Number of Structures and Expenditure incurred on Mitigation

S. No	Name of the item	No. of Structures	Expenditure (in Crore)
1.	Viaduct	4	113.54
2.	Animal Under Pass	6	57.54
3.	Animal Over Pass	2	21.24
Total (in Crore)			**192.32**

Regional Office Raipur

Functioning within a predominantly forested and biodiversity-rich region of central India, RO Raipur has incorporated wildlife mitigation measures in 02 National Highway projects, which are currently under construction. Considering the presence of contiguous forest belts and wildlife movement routes, the measures include tunnel, guidance fencing, monkey canopy, reptile crossing. These interventions are being planned to minimize ecological disturbance, maintain habitat connectivity, and ensure adherence to forest and environmental clearance stipulations applicable to sensitive forest corridors of Chhattisgarh

Table-29: RO Raipur - Number of Structures and Expenditure incurred on Mitigation

S. No	Name of the item	No. of Structures	Expenditure (in Crore)
1.	Viaduct	24	204.38
2.	Animal Under Pass	15	21.12
3.	Animal Over Pass	2	2.26
4.	Tunnel	1	555.02
5.	Noise barrier/ fencing (km)	7.18	4.01
6.	Reptile Crossing	67	2.27
7.	RWH cum water holes	75	2.12
8.	Monkey Canopy	29	4.13
9.	Any other Structures and measures	3	2.73
Total (in Crore)			**798.04**



Figure-71: Box Culvert in (CG-2) (Lot-3/Odisha & Jharkhand/Package-2)
Raipur- Vishakhapatnam in Chhattisgarh



Figure-72: AUP in (CG-2) (Lot-3/Odisha & Jharkhand/Package-2)
Raipur- Vishakhapatnam in Chhattisgarh

Regional Office Ranchi

Across 7 National Highway projects in Jharkhand, RO Ranchi is adopting wildlife mitigation interventions suited to the region's plateau terrain and forest tracts. Of these, 2 projects are completed and 5 are under construction. It is facilitating the incorporation of designated wildlife crossing passages, modified bridge configurations over natural corridors, and protective installations along sensitive stretches. These measures form part of the environmental provisions being integrated into project development to address site-specific ecological considerations and regulatory requirements.

Table-30: RO Ranchi - Number of Structures and Expenditure incurred on Mitigation

S. No	Name of the item	No. of Structures	Expenditure (in Crore)
1.	Animal Under Pass	28	57.26
2.	Animal Over Pass	2	26.23
3.	Minor bridge cum AUP	5	9.29
4.	Noise barrier/ fencing (km)	4.978	3.19
5.	Any other Structures and measures	2	7.01
Total (in Crore)			**102.98**



Figure-73: Elephant Underpass in Operation and maintenance work for the stretch Rampur to Chauka Section of NH-33 in Jharkhand



Figure-74: Elephant Underpass in Operation and maintenance work for the stretch Rampur to Chauka Section of NH-33 in Jharkhand



Figure-75: Signages in Operation and maintenance work for the stretch Rampur to Chauka Section of NH-33 in Jharkhand

Regional Office Vijayawada

RO Vijayawada is incorporating environmentally responsive design features in 09 National Highway projects across Andhra Pradesh. In corridors influenced by river systems and forest-edge landscapes, wildlife crossing provisions, adapted bridge configurations over natural channels, tunnels, and watchtowers are being integrated as part of the project design. These measures are being embedded within project planning to reflect local landscape conditions and ensure conformity with applicable environmental safeguard requirements.

Table-31: RO Vijayawada - Number of Structures and Expenditure incurred on Mitigation

S. No	Name of the item	No. of Structures	Expenditure (in Crore)
1.	Viaduct	15	798.65
2.	Animal Under Pass	47	1003.18
3.	Tunnel	3	180.13
4.	Minor bridge cum AUP	4	8.09
5.	Major bridge cum AUP	1	6.47
6.	Noise barrier/ fencing (km)	33.9	2.50
7.	Reptile Crossing	2	0.72
8.	Watch Tower	2	0.25
9.	Monkey Canopy	32	
10.	Any other Structures and measures		32.17
Total (in Crore)			**2032.16**



Figure-76: Minor Bridge cum AUP in 4L Bangalore-Chennai Expressway of Baireddypalle to Bangarupalem Section of NE-7 in Andhra Pradesh (Phase II /Package-II)

Regional Office Kerala

RO Kerala is incorporating wildlife mitigation measures in 3 National Highway projects traversing coastal belts and Western Ghats-influenced Forest stretches, of which 2 projects are in the DPR stage and 1 is under construction. Given the ecological sensitivity of the region, the projects are integrating minor and major bridges cum animal underpasses (AUP) and fencing along identified corridors. These interventions are being embedded within project execution frameworks to address biodiversity considerations characteristic of Kerala's forested and high-rainfall landscapes, while ensuring adherence to environmental and forest clearance stipulations.

Table-32: RO Kerala - Number of Structures and Expenditure incurred on Mitigation

S. No	Name of the item	No. of Structures	Expenditure (in Crore)
1.	Viaduct	7	357.09
2.	Animal Under Pass	3	0.68
3.	Animal Over Pass	2	24.80
4.	Minor bridge cum AUP	1	
5.	Major bridge cum AUP	1	18.29
6.	Noise barrier/ fencing (km)	6	5.65
7.	Monkey Ladder	28	0.04
Total (in Crore)			**406.55**

Summary

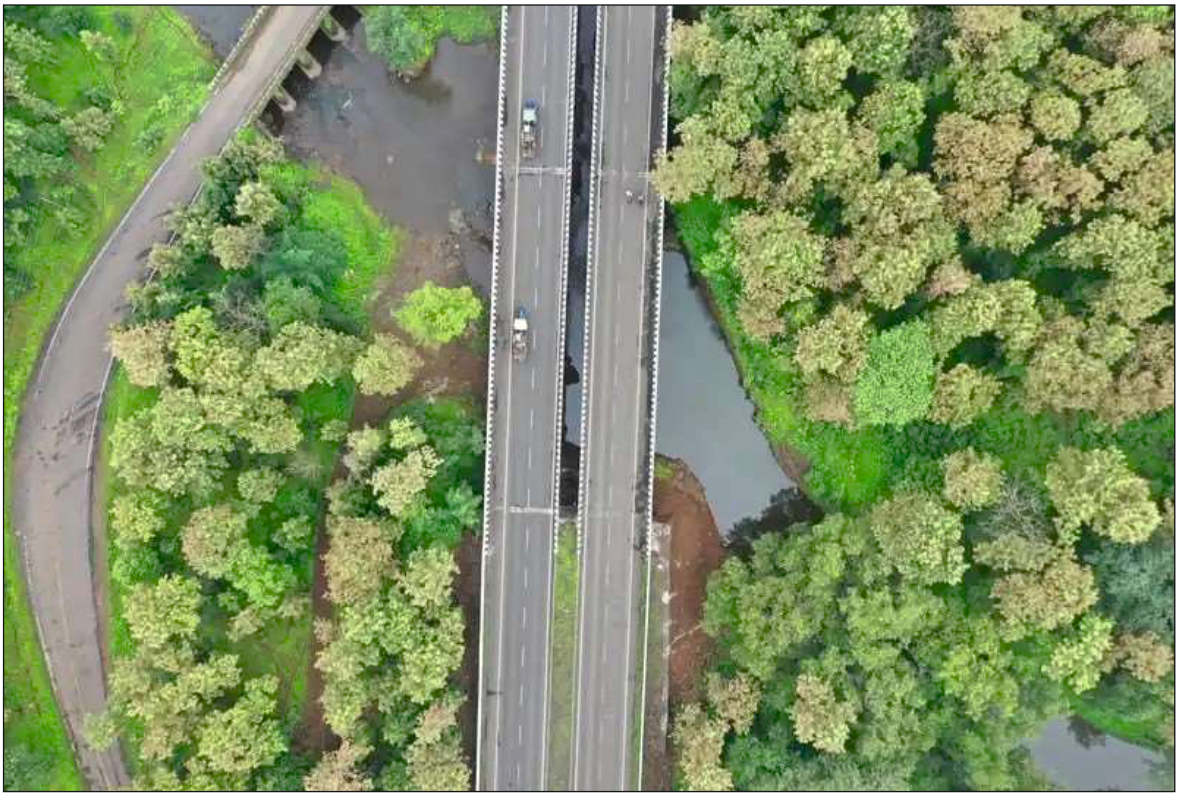
In overall, NHAI have incorporated wildlife-sensitive provisions across 102 National Highway projects in different regions situated in ecologically important landscapes over the past five to seven years. These efforts encompass a range of structural and non-structural options—such as dedicated tunnels, modified bridges, canopy crossings, noise barriers, water conservation features, and controlled edge treatments—integrated as part of project design requirements. Implemented in line with statutory approvals and environmental management commitments, these measures demonstrate a coordinated approach to accommodating infrastructure growth while addressing biodiversity and habitat continuity considerations along highway corridors.

Table-33: Summary of Number of Structures and Expenditure incurred on Mitigation

S. No	Name of the item	No. of Structures	Expenditure (in Crore)
1.	Viaduct	91	8353.36
2.	Animal Under Pass	1325	4604.45
3.	Animal Over Pass	40	657.62
4.	Tunnel	8	2831.76
5.	Minor bridge cum AUP	179	528.71
6.	Major bridge cum AUP	48	2503.77
7.	Noise barrier/ fencing (km)	302.206	185.65
8.	Monkey Ladder	43	1.19
9.	Reptile Crossing	91	28.95
10.	Watch Tower	12	1.07
11.	Salt Licks	17	0.55
12.	RWH cum water holes	120	5.69
13.	Monkey Canopy	111	14.85
14.	Any other Structures and measures	14	80.81
Total (in Crore)			**19798.43**







Chapter 7: Trail-Blazers and Path-Makers

Some of the Regional Offices of NHAI have done exemplary work with regard to protection and conservation of wildlife while undertaking construction of linear projects. In the process, these Regional Offices can be called as *Trail-Blazers and Path-Makers* for their conservation efforts. The details of such endeavour are as under.

.7.1 Bhopal Regional Office

7.1.1 Red Roads, Green Intent: NH-45 Bhopal–Jabalpur Highway

India's First 'Table-Top Red Marking' on a Highway has been carried out on a 2 Km Ghat section of NH-45 passing through the Veerangana Durgavati Tiger Reserve, Madhya Pradesh.

India's First 'Table-Top Red Marking' on a Highway:
A 5 mm thick hot-applied thermoplastic red surface layer has been laid across the carriageway in the identified danger zone. The bright red colour visually alerts drivers that they are entering a speed-restricted, wildlife-sensitive corridor. Additionally, the slightly raised surface generates mild tactile and audible feedback, naturally encouraging drivers to slow down, without causing discomfort or sudden braking.

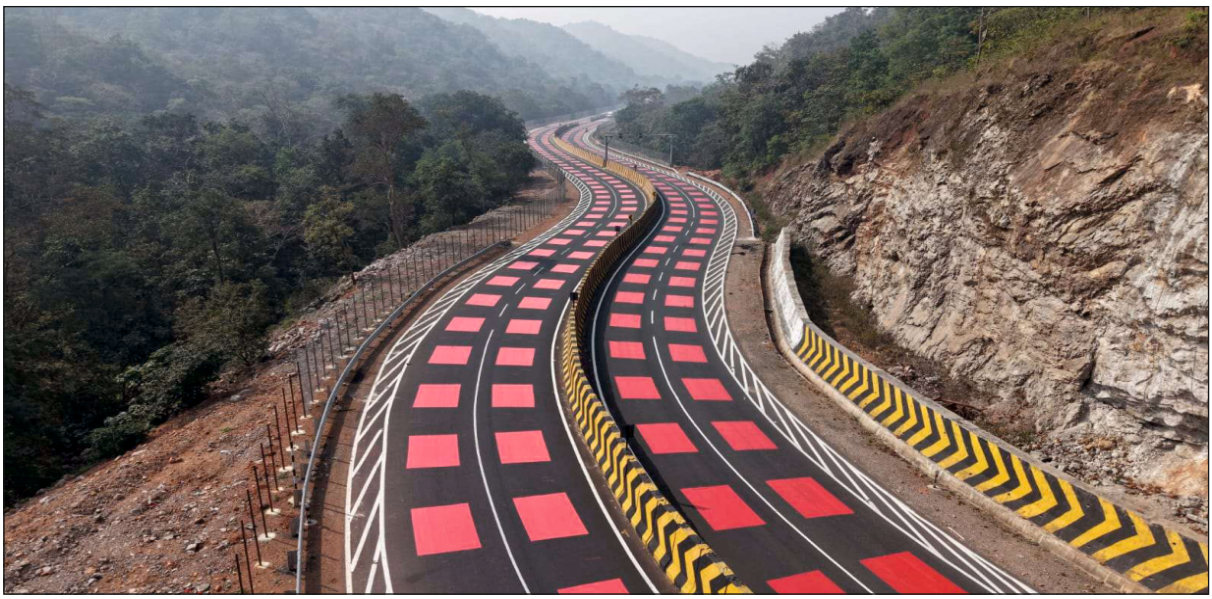


Figure-77: Red markings on Balance Nauradehi section

Minimal Impact, Maximum Protection:
What makes this intervention truly significant is its low ecological footprint:

- No disturbance to wildlife movement or habitat.
- No alteration to pavement structure or drainage.
- Lower noise than conventional rumble strips.
- Easy to maintain and fully reversible.
- Psychological design: The red surface creates an instant psychological cue that encourages drivers to slow down without physical speed breakers.

Other Features for Wild animals on NH-45:
11.96 KM of NH-45 passes through the Veerangana Durgavati Tiger Reserve. Measures taken by NHAI serves to protect the key species from road accidents: leopards, sloth bears, chital (spotted deer), sambar, nilgai, wild boars, wolves, jackals, hyenas, langurs, rhesus macaques, peacocks, porcupines, mongooses, and other small mammals and reptiles.

Comprehensive Wildlife Safety Measures:
Beyond speed management, NHAI has taken a holistic approach to wildlife protection along this corridor:

- 25 dedicated animal underpasses have been provided along the 11.96 km stretch at identified animal movement locations.
- These underpasses are integrated with natural ground levels and drainage paths to encourage regular animal use.
- Continuous chain-link fencing (except in deep cutting sections) has been installed on both sides of the highway to prevent animals from entering the carriageway and to guide them toward underpasses.
- Cameras installed on minor bridges, which also function as animal crossing points, help monitor wildlife movement.
- Solar lighting at bridges and junctions enhances visibility at conflict points without adding environmental burden.

Results after implementation:

- **Wildlife fatalities:** Zero fatalities reported in the 2 km zone in the first 6 months of the pilot.
- **Driver behaviour:** Red surface + texture gives psychological + physical cue to slow down without sudden break.
- **Ecological impact:** No disturbance to wildlife movement or habitat. No change to pavement structure or drainage.
- **Maintenance:** Lower noise vs rumble strips. Easy to maintain and fully reversible.
- **Praised by one and all:** The red table top road immediately caught attention of media, drivers and wild lifers and is being praised over entire globe.

7.1.2 NH-44 through Pench Tiger Reserve

A 29 KM stretch of NH-44 passes through Pench Tiger Reserve in Seoni district, Madhya Pradesh, before entering Maharashtra. Four-laning of this stretch stands as a landmark in India's idea of highway development—where engineering excellence advances in harmony with nature.

Recognised as **India's first light- and sound-sensitive highway corridor**, the project has been envisioned to ensure seamless mobility for road users while preserving the sanctity of a dense forest ecosystem. Carefully planned design interventions allow traffic to flow efficiently, even as wildlife continues to move freely and safely across the landscape.

More than an infrastructure upgrade, this project represents a conscious shift towards empathetic, future-ready development—demonstrating that progress need not come at the cost of the environment. It sets a national benchmark for highways that are safe, resilient, and ecologically responsible.



Figure-78: Noise Barrier in Four-Laning of the delinked stretch of NH-44 (Seoni–MP/MH Border)



Figure-79: Animal Underpass in Four-Laning of the delinked stretch of NH-44 (Seoni–MP/MH Border)

Key Highlights:

- **India's First of Its Kind:** Developed as the country's first highway corridor with integrated light- and sound-sensitive planning, ensuring minimal disturbance to surrounding wildlife habitats.
- **Dedicated Wildlife Crossings:** Provision of **14 animal underpasses**, enabling safe and uninterrupted movement of wildlife beneath the highway and significantly reducing the risk of animal–vehicle collisions.
- **Robust Bridge Network:** The project includes **10 minor bridges and 1 major bridge**, designed to ensure natural water flow, structural stability, and long-term durability.
- **Safety-First Design:** Elevated sections and underpasses enhance safety for both motorists and wildlife, creating a balanced interface between mobility and conservation.
- **Ecology-Aligned Infrastructure:** Engineering solutions have been carefully integrated with the natural terrain, maintaining forest continuity while supporting high-capacity highway movement.
- **Strengthened Regional Connectivity:** The upgraded NH-44 stretch improves seamless connectivity between Madhya Pradesh and Maharashtra, supporting economic activity without compromising environmental values.

Habitat acceptance by the wildlife:

The project was completed in 2019 and in 2020, camera traps installed by WII, Dehradun proved that it worked well.

- 468 captures of 15 species in 90 days – tigers, bison, deer, wild dogs, sloth bear, leopards.
- Natural behaviour returned: Animals hunt, nap, play, and cross day and night because it's quiet and dark below.
- Total of 18 different wild species were captured during the monitoring in the year-2020. These include wild ungulates viz., spotted deer, sambar, Indian Bison, Nilgai and wild pig, large and medium-sized carnivores viz., tiger, leopard, sloth bear, jackal and wild dog, small mammals viz., hare, jungle cat, mongoose, common palm civet, porcupine, rusty spotted cat and small Indian civet. Monitor lizards were also captured using the structures twice. Highest captures were obtained under the crossing structures were of spotted deer/chital (n=3165), followed by wild pig (n=677) and small mammals like hare (n=311) and jungle cat (n=212). Among carnivores, wild dogs (n=242) were captured the most.

Before this corridor, NH-44 expansion there had been instances of wild animal kill in vehicle hits. It turned NH-44 into a model where ***"development doesn't have to come at nature's cost".***

7.1.3 NH-46 Obedullaganj-Betul Section

Carved through the ecologically sensitive Ratapani Tiger Reserve, the 22 KM long four-lane stretch of NH-46 reflects a progressive approach to highway development—one that places equal emphasis on mobility, safety, and environmental stewardship. Designed with wildlife at its core, this corridor demonstrates how thoughtful engineering can enable seamless traffic movement while preserving the tranquillity and integrity of a protected forest ecosystem. The Ratapani stretch stands as a defining example of environment-responsive infrastructure, reinforcing NHAI's commitment to building roads that serve both people and nature responsibly.

Key Highlights

- State's first soundproof highway corridor designed specifically for wildlife protection.
- Extended noise-attenuation system using insulated polycarbonate panels to minimize traffic disturbance.
- Four-lane divided carriageway with 18-metre width, ensuring smooth and uninterrupted traffic flow.
- Light-dimming barriers to prevent headlight glare from impacting nocturnal animal movement.
- Specially engineered wildlife underpasses, enabling safe and natural animal crossings.
- Removal of sharp curves and bottlenecks, improving safety and driving comfort.
- Significant reduction in congestion, transforming a slow-moving forest stretch into a free-flow corridor.
- Effective noise reduction extending deep into protected area, maintaining forest serenity.
- Eco-sensitive construction practices, aligned with conservation norms of tiger reserve zones.
- Model for sustainable highway development, integrating transport efficiency with biodiversity protection.

This enables animals such as Tigers, Leopards, Sloth bears, Gaur/Indian Bison, Sambar, Chital, Barking deer Wild dogs/Dhole and other wild animals to move between forest areas, thereby fostering genetic exchange. Camera traps installed in similar corridors in Madhya Pradesh have recorded tigers traveling distances of over 120 km.



Figure-80: Noise Barrier cum AUP at Ratapani Wildlife Sanctuary in Four-Lane stretch of NH-46



Figure-81: AUP at Ratapani Wildlife Sanctuary in Four-Lane stretch of NH-46

7.2 Chandigarh (PB) Regional Office

7.2.1 NH-62 Four laning from Malout to Sadhuwali

A small portion of the old 2-lane road passed through the wildlife conservation area of Gumjal Community Reserve. Traffic on this stretch posed significant risks to wild animals such as Nilgai, Common Mongoose, Golden Jackal, Porcupine, etc. and domestic animals such as buffaloes, cows frequently crossing the carriageway. With the upgradation of this stretch to a 4-lane highway, the risk of such incidents was expected to increase further due to higher traffic volume and speed. To address this, NHAI constructed a strategically located cattle-cum-animal underpass of 17.0 m width and 3.0 m height during FY 2023–24, designed specifically to accommodate both wildlife and local livestock movement.

Following its implementation, the corridor has become significantly safer, ensuring smooth and uninterrupted passage for animals, reducing accident risks and maintaining ecological connectivity while supporting modern highway infrastructure.



Figure-82: Animal Under Passes in Four laning from Malout via Abohar to Sadhuwali of NH-62



7.3 Chandigarh (HR) Regional Office

7.3.1 NH-7 Yamunanagar–Panchkula PKG 3 Section

The existing 2-lane highway passing through the Khol Hi Raitan Wildlife Sanctuary fragmented the habitat and acted as a major barrier to wildlife movement. Animals such as leopards, Chital or Spotted Deer, Sambar, Wild Boar, Rhesus Monkey, Langur, Hyena, Jungle Cat, Common Mongoose, Indian Fox, Jackal, Porcupine, etc. frequently attempted to cross the road, resulting in accidents. The challenge was further intensified due to the hilly topography on both sides of the road, restricting safe passage for wildlife.

The project for up gradation of this stretch to a 4-lane highway included recommendations of WII, Dehradun for construction of overhead wildlife crossing structures to maintain ecological connectivity between forest patches. Acting on these scientific recommendations, NHAI implemented two animal overpasses (overhead bridges), each designed with spans of 24.5 m (configured as 2 spans) and 7 m width, during FY 2019–20, ensuring they blended seamlessly with the natural habitat. Additional mitigation measures such as guiding walls, strategic fencing and habitat improvements were also incorporated to channel animal movement and reduce human-wildlife conflict.

Following these interventions, the corridor has transformed into a safe and wildlife-friendly passage, significantly reducing animal fatalities, ensuring smoother traffic flow and restoring ecological balance by reconnecting fragmented habitats.



Figure-83: Animal Over Pass in 4-Laning of Yamunanagar–Panchkula PKG 3 Section of NH-07

7.4 Dehradun Regional Office

7.4.1 Delhi–Dehradun Economic Corridor

The Delhi–Dehradun Economic Corridor is widely regarded as a successful example of sustainable infrastructure development that integrates environmental protection with economic growth. It passes through the Eco-sensitive area of Rajaji National Park and crosses the geologically fragile Shivalik Hill into the Doon Valley. The Forests of these areas are an important habitat and corridor for megaherbivores like Elephants (flagship species) and other wild species.

Construction of conventional highway would have fragmented the habitat and had resulted in increased road kills incidents. Following the recommendations of the WII and leading forestry experts, wildlife safety has been positioned as the highest priority for the project. To integrate these precautionary measures, the NHAI has adopted the construction of elevated corridor featuring an innovative ecological design.

The project includes one of the Asia's longest elevated wildlife corridors of around 12 km. This corridor includes Elephant Underpass (EUP) and Animal Underpasses (AUPs) to ensure safe movement of wildlife beneath the road. This infrastructure specifically incorporates advanced sound and light barriers designed to significantly mitigate the impact of noise and light pollution on local wildlife, ensuring safe and undisturbed movement within the natural habitat.

Objectives:

- Ensure high-speed, efficient connectivity between Delhi and Dehradun.
- Maintain ecological continuity across forest landscapes.
- Enable safe and unobstructed wildlife movement.
- Minimize human-wildlife conflict and road accidents.

Key Interventions:

- Implementation of elevated structures and wildlife mitigation measures.
- Design and placement of crossing structures based on species-specific movement patterns.
- Deployment of systematic monitoring protocols, including camera traps and passive acoustic recorders, to quantify wildlife usage and disturbance gradients.
- Identification and prioritization of critical wildlife crossing zones.
- Noise mitigation strategies.
- Optimization of infrastructure design to minimize habitat fragmentation and edge effects within forested landscapes.

The development of the Delhi–Dehradun Economic Corridor has significantly reduced the risk of human–wildlife conflict and minimized habitat fragmentation within the Shivalik landscape. By ensuring ecological connectivity, the project supports long-term conservation of wildlife populations and prevents isolation of species.

Table-34: Wild Faunal species found around the NH72A

S. No.	Common Name	Scientific Name	IUCN (Global)
1.	Asian Elephant	*Elephas maximus*	EN
2.	Golden Jackal	*Canis aureus*	LC
3.	Nilgai	*Boselaphus tragocamelus*	LC
4.	Sambar	*Rusa unicolor*	VU
5.	Indian hare	*Lepus nigricollis*	LC
6.	Spotted deer	*Axis axis*	LC
7.	Rhesus Macaque	*Macaca mulatta*	LC
8.	Indian Peafowl	*Pavo cristatus*	LC
9.	Wild boar	*Sus scrofa*	LC
10.	Small Indian Civet	*Viverricula indica*	LC
11.	Porcupine	*Hystrix indica*	LC
12.	Common leopard	*Panthera pardus*	VU
13.	Common Palm civet	*Paradoxurus hermaphroditus*	LC
14.	Grey mongoose	*Urva edwardsii*	LC
15.	Monitor lizard	*Varanus bengalensis*	NT
16.	Rusty spotted cat	*Prionailurus rubiginosus*	NT
17.	Red Junglefowl	*Gallus gallus*	LC
18.	Terai grey langur	*Semnopithecus entellus*	LC

NHAI continues to prioritize environmental sustainability in highway development by integrating innovative, science-based mitigation strategies. This initiative demonstrates how data-driven planning and engineering can effectively balance infrastructure growth with ecological preservation, setting a benchmark for future projects across the country.

Figure-84: Wild Species documented using camera traps and Audio Moth acoustic recorders significantly indicating the purpose of underpass structures along the NH-72A corridor





Asian Elephant





Common Leopard



Golden Jackal



Porcupine



Rhesus Macaque



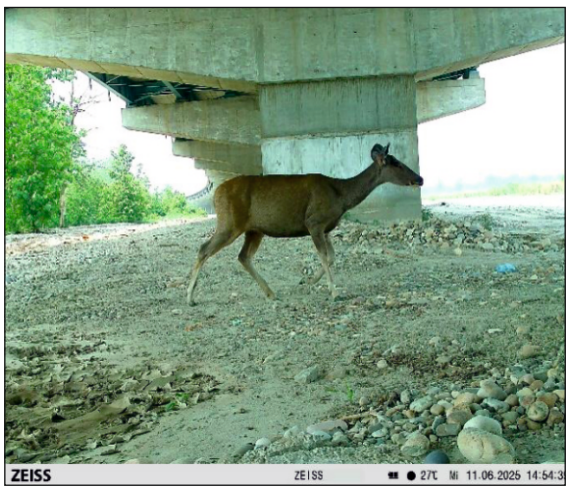
Rusty Spotted Cat



Spotted Deer



Indian Hare



Sambar



Indian Peafowl



Small Indian Civet



Nilgai

Figure-85: Wildlife Mitigation Structures along the NH-72A Corridor













Figure-86: Glimpse of Inauguration Ceremony Delhi-Dehradun Economic Corridor





7.5 Madurai Regional Office

7.5.1 NH-744A Madurai Ring Road

The NHAI, Regional Office, Madurai, has achieved a remarkable milestone in sustainable infrastructure through the four-laning of the Madurai Ring Road (NH-744A). This project is not merely about improving connectivity—it stands as a pioneering example of ecological responsibility and innovation.

Passing through the ecologically sensitive forest stretch between Vaguthamalai and Vannathikaradu, the project involved the diversion of about 1.28 hectares of forest land. This region supports a diverse range of wildlife, including Indian bison (gaur), spotted deer, wild boar, Indian hare, mongoose, reptiles such as monitor lizards, and bird species like peafowl and owls. Ensuring the safe movement of these species was a key priority during project planning.

As per the recommendations of the Wildlife Mitigation Plan, the NHAI introduced a significant wildlife mitigation measure—an Animal Over Pass measuring 35.2 meters by 20 meters. This structure is specifically designed to facilitate the safe and uninterrupted movement of wildlife across the highway, thereby reducing the risk of road accidents and maintaining habitat connectivity.



Figure-87: Animal Overpass in Four Laning of Madurai Ring Road Sec. of NH-744 A

Notably, this Animal Over Pass is the first of its kind in the state of Tamil Nadu, marking a major advancement in integrating wildlife conservation with highway infrastructure and setting a benchmark for future projects. To further enhance its effectiveness, noise barrier sheets have been installed along the overpass. These barriers help reduce vehicular noise and light disturbances, creating a calm and natural environment for animals, particularly benefiting sensitive and nocturnal species.

Today, the Animal Over Pass constructed on the Madurai Ring Road stands as a successful example of wildlife mitigation measures in infrastructure development. It symbolizes a progressive approach that balances development with environmental conservation, ensuring safer habitats for wildlife while promoting sustainable growth.



Figure-88: Animal Overpass in Four Laning of Madurai Ring Road Sec. of NH-744 A

7.5.2 NH-785E Natham -Thuvarankurichi Section

As per the recommendations of the Tamil Nadu Forest Department and the Wildlife Mitigation Plan, the NHAI Regional Office, Madurai implemented a series of targeted and innovative mitigation measures aimed at habitat improvement and species protection. Construction of check dams, removal of Lantana and other invasive alien species, habitat improvement for Slender Loris through Thirugukalli and Kiluvai plantations, chain-link fencing, installation of signboards, and scientific study are some of the measures taken.

This four laning stretch passes through the ecologically significant Chinnayampattikaradu Reserve Forest in the Dindigul Forest Division, involving the diversion of 3.708 hectares of forest land. Characterized by mixed scrub jungle, this reserve forest is considered one of the oldest in the region and supports unique and sensitive biodiversity. Among its most notable inhabitants is the Slender Loris—an elusive, nocturnal primate recognized by the International Union for Conservation of Nature (IUCN) as a species of conservation concern.

Understanding the ecological importance of this habitat, a scientific study was undertaken by the National Institute of Advanced Studies, Bengaluru. The study provided deep insights into the habitat requirements and movement patterns of the Slender Loris, forming the foundation for a comprehensive Wildlife Mitigation Plan. One of the key initiatives was habitat enrichment through native plantation, including species like Thirugukalli and Kiluvai, which are known to support the ecological needs of the Slender Loris. These plantations help restore natural vegetation and provide food sources, shelter, and safe movement pathways for the species.

To address water scarcity within the reserve forest, check dams were constructed, ensuring the availability of water throughout the year. These structures not only benefit the Slender Loris but also support a wide range of other wildlife, enhancing the overall ecological balance of the forest.

Recognizing the risks posed by highways to wildlife, chain-link fencing was installed along the outer boundaries of the reserve forest. This measure helps regulate animal movement and significantly reduces the chances of wildlife-vehicle collisions, thereby improving safety for both animals and road users.

In addition, awareness signboards have been strategically placed along the highway to alert drivers about wildlife presence, encouraging cautious driving in sensitive zones. The project also emphasizes continued scientific monitoring and study, ensuring that conservation efforts remain adaptive and effective over time.

Figure-89: HABITAT IMPROVEMENT AND SPECIES PROTECTION OF SLENDER LORIS



Slender Loris—an elusive, nocturnal primate recognized by the International Union for Conservation of Nature as a species of conservation concern

CONSTRUCTION OF CHECK DAMS



Figure-90: Check dam in Four Laning of Natham -Thuvarankurichi Sec. of NH-785 E



Figure-91: Kiluvi Plantation in Four Laning of Natham -Thuvarankurichi Section of NH-785 E



Figure-92: Thirukugalli Plantation in Four Laning of Natham -Thuvarankurichi Section of NH-785 E



Figure-93: Plantation in Four Laning of Natham -Thuvarankurichi Section of NH-785 E



Figure-94: Chain Link Fencing in Four Laning of Natham -Thuvarankurichi Section of NH-785 E





Figure-95: Warning Sign Boards in Four Laning of Natham -Thuvarankurichi Section of NH-785 E

7.5.3 NH-785 Chettikulam Natham Section

The NHAI, Regional Office, Madurai, continues to set benchmarks in eco-sensitive infrastructure through the four-laning of the Chettikulam–Natham stretch. This project reflects a thoughtful balance between development and conservation, particularly in ecologically rich forest regions.

The project involved the diversion of 2.3824 hectares of forest land across the Kiluvamalai area in Usilampatti and the Alagarmalai Reserve Forest, a biologically significant landscape known for its diverse wildlife. The Alagar Hill Reserve Forest is home to species such as deer, monkeys, and Indian bison (gaur), all of which depend on safe and continuous movement across forest habitats.

Understanding the risks posed by highway expansion—particularly animal-vehicle collisions and habitat fragmentation—based on the recommendations of the Tamil Nadu Forest Department and as per the Wildlife Mitigation Plan, animal underpasses have been incorporated into the highway structures and strategically placed to facilitate the safe crossing of wildlife beneath the highway. These underpasses serve as critical ecological corridors, allowing animals like deer and monkeys to move freely without encountering vehicular traffic. Larger animals such as bison also benefit from these safe passages, significantly reducing the risk of fatal accidents.

These structures not only enhance wildlife safety but also contribute to road user safety, minimizing unexpected animal crossings on high-speed corridors. By maintaining habitat connectivity, the project supports the natural behavior and migration patterns of wildlife in the Alagar Hill region.



Figure-96: Animal Underpass in Four Laning of Chettikulam Natham Section of NH 785

7.6 Chennai Regional Office

7.6.1 Bangalore - Chennai Expressway - Hills of Vellore

The project presently is under construction and as per the advice of State Forest Department and the Chief Wildlife Warden mitigation structure measuring 90 m × 25 m × 5.5 m, which offers a more open and natural crossing environment has been provided as the surrounding forests support a rich variety of wildlife, including Indian gaur, panther, spotted deer, wild boar, Indian jackal, hare, porcupine and other wild animals. The animal overpass has been designed to safely accommodate both wildlife and livestock movement, helping reduce the risk of accidents while maintaining connectivity between habitats.



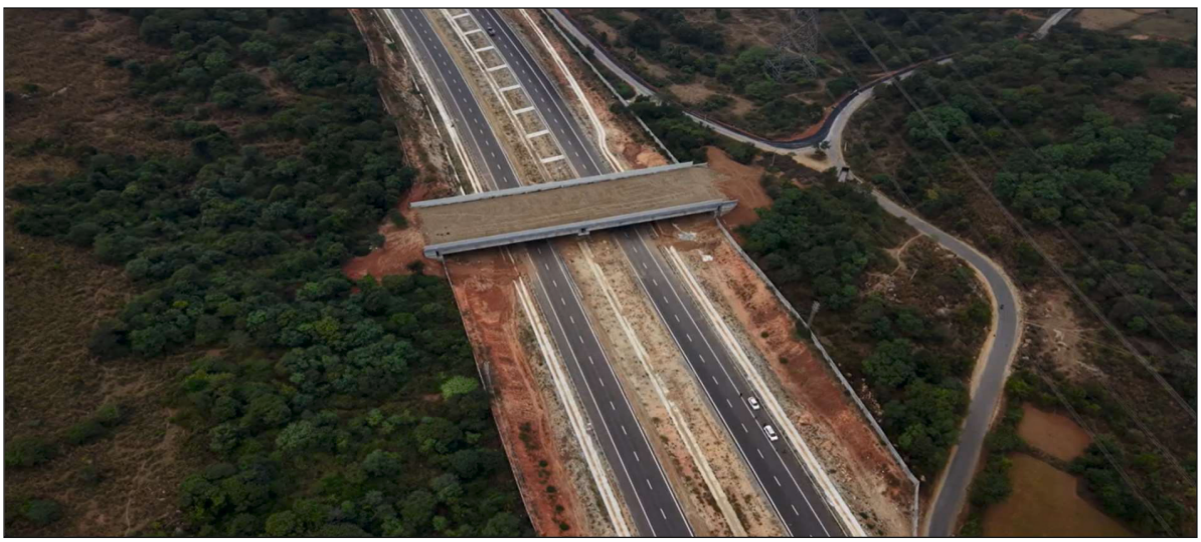


Figure-97: Animal Over Pass in Bangalore - Chennai Expressway

7.7 Mumbai Regional Office

7.7.1 NH-66 Mumbai Goa Highway

The Panvel–Indapur stretch of NH-66 passes through ecologically sensitive forest patches associated with the Karnala Bird Sanctuary. Recognizing the presence of arboreal wildlife and rich avifaunal diversity, targeted mitigation measures were implemented along this corridor to ensure safe wildlife movement and reduce ecological disturbance. Special emphasis was given to maintaining canopy connectivity and supporting habitat functions during and after construction.



Figure-98: Monkey Ladder in Panvel-Indapur stretch of NH-66 (Mumbai-Goa Highway)

Baseline assessments carried out indicated frequent ground crossings by primates and limited nesting opportunities for birds due to habitat modification. Roadkill monitoring before this implementation recorded as approximately **50 wildlife-vehicle collision (WVC) incidents annually**, primarily involving small mammals and reptiles. A combination of **canopy crossing structures (monkey ladders)** and **artificial nesting boxes** have been deployed across the stretch. A total of **2 monkey ladders** have been installed at identified movement hotspots, enabling arboreal species such as Bonnet Macaques and Hanuman Langurs to cross the highway without descending to the road surface. In addition, **more than 50 artificial nesting boxes** have been placed within adjacent forest areas to compensate for the loss of natural nesting cavities.

Monitoring of nesting boxes revealed encouraging results. Out of the installed units, **approximately 60–65% showed occupancy** within the first breeding season. Species observed utilizing these structures included Common Myna, Coppersmith Barbet, and Rose-ringed Parakeet, with successful breeding recorded in a significant proportion of occupied nests. Such measures not only reduce wildlife-vehicle conflict but also help maintain ecological continuity and support biodiversity conservation in fragmented landscapes.

The NH-66 mitigation efforts demonstrate that even small-scale, site-specific interventions can deliver measurable ecological benefits. By enabling safe animal movement and enhancing habitat features, the corridor now functions as a more wildlife-friendly infrastructure system, balancing development needs with environmental sustainability.

Together, these interventions ensure that both primates and avian species continue to thrive without disruption. What was once a sensitive stretch is now a safer, more inclusive ecological corridor—benefiting wildlife while maintaining efficient traffic flow. This initiative reflects our commitment to infrastructure that not only connects people, but also actively supports and enhances biodiversity in protected landscapes.

Key Outputs

- Safe overhead crossings (monkey ladders) enabling arboreal wildlife to cross without descending to road level.
- Installation of artificial bird nesting boxes to support breeding and shelter for local bird species.
- Strengthened ecological support within Karnala Bird Sanctuary

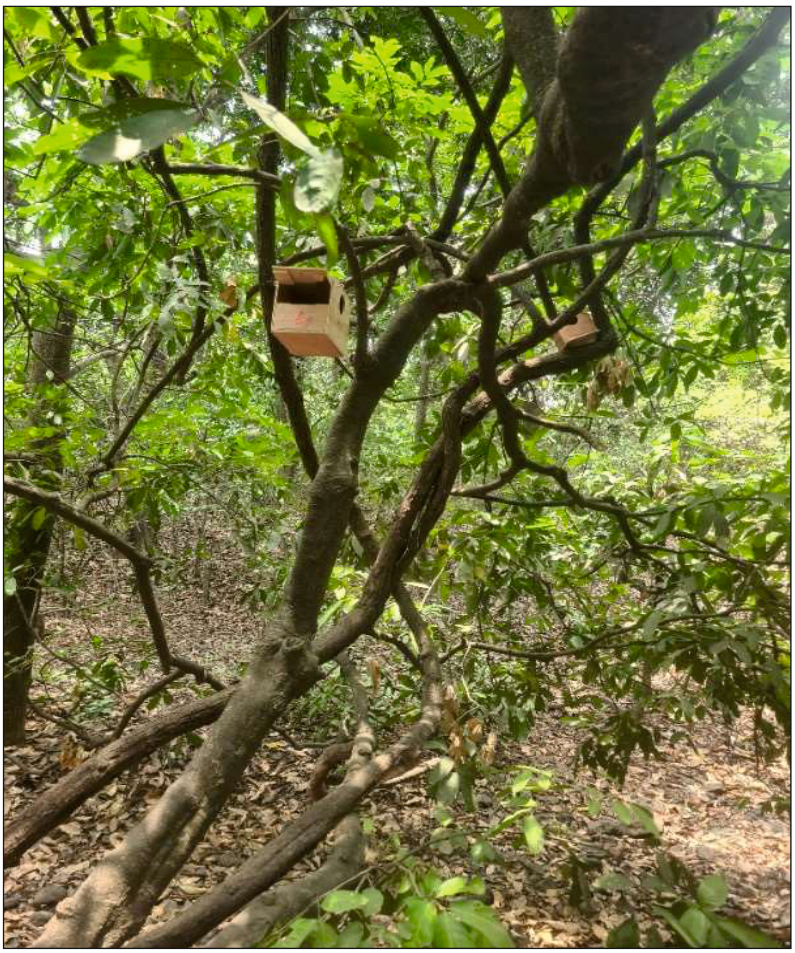


Figure-99: Bird nest at Karnala Bird Sanctuary in Panvel-Indapur stretch of NH-66 (Mumbai-Goa Highway)

7.8 Nagpur Regional Office

7.8.1 NH-53 Bhandara Bypass -Securing the Tiger Corridor

The Nagpur Bhandara Bypass is a stretch of 14.8 KM of NH-53 cutting across the e co-sensitive Zone of Navegaon-Nagzira Tiger Reserve (NNTR). This section serves as a critical bridge for wildlife moving toward the Umred-Karhandla and Paoni Wildlife Sanctuary, south-west of the highway. As the NHAI initiated the six-laning of this section, concerns arose regarding habitat fragmentation. High-speed traffic posed a severe risk of wildlife mortality for tigers and other species, potentially creating a physical barrier to natural movement.

Through a partnership between NHAI, the Maharashtra Forest Department, and the WII, Dehradun a technical mitigation plan was developed. The strategy focused on identifying a 2.3 km high-priority segment where wildlife movement was most likely and providing suitable underpasses for it.

Key Highlights

- **Scientifically Targeted Mitigation:** Focused engineering on a 2.3 km high-priority zone identified through collaborative technical studies with the WII.
- **Enhanced Connectivity:** Integration of two additional 40-meter-wide structures alongside existing bridges to maximize natural animal movement.
- **Pillar-Type Visual Design:** Utilization of pillar-based supports rather than solid walls to eliminate the "tunnel effect" and provide lateral visibility for crossing wildlife.
- **Noise & Light Suppression:** Installation of 2-meter-high tilted sound barriers and fiberglass median coverings to shield the forest from traffic disturbances.
- **Tiger-Specific Clearances:** All underpasses maintain a minimum clearance height of 4 meters to accommodate the comfortable passage of large mammals.
- **Genetic Preservation:** Restores vital corridors between NNTR and UK&PWLS, ensuring long-term genetic health and population stability for regional tigers.
- **Safety-First Infrastructure:** Dramatically reduces the risk of wildlife-vehicle collisions, protecting both biodiversity and commuters.

By integrating these specific engineering interventions, the project successfully transformed a potential barrier into a wildlife-friendly permeable landscape and corridor. The warning boards now educate commuters on the area's ecological importance, fostering a culture of co-existence.



Figure-100: Animal Under Pass 1 at Paladi on NH53

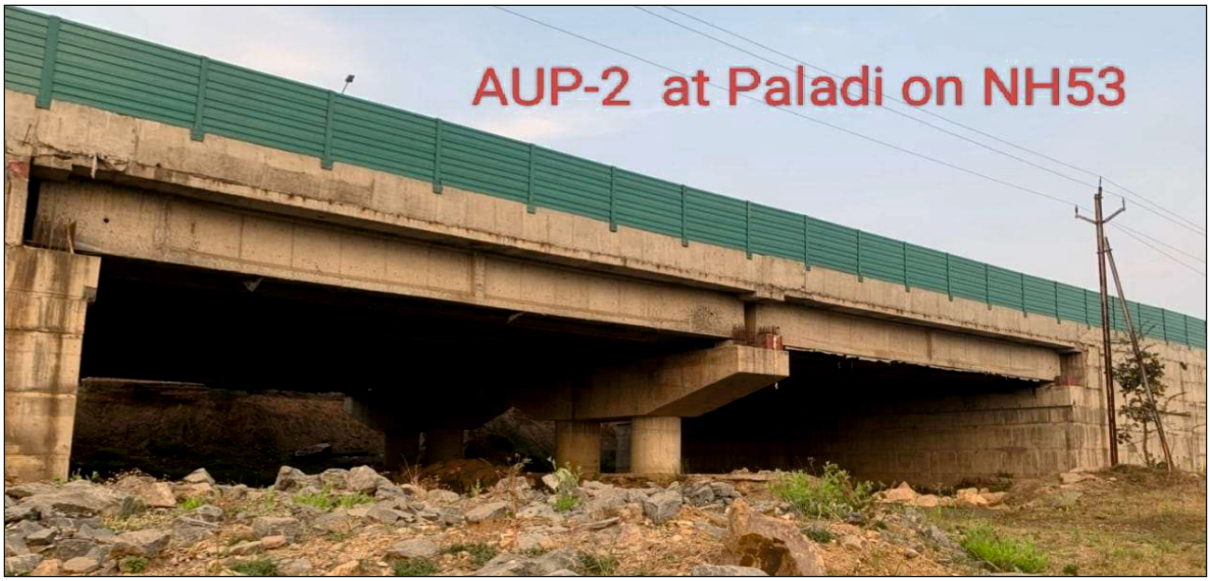


Figure-101: Animal Under Pass 2 at Paladi on NH53

7.8.2 NH-353B - Reconnecting the Tadoba-Kawal Tiger Corridor

The expansion of the Govindpur-Rajura section of NH-353B demonstrates that industrial progress and biodiversity conservation can thrive together. As a vital link for mineral transport between Maharashtra and Telangana, this 56.18 km highway traverses the essential tiger landscape connecting Tadoba-Andhari and Kawal Tiger Reserves. By adopting “Green Infrastructure" principles, the project ensures that the flow of commerce never disrupts the flow of life.

Two specific segments (totaling 4.5 km) were identified as high-priority "Tiger Corridors" by the WII. Without intervention, the widened highway and increased industrial traffic posed a significant risk of habitat isolation and wildlife-vehicle collisions, threatening the movement of tigers and other co-predators in the **Eastern Vidarbha Landscape.**

Working under the guidance of WII, Dehradun and the Maharashtra Forest Department, NHAI PIU-Chandrapur integrated a comprehensive Wildlife Mitigation Plan into the project's execution that included the following -

- **Strategic Animal Underpasses (AUPs):** Multiple dedicated underpasses placed precisely at documented wildlife crossing points to facilitate safe passage beneath heavy industrial traffic.
- **Anti-Confinement Engineering:** Structures optimized with a minimum 4-meter height and spans up to 50 meters to prevent the "confinement effect" that deters apex predators.
- **Reinforced Barrier Systems:** Specialized fencing and crash barriers installed along forest stretches to guide animals safely toward designated underpasses.
- **Low-Impact Construction:** Use of pre-fabricated structures to shorten construction timelines and minimize the human "footprint of disturbance" within sensitive habitats.
- **Economic & Ecological Synergy:** Supports the efficient transport of coal, cement, and paper while maintaining the genetic connectivity of the Eastern Vidarbha Landscape.
- **Investment in Conservation:** A dedicated 2% of the project cost was allocated specifically to wildlife mitigation and the management of man-animal conflict.
- **A Model for Sustainability:** Successfully balances the 4-laning of a high-traffic industrial corridor with the rigorous environmental standards required for tiger landscape protection.

The completion of the NH-353B widening project stands as a testament to **"Green Infrastructure."**

- **Safe Passage**: The project has successfully maintained the connectivity of the Tadoba-Kawal corridor, ensuring that the genetic flow of the tiger population remains uninterrupted.
- **Economic & Ecological Synergy**: While the 4-laning has drastically improved the efficiency of industrial logistics between Maharashtra and Telangana, the concurrent mitigation measures have ensured that this growth does not come at the cost of biodiversity.



Figure-102: Animal Under Pass at 74+194 Near Hardona Village (7m Span X 4.5m Height)



Figure-103: Animal Under Pass at 42+090 Near Akola Village (7m Span X 4.5m Height)



Figure-104: Noise Barrier on BHS @ AUP near Pendhari Rith



Figure-105: Animal Under Pass at 35+037 near Govindpur Village (14m Span X 4.5m Height)



Figure-106: Animal Under Pass near Pendhari Rith Village (50m Span X 5m Height)

7.9 Ranchi Regional Office

7.9.1 NH-33 Jamshedpur–Mahulia Section, Package IV

The project represents a significant step towards integrating infrastructure development with wildlife conservation. The project corridor passes through ecologically sensitive regions that form part of the Singhbhum Elephant Reserve/Elephant corridor, the first Elephant Reserve of the country, established in 2001 under Project Elephant. The Reserve spans an area of 13,440 sq. km across East Singhbhum, West Singhbhum, and Saraikela - Kharsawan districts of Jharkhand. It was created for the scientific and planned management of elephant habitats, conservation of viable wild populations of Asiatic elephants, ecological restoration of natural habitats and migratory routes, and mitigation of human-elephant conflict in affected areas.

Considering the frequent movement of elephants across this highway stretch and the associated risks of habitat fragmentation and accidents, dedicated wildlife mitigation measures were incorporated into the project design. Two major Elephant Underpasses were constructed at strategically identified locations along established elephant corridors to ensure safe and uninterrupted movement of elephants.

Wildlife Mitigation Structures:

In response, the NHAI, considering the frequent movement of elephants across this highway stretch and the associated risks of habitat fragmentation and accidents, incorporated dedicated wildlife mitigation measures into the project design.

This initiative by the NHAI is a model example of balancing infrastructure development with ecological priorities. The successful implementation of these wildlife mitigation structures highlights the importance of integrating conservation measures into projects, especially in ecologically sensitive areas. To further enhance its effectiveness, noise barrier sheets have been installed along the underpass. These barriers reduce vehicular noise and light disturbance, creating a calm and natural environment for animals — especially beneficial for sensitive and nocturnal species.

Measurable Impact on Wildlife and Local People:

The outcomes of these interventions have been both ecological and social:

- **Restored Habitat Connectivity**: The underpasses have reconnected fragmented forest patches, allowing safe and uninterrupted wildlife movement.
- **Reduced Wildlife–Vehicle Collisions**: By guiding animals away from road surfaces, the structures have significantly lowered accident risks.
- **Improved Human Safety:** Local communities and road users now face fewer risks from sudden wildlife crossings.
- **Mitigation of Human–Elephant Conflict:** Safe passage for elephants has reduced their interaction with nearby villages and agricultural lands.
- **Strengthened Biodiversity Conservation:** Continuous monitoring and research provisions under the WMP ensure adaptive management and long-term sustainability.



Figure-107: Elephant Underpass in Four/Six Laning of Jamshedpur–Mahulia Section of NH-33 in Jharkhand (Pkg.-IV)

7.9.2. NH-43 Palma–Gumla Section

The project corridor is located in close proximity to the Palkot Wildlife Sanctuary, an ecologically important area known for its rich biodiversity and the presence of wild Asiatic elephants. Considering this proximity and the likelihood of elephant movement in the adjoining landscape, appropriate wildlife-friendly design measures have been incorporated into the project. The region is characterized by Northern Tropical Dry Deciduous Forests dominated by Sal (*Shorea robusta*), along with species such as Mahua, Kend, Khair, and Salai. This habitat supports diverse wildlife including elephants, wolves, hyenas, jackals, jungle cats, and reptiles like rock pythons.

The project adopted a proactive and science-based Wildlife Management Plan (WMP). The focus was not only on compliance but on long-term ecological sustainability. Special emphasis was placed on ensuring the three fundamental needs of wildlife—food, water, and shelter—while also maintaining habitat connectivity.

The 4-laning of the Palma–Gumla section of NH-43 in Jharkhand stands as a strong example of how infrastructure development can move forward without compromising ecological integrity. The project involved diversion of about 7.8755 hectares of forest land. Spread across parts of Ranchi and Gumla Forest Divisions, the project influences 7 villages—Palma, Gargaon, Jariya, Nagadi, Hatu, Ita, and Lamkana—and nearly 13 additional villages in Gumla.

These communities largely depend on agriculture and seasonal migration, making them closely connected to the surrounding natural landscape.

A key milestone of this effort was the construction of three dedicated Elephant Underpasses, each measuring 30 m × 32 m × 7 m. These structures were strategically located based on wildlife movement patterns and designed to replicate natural pathways. Their scale and openness ensure that even large elephant herds can pass through comfortably without stress or disturbance.

These underpasses provide adequate space and height for the natural movement of elephant herds, ensuring minimal disturbance and maintaining ecological connectivity. The structures are designed to simulate natural pathways, thereby encouraging usage by wildlife and reducing the risk of animals crossing the highway at grade.



Figure-108: Elephant Underpass in 4-Lane of Palma–Gumla Section of NH-43 (Old NH-23)



Figure-109: Elephant Underpass in 4-Lane of Palma–Gumla Section of NH-43 (Old NH-23)



Figure-110: Elephant Underpass in 4-Lane of Palma–Gumla Section of NH-43 (Old NH-23)

7.9.3 NH- 33 Jamshedpur – Mahulia Section, Package II

This stretch passes through the ecologically sensitive Elephant Corridor the project involved diversion of about 26.6978 hectares of forest land. This region supports a diverse range of wildlife, including wild elephants, wild boar, Jackal, reptiles like monitor lizards, and bird species. Protecting the natural movement of these species became a key priority during project planning.

In response, the NHAI Ranchi PIU and Forest Department introduced a solution as two structures after the study done by the Forest Department —an Elephant Underpass measuring 4m x 25m x 8m and 3m x 25m x 8m. These structures are specially designed to allow safe and uninterrupted movement of wildlife across the highway, reducing the risk of accidents and preserving habitat connectivity.

It enhanced environmental safety, strengthened forest conservation, and supported long-term wildlife protection by reduction in wildlife-vehicle collisions, improved connectivity of fragmented elephant habitats, mitigation of human-elephant conflict in the region, and promotion of sustainable and eco-friendly highway development practices.

Elephant Underpass: 4 m × 25 m × 8 m



Figure-111: Elephant Underpass in Four laning of Jamshedpur – Mahulia Sectionof NH- 33 of Rampur–Chauka Section of NH-33 (Pkg.-II)

Elephant Underpass: 3 m × 25 m × 8 m



Figure-112: Elephant Underpass in Four laning of Jamshedpur – Mahulia Sectionof NH- 33 of Rampur–Chauka Section of NH-33 (Pkg.-II)

7.10 Delhi Regional Office

7.10.1 NH-119 Animal Underpasses on Behsuma - Bijnor Section

A 39.56 km stretch of the National Highway 119 (New NH-34) connecting Behsuma and Bijnor passes through critical ecological zones, including Protected Forest Land and the periphery of the Hastinapur Wildlife Sanctuary. As the road width increases, the risk of habitat fragmentation and wildlife-vehicle collisions (WVCs) rises exponentially.

Main animals found in this belt are a large population of leopards (locally called guldar), along with swamp deer, sambar, cheetal, hog deer, wild boar, and sloth bears.



Figure-113: Animal Underpass on NH-119 (Behsuma to Bijnor Section)



Figure-114: Animal Underpass on NH-119 (Behsuma to Bijnor Section)

7.11 Jammu Regional Office

7.11.1 Wildlife Mitigation in Delhi–Amritsar–Katra Expressway

Development and Upgradation of Sidhra to Ban Village section of the Delhi Amritsar Katra Expressway is ongoing. Wildlife mitigation measures have been incorporated at the **planning stage** to maintain ecological connectivity. The project corridor supports key species such as leopard, Asiatic black bear, musk deer, goral, barking deer, langur, wild boar, etc. These species depend on continuous habitat connectivity for movement, feeding, and survival.

To address habitat fragmentation, wildlife crossings have been integrated at the design stage itself. These measures have been planned to maintain natural movement of wildlife across the project area and reduce habitat disturbance. Early integration at the design stage helped avoid changes during construction and ensured smooth coordination with forest authorities.

The project includes 4 Viaducts, 13 Animal Underpasses (Box Culverts), 7 Minor Bridge Animal Passages, and 2 Major Bridge Animal Underpasses

The structures are designed based on terrain and natural animal movement paths. Larger crossings support movement of large mammals, while smaller underpasses cater to small and medium fauna.



Figure-115: Viaduct in Delhi–Amritsar–Katra Expressway



Figure-116: Minor Bridge in Delhi–Amritsar–Katra Expressway

7.12 Vijayawada Regional Office

7.12.1 Bangalore-Kadapa-Vijayawada Greenfield Economic Corridor

The Bangalore-Kadapa-Vijayawada corridor is a six-lane Greenfield Economic Corridor designed to meet the increasing demand for travel between Vijayawada and Bangalore. This dedicated corridor provides the shortest distance and fastest travel time. It offers high-speed, access-controlled connectivity, facilitating the smooth movement of traffic. The alignment passes through four forested areas, including a significant stretch that connects the Nagarjunasagar Srisailam Tiger Reserve (NSTR) and Sri Venkateshwara National Park in Andhra Pradesh.

NSTR is located in the Nallamala hill ranges, which are part of the Eastern Ghats in Andhra Pradesh spans a total area of 3,727.82 square kilometers, making it India's largest Tiger Reserve. The reserve comprises two wildlife sanctuaries: the Rajiv Gandhi Wildlife Sanctuary and the Gundla Brahmeshwaram Wildlife Sanctuary. Significant plant species found in the area include Axlewood, Odcha, Anjan tree, Salai, Teak, and various silk plants. The main mammals in the reserve include the Bengal Tiger, Leopard, Sloth Bear, Chital, Sambar Deer, Crocodile, Python, Cobra, Star Tortoise, and Indian Peafowl.

To ensure the safe movement of wildlife across the project area, the NHAI is implementing advanced mitigation measures designed to maintain ecological connectivity. A primary feature of this effort is a massive 2,070-meter viaduct, which elevates the highway and allows animals to pass freely at ground level without the risk of vehicle strikes. This is complemented by a 615-meter tunnel that preserves the natural terrain and the forest canopy above, as well as a 130-meter cut-and-cover structure that serves as a dedicated green bridge.



Figure-117: RHS Viaduct (Span 23m*40m = 920.00m)

Together, these engineering solutions ensure that the high-speed corridor does not fragment the vital habitats of the region's diverse species.



Figure-118: LHS Viaduct (Span 22m*40m = 880.00m)

7.12.2 NE-07 Bangalore-Chennai Expressway

The journey between Bangalore and Chennai is more than a simple commute; it serves as an economic lifeline for Southern India. In this context, the NHAI is constructing Phase II of the Bangalore-Chennai Expressway (NE-07), which is an 85 km high-speed corridor connecting Kolar in Karnataka to Chittoor in Andhra Pradesh. This project is noteworthy not only for its engineering but also for its role in protecting the Kaundinya Wildlife Sanctuary, the only elephant sanctuary in Andhra Pradesh.

The project section passes through Palamaner Reserved Forest. The project alignment does not intersect with the Eco-Sensitive Zone (ESZ) of the Wildlife Sanctuary. However, the segment of the project lies within a 10 km radius of the outer boundary of Kaundinya Wildlife Sanctuary. Since the boundary of the Eco-Sensitive Zone has not yet been officially notified, it has been regarded as an Eco-Sensitive Zone in accordance with the Supreme Court's directive. The closest point of the project alignment is 2.207 Km from the boundary of Kaundinya Wildlife Sanctuary.

Kaundinya Wildlife Sanctuary is located in the Palamaner-Kuppam forest ranges of Chittoor District in Andhra Pradesh. The sanctuary is home to a rich biodiversity, including species such as elephants, sloth bears, panthers, cheetal (spotted deer), chowsingha (four-horned antelope), and wild boars. It also hosts unique animals like the slender loris and the star tortoise. The vegetation within the sanctuary is equally diverse, featuring species such as Albizia amara, various Acacia species, Lagerstroemia, Ficus, and bamboo. The Government of Andhra Pradesh has expanded the Kaundinya Wildlife Sanctuary to enhance the movement of elephants, issuing a notification for the creation of the Rayala Elephant Reserve.

The project alignment passes through the designated area of the Rayala Elephant Reserve. Herds of elephants have been observed at three locations along the project route. Since forest pockets are situated on both sides of the project alignment in the forest section, the construction of the expressway may obstruct the movement of wildlife and contribute to habitat fragmentation.

To address these concerns, adequate measures have been incorporated into the design, including the construction of bridges, elephant underpasses, and culverts within the forest area.

Specifically, 06 elephant underpasses, 02 minor bridge-cum-animal underpasses, 02 Hume pipe culverts, and one viaduct have been proposed and are currently under construction. Additionally, chain-link fencing will be installed along the entire length of the expressway, including necessary transverse sections at structural locations. The total height of the fencing will be 2.5 meters above ground.



Figure-119: Elephant Underpass (Span 2 No x 30m), Length: 60.0 m, Avg. Height: 7.0 m



Figure-120: Elephant Underpass (Span 20 No x 32.5m), Length: 650.0 m, Avg. Height: 7.5 m



Figure-121: Elephant Underpass (Span 44 No x 31.875m), Length: 1402.0 m, Avg. Height: 7.5 m



Figure-122: Elephant Underpass (Span 14 No x 32.5m), Length: 455.0 m, Avg. Height: 7.5 m



Figure-123: Elephant Underpass (Span 10 No x 31.875m), Length: 318.75 m, Height: 22.0 m



Figure-124: Elevated Viaduct (Span 6 No x 32.5m + 52 No x 65m + 12 No x 32.5m), Length: 3965.0 m, Height: 7.0 m to 50.0 m



Figure-125: Hume Pipe Culvert (2 No x 1.2m) at km 116+200



Figure-126: Minor Bridge cum AUP (Span 1No x 8m), Length: 8.0 m, Height: 7.1 m

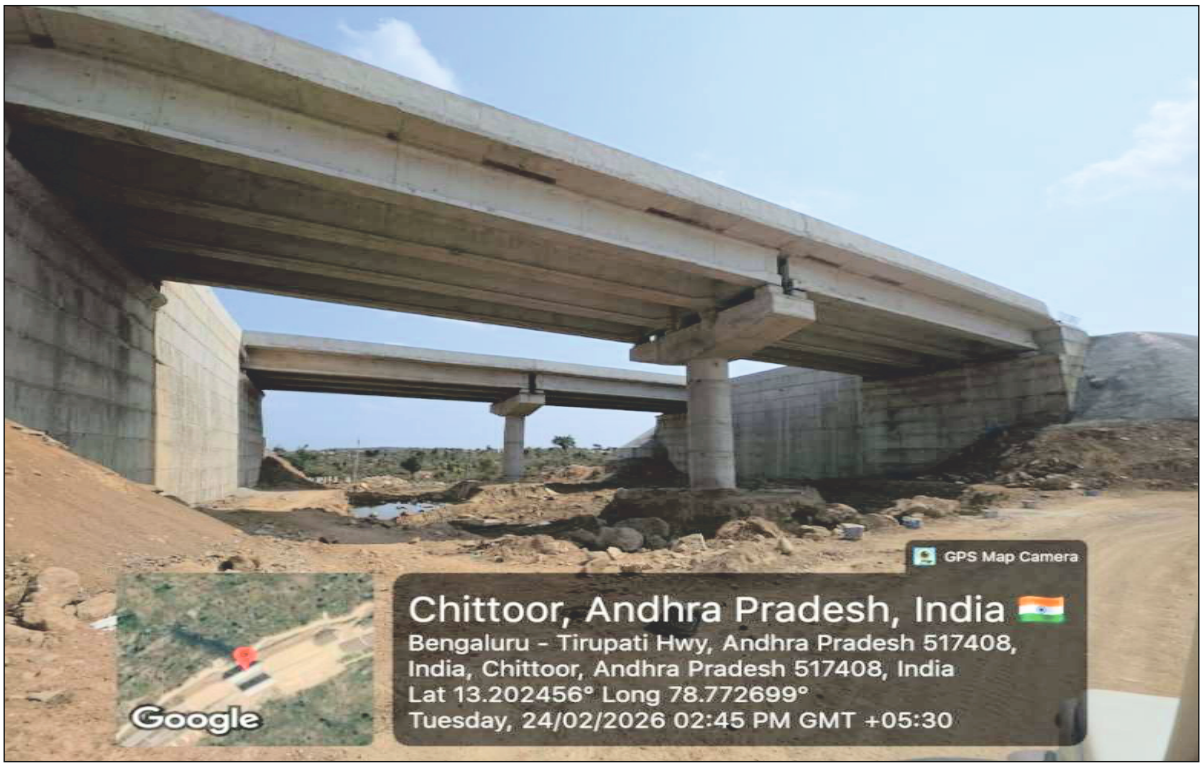


Figure-127: Minor Bridge cum AUP (Span 2 No x 25m), Length: 50 m, Height: 11.0 m

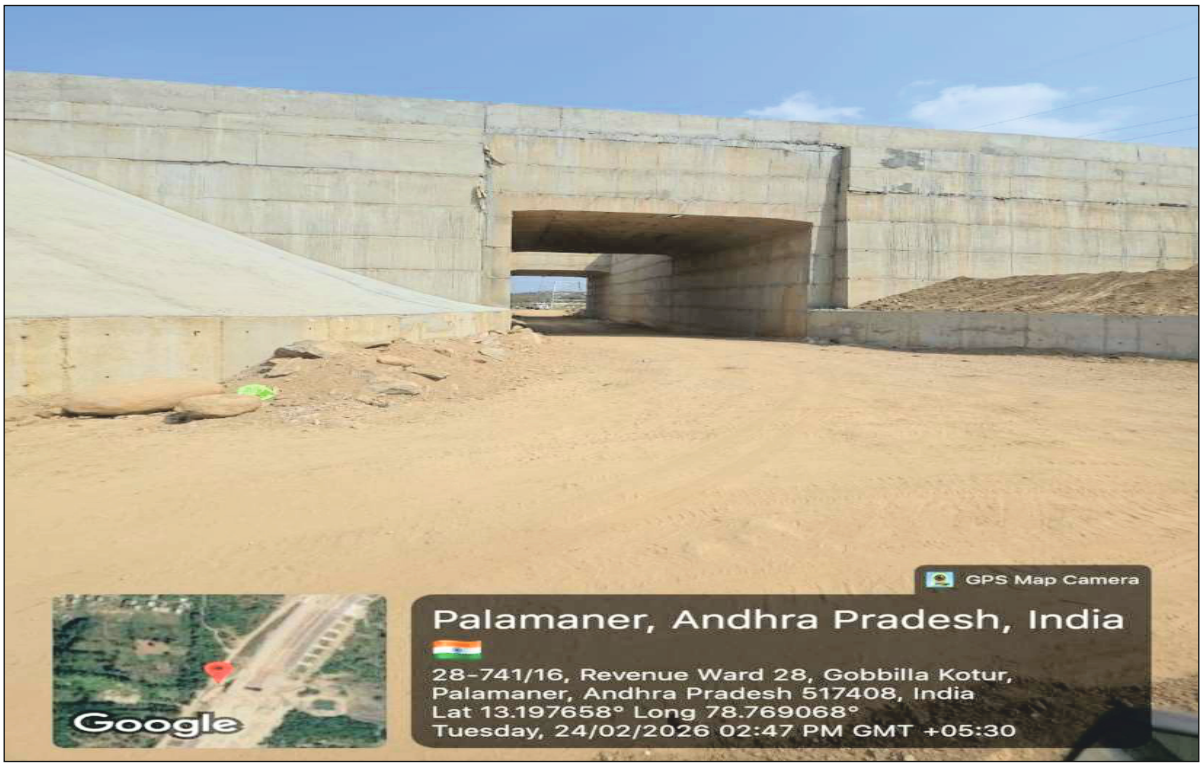


Figure-128: Minor Bridge cum AUP (Span 1 No x 10m), Length: 10.0 m, Height: 7.4m

7.13 Hyderabad Regional Office

7.13.1 NH 363 - Mancherial to Chandrapur

This is an economically important highway particularly for backward area which connects Telangana with Maharashtra, enhancing the interstate connectivity and regional development. In this section, the total forest area involved was 5.7414 Ha of forest land in Asifabad Division, and is a Tiger Corridor area linking Kawal, Tadoba & Indravati Tiger reserves). It also passes through the Manikgarh East Reserved Forest along the Maharashtra–Telangana border. It supports a diverse range of wildlife, including members of the Panthera family (Tigers and Leopards), as well as Gaur and Nilgai. The forest on the Maharashtra side is contiguous with the Tadoba–Andhari Tiger Reserve, and holds a significant and growing tiger population and provides high-quality habitat.

As tiger population increases in Tadoba Tiger reserve, Maharashtra State, the Tigers are moving into surrounding reserve forests, including the Kawal Tiger Reserve in Telangana. Manikgarh Reserve Forest is emerging as an important tiger corridor, facilitating the movement of tigers between Tadoba–Andhari Tiger Reserve, Kawal Tiger Reserve and Indravati Tiger Reserve.

This stretch of NH 363 thus falls across a crucial wildlife corridor, highlighting the urgent need to incorporate animal friendly structures. Accordingly, as per the advisory of the Wildlife Committee, an Animal Overpass (AOP) and Animal Underpass (AUP) were constructed. The NHAI has taken up the construction as a part of implementation of Wildlife Mitigation Measures. The overpass and underpass constructed on NH 363 specifically designed for facilitating Tiger and other wild animal movements and serves as a Corridor connecting the TATR (Tadoba-Anderi Tiger Reserve) in Maharashtra, which allow the Tigers to enter into Kawal Tiger Reserve (KTR), Telangana.

Bamboo, shrubs, and herbs have been planted by the concessionaire, and a one-foot-thick layer of soil has been laid over the concrete slab of AOP. This surface has been vegetated with grass and shrubs to help camouflage the structure and make it more natural for wildlife. As a result, animals are moving freely from one hillock to another without being obstructed by fast-moving traffic. Similarly, AUP have been constructed to enable safe and uninterrupted movement of wildlife across the landscape, allowing animals to access fodder and water on either side of the road.



Figure-129: Tiger Pugmark

Figure-130: Tiger Movement at the Animal Overpass (Eco Bridge)



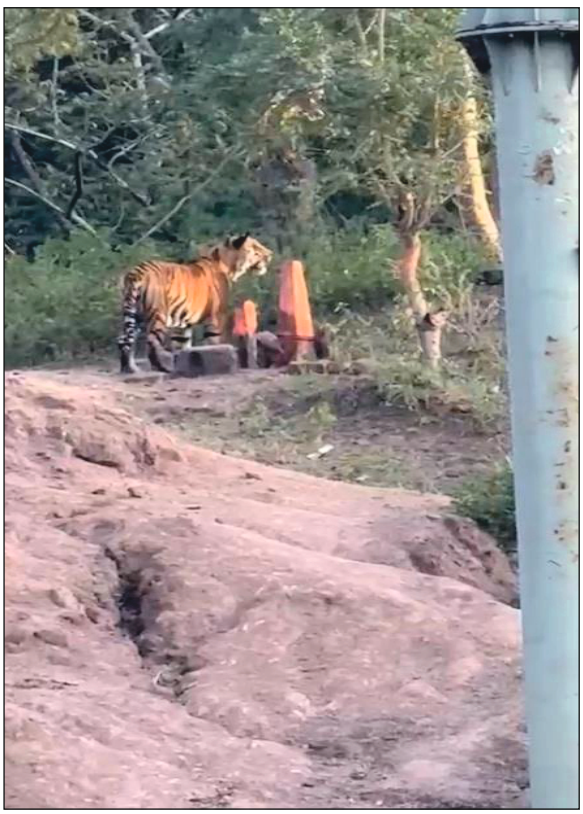


Figure-131: Animal Overpass (Eco Bridge) at Comp. No. 238 (From Km.94+400 to Km.94+550





Figure-132: Animal photographs are captured by the CCTV installed by DFO; Asifabad at Overpass constructed on NH 363

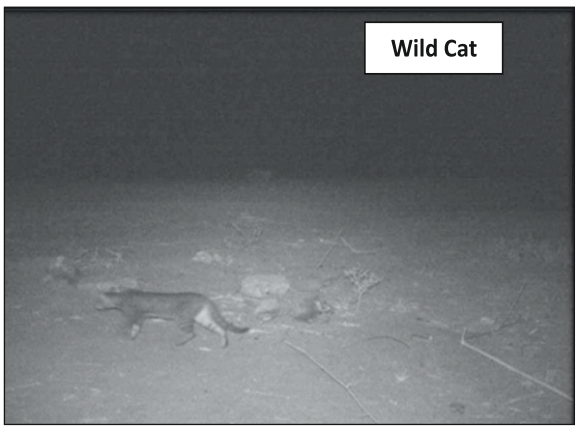






Figure-133: Animal Underpass at Compartment No. 306

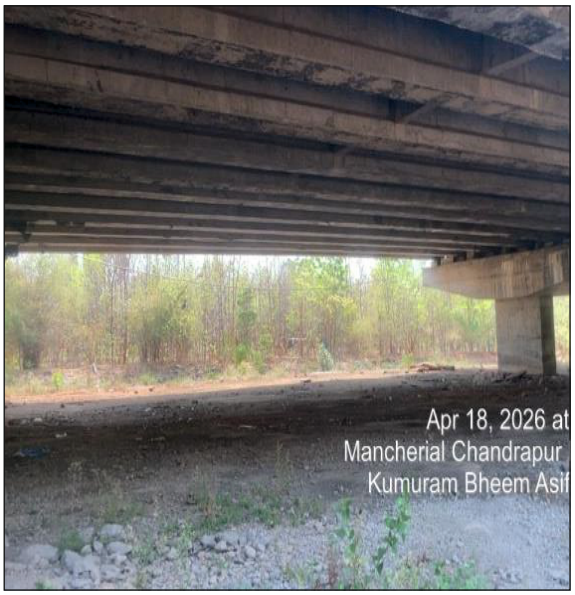




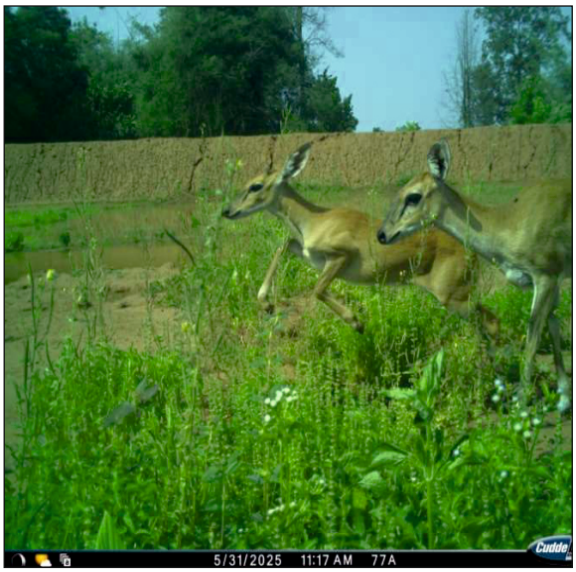


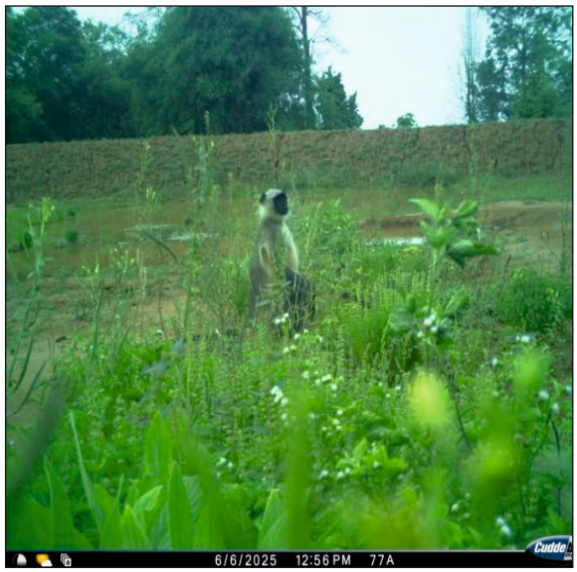


Figure-134: Wildlife Photos and Pugmarks of Tiger in and around the Compensatory Afforestation (CA) area of 33 Ha, CA contributes to the thriving wildlife and increased habitat









7.14 Jaipur Regional Office

7.14.1 Delhi-Vadodara Expressway

In the heart of Rajasthan's pristine wilderness, spanning the Lakheri area of District Bundi, lies a visionary 11.63 km, 8-lane greenfield expressway segment of the iconic Delhi-Vadodara Greenfield Expressway under Bharatmala Pariyojana. This transformative infrastructure project stands as a shining testament to NHAI's unwavering commitment to sustainable development — where cutting-edge engineering seamlessly converges with ecological preservation. Here, progress does not come at the cost of nature. Instead, it embraces and protects it.

This landmark stretch introduces **India's first large-scale Animal Overpasses** — a pioneering initiative that redefines the future of wildlife-friendly infrastructure in the country. Spanning a staggering 2.5 kilometers, these five magnificent overpasses (each 500 meters long) form a monumental green corridor, allowing unhindered movement of wildlife across the expressway.

Camouflaged with lush native vegetation, these eco-friendly overpasses blend harmoniously into the surrounding landscape, appearing as natural extensions of the forest rather than man-made structures. This innovative “open tunnel” design ensures that large mammals, including the majestic tiger, can traverse safely above the high-speed corridor without fear or disruption — preserving ancient migratory paths and safeguarding biodiversity for generations to come.

Complementing this is a 1.2 km (1,200 meters) Animal Underpass, strategically integrated within the dense forested zone. This subterranean passage provides a secure, shaded pathway for smaller and nocturnal species, further reinforcing the project's deep respect for every creature that calls this region home.

NHAI has gone far beyond conventional infrastructure development by embedding world-class environmental safeguards into every aspect of Package 11:

- **Polyurethane (PU) Mats on Drain Side Walls**: Advanced vibration-dampening technology has been deployed to minimize the transmission of traffic-induced vibrations into the surrounding ecosystem. This thoughtful measure protects sensitive wildlife habitats from disturbance, ensuring serenity even as the expressway pulses with life.
- **4-Meter-High Precast Boundary Wall**: A robust, aesthetically designed access-controlled perimeter that effectively prevents the ingress of animals and pedestrians onto the high-speed carriageway, while allowing free and safe movement of wildlife through the elevated and underground passages.
- **2-Meter-High Sound-Absorbing Noise Barriers**: Recognizing that noise pollution can cause chronic stress, disorientation, and behavioural disruption among wildlife, NHAI has installed state-of-the-art acoustic barriers. These barriers significantly attenuate traffic noise, creating a calmer, more harmonious environment that supports natural behaviours — from feeding and mating to nesting and rearing young.

In the area of **Carbon Emission Reduction and Use of Renewable Energy**, the project has achieved substantial environmental gains. The use of 120 MT of biomass pellets for heating bitumen resulted in a reduction of 162 MT of carbon emissions and saved 62,000 liters of diesel. Additionally, the utilization of 76 lakh KW of electricity board (EB) power helped reduce 7,986 MT of carbon emissions and saved 3,036 KL of diesel. Furthermore, solar panels installed on site have the potential to generate 200 KW per year, which is expected to reduce 316 MT of carbon emissions and save 120 KL of diesel annually.

Under **Eco-Friendly Practices**, over 35,000 native plants have been planted along the project stretch. Rainwater harvesting structures have been installed every 500 meters, while drip irrigation systems for median plants have resulted in water savings of more than 50% compared to conventional tanker-based methods. The adoption of modular formwork has also delivered significant benefits by enabling high repetitions, reducing construction waste, shortening cycle time, and lowering the overall environmental impact while maintaining superior durability.

Beyond the engineering achievement, early indications suggest the animal passages are already proving effective. NHAI engineers and ground staff have reported multiple sightings of wildlife using the dedicated Animal Overpasses (AOPs) and Underpasses (AUPs), including majestic leopards, sloth bears, wild boars, hyenas, and herds of deer moving across the structures. These observations, based solely on direct visual encounters rather than tracking devices, offer promising real-world evidence of animals adapting to the new corridors.

Figure-135: Animal Overpasses on Delhi-Vadodara Expressway – Package 11



Animal Overpasses on Delhi-Vadodara Expressway – Package 11





Figure-136: Animal Underpasses on Delhi-Vadodara Expressway – Package 11





Mukundara Eco-Tunnel:

An ultra-wide twin-tube eco-tunnel passing directly beneath ecologically sensitive Mukundara Hills Tiger Reserve (MHTR) completely hides heavy traffic out of sight. The total structural length is 4.894 km which includes a 3.650 km deep underground bored section and a 1.244 km cut-and-cover section.



The rugged cliffs and dry deciduous forests of the Mukundara Hills serve as a vital sanctuary for an array of flagship Indian wildlife. Key species include Bengal Tigers, Indian Leopards, Striped Hyenas, Sloth Bears, Chital (Spotted Deer), Sambar Deer, and rare river reptiles like Gharials and Marsh Crocodiles along its water boundaries. By burying the expressway underground, this engineering marvel offers three critical lifelines to the reserve's wildlife:

- **Unbroken Genetic Corridors:** The 4.894 km tunnel keeps natural migratory paths intact. This allows solitary carnivores like tigers to safely seek out expansive, connected territories to hunt and find unrelated mates, preventing genetic isolation.
- **Zero Noise and Light Pollution:** Vehicles, jet fans, and internal security systems are sealed tightly inside the concrete tubes. The surface forest floor stays dark and quiet, ensuring nocturnal animals can hunt and communicate naturally without distress.
- **Absolute Elimination of Roadkill:** With traffic routed entirely beneath the reserve, the risk of high-speed wildlife-vehicle collisions within this critical zone drops to absolute zero, keeping both the animals and motorists safe.

7.15 Bengaluru Regional Office

7.15.1 NH-948 Agara–Tataguni Cross stretch

The NH-948 stretch near Agara–Tataguni Cross in Karnataka is identified as a critical location requiring immediate intervention due to road safety concerns and ecological sensitivity. This black spot is also an active wildlife movement corridor, particularly for elephants. Recognizing the need to address both aspects simultaneously, the Regional Office NHAI, undertook a comprehensive project integrating infrastructure development with appropriate wildlife mitigation measures.

The project location presented a dual challenge of ensuring road safety and preserving ecological continuity. The spot was prone to accidents and frequent wildlife crossings in the area leading to collisions and also creating hazardous situations for commuters. A conventional road improvement approach alone was insufficient, as it could further disrupt wildlife movement. Therefore, a balanced and carefully designed intervention was necessary to improve safety and maintaining natural ecological connectivity.

A major highlight of the project is the construction of an EOP, designed as a box structure measuring 40 m × 45 m. This structure provides a safe and dedicated passage for elephants and other Wildlife and significantly reducing the risk of wildlife-vehicle collisions and ensuring continuity of their natural movement. The project also incorporates cross drainage works in the form of box culverts of 2 × 2 m span to maintain natural water flow and prevent waterlogging.



Figure-137: Elephant Overpass in NH-209 (New NH-948) near Agara–Tataguni Cross in Karnataka



Figure-138: EOP with pit for planting in NH-209 (New NH-948) near Agara–Tataguni Cross in Karnataka

The project has successfully transformed a hazardous spot into a safe and efficient road segment duly incorporating essential wildlife mitigation measures. The Elephant Over Pass (EOP) ensures safe passage for Elephant and other Wildlife, reducing the risk of accidents and preserving valuable life of Wild Animal. Overall, the project demonstrates a sustainable approach to highway development by effectively integrating engineering solutions with environmental considerations. It stands as a model for future infrastructure projects in ecologically sensitive areas, showcasing how development and conservation can be achieved in harmony.

After construction of Civil structure of 40*45 m there was challenge to convert it into natural habitat. For this, soil was brought in and laid over the bridge portion. Thereafter, seeds of grasses are dibbled over it to give the area a natural look. During the monsoon herbs, shrubs and trees of local Species were planted and maintained till date. Major plants planted are Bamboo, Pongamia, Tamarind and Jamun, beside other herb, shrub and grasses. On either side of Bridge small waterholes were created to attract the animal to pass through this bridge and move either to BM Kaval or Bannerghatta National Park.

To monitor the movement of Wildlife either side of the bridge 2 number of camera were installed. To avoid the distraction to wildlife from light and sound, the wall of bridge is raised up to 12 feet so that it can act as light and sound barrier. Initially animals were hesitant and were avoiding movement over EOP because approach and terrain were different from the adjoining area. Once the planted shrubs and trees grew, small wild animals (Deer, Rabbits etc.) started moving over the EOP. This was followed by movement of Leopard and ultimately Elephants also crossed the bridge back and forth between Tathguni Estate towards BM Kaval back toward Bannerghatta National Park.

The movement of these animal are captured in camera trap installed by NHAI and information about their movement was shared with local Forest Officials. The movement of wild life animals over this EOP is a heartening feature and the efforts of NHAI to construct EOP to provide safe passage paid dividend when wildlife started using this corridor.



Figure-139: Camera Trap of Elephants over EOP





Figure-140: Camera Trap of Leopard over EOP

7.16 Bhubaneshwar Regional Office

7.16.1 NH-55 Angul–Sambalpur Section

The Angul - Sambalpur section of NH-55 traverses through ecologically sensitive forest regions that support a variety of wildlife, particularly elephants, which require large and continuous habitats for their movement. The widening of the highway into a four-lane corridor posed a significant threat to these ecosystems by creating physical barriers that disrupt natural wildlife movement patterns. Animal Under Passes (AUPs) have been introduced as a key mitigation measure to address these challenges.

The planning and design of AUPs were carried out using a scientific and field-based approach. Detailed field surveys and joint inspections were conducted by the NHAI in coordination with the State Forest Department. The Divisional Forest Officers played a critical role in identifying suitable locations based on evidence of wildlife movement, such as footprints, dung presence, and local knowledge of animal trails. The selected sites correspond to natural crossing points and forest connectivity zones, thereby increasing the likelihood of usage by wildlife.

Table-35: Location details Animal Under Passes on 4-Laning of Angul-Sambalpur Section of NH-55

Division	Location / Village	Span / Height
Angul	Between Katarba RF & Angul Division (Soum RF side)	100 m span × 6 m height
Athmallik	Jamalani	100 m span × 6 m height
	A Kutasingha	100 m span × 6 m height
Sambalpur	Pandimunda (Kunjamura)	50 m span × 6 m height
	Nuamuhal	50 m span × 6 m height
	Hirakud	50 m span × 6 m height
	Bhatli	50 m span × 6 m height
	Jhankarpali	50 m span × 6 m height

In terms of design, the AUPs have been constructed with large spans ranging from 50 to 100 meters and a height of approximately 6 meters. These dimensions are specifically chosen to accommodate large mammals like elephants and to provide a sense of openness that encourages animals to use the structures. The alignment of AUPs with natural terrain and drainage channels further enhances their effectiveness, as animals tend to follow these features during movement. Additionally, complementary measures such as guiding structures, plantation, and awareness initiatives have been integrated to direct wildlife towards these safe crossing points.



Figure-141: Animal Under Pass on 4-Laning of Angul–Sambalpur Section of NH-55 (Old NH-42)

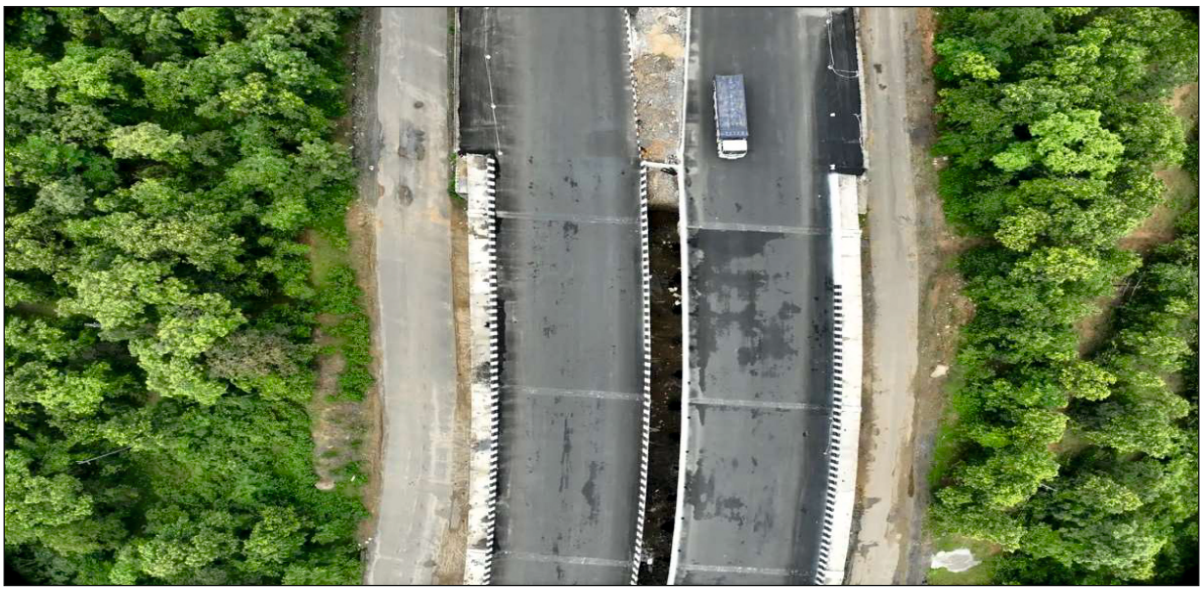


Figure-142: Animal Under Pass on 4-Laning of Angul–Sambalpur Section of NH-55 (Old NH-42)

The provision of AUPs in the Angul-Sambalpur highway project represents a well-planned and scientifically informed approach to mitigating the ecological impacts of linear infrastructure. By ensuring safe wildlife movement across the highway, these structures significantly reduce the risks of habitat fragmentation, road accidents, and human-wildlife conflict. The collaborative efforts of NHAI and the Forest Department, combined with field-based validation, have resulted in the effective placement and design of these underpasses. This initiative not only safeguards biodiversity but also sets a benchmark for integrating environmental sustainability into infrastructure development projects across forested landscapes.

7.16.2 NH-130CD Greenfield Karki to Kaligura section

Table-36: List of Structures

Sl. No.	Structure Type	Size / Dimension	Number
1.	Viaduct	3 × 30 m	1
2.	Animal Underpass (Box Culvert)	3 × 2.75 m	23
		4 × 2.75 m	5
		6 × 4 m	5
		6 × 2.75 m	1
		7 × 8.5 m	1
		7 × 6 m	1
3.	Minor Bridge cum AUP	1 × 15 m	4
		1 × 20 m	1
		1 × 30 m	2
4.	Major Bridge cum AUP	3 × 30 m	1
		4 × 30 m	1
		5 × 30 m	1
5.	Noise Barrier / Fencing	4320 Rmt	
6.	Monkey Canopy	1 × 30 m	3

The mitigation strategy for the project was developed through a comprehensive scientific approach involving field surveys, ecological assessments, and stakeholder consultations. Detailed field visits were conducted by experts along with forest officials to understand habitat conditions, wildlife presence, and movement patterns. Information was gathered from local communities and forest staff regarding frequently used animal paths, conflict zones, and ecological sensitivities.

A critical step in the planning process was the joint field verification carried out by the NHAI and the State Forest Department. As per official records, joint inspections were conducted to identify and finalize suitable locations for AUPs and monkey canopy bridges. These locations were selected based on ground conditions, presence of wildlife movement indicators, and ecological suitability of the terrain. The DFO played a key role in confirming these locations to ensure that the structures align with actual wildlife usage patterns rather than theoretical assumptions.

AUPs were incorporated into the project design to ensure safe and uninterrupted movement of terrestrial wildlife across the highway. These structures were designed in multiple sizes to accommodate a wide range of species, from small reptiles and amphibians to medium-sized mammals and larger animals such as sloth bear and leopard. The placement of AUP was carefully aligned with natural drainage channels and existing animal trails, as these features are commonly used by wildlife for movement. This approach increases the likelihood of animals adopting these structures naturally, thereby maintaining landscape connectivity.



Figure-143: AUP 1 x 30m in 6L Greenfield Karki to Kaligura section of NH-130CD Road (Pkg. - OD-4)

Monkey canopy bridges were provided to address the needs of arboreal species that rely on continuous tree cover for movement. The clearing of vegetation for road construction often results in canopy gaps, forcing animals such as monkeys and squirrels to descend to the ground, which exposes them to traffic hazards. The canopy bridges were, therefore, installed at locations identified during field surveys where tree continuity was disrupted. The finalization of these locations was carried out through joint inspections led by the Divisional Forest Officer, ensuring that the structures are placed at ecologically relevant points where arboreal movement is most frequent.

Noise barriers and fencing were implemented to reduce the impact of vehicular disturbance on wildlife. The conservation plan indicates that noise and light disturbances can significantly alter animal behaviour, leading to avoidance of habitat areas near the road and increased stress levels.

By installing noise barriers along sensitive stretches, the project minimizes sound penetration into the forest and creates a more conducive environment for wildlife. At the same time, fencing helps guide animals toward designated crossing structures such as underpasses, thereby reducing the chances of random road crossings and associated accidents.



Figure-144: Monkey Canopy in 6L Greenfield Karki to Kaligura Sec. of NH-130CD Road (Pkg. - OD-4)



Figure-145: Light & Sound Barrier 6L Greenfield Karki to Kaligura Sec. of NH-130CD (Pkg. - OD-4)

7.17 Guwahati Regional Office

7.17.1 NH-54E Udali to Manderdisa section

The following mitigation measures have been successfully implemented by NHAI in accordance with the recommendations of the WWF multidisciplinary team. To prevent light disturbance to wildlife, 1.5 m high opaque barricading from FRL has been installed on Major Bridges No. 45/3 and 52/3 to shield wildlife from night-time glare. Landscaping below the major bridges has been completed, reducing structural impact while maintaining the required 10 m vertical clearance. Major Bridge No. 52/3, with a length of 140 m, and Major Bridge No. 45/3, with a length of 200 m, are located within an elephant corridor, and a vertical clearance of 12.0 m has been maintained to facilitate the smooth movement of elephants. Similarly, Minor Bridges No. 50/2 and 54/2, which also fall within the elephant corridor, have been provided with two additional spans of 6.0 m each on either side of the proposed 25.0 m and 10.0 m span structures, maintaining a vertical clearance of 6.0 m.

To regulate vehicle speed and enhance road safety in wildlife-sensitive areas, advance warning signs, cautionary and informatory boards, speed limit signs, and rumble strips have been installed, while smooth gradients have been maintained to support elephant movement. All culvert structures meet or exceed the prescribed 2 m clearance requirement for the movement of small animals. Crash barriers have been strategically provided only at designated approaches so as not to create continuous barriers to wildlife movement. In addition, necessary traffic signs, road markings, and road appurtenances such as chevrons, caution boards, traffic hazard signs, delineators, and other related measures have been installed on both sides of the road to control vehicle speed, in compliance with the directions of the MoEF&CC.



Figure-146: Animal Underpass 4 - laning from Udali to Manderdisa Sec. of NH-54 E in Assam (AS-27)

The **objective of mitigation measures undertaken was to** ensure the safety of wildlife (specifically elephants) and road users by implementing specialised infrastructure that buffers human interference within natural animal territories in the total project length of 20.50 km of which the impact area 16.78 km falls within the Lumding Reserved Forest.

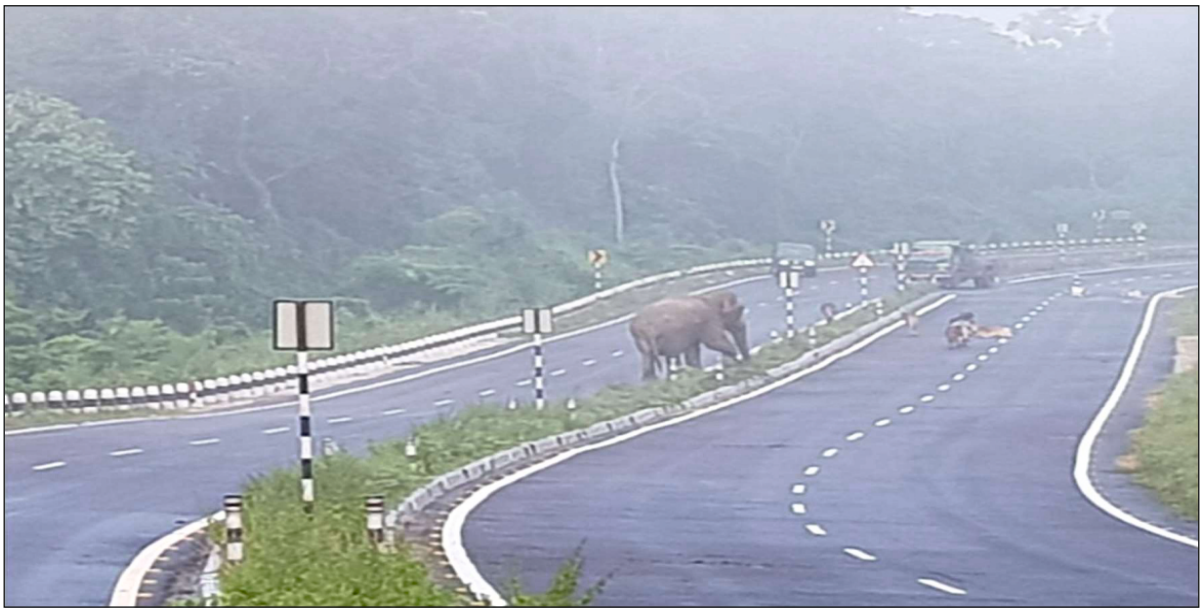


Figure-147: HEC areas in the old NH-54 before the execution of wildlife mitigation structures

Details of Mitigation Measures taken viz. No./Length of Underpasses, Overpasses, Tunnels, Bridges, Elevated structures, Fencing, Noise Barriers, etc.

Major bridge 52/3 (140 m) & 45/3 (200 m)
A Viaduct was provided for safe passage of elephants





Figure-148: Major Bridges to facilitate the movement of wildlife particularly elephants

Minor bridge 50/2 & 54/2

Additional bays of 6m at both ends have been provided for safe passage









Figure-149: Minor bridges with additional bays for smooth passage of elephants

Opaque Sheet Barrier over the Crash Barrier for light prevention along the Overpass and its approaches on each side



Figure-150: Opaque sheet barrier over the crash barriers for light prevention

Figure-151: Cautionary Sign Boards and Speed Limits





Figure-152: Cautionary Sign Boards for Elephant Corridor









Figure-153: Barbed wire fencing at cutting portions to restrict the movement of animals over the main carriageway



7.18 Gandhinagar Regional Office

7.18.1 NH-751 Pipli– Bhavnagar section

The successful completion of highway projects in Gujarat, including the Pipli– Bhavnagar section NH751 corridors, stands as a model example of balancing infrastructure growth with environmental conservation.

The Pipli–Bhavnagar project, passing through ecologically sensitive zones such as Velavadar Blackbuck National Park and surrounding forest areas, was upgraded from a 10 m two-lane road to a modern four-lane highway with rigid pavement and improved safety features. Despite challenges posed by wildlife habitats and forest regions, the project was executed with a strong focus on sustainability.

A comprehensive wildlife mitigation plan was implemented, which included the construction of 03 number of Underpass, an elevated corridor and installation of chain-link fencing to guide animals safely across the highway. Beyond structural interventions, NHAI has allocated a substantial provision for habitat improvement within the sanctuary. As part of these efforts, several supporting measures have been implemented, including the development of 10 water ponds, 5 water tanks, circular platforms and installation of cautionary signboards. These initiatives are aimed at maintaining ecological balance while ensuring safer interaction between wildlife and road users.

Key Outcomes

- Significant reduction in Blackbuck-related accidents and associated road fatalities along the highway corridor.
- Ensured safe and uninterrupted movement of Blackbuck across designated crossing structures.
- Effective conservation of Blackbuck population, contributing to preservation of biodiversity and natural habitats.
- Enhanced road safety and smoother traffic flow by minimizing wildlife–vehicle conflicts involving Blackbuck.
- Promoted sustainable infrastructure development, strengthening regional connectivity while safeguarding Blackbuck habitats.

This project demonstrates how modern highway engineering can coexist with nature. Through proactive planning and effective implementation of mitigation measures, the project has become a benchmark for eco-friendly infrastructure development in India—ensuring that progress does not come at the cost of wildlife, but rather supports its protection and survival.

Figure-154: Elevated Corridor on Pipli– Bhavnagar section NH751 corridors





Figure-155: Animal Underpass on Pipli– Bhavnagar section NH751 corridors





Figure-156: Circular Platforms on Pipli– Bhavnagar section NH751 corridors



Figure-157: Water Pond on Pipli– Bhavnagar section NH751 corridors



Figure-158: Cautionary Signboards on Pipli– Bhavnagar section NH751 corridors





7.18.2 NH-8E Kagvadar–Una Section

This project stands as a commendable example of sustainable infrastructure development. Spanning a total length of 40.98 km, the project demonstrates how economic growth and ecological preservation can be effectively balanced in environmentally sensitive regions.

A key highlight of this project is its scientifically planned and successfully implemented wildlife mitigation strategy, specifically designed to protect the endangered Asiatic lion population. The project corridor falls within an important landscape that supports the natural movement of these lions, primarily originating from the Gir National Park and its surrounding habitats.

Recognizing the ecological significance of this region, six dedicated Lion Underpasses (LUPs) were constructed at strategically identified locations. These structures were developed based on detailed field studies, wildlife movement analysis, and expert consultations to ensure alignment with natural animal corridors. The design parameters—such as adequate width, height, natural substrate flooring, and minimal human disturbance—were carefully incorporated to encourage usage by wildlife.

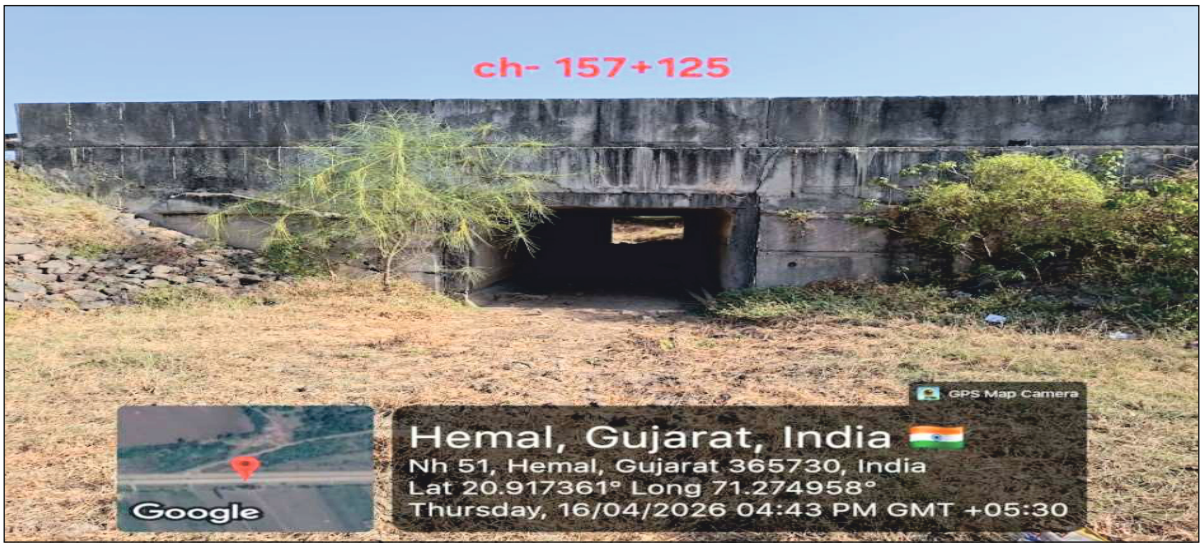
The outcomes of these mitigation measures have been highly encouraging. The underpasses are actively being used by Asiatic lions and other fauna, enabling safe, uninterrupted cross-movement across the highway. This has significantly reduced incidents of wildlife mortality due to vehicular collisions, thereby enhancing both road safety and wildlife protection. Importantly, the preservation of these natural corridors supports genetic exchange among lion populations, which is critical for their long-term survival and resilience.

Sustainability of the Asiatic Lion Population:
The project contributes meaningfully to the long-term sustainability of the Asiatic lion in the following ways:

- **Habitat Connectivity:** By maintaining ecological corridors between fragmented habitats, the project ensures that lions can access wider territories for hunting, breeding, and dispersal.
- **Reduction in Human-Wildlife Conflict:** Safe crossings minimize accidental encounters on highways, reducing risks to both animals and humans.
- **Genetic Diversity Conservation:** Facilitating free movement helps avoid inbreeding by enabling interaction between different lion groups.
- **Adaptation to Expanding Range:** Asiatic lions have been expanding beyond protected areas; such mitigation measures support their adaptation to human-dominated landscapes.

Beyond ecological benefits, the project has also delivered substantial socio-economic advantages. The upgraded highway has improved regional connectivity, ensuring smoother and faster transportation. It has significantly enhanced access to major pilgrimage destinations such as Somnath Temple and Dwarkadhish Temple, thereby boosting religious tourism and contributing to local economic development.

Figure-159: Lion Underpasses in Four-Laning of Kagvadar–Una Section of NH-8E (Pkg.-IV)



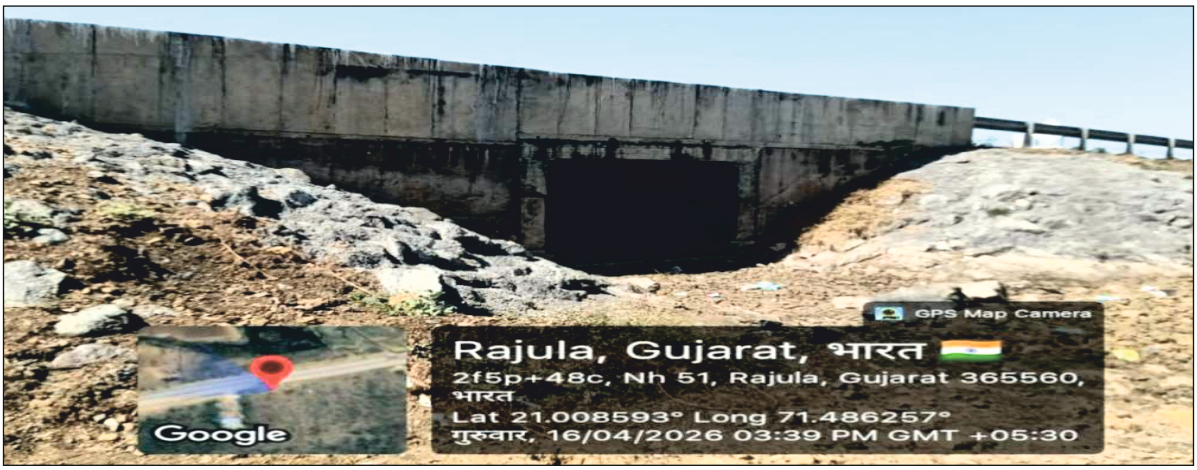






Figure-160: Cautionary Signboards in Four-Laning of Kagvadar–Una Section of NH-8E (Pkg.-IV)





7.19 Raipur Regional Office

7.19.1 NH-130A Eco-Economic Green Corridor: Urga–Pathalgaon

The Urga-Pathalgaon section of NH-130A, part of the Raipur–Dhanbad Economic Corridor (262 km lies in the State of Chhattisgarh), shows a balance between development and wildlife conservation. It improves connectivity between Raipur and Dhanbad, reduces travel time and transport costs, and supports trade and business movement. Through green infrastructure principles, the project ensures that economic growth continues without disturbing natural life.

Species that cross here: Indian elephant is the recorded target species of this movement path. Sloth bear, chital and wild boar, leopard, chital, nilgai, barking deer, four-horned antelope, jackal and Indian peafowl are also use these open passages.

Key Highlights:

- **Wildlife Under & Over Passes:** To reduce human-animal conflict along the route, EUP (Underpasses) and EOP (Overpasses) were constructed at major wildlife structures to ensure safe animal movement. These structures enable safe crossings and prevent accidents or traffic disruption during wildlife movement.
- **Eco-friendly Green Infrastructure:** Adoption of sustainable design principles to balance transportation development with wildlife protection. It promotes eco-friendly practices to ensure long-term ecological stability along with economic growth.
- **Financial Commitment to Conservation Efforts:** About **2% of the total project cost** was allocated to wildlife protection and conservation. This supports safe passages, mitigation structures, and eco-friendly infrastructure to protect animals and their habitats.
- **Integrating Economy with Ecology:** Support the transport of various types of minerals and boost business and trade activities, as this corridor demonstrates a strong balance between economic development and ecological conservation.



Figure-161: EOP on NH-130A: 50m length, 2×25 m spans, 55m width



Figure-162: EUP on NH-130A: 2×11.6m width, 8m×30 m span



Figure-163: EUP on NH-130A: 2×11.6m width, 8m×30 m span

7.19.2 NH-130 CD Six-Lane Raipur–Visakhapatnam Economic Corridor

The Raipur–Visakhapatnam Economic Corridor is one of India's key Greenfield highway projects under Bharatmala Pariyojana, redefining connectivity between the mineral-rich heart of Central India and the major port of Visakhapatnam. The alignment passes through the Dhamtari, Kanker and Keshkal Forest Divisions. Although the general project right-of-way is 60 m, the width within forest stretches has been restricted to 45 m in order to limit forest impact. The diverted forest land is to the tune of 147.6694 Ha in Dhamtari Division, 39.0869 Ha in Kanker Division and 41.2862 Ha in Keshkal Division.

Further, approximately 35.02 Km of the project alignment runs alongside the Eco-Sensitive Zone of the Udanti–Sitanadi Tiger Reserve and a tiger corridor, due to which NOC from National Tiger Conservation Authority (NTCA) & Wildlife Clearance from National Board for Wildlife (NBWL) were secured before execution.

To keep wildlife habitats connected, the corridor provides dedicated 02 Animal Overpasses (span arrangement of 2 x 22.5 m and structure width of 10 m), 15 Animal Underpasses (span length varying from 10 m to 30 m with minimum vertical clearance of 5 m), 10 Elephant Underpasses (span length varying from 60 m to 360 m with minimum vertical clearance of 7 m), 67 reptile crossings (600 mm dia NP4 pipe) and a series of 29 monkey canopies (span arrangement 1 x 45 m and length 21 m having 5 arboreal path of 1 m width with minimum vertical clearance of 8 m) over the carriageway for arboreal species, along with the noise and light barriers. The tunnel and viaducts in the Ghat further minimize hillside excavation and tree felling, protecting the fragile forest ecosystem.

In addition to the mitigation structures, Wildlife Conservations & Management Plan includes improvement of water availability, soil-and-moisture conservation, removal of invasive alien species, pasture development, gap plantation of fruit-bearing trees, fire protection, establishment of an early-warning elephant alert system etc.

Figure 164: Wildlife Mitigation Structures on Raipur–Visakhapatnam Economic Corridor

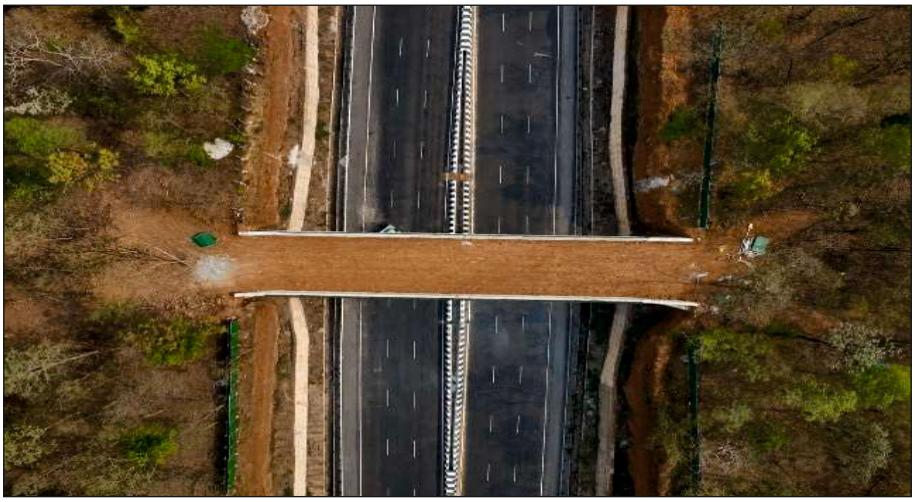


Monkey Canopy



Monkey Canopy

Animal Overpass



Elephant Underpass



Animal Underpass

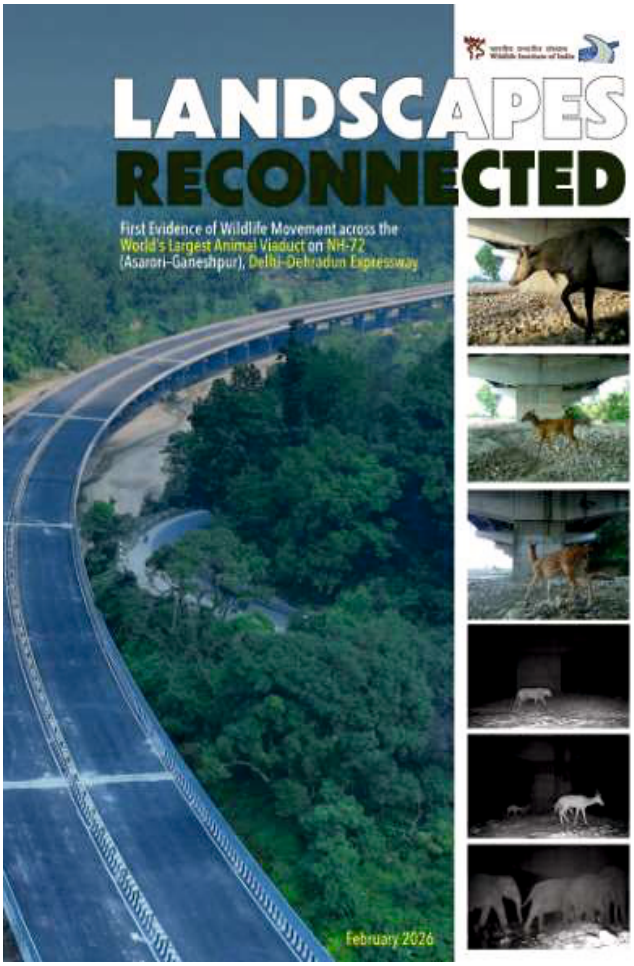


Chapter 8: Empirical Validation by Third Party – Landscapes Re-connected

The wildlife conservation efforts of NHAI while undertaking construction of linear projects have been got validated by the third party i.e., Wildlife Institute of India, Dehradun, which is a premier organization of national and international repute. Herein, two projects have been discussed viz. *NH-72 (Asarori–Ganeshpur), Delhi–Dehradun Expressway* and *National Highway 44 passing through Pench Tiger Reserve, Maharashtra*

8.1 - Delhi–Dehradun Expressway

The analysis draws upon the study titled "Landscapes Reconnected: First Evidence of Wildlife Movement Across the World's Largest Animal Viaduct on NH-72 (Asarori–Ganeshpur), Delhi–Dehradun Expressway (February 2026)", conducted by the Wildlife Institute of India (WII) under the project "Monitoring of Wildlife Underpasses in Dehradun–Delhi Highway (NH-72A)". This study provides the assessment and empirical findings on wildlife mitigation measures. The corridor marks a significant milestone in development of sustainable infrastructure, demonstrating that National Highway development can coexist with the preservation of ecologically sensitive areas.



As post-monitoring becomes important in terms of understanding the use of crossing structures by animals, the project funded by the National Highways Authority of India (NHAI) set out with the following objectives:

- To assess the patterns of underpass, use by wildlife.
- To assess the factors affecting the use of underpasses by different wild species.
- To assess the effectiveness of underpasses.





In India, Protected Areas (PAs) cover approximately 5.69% of the total geographic area. Additionally, the majority of the PAs are tiny and isolated patches, while a significant road network passes through forested regions, with further expansion planned. This can pose challenges for wildlife conservation, particularly in large and continuous landscapes.

The Terai Arc Landscape (TAL), extending from the Yamuna River in India to the Bagmati River in Nepal, is a biodiversity-rich region supporting species such as Tiger, One-horned Rhinoceros (*Rhinoceros unicornis*) and Asian Elephant (*Elephas maximus*) (Umariya et al., 2021). Several roads pass through this landscape, affecting long-term conservation goals

National Highway 72, connecting Delhi and Dehradun, passes through ecologically sensitive areas including Rajaji Tiger Reserve. Considering the wildlife value of the region, the Wildlife Institute of India (WII) conducted assessments and recommended mitigation measures.

The 20 km-long stretch between Ganeshpur and Asharodi features a total of 10.97 km long animal underpass designed specifically to facilitate unobstructed animal movement.



This engineering milestone includes Asia's largest wildlife elevated corridor standing at an average height of 6 to 7 meters to accommodate even the largest mammal.

Zone 1 of the corridor, it stands between Ganeshpur and Mohand and passes through flat terrain along the riverbed. It is primarily located in the Shivalik Forest Division (UP). Ecologically, it abuts the Rajaji Tiger Reserve (Mohand Range).

Zone 2 marks the section starting from the Mohand settlement and extending all the way up to the Asarodi police check post. This part goes through the hilly terrain of the area.

Zone 3 starts from the Asarodi police check post and extends up to the edge of the Mohabewala settlement in the Doon valley. The road in this zone passes through mixed stretches of Sal forest.

Landscapes Re-connected







8.1.1 Findings

a. Camera trap data

Observations over a 40-day period show that a wide range of wildlife species actively use the underpasses along the NH72 corridor, indicating that these crossing structures perform as an effective mitigation strategy for maintaining natural movement patterns near the roadways.

About 18 wild animal species were observed utilizing the structures, demonstrating their acceptability by generalist wildlife species including various carnivores, herbivores, ungulates, pheasants, and primates. The Golden Jackal was the most frequently captured, followed closely by Nilgai, Sambar, and Spotted Deer. Smaller mammals, including the Indian Hare also showed consistent movement through the structures. Notably, the study also recorded 60 instances of the elephants safely utilizing the corridors, establishing that the even the largest wild animals can navigate the new infrastructure to maintain their natural migration patterns.

b. Acoustic indices

The research identified the strategic management of the soundscape as a primary factor in facilitating natural wildlife behaviour beneath the corridor. The data indicate that while generalist species, such as golden jackals and wild boar, have habituated to significant traffic sound, sensitive species like elephants and spotted deer selectively utilize underpass segments with lower sound levels. Further, deployment of advanced noise reduction strategies including targeted sound barriers in high-frequency crossing areas, will further enhance passage for noise-sensitive species. The development of Delhi – Dehradun Economic Corridor has not only significantly reduced the probability of Human – wildlife conflict but also mitigated the risk of population isolation in the Shivalik landscape. The study reaffirms that well-planned infrastructure interventions, including underpasses and elevated corridors, play a crucial role in preserving the natural habitat of the wild animals and maintaining ecological connectivity.



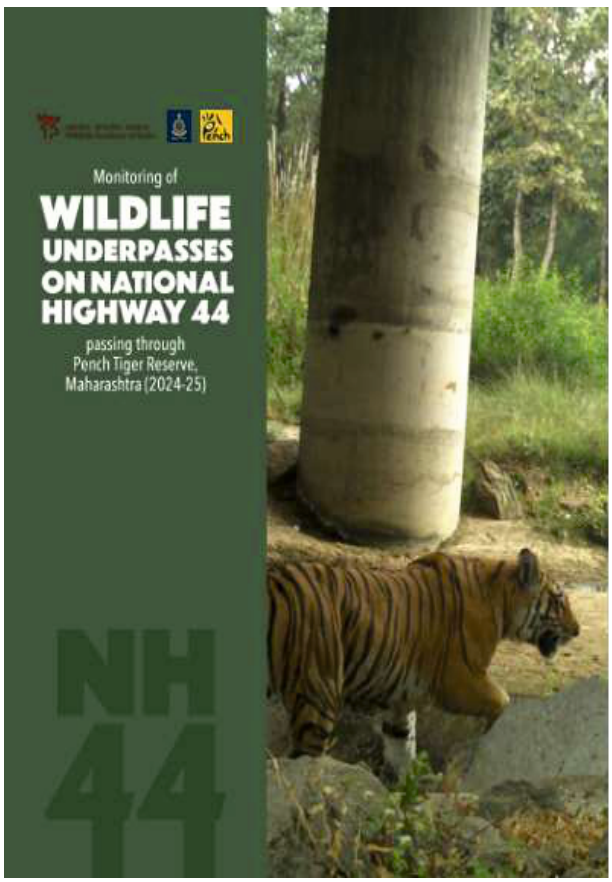
NHAI remains committed to integrating environmental sustainability into National Highway development and will continue to adopt innovative and data driven approaches to balance infrastructure growth with ecological conservation.





8.2 - Pench Tiger Reserve

Another study titled "*Monitoring of Wildlife Underpasses on National Highway 44 passing through Pench Tiger Reserve, Maharashtra (2024)*" encompasses key sections including Executive Summary, Introduction, Study Area, Objectives, Use of crossing structures by mammal community, Activity patterns of animals using underpasses, Use of crossing structures by tigers, and conclusion on the effectiveness of mitigation measures.



8.2.1 Objectives

- To monitor trends and frequency of use of crossing structure by the mammal community,
- To compare the activity patterns of different species using crossing structures and adjacent forest,
- To monitor the use of crossing structures



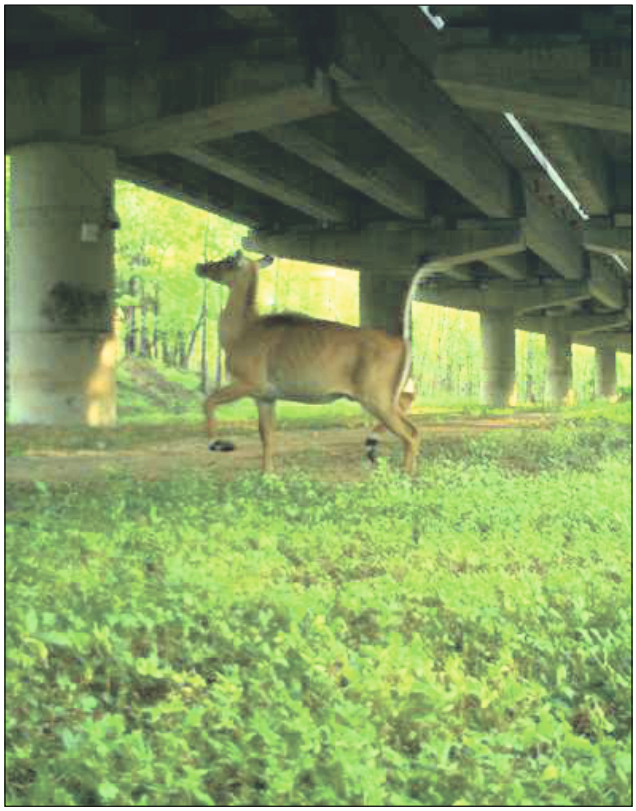
8.2.2 Findings

The Wildlife Institute of India (WII), in collaboration with the Maharashtra Forest Department, has been monitoring **nine wildlife crossing structures** (CS) on NH-44 passing through Pench Tiger Reserve (TR) since 2019 using camera traps.

The aim of the long-term monitoring exercise is to evaluate the role of the CS in maintaining ecological connectivity across this critical tiger landscape.



The 2024 results recorded **23 mammal species** using the structures, ***Carnivores,*** including tiger, leopard, wild dog, sloth bear, Indian wolf, and jackal; ***ungulates,*** including chital, sambar, gaur, wild pig, barking deer, nilgai, and four-horned antelope; and ***small mammals,*** including jungle cat, Bengal fox, honey badger, Indian hare, rusty-spotted cat, small Indian civet, common palm civet, Indian crested porcupine, Indian pangolin, and grey mongoose were documented including capturing honey badger and Bengal fox for the first time in 2024, suggesting an intergenerational habituation and gradual adaptation by wildlife.



Species-specific preferences were observed, with higher usage in structures near forested areas and minimal human disturbance, while larger structures (750 m) supported greater species diversity. Activity pattern analysis showed ***increased nocturnal and crepuscular behavior***, reflecting adaptation to avoid human disturbance.

A total of **28 individual tigers**, including dispersing individuals and breeding females with cubs, were recorded using the structures, highlighting their effectiveness in supporting movement and connectivity. The continued and expanding use of these structures highlights the growing ecological integration and wildlife's adaptive responses to mitigation measures. Structure management measures such as increased vegetation cover near the underpasses is made crucial for enhancing use by ungulates and small mammals.

Tigers have used all nine CS, including breeding females moving with cubs. Structural attributes such as width, vegetation cover, and proximity to protected areas were found to significantly influence use by wildlife, underscoring the need for CS design that is sensitive to the ecological needs of multiple species.



Overall, the findings reaffirm that the crossing structures are ***functionally effective, ecologically integrated, and increasingly utilized,*** with continued monitoring and management essential for enhancing their performance.



The ongoing monitoring holds national importance, providing comprehensive data on ecological performance of crossing structures and supporting improved mitigation design and policy recommendations. This report presents the current status of the monitoring program, focusing on results from 2024 and reinforcing the importance of sustained evaluation.



The findings reaffirm that crossing structures are functionally effective in supporting wildlife movement and ecological connectivity, while highlighting the importance of long-term monitoring and management interventions for sustained performance.



















8.2.3 Tigers of NH44

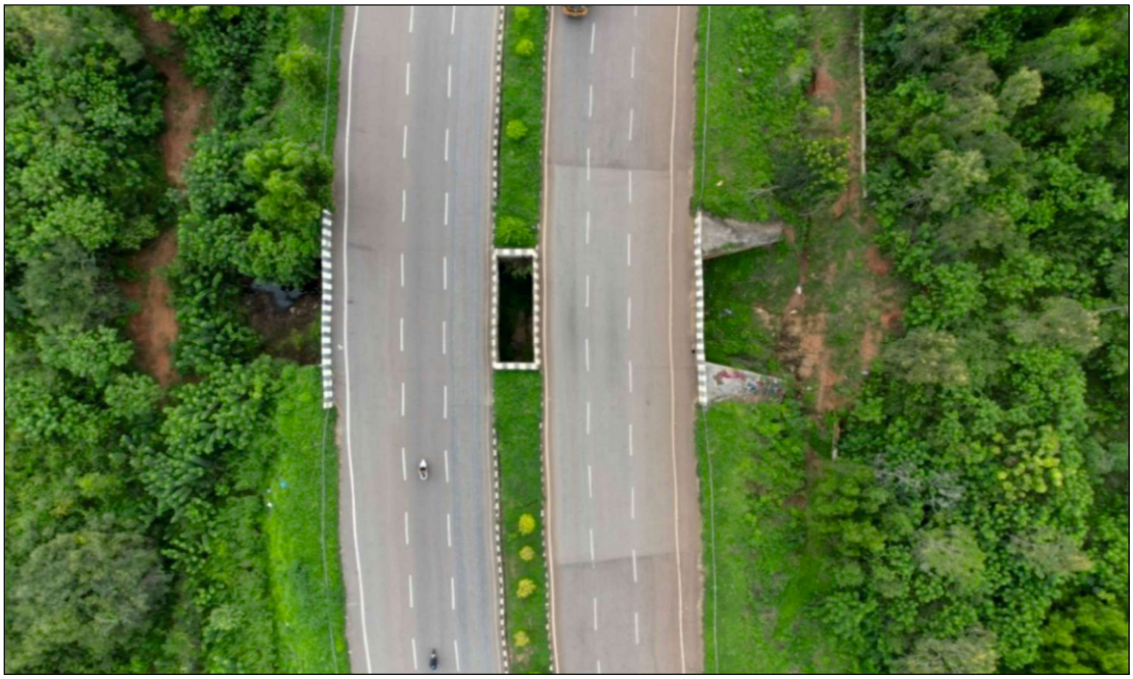







8.3 Conclusion

Both these reports emphatically provide empirical evidence of the efficacy of Wildlife Mitigation Measures and Structures provided by NHAI while undertaking highways construction and demonstration of sustainable development in true sense wherein nature, wild animals and humans are in harmony with each other.



Underpass at Km 39+290 in Four Laning of Mallasandra to Karadi Sec. of NH 206 (Pkg.1) – Bengaluru



Underpass at Km 40+775 in Four Laning of Mallasandra to Karadi Sec. of NH 206 (Pkg.1) - Bengaluru

Chapter 9. Social-Media & Wildlife Conservation - Use of AI Tools

Realizing the connect between social media and wildlife protection & conservation, NHAI has used Artificial Intelligence (AI) tools in explaining environmental discussions in social media and the public response to eco-sensitive infrastructure launch by the Hon'ble Prime Minister. The findings are as under:

Social media monitoring by the NHAI's AI Cell reveals that a 12-km elevated wildlife corridor near Rajaji Tiger Reserve, designed to allow elephants and other species to cross safely beneath the highway is an endeavour where *"infrastructure meets nature"* narrative resonated powerfully with the public.

In the April 1-21 snapshot used, the listening tool scanned 37,809 posts across X (Twitter), Facebook, Instagram, YouTube, online news portals, and blogs. Of these, 11,925 posts (31.5%) were directly relevant to environment, wildlife, or the Delhi-Dehradun Expressway. The launch day alone generated 3,469 environment-related posts - a spike of nearly 2x over neighbouring days - with environment and wildlife content accounting for 67% of all expressway chatter that day.

Crucially, sentiment on launch day skewed decisively positive. This was driven by the NHAI–Wildlife Institute of India (WII) *"Landscapes Reconnected"* study, which revealed that 18 animal species had already been recorded using the underpasses even before the expressway was formally opened.

37,809	11,925	~2x	2.4: 1
Total Posts Scanned	Env-Relevant Posts	Launch-Day Spike	Sentiment Ratio

9.1 Volume & Spike Analysis

The table below summarizes the five-day volume windows tracked by the Entity's AI Cell's social listening tool:

Table-37: Volume & Spike Analysis

Window	Total Posts	Env-Relevant	Share (%)	Trend
Apr 01 – 05	9,449	809	8.6%	Baseline
Apr 06 – 10	7,189	2,511	34.9%	↑Build-up
Apr 11 – 15	14,524	7,978	54.9%	↑↑Peak
Apr 16 – 20	6,256	596	9.5%	↓Cool-down
Apr 21+	391	31	7.9%	↓↓Residual

The environment share of total conversation surged from a baseline of 8.6% in the first week to 54.9% during the launch window (April 11-15), before dropping back to single digits in the later snapshot windows. This demonstrates that the wildlife corridor angle genuinely captured public attention and was not merely incidental noise. However, the April 16 onward comparisons should be read directionally, because the later windows rely primarily on the sl_posts stream after April 15 rather than on the full mixed-source snapshot used for the launch window.

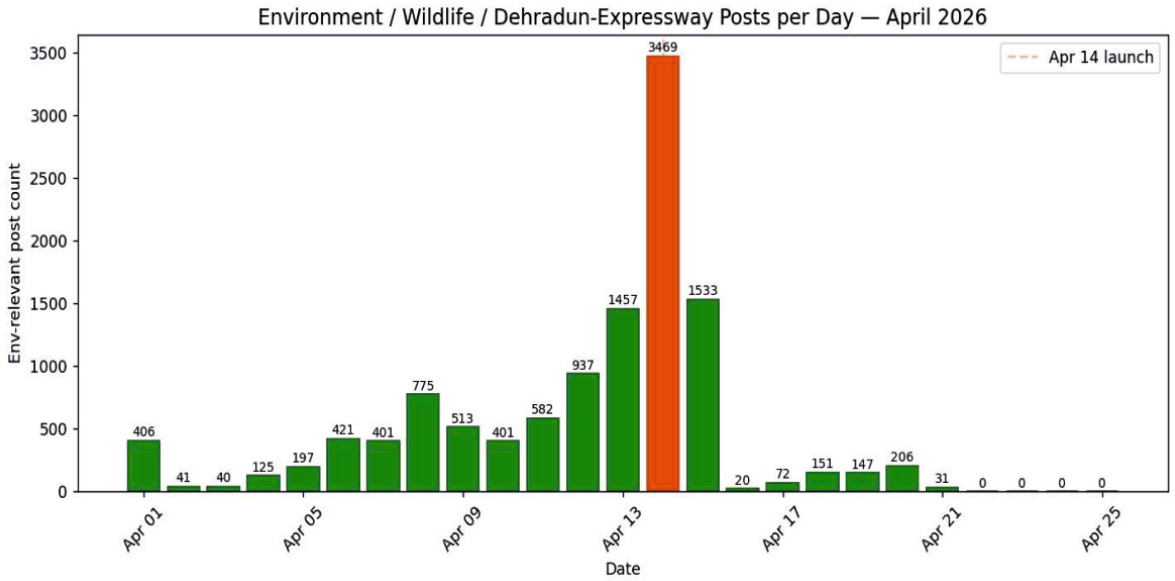


Figure-165: Daily environment/wildlife/DDE-relevant posts, April 2026. The Apr 14 launch day (orange) shows a clear ~2x spike

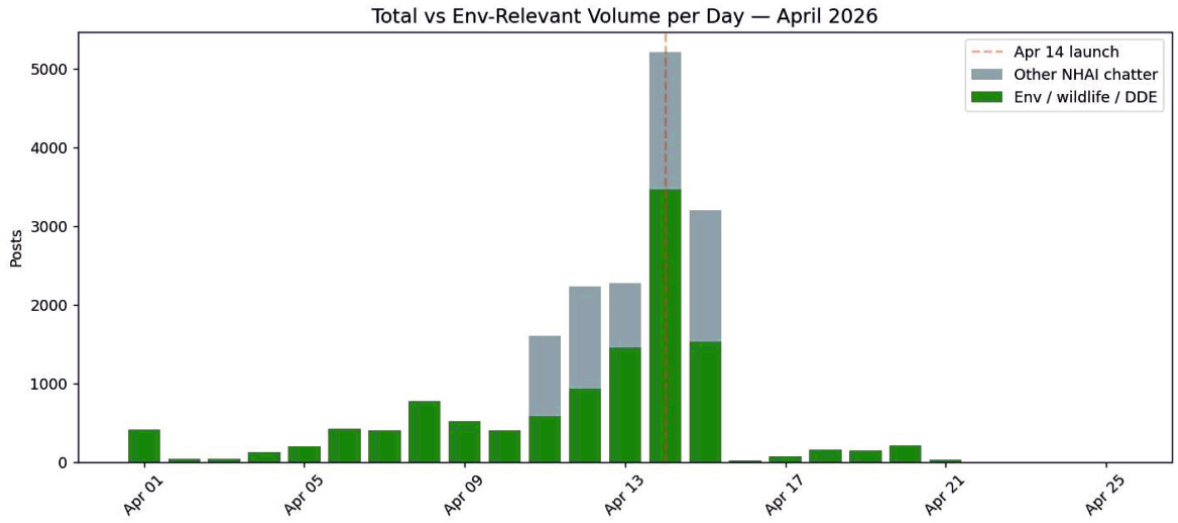


Figure-166: Total social media volume vs. environment-relevant posts. Green = env/wildlife/DDE; grey = other NHAI chatter

9.2 Launch Day Hourly Pulse

The hourly distribution on April 14 shows a steady climb from pre-dawn hours, peaking during the inauguration ceremony window (1:00–4:00 PM IST), with a secondary shoulder around 9:00–10:00 PM driven by Hindi evening news cycles.

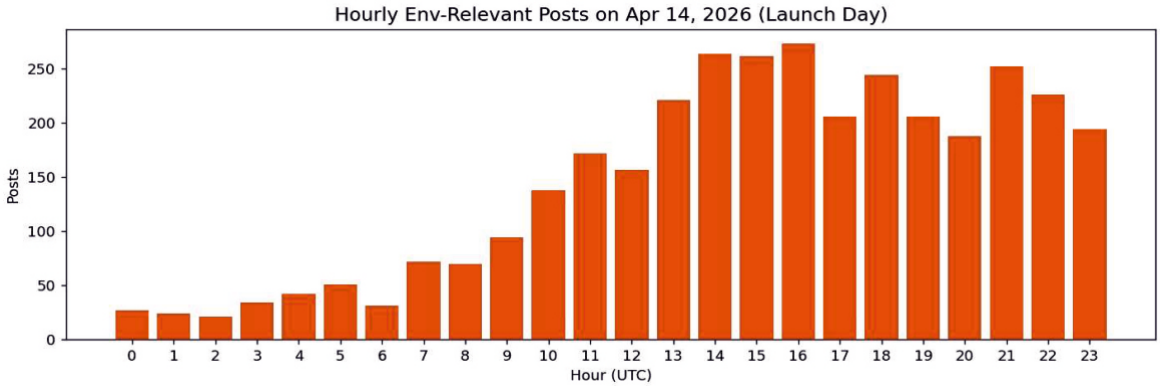


Figure-167: Hourly env-relevant posts on Apr 14 (Launch Day). Peak activity of 273 posts/hr at 4:00 PM IST (inauguration window)

9.3 Theme Breakdown

The NHAI AI Cell's tool categorized all 11,925 environment-relevant posts into thematic buckets. The distribution reveals what the public was actually talking about:

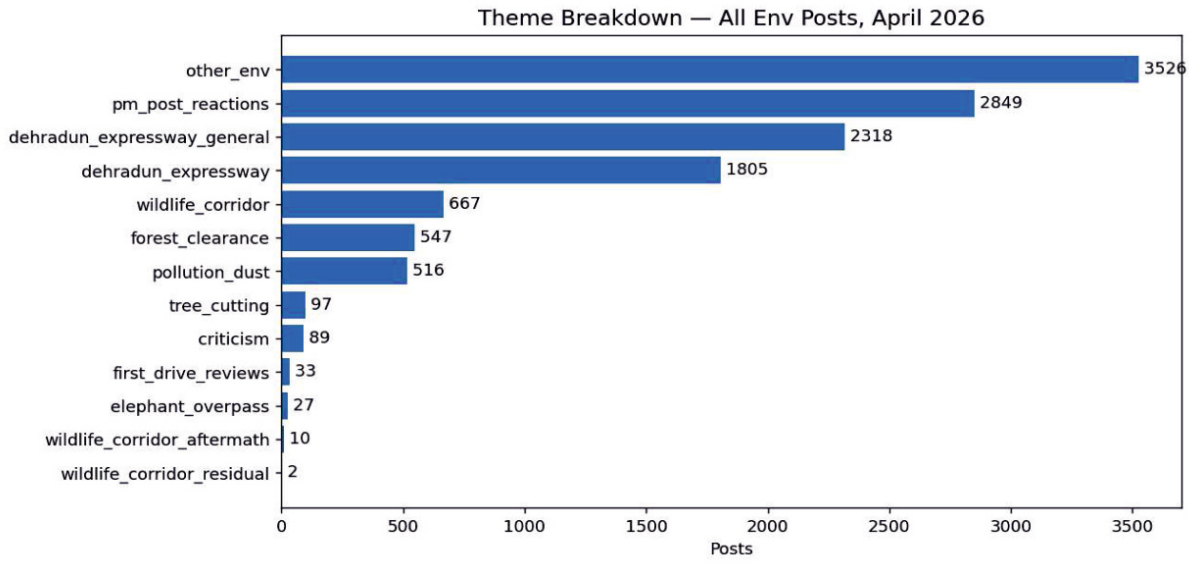


Figure-168: Theme breakdown across all env/wildlife posts, April 2026

Theme	Posts	Share of Env Posts
PM Post Reactions (inauguration)	2,849	23.9%
Dehradun Expressway — General	2,318	19.4%
Dehradun Expressway — Specific	1,805	15.1%
Wildlife Corridor	667	5.6%
Forest Clearance Concerns	547	4.6%
Pollution / Dust / AQI	516	4.3%
Tree Cutting	97	0.8%
Criticism (General)	89	0.7%
First-Drive Reviews	33	0.3%
Elephant Overpass Mentions	27	0.2%
Other Environment	3,526	29.6%

Table-38: Theme Breakdown

The wildlife corridor itself accounted for 667 dedicated posts (5.6%), but its influence extended far beyond this bucket — it shaped the tone of the PM inauguration reactions (2,849 posts) and the broader expressway conversation. The corridor was the differentiating descriptive element that positioned the project as environment-conscious rather than a standard highway launch.

9.4 Conclusion

The above analysis establishes the connect between social media and wildlife protection and conservation. The social media monitoring using AI tools revealed that inauguration of the elevated wildlife corridor near Rajaji Tiger Reserve, designed to allow elephants and other species to cross safely beneath the highway by the Hon'ble Prime Minister resonated powerfully with the public. Such instances help in promoting wildlife protection and conservation.

Glossary

Abundance: The total number of species in a particular ecosystem

Allee effect: The positive correlation between population density and individual fitness

Amphibian: Cold-blooded organisms that begin their lives in water and then adapt to live on land as adults

Animal trail: A path in the forest made by repetitive use or passage of animals

Arboreal: Meaning tree; related to animals that depend on trees to provide all or part of their life requirements

Auditory signal: A call or vocalization for communication among animals

Barrier effect: The extent to which roads or other linear features prevent, or filter, animal movement. The barrier effect can be quantified by species, populations and so on

Bask: Behaviour of exposing the body to the sun or warm surfaces to regulate body temperature exhibited by cold-blooded animals

Biodiversity: The variety of life at any given spatial scale including all the levels contained within, including genes, species, communities and ecosystems and their complex interactions

Bottleneck: Defined area (e.g., particularly narrow part of a habitat corridor that, due to the presence of transport infrastructure or encroachment of other land use, has become a limiting factor to animal migration or dispersal

Buffer: Areas peripheral to a protected area where restrictions on resource use and special development measures are undertaken

Camera trapping: A method for capturing wild animals on film in absence of humans; the data is then used for ecological research

Canopy: Collection of above-ground individual plant crowns

Carnivore: Animal that feeds on meat of other animals

Carrying capacity: The maximum number of individuals of a given species that a given area's resources can sustain indefinitely without significantly depleting or degrading those resources

Connectivity: The degree to which a landscape facilitates or impedes movement among habitat patches. The concept of connectivity is used to describe how the spatial arrangement and quality of elements in the landscape affect the movement of organisms among habitat patches.

Conspecific: Members of the same species

Core: Areas within protected areas free of all human activities, also referred to as “inviolate” areas

Corridor: Components of the landscape that facilitate movement of organisms and continuation of ecological processes between areas of intact habitat

Crossing zones: Stretches of linear infrastructure frequently used by animals to cross from one side to the other

Cryptic: Organisms that avoid observation or detection by their prey or predators, through camouflage, mimicry or by being nocturnal

Critically Endangered: The most severe conservation status for wild populations on the IUCN's Red List

Culvert: Buried pipe or channel structure, that allows a watercourse and/or road drainage to pass under a road or rail route

Density: Number of organisms of a species present within an area

Dispersal: Ecological process that involves the movement of one or more individuals away from the population in which they were born to another location, or population, where they will settle and reproduce

Diurnal: Activity pattern where animals are active during the day

Ecosystem service: Benefits such as goods and services, provided to society by ecosystems, for example production of food and water, control of climate and disease, nutrient cycles and pollination

Ecosystem: The community of living organisms (plants, animals, microbes) and non-living components of their environment (air, water, soil) interacting as a functional unit

Endangered: The second most severe conservation status for wild populations on the IUCN's Red List, after Critically Endangered

Endemic: An ecological state of a species being unique to a defined geographical location – either the particular country or a local area (narrow or local endemic)

Extinction: The end of organism or a group of organisms after the death of the last individual of the species

Fatality hotspot: Stretches along a road/railway line where maximum number of animal mortalities is concentrated

Faunal passage: Measure installed to enable animals to cross over or under a road, rail or canal passageway without coming into contact with the traffic

'Flight or fight' response: A physiological response to a perceived harmful attack or threat to survival wherein the animal either fights or flees

Fire regime: Pattern, frequency and intensity of wildfires that prevail in an area

Foraging: Searching for wild food resources

Furniture: Logs, branches, rocks and other enrichment structures placed in wildlife crossing structures to provide shelter and/or protection from predators

Gene flow: The transfer of alleles or genes from one population to another

Genetic drift: Change in frequency of an allele in a population due to random sampling

Granivorous: Animals feeding on the seeds or grains of plants

Green infrastructure: Infrastructure that is designed and developed by considering conservation values and actions in concert with land development, growth management and built infrastructure planning

Habitat degradation: Process of change in the characteristics of an area that renders it functionally unable to support the species present

Habitat fragmentation: Process by which habitat loss results in the division of large, continuous habitats into smaller, more isolated remnants

Habitat matrix: A combination of 'non-habitat' and range of native habitat areas, or a portion of a landscape where habitat patches and corridors are embedded in a wider mix of land uses

Habitat: An area, usually consisting of predominantly native vegetation that is inhabited by a particular species

Herbaceous vegetation: Vegetation composed mostly of herbs (plants which have no persistent woody stem above ground)

Herpetofauna: The reptiles and amphibians of a particular region, habitat or geographical period

Home range: The area in which an animal lives and accesses for normal daily activities such as food gathering, obtaining shelter, mating and caring for offspring

Important Bird Area: An area recognized as being globally important habitat for the conservation of bird populations

Inbreeding depression: Reduced biological fitness in a given population as a result of inbreeding, or breeding of related individuals

Invasive species: Plants, animals or pathogens that are non-native to an ecosystem and whose introduction is likely to cause harm to, or oust, native species

Invertebrates: Animals that do not possess or develop a vertebral column; e.g., insects, snails, worms

IUCN Red List: A comprehensive inventory of the global conservation status of biological species

Landscape ecology: The study of the pattern and interaction between ecosystems within a region, and the way these interactions affect ecological processes

Landscape: A heterogeneous land area composed of a cluster of interacting ecosystems that creates a specific, recognizable pattern

Linear infrastructure: Structures such as roads, railway lines, power transmission lines and canals that cause linear breaks in an otherwise contiguous and connected landscape

Long-ranging species: Animals that tend to cover great distances

Meta-population: Set of local populations of a species that are spatially separated within some larger area, but which interact at some level. Genetic diversity is maintained by the dispersal of individuals from one local population to another

Meta-population dynamics: The study of the interactions between meta-populations

Migration: Journey undertaken by some species in response to changing seasons or climatic events, such as rainfall

Minimum viable population: A lower bound on the population of a species such that it can survive in the wild

Mitigation: Action to avoid or prevent, reduce or minimize the severity of, or compensate for an adverse impact

Nesting: Behaviour of animals such as birds to build nests near the breeding season

Nocturnal: Activity pattern of animals such as bats and fireflies that are active during the night

Pheromones: Hormones secreted by animals for communication and other signals

Physiology: Study of how organs and other systems of the body function

Poaching: Illegal hunting or killing of wild animals to obtain animal products

Population viability: The probability that a population will persist in the long term or within a given number of years, with given environmental conditions (or go extinct)

Population: Total of all individuals of a species living in a particular area that have the capability to interbreed. It represents a functional group of individuals that interbreed within a given, often arbitrarily chosen, area

Predator: An animal that naturally preys on other animals

Prey: An animal that is hunted or killed by another for food

Protected area: A clearly defined geographical space recognized, dedicated and managed to achieve long-term conservation of nature

Radio telemetry: Involves monitoring radio signals sent from a device attached to an animal to track its movements

Rare: Species that are uncommon, scarce or infrequently encountered

Right-of-way: The entire width of the reserved strip of land on which the linear infrastructure is built

Road Corridor: Linear surface used by vehicles plus any associated verges (usually vegetated). It includes the area of land immediately influenced by the road in terms of noise, visual, hydrological and atmospheric impacts; typically, an area of 50 to 100 m from the edge of the road

Road verge: The vegetated area adjacent to roads; generally located outside the road shoulder

Road kill: Animals that have died as a result of collision with vehicles or trains

Rodents: Mammals of the order Rodentia characterized by a single pair of incisors in each of the upper and lower jaws

Runoff: Flow of water on the earth's surface that occurs as a result of precipitation. Excessive runoff may lead to erosion of soil

Salt-lick: A place where animals go to lick essential mineral nutrients from a deposit of salts

Scat: Faeces of a carnivorous animal

Smart infrastructure: Comparable to 'green infrastructure', it refers to infrastructure that has been located and designed to foster sustainable development, taking into account biodiversity conservation issues along with other social, economic and health factors

Source-sink dynamics: A theoretical model used by ecologists to describe how variation in habitat quality may affect the population growth and decline of organisms

Species diversity: A measure of the diversity within an ecological community incorporating both species richness and evenness of species abundance

Species range: The geographical area where a particular species can be found during its lifetime and includes areas where individuals or communities may migrate or hibernate

Sustainable development: Development that meets the needs of the present without compromising the ability of future generations to meet their own needs

Target species: The species or group of species intended to benefit from proposed mitigation

Taxa: Taxon (pl. taxa) is a group of one or more populations of an organism or organisms considered by taxonomists to form a unit

Terrestrial: Pertaining to the land or earth

Territory: An area defended by an organism or a group of similar organisms for mating, nesting, roosting, feeding or breeding

Thermoregulation: Ability of an organism to maintain its internal temperature within certain boundaries, even when ambient environmental temperatures are different

Tiger reserve: A protected area considered significant for protecting tigers and their habitat

Ungulates: Animals with hooves (an enlarged toenail) e.g., sambar, spotted deer

Vertebrates: Animals with a vertebral column

Water hole: A depression in the ground in which water can collect

Wetland: Lands that are transitional between terrestrial and aquatic systems where the water table is usually at or near the surface, or the land is periodically covered with shallow water. They generally contain plant communities that are adapted to periodic inundation

Wildlife community: An assemblage of plant and animal populations living in a particular habitat and interacting with each other

Wildlife conservation: Practice of protecting and managing wild plant and animal species and their habitats, to ensure their persistence in the long term

Wildlife overpass: Physical structure built over road or rail infrastructure in order to connect the habitats on either side. The surface is at least partly covered with soil or other natural material that allows the establishment of vegetation

Wildlife underpass: Physical structure situated underneath linear infrastructure in order to connect the habitats on either side. The surface is at least partly covered with soil or natural material that allows the establishment of vegetation





References

- Andrews, K. M., & Gibbons, J. W. (2005). How do highways influence snake movement? Behavioral responses to roads and vehicles. *Ichthyology & Herpetology*, *2005*(4), 772-782.
- Andrews, K. M., Gibbons, J. W., Jochimsen, D. M., & Mitchell, J. (2008). Ecological effects of roads on amphibians and reptiles: a literature review. *Herpetological Conservation*, *3*(1), 121-143.
- Ashley, E. P., & Robinson, J. T. (1996). Road mortality of amphibians, reptiles and other wildlife on the Long Point Causeway, Lake Erie, Ontario. *Canadian Field Naturalist*, *110*(3), 403-412.
- Barber, J. R., Crooks, K. R., & Fristrup, K. M. (2009). The costs of chronic noise exposure for terrestrial organisms. *Trends in ecology & evolution*, *25*(3), 180-189.
- Baxter-Gilbert, J. H., Riley, J. L., Lesbarrères, D., & Litzgus, J. D. (2015). Mitigating reptile road mortality: fence failures compromise ecopassage effectiveness. *PLos one*, *10*(3), e0120537.
- Beier, P. (2006). Effects of artificial night lighting on terrestrial mammals. *Ecological consequences of artificial night lighting*, *2*, 19-42.
- Benedict, M. A. (2000). Green infrastructure: A Strategic approach to land conservation. *American Planning Association. Planning Advisory Service Memo. Chicago, IL*.
- Benedict, M. A., & McMahon, E. T. (2002). Green infrastructure: Smart conservation for the 21st century.
- Bernardino Jr, F. S., & Dalrymple, G. H. (1992). Seasonal activity and road mortality of the snakes of the Pa-hay-okee wetlands of Everglades National Park, USA. *Biological Conservation*, *62*(2), 71-75.
- Brattstrom, B. H. (1965). Body temperatures of reptiles. *American Midland Naturalist*, 376-422.
- Clark, R. W., Brown, W. S., Stechert, R., & Zamudio, K. R. (2010). Roads, interrupted dispersal, and genetic diversity in timber rattlesnakes. *Conservation Biology*, *24*(4), 1059-1069.
- Davenport, J., & Davenport, J. L. (Eds.). (2006). *The ecology of transportation: managing mobility for the environment* (Vol. 385). Dordrecht, The Netherlands: Springer.
- Fletcher, J. L., & Busnel. R. G. (1978). *Effects of noise on wildlife.* Academic Press, London.
- Forest Survey of India. (2023). India State of Forest Report (ISFR). http://www.wii.gov.in/national_wildlife _database
- Forman R.T.T., Friedman, D.S., Fitzhenry, D., Martin, J.D., Chen, A.S., & Alexander, L.E. (1997). Ecological effects of roads: Toward three summary indices and an overview for North America. In: *Habitat Fragmentation & Infrastructure* (eds. Kees Canters, Annette Piepers and Dineke Hendriks-Heersma), 40 - 54. Proceedings of the international conference on habitat fragmentation, infrastructure and the role of ecological engineering, 17-21 September 1995, Maastricht and The Hague, The Netherlands.
- Forman, R. T. T., Sperling, D., Bissonette, J. A., Clevenger, A. P., Cutshall, C. D., Dale, V. H., Fahrig, L., France, R., Goldman, C. R., Heanuk, K., et al. (2003). *Road Ecology: Science and Solutions*. Island Press, Washington, D.C., USA.
- Forman, R. T., & Alexander, L. E. (1998). Roads and their major ecological effects. *Annual review of ecology and systematics*, *29*(1), 207-231.
- Foster, M. L., & Humphrey, S. R. (1995). Use of highway underpasses by Florida panthers and other wildlife. *Wildlife Society Bulletin*, 95-100.
- Francis, C. D., Ortega, C. P., & Cruz, A. (2009). Noise pollution changes avian communities and species interactions. *Current biology*, *19*(16), 1415-1419.
- Grossi, J. L., Coffre, H. E. R. V. É., & Marciau, R. O. G. E. R. (2001). Conservation strategy for amphibians in the Rhone-Alpes region. *Tools in preserving biodiversity in nemoral and boreonemoral biomes of Europe, Naconex*, 76-79.

- Habib, B. Saxena, A. & Maheshwari, V. (2026). Monitoring of Wildlife Underpasses on National Highway 44 passing through Pench Tiger Reserve, Maharashtra (2024-25). Wildlife Institute of India.
- Habib, B., Pandav, B., Nath, A., Parab, T., Kadam, R., Haldar, N. & Bhave, M. (2026). Landscapes Reconnected: First Evidence of Wildlife Movement Across the World's Largest Animal Viaduct on NH-72 (Asarori-Ganeshpur), Delhi-Dehradun Expressway (February 2026). Wildlife Institute of India.
- Harris, L. D. (1984). *The fragmented forest: island biogeography theory and the preservation of biotic diversity*. University of Chicago press.
- Hels, T., & Buchwald, E. (2001). The effect of road kills on amphibian populations. *Biological conservation*, *99*(3), 331-340.
- Hayer, W. R., Donnelly, M. A., McDiarmid, R.W., Hayekand, L. A. C., & Foster, M. S. (eds.) (1994). *Measuring and monitoring biological diversity: standard methods for amphibians*. Smithsonian Institution.
- Hill, D. A. (1992). *The impact of noise and artificial light on waterfowl behaviour: a review and synthesis of available literature*. British Trust for Ornithology.
- Huntley, B. J., & Redford, K. H. (2014). Mainstreaming biodiversity in practice: A STAP advisory document. *Global Environment Facility, Washington, DC*, *88*.
- Indian Road Congress. *IRC Guidelines*. https://law.resource.org/pub/in/bis/manifest.irc.html
- Jackson, S. D., & Tyning, C. R. (1989). Effectiveness of drift fences and tunnels for moving spotted salamanders Ambystoma maculatum under roads. In *Amphibians and Roads: Proceedings of the Toad Tunnel Conference* (Vol. 1, pp. 93-99). Shefford, UK: ACO Polymer Products.
- Jalkotzy, M. G., Ross, P. I. & Nasserden, M. D. (1997). *The effects of linear developments on wildlife: a review of selected scientific literature*. Calgary, Prepared for Canadian Association of Petroleum Producers, 1-354. Arc Wildlife Services Ltd.
- Keller, V., Bekker, H., Cuperus, R., Folkeson, L., Rosell Pagès, C., & Trocmé, M. (2003). Avoidance, Mitigation and Compensatory Measures and their Maintenance. In: Trocmé, M., Cahill, S., De Vries, J.G., Farall, H., Folkeson, L., Fry, G.L., Hicks, C., & Peymen J. (eds) *COST 341 - Habitat Fragmentation due to transportation infrastructure. The European*
- *Review, 129-174*. Office for Official Publications of the European Communities, Luxembourg.
- Kosmus, M., Renner, I., & Ullrich, S. (2012). *Integrating ecosystem services into development planning. A stepwise approach for practitioners based on the TEEB approach, GIZ*.
- Krikowski, L. (1989). The'light and dark zones': two examples of tunnel and fence systems. In *Amphibians and Roads Proceedings of the Toad Tunnel Conference. ACO Polymer Products, Shefford, England* (pp. 89-91).
- Langen, T. A. (2011). Design considerations and effectiveness of fencing for turtles: three case studies along northeastern New York State highways. In *Proceedings of the 2011 International Conference on Ecology and Transportation. PJ Wagner, D. Nelson, and E. Murray (eds.). Center for Transportation and the Environment, North Carolina State University, Raleigh, North Carolina* (pp. 521-532).
- Lucius, I., Dan, R., Caratas, D., Mey, F., Steinert, J., & Torkler, P. (2011). Green infrastructure. Sustainable investments for the benefit of both people and nature. European Regional Development Fund and SURF-Nature Project. *WWF Danube-Carpathian Programme, WWF Germany, Giurgiu County Council*.
- Malt, J., Bio, R. P., & Region, S. C. (2012). Assessing the effectiveness of amphibian mitigation on the Sea to Sky Highway. Population-level effects and best management practices for minimizing highway impacts. *Ministry of Forests, Land and Natural Resource Operations, South Coast Region*.

- Mastro, L. L., Conover, M. R., & Frey, S. N. (2008). Deer–vehicle collision prevention techniques. *Human-Wildlife Conflicts*, *2*(1), 80-92.
- Mathur, V. B., & Rajvanshi, A. (2016). *Eco-friendly measures to mitigate impacts of linear infrastructure on wildlife*. Wildlife Institute of India.
- Mazerolle, M. J., Huot, M., & Gravel, M. (2005). Behavior of amphibians on the road in response to car traffic. *Herpetologica*, *61*(4), 380-388.
- Ministry of Environment, Forest and Climate Change. (1972). *Wildlife (protection) act, 1972* and the Wildlife (Protection) Amendment Act, 2022. Government of India. https://www.indiacode.nic.in/bitstream/123456789/1726/1/aA1972-53.pdf
- Ministry of Environment, Forest and Climate Change. (1980). *Van (Sanrakshan Evam Samvardhan) Adhiniyam, 1980*. Government of India. https://forestsclearance.nic.in/writereaddata/ACT/FC_1980_Hindi.pdf
- Ministry of Environment, Forest and Climate Change. (1986, May 23). *Environment (protection) Act, 1986*. No. 29 of 1986. https://moef.gov.in/uploads/2017/06/eprotect_act_1986.pdf
- Ministry of Environment, Forest and Climate Change. (2000). Noise Pollution (Regulation and Control) Rules, 2000. https://cpc.parivesh.nic.in/writereaddata/ENV/noisepollution/noise1.pdf
- Ministry of Environment, Forest and Climate Change. (2006, September 14). *Environmental Impact Assessment Notification, 2006*. SO1533E. Government of India. https://environmentclearance.nic.in/writereaddata/EIA_Notifications/1_SO1533E_14092006.pdf
- Ministry of Environment, Forest and Climate Change. (2013, August 22). Amendments in *Environmental Impact Assessment notification, 2006*. SO2559E. Government of India. https://environmentclearance.nic.in/writereaddata/EIA_Notifications/11_SO2559E_22082013.pdf
- Ministry of Environment, Forest and Climate Change. (2019, January 18). *Coastal regulation zone notification, 2019* (as amended on November 24, 2022). G.S.R 37(E). Government of India. https://environmentclearance.nic.in/writereaddata/CRZ_Notifications/CRZ_Notification_2019/0.pdf
- Ministry of Environment, Forest and Climate Change. (2022, May 9). Amendments in *Environmental Impact Assessment notification, 2006*. S.O. 2559(E). https://environmentclearance.nic.in/writereaddata/EIA_Notifications/11_SO2559E_22082013.pdf
- Ministry of Environment, Forest and Climate Change. (2022, November 24). Amendments in *Coastal regulation zone notification, 2019*. S.O. 5494(E). Government of India. https://environmentclearance.nic.in/writereaddata/CRZ_Notifications/S-O-5494-E-DATED%2024-11-2022.pdf
- Ministry of Environment, Forest and Climate Change. (2023, December 29). *Consolidated guidelines and clarifications issued under Van (Sanrakshan Evam Samvardhan) Adhiniyam, 1980 and Van (Sanrakshan Evam Samvardhan) Rules, 2023*. Government of India. https://forest.mizoram.gov.in/uploads/attachments/2024/02/bfca395fbb928627fc68b688d70fa7ab/consolidated-guidelines-and-clarifications-issued-under-van-sanrakshan-evam-samvardhan-adhiniyam1980-and-van-sanrakshan-evam-samvardhan-rules2023-.pdf

- Ministry of Environment, Forest and Climate Change. (2023, November 23). *Notification for Van (Sanrakshan Evam Samvardhan) Rules, 2023*. G.S.R. 869(E). Government of India. https://forestsclearance.nic.in/writereaddata/Rules/VanSanrakshanEvamSamvardhanRules2023.pdf
- Ministry of Environment, Forest and Climate Change. About Parivesh and its objectives. NIC. https://parivesh.nic.in/#/about 294
- Ministry of Road Transport and Highways. (2025, May 6). *Land acquisition, forest & wildlife clearances—Milestones for approval, award and declaration of appointed dates*. NH-24028/02/2024-H. Government of India. https://morth.gov.in/backend/old_files/circulars_document/LA-Forest-NH-13052025.pdf
- Ministry of Road Transport and Highways. (2015). *Green Highways (Plantation, Transplantation, Beautification & Maintenance) Policy, 2015*. Government of India. https://morth.gov.in/backend/documents/uploaded/1753168814_Green_Highways_Policy.pdf
- Moore, R. G. (1978). Seasonal and daily activity patterns and thermoregulation in the southwestern speckled rattlesnake (Crotalus mitchelli pyrrhus) and the Colorado desert sidewinder (Crotalus cerastes laterorepens). *Copeia*, 439-442.
- National Highways Authority of India. (2023-24). *NHAI's Contribution to India's Sustainable Infrastructure, Circular Economy and Mission Life*. NHAI Sustainability Report. https://nhai.gov.in/nhai/sites/default/files/2025-07/Sustainability-Report-of-NHAI-for-FY-2023-24.pdf
- National Highways Authority of India. (2022, June 2). *Mandating the use of New/Alternative Material and Technology in construction of Highways*. Policy Circular No. 13.24/2022. https://library.nhai.org/Circulars.
- *Noise exposure limits for different species*. US Department of Transportation, Federal Highway Administration. https://www.fhwa.dot.gov/
- Olbrich, P. (1984). Untersuchung der wirksamkeit von wildwamreflektoren und der eignung von wilddurchlassen (in German). *In Zeitschrift fur Jagdwissenschaft*, 30, 87-91.
- Parris, K. M., Velik-Lord, M., & North, J. M. (2009). Frogs call at a higher pitch in traffic noise. *Ecology and Society*, *14*(1).
- Perry, G., & Fisher, R. N. (2006). Night lights and reptiles: observed and potential effects. *Ecological consequences of artificial night lighting*, 169-191.
- Pittman, S. E., Osbourn, M. S., & Semlitsch, R. D. (2014). Movement ecology of amphibians: a missing component for understanding population declines. *Biological Conservation*, *169*, 44-53.
- PM Modi goes on 20-km jungle safari at Bandipur Tiger Reserve; see pics. Business Today. https://www.businesstoday.in/latest/trends/story/pm-modi-goes-on-20-km-jungle-safari-at-bandipur-tiger-reserve-see-pics-376643-2023-04-09
- PM Modi visits Kuno-Palpur National Park, releases 8 Namibian cheetahs: See photos here. CNBC TV 18. https://www.cnbctv18.com/photos/india/pm-modi-visits-kuno-palpur-national-park-releases-8-namibian-cheetahs-see-photos-here-14747311.htm
- Poot, H., Ens, B. J., de Vries, H., Donners, M. A., Wernand, M. R., & Marquenie, J. M. (2008). Green light for nocturnally migrating birds. *Ecology and society*, *13*(2).
- Pragatheesh, A., & Rajvanshi, A. (2013). Spatial patterns and factors influencing the mortality of snakes on the national highway-7 along Pench Tiger reserve, Madhya Pradesh, India. *Oecologia Australis*, *17*(1), 20-35.

- Press Information Bureau. Transforming India's Transport Infrastructure (2014- 2025). Government of India. https://www.pib.gov.in/PressNoteDetails.aspx?NoteId=154624&ModuleId=3&reg=3&lang=1
- Prime Minister Narendra Modi's Visit at Kaziranga National Park During Assam Tour. Kaziranga National Park. https://www.kaziranga-national-park.com/blog/pm-visit-kaziranga/

- Puky, M. (2003). Amphibian mitigation measures in Central-Europe. Irwin, C. L., Garrett, P., & McDermott, K. P. editors. Proceedings of Conference on Ecology and Transportation, 413-429. Center for Transportation and the Environment, North Carolina State University, Raleigh, N.C.
- Putmam, R. J. (1997). Deer and road traffic accidents: options for management. *Journal of environmental management*, *51*(1), 43-57.
- Rajvanshi, A., Mathur, V. B., Teleki, G. C., & Mukherjee, S. K. (2001). *Roads, sensitive habitats and wildlife: environmental guideline for India and South Asia.* Wildlife Intstitute of India.
- Rajvanshi, A., Mathur, V. B., & Pragatheesh, A. (2013). Ecological Effects of Road Through Sensitive Habitats: Implications for Wildlife Conservation. *Dehradun: Wildlife Institute of India*.
- Reed, D. F., & Ward, A. L. (1987). Efficacy of Methods Advocated to Reduce Deer-Vehicle Accidents: Research and Rationale in the USA. In the Highway and Wildlife Relationships. In *Conference Proceedings. Held in Strasbourg, France, June* (Vol. 5, p. 285).
- Reed, D. F., & Woodard, T. N. (1981). Effectiveness of highway lighting in reducing deer-vehicle accidents. *The Journal of Wildlife Management*, *45*(3), 721-726.
- Reed, D. F., Woodard, T. N., & Bock, T. D. I. (1979). Regional deer-vehicle accident research. *Report Number FHWA-CO-RD-79-11, Colorado Division of Wildlife, Denver, Colorado.*
- Reed, D. F., Woodard, T. N., & Pojar, T. M. (1975). Behavioral response of mule deer to a highway underpass. *The Journal of wildlife management*, 361-367.
- Rijkswaterstaat (1997). *Road and Hydraulic Engineering Division. Programme Plan Ontsnippering 1997 - 2001. Delft, The Netherlands.*
- Rijkswaterstaat, Dienst Weg -en Waterbouwkunde (1993). *Projectplan Versnippering [Project plan fragmentation].*
- Rosen, P. C., & Lowe, C. H. (1994). Highway mortality of snakes in the Sonoran Desert of southern Arizona. *Biological Conservation*, *68*(2), 143-148.
- Rouse, J. D., Willson, R. J., Black, R., & Brooks, R. J. (2011). Movement and spatial dispersion of Sistrurus catenatus and Heterodon platirhinos: implications for interactions with roads. *Ichthyology & Herpetology*, *2011*(3), 443-456.
- Saha, D. C., & Padhy, P. K. (2011). Effect of air and noise pollution on species diversity and population density of forest birds at Lalpahari, West Bengal, India. *Science of the Total Environment*, *409*(24), 5328-5336.
- Seiler, A. (2002). Effects of Infrastructure on nature. Habitat fragmentation due to transportation infrastructure. *The European Review, Pp.31-50. European Commission, Directorate-General for Research, Brussels.*

- Shine, R., Lemaster, M., Wall, M., Langkilde, T., & Mason, R. (2004). Why did the snake cross the road? Effects of roads on movement and location of mates by garter snakes (Thamnophis sirtalis parietalis). *Ecology and Society*, *9*(1).
- Simpson, M. A. (1976). *Noise barrier design handbook* (No. FHWA-RD-76-58 Final Rpt.).
- Slabbekoorn, H., & Halfwerk, W. (2009). Behavioural ecology: noise annoys at community level. *Current biology*, *19*(16), R693-R695.
- Stoner, D. (1925). The toll of the automobile. *Science*, *61*(1568), 56-57.
- Stout, R. J., Stedman, R. C., Decker, D. J., & Knuth, B. A. (1993). Perceptions of risk from deer-related vehicle accidents: implications for public preferences for deer herd size. *Wildlife Society Bulletin (1973-2006)*, *21*(3), 237-249.
- Sullivan, B. (1981). Observed differences in body temperature and associated behavior of four snake species. *Journal of Herpetology*, *15*(2), 245-246.
- Trocmé, M., Cahill, S., De Vries, J. G., Farall, H., Folkeson, L., Fry, G. L., Hicks, C., & Peymen, J. (eds.) (2003). *COST 341 - Habitat Fragmentation due to Transportation Infrastructure. The European Review, pp. 31-50.* Office for Official Publications of the European Communities, Luxembourg.
- Trombulak, S. C., & Frissell, C. A. (2000). Review of ecological effects of roads on terrestrial and aquatic communities. *Conservation biology*, *14*(1), 18-30.
- Van Der Ree, R., Smith, D. J., & Grilo, C. (2015). The ecological effects of linear infrastructure and traffic: challenges and opportunities of rapid global growth. *Handbook of road ecology*, 1-9.
- Van der Zande, A.N., W.J. ter Kerurs and Van der Weiden (1990). The impact of roads on the densities of four bird species in an open field habitat evidence of a long distance effect. *Biological conservation* 18, 299-321.
- Ward, A. L. (1982). *Mule deer behavior in relation to fencing and underpasses on Interstate 80 in Wyoming* (No. 859).
- Warren, P. S., Katti, M., Ermann, M., & Brazel, A. (2006). Urban bioacoustics: it's not just noise. *Animal behaviour*, *71*(3), 491-502.

Acknowledgement



Shri. Vishal Chauhan IAS
Member Administration, NHAI.

The following NHAI personnel of Environment Division, NHAI besides the Regional Offices have actively contributed to highlighting the organization's best practices, which have been incorporated into this Report on Wildlife Mitigation Measures & Structures. Their efforts and contribution are duly appreciated.



Sh. Suneet Bhardwaj, IFS
GM (Environment & GHD),
Env. & GHD Division, NHAI.



Dr. Nagin Nanda IFS Retd.
Advisor (Environment & Clearances)
Environment Division, NHAI.



Saakshi Sahu
Environment Associate
Environment Division, NHAI.



Yokeshwar D
Environment Associate
Environment Division, NHAI.

NOTES

NOTES



National Highways Authority of India

Ministry of Road Transport & Highways

Government of India

www.nhai.gov.in