Framing ecologically sound policy on linear intrusions affecting wildlife habitats

Background paper for the National Board for Wildlife

Prepared by

T. R. Shankar Raman

Nature Conservation Foundation, Mysore

20 January 2011

CONTENTS

Cover photographs

Clockwise from top left:
Railway line through Hollongapar Gibbon Wildlife Sanctuary (Narayan Sharma)
Penstock pipes to Sholayar power house Anamalai Tiger Reserve (T. R. Shankar Raman)
Wildlife on the road: elephant crossing and raodkills (Kalyan Varma)
Canal from Bhoothathankettu (Thattekkad) to Kalady (James Zacharias)
Hgh-tension powerline fragmenting rainforest in Vazhachal Reserved Forest (T. R. Shankar Raman)
Tetrapods along the coast in Lakshadweep (Kartik Shanker)

Framing ecologically sound policy on linear intrusions affecting wildlife habitats

1 INTRODUCTION

Man-made linear infrastructure such as roads, highways, powerlines, railway lines, canals, pipelines (water, gas, petroleum), electric fences, and firelines, are now widely recognised to have many highly detrimental ecological effects in both terrestrial and aquatic natural ecosystems. Such linear intrusions into natural areas cause habitat loss and fragmentation, spread of invasive alien species, desiccation, windthrow, fires, animal injury and mortality (e.g., roadkill), changes in animal behaviour, increased developmental, tourist and hunting pressures, increase in pollution, garbage, and various disturbances. They may also have negative effects on indigenous and marginalised people, rural and forest-dwelling communities both directly through exposure to new social and market pressures, loss of land and relocation, as well as by inequitous distribution of costs and benefits from infrastructure projects. In present-day India, infrastructure expansion and proliferation of linear intrusions without heed to ecological and social impacts is creating immense pressures on natural areas, thereby compromising the long-term value of these areas, their ecosystem services, and imperilling the prospects for more holistic and sustainable development.

Most of the linear intrusions implicated in such ecological and social impacts are considered crucial infrastructure for economic sectors such as transportation, power, and irrigation. Modern improvements, incorporating landscape and ecological considerations, on the design and placement of linear infrastructures are available but remain virtually ignored. Many infrastructure projects are also frequently implicated in poor and unlawful practices in relation to project development, implementation, monitoring, and appraisal. While a range of legal stipulations, orders and guidelines exist, these are not well organised, often ignore important ecological and social science considerations, are poorly enforced by authorities, and frequently flouted by project proponents. Affected parties seek redressal through litigation, activism, or media pressures resulting in revisions, cancellations, or delays in project implementation. This situation urgently requires the formulation of a comprehensive and broadly applicable national policy and appropriate rules for implementation of ecologically sound practices and alternatives to harmful linear intrusions in natural areas.

2 THE NATIONAL BOARD FOR WILDLIFE INITIATIVE

During the 5th meeting of India's National Board for Wildlife (NBWL) held on 18 March 2010, under the Chairmanship of the Honourable Prime Minister, it was decided that there is a need to evolve guidelines to mitigate the growing impact of various linear intrusions such as roads, pipelines, transmission lines, etc., in wildlife habitats. It was also decided that project authorities would be actively encouraged to provide alternative alignments to bypass Protected Areas. Earlier, at a meeting convened by the Secretary, Ministry of Environment and Forests on 22 December 2008, the non-official members of the NBWL presented that most highway projects were trying to force a *fait accompli* by making huge public investments and starting work on non-forest land and then approaching the Ministry for permissions for sections passing through Protected Areas. The members suggested that grants of *ex post-facto* approvals must be stopped and that the Regional Office must prosecute violations. It was also suggested that every proposal must contain a detailed report on alternatives explored and reasons why it is not feasible along with a signed undertaking that work has not been started on forest land or non-forest land. The matter was referred to the Standing Committee of the NBWL for deliberation.

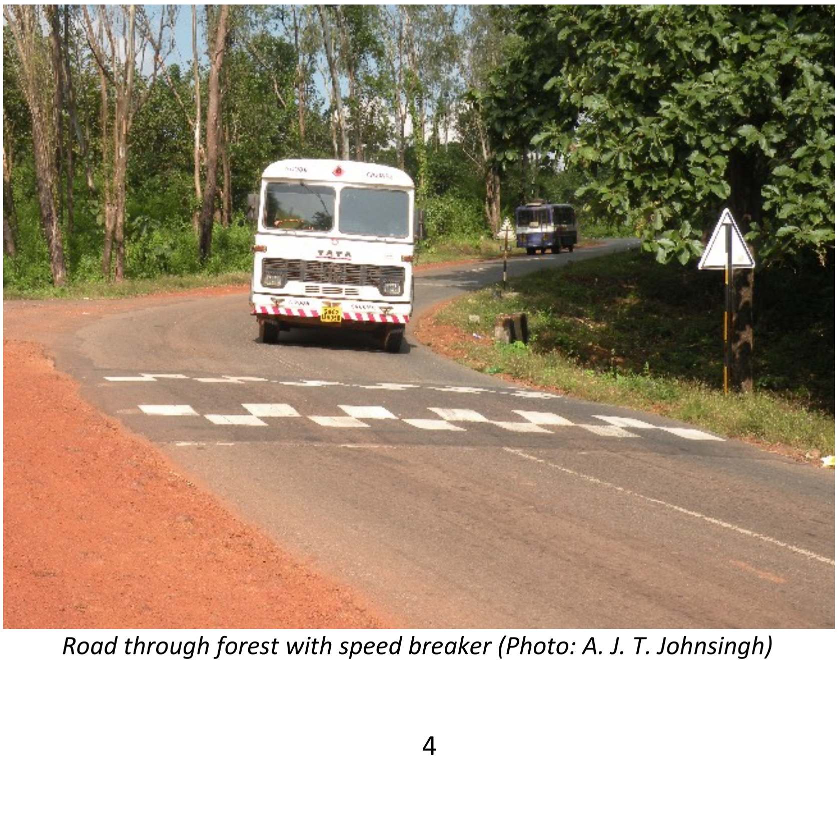
In the 20th meeting of the Standing Committee of the NBWL held on 13 October 2010, it was discussed that linear intrusions were a serious issue and a sound policy needs to be framed consulting various experts. The Chairman requested the member of the Standing Committee from the Nature Conservation Foundation, Mysore, to prepare a background paper that could be discussed at the next meeting to move towards the formulation of a policy on linear intrusions at the national level. An effort was then made by the member to collate existing information, consult subject experts and other members of the NBWL. This background paper summarises findings and key concerns and proposes an outline of urgently-needed policy measures, rules for practice, implementation and monitoring.

3 GOALS AND MISSION STATEMENT

GOAL: To establish, as an essential part of long-term sustainable development in India, ecologically-sound policy and practice in the creation, maintenance, removal, and realignment of linear infrastructures in order to avoid or minimise the negative impacts on natural areas and biodiversity.

MISSION: To re-design and re-engineer ecologically-sound policy and praxis to protect and restore the ecology of natural areas threatened or negatively affected by linear intrusions such as roads and highways, canals, pipelines, transmission powerlines and electric fences, railway lines, firelines, sea walls, and other such man-made structures and clearings.

> **Challenge:** To meet the requirements of a growing economy and need for reliable and safe transportation, communication, power, and irrigation infrastructure while avoiding or minimising negative impacts on nature conservation and ecological sustainability.
>
> **Opportunity:** To integrate the best knowledge from ecology, engineering, and other sciences including the social sciences to ensure that biological and physical systems in the landscape are considered along with human needs and applied to shape and preserve our landscapes and communities into the future in an ecologically-sound, cost-efficient manner.



Road through forest with speed breaker (Photo: A. J. T. Johnsingh)

4 IMPACTS OF LINEAR INTRUSIONS: THE SCIENTIFIC BASIS

4.1 Roads and highways

With over 3.3 million kilometres of roads, India has second largest road network after the USA. This is also poised to expand rapidly due to targets sets by the Ministry of Road Transport. This extensive network of roads and the associated vehicular traffic cause a number of impacts on natural areas and wildlife species. The effects of roads is now a serious global concern, spawning hundreds of research studies in the emerging field of road ecology that focusses on the interaction of organisms and the environment linked to roads and vehicles (Spellerberg 2002, Forman *et al.* 2003).

Wildlife populations often decline due to the cumulative impacts of roads over time. It is important to note that it is not merely the length of the road (or area under the road surface itself) that is of relevance in assessing impact but many additional factors (Rajvanshi *et al.* 2001). As these different impacts can affect varying extent of areas on either side in the habitats that they pass through, the cumulative impact of roads and the road network can be substantial and severe or more detrimental than other effects such as forestry or land-use conversion. **The area of forest habitat affected by roads (ecological footprint) may be much larger than the actual cleared footprint due to negative edge effects that penetrate the forest to varying distances** (Goosem *et al.* 2010). Broadly, the various impacts of roads be categorised as:

- Roads as cause for wildlife mortality (roadkill)
- Roads as cause for habitat loss and degradation
- Roads as barriers, and cause for habitat fragmentation
- Roads as conduits for invasive alien species
- Roads and genetic effects on animals
- Roads as cause for landslides and soil erosion
- Roads through closed-canopy forests: effects on arboreal animals and vegetation
- Road impacts on aquatic ecosystems
- Roads as ecological traps
- Roads and change in animal behaviour
- Roads, people and pollution
- Road impacts on local and indigenous peoples
- Roads as a drain on public money and economic valuation of roads

Roads as cause for wildlife mortality (roadkill)

Perhaps the most obvious direct effect of existing roads is the effect on faunal mortality and injury due to collisions with vehicles. The few studies that are available from India, indicate a grave situation already (**Annexure 1**). A wide variety of species are affected, ranging from invertebrates and herpetofauna, to many birds and mammals, including large mammals such as Asian elephants and sambar and carnivores such as tiger and leopard. A study from Mudumalai Tiger Reserve, found road mortality of 40 animal species, including amphibians, reptiles, birds, and mammals (Baskaran and Boominathan 2010). Reptiles and amphibians are amongst the most severely affected taxa. In Kaziranga, a survey revealed 21 species of reptiles to suffer from road mortality (Das *et al.* 2007).

Studies also reveal that rates of road kill, measured on a per kilometre or per km/day basis can also be substantial. In Sharavathi river basin **amphibian kill rate on roads averaged around 10 kills/km per day on a National Highway** during the monsoon (Seshadri *et al.* 2009). A study in Nagarahole – Bandipur in southern India, with traffic intensity of 50 – 100 vehicles/hour around noon, found 40 kills/10 km per day of insects such as butterflies and dragonflies, doubling over the weekends with increased traffic. A rough calculation indicates that vehicles here kill around 15,000 insects every year in just that 10 km of road (Rao and Girish 2007). In the Anamalai hills of southern

India, a study of road kills of reptiles and amphibians found that around 6 were killed per 10 km of road every day during the monsoon (Vijayakumar *et al.* 2001). Conservative extrapolation would suggest that a 100 km stretch of road through forests here witnesses an annual kill of around 10,000 amphibians and reptiles, a large proportion being species endemic to the Western Ghats. This estimate, based on a study carried out 10 years ago when traffic volumes were lower, may need to be revised upwards following widening of roads and unregulated, ill-planned tourist influx in recent times (Raman 2009). Rajvanshi *et al.* (2001) also reported **numbers of large mammals, including species such as tigers, lions, leopards, and sambar in roadkills within Tiger Reserves, National Parks and Wildlife Sanctuaries.** Nation-wide figures for these and many other threatened mammal species are not available.

Even when dead animals on the road are noticed, other pervasive problems related to the road within forest areas are overlooked. This includes animals killed during road construction, earthwork and annual maintenance operations, particularly slow-moving and burrowing species such as turtles, snakes, and soil fauna. Direct impacts include plant and animal death caused by road construction equipment (Goosem *et al.* 2010).

No study has yet comprehensively addressed all animal taxa from invertebrates such as snails and ants to large creatures such as peafowl and elephants in a given location. Even the studies carried out so far may underestimate the true damage. Many animals are struck and badly wounded by vehicles along roads but manage to flee or drag themselves away from the road corridor to die unseen and unrecorded by researchers some distance away. It is not unusual for road-killed animals to be removed off the road or consumed by scavengers, including people, and thereby the kills go unrecorded. Another compounding factor is the attraction of animals to road-killed carcasses, which may lead to further deaths from speeding vehicles until the carcass is safely disposed away from the road.

Some forest managers and highways engineers erroneously believe that the number of animals killed on roads is an indicator of a healthy animal population (T. R. S. Raman, pers. obs.), despite no scientific evidence for such a claim. Available evidence strongly points to the contrary. The additional mortality on roads can tilt the demographic scales against a population that already grapples with various natural factors and human-caused disturbances for survival. Studies from elsewhere have revealed that the negative effects of high traffic density can be as serious as direct loss of forest cover for amphibians, with a need to avoid or regulate traffic at low density for up to 2 km around breeding ponds if frog diversity is to be conserved in the landscape (Eigenbroda *et al.* 2008). Another study estimates that if 10% or more of the adults annually risk being killed by vehicles along roads near breeding areas, the population will eventually perish (Gibbs and Shriver 2005). While estimates of population-level mortality rate are unavailable from India, studies from other areas have revealed that these can be severe and approaching critical thresholds of survival. A study in Denmark, by Hels and Buchwald (2001) showed that in a road with a traffic load of 3207 vehicles/day, probability of an amphibian being killed ranged from 34% to 61%, increasing up to 98% while crossing a motorway. In the same study, it was found that annually 10% of the entire adult population of three frog species was being killed on the road.

Fahrig and Rytwynski (2009) performed a comprehensive review of the empirical literature on effects of roads and traffic on animal abundance and distribution. Of 79 studies, with results for 131 species and 30 species groups, **the number of documented negative effects of roads on animal abundance outnumbered the number of positive effects by a factor of 5.** In total, 114 responses were negative, 22 were positive, and 56 showed no effect. Amphibians and reptiles tended to show negative effects, birds mainly negative or no effects, with a few positive effects for some small birds and for vultures. Small mammals generally showed either positive effects or no effect, mid-sized mammals showed either negative effects or no effect, and large mammals showed predominantly negative effects. The authors conclude that **the evidence for population-level effects of roads and**

Roadkill of animals due to collisions with speeding vehicles is a direct and increasing threat to wildlife in natural areas of the country. Clockwise from top: lion-tailed macaque in a road through rainforest fragment in the Anamalai hills (Photo: Kalyan Varma), sambar killed in Bijnor Forest Division, Uttarakhand (Photo: A. J. T. Johnsingh), monitor lizard roadkill (Photo: Kalyan Varma), pit viper killed on rainforest road (Photo: T. R. Shankar Raman), two red foxes killed on road, probably while trying to scavenge on a langur killed on the same spot (Photo: A. J. T. Johnisngh)

traffic is already strong enough to merit routine consideration of mitigation of these effects in all road construction and maintenance projects. In a related study, Rytwynski and Fahrig (*in press*) found that among mammals, those species with lower reproductive rates, larger home ranges, or body size were more vulnerable and suggest that *priority should be placed on mitigating road effects on large mammals with low reproductive rates*.

A key concern in India is that a large number of Protected Areas have existing State Highways (SH) and National Highways (NH) and other roads passing through them. The *laissez faire* approach to existing roads and highways, as well as all proposed expansion and widening, pose serious threats to wildlife that need to be addressed.

Roads as cause for habitat loss and degradation

There is direct loss of habitat during establishment and maintenance of roads and highways. This may happen due to clearing of vegetation, dumping of excavated earth and materials, movement of heavy vehicles and earth-movers, creation of labour camps etc. The effects of these disturbances may persist in the landscape for years to decades.

The road surface and clearing on either side represent direct habitat loss (Photos: NCF)

No study has yet catalogued the extent of roads through natural areas, especially forests, across India or the loss of forest cover due to roads. A notable exception, from Garo Hills in Meghalaya, showed that just in this region, an area of 456 ha of biodiversity-rich forest was lost to roads between 1971 and 1991 (Bera *et al.* 2006).

In four tiger reserves in Karnataka, a geographic information system analysis showed that they have a high **road density**: around one km of forest road per square kilometre of forest (Gubbi 2010). This network of roads increases in tourism zones. The tourism zone in Bandipur Tiger Reserve has a road density 2.25 km of road per square kilometre of forest, and the road density is so high that the distance between one road and another is less than 50 m in some places (Prasad 2009). Taking just the 800 km of road in Bandipur Tiger Reserve (Gubbi 2010), and assuming an average width of 10 m of the road itself, this translates into 800 hectares (8 km²) of direct habitat loss.

Clearing on either side of these roads as 'viewlines' for wildlife resulting in a cleared width of 30 – 40 m, imply that the direct loss of habitat due to associated roadside clearing can be even higher. Prasad (2009) also found that **tree death is 250% higher along roads than forest interior**. Besides the direct cleared area of the road and viewline, we need to consider the physical and biotic (plant and animal communities) characteristics such as weed invasion and tree death, which are **added edge effects spreading on either side of the cleared area**. Laurance *et al.* (2009) in a review state that tropical forests within 50 – 100 m of edges experience greater diurnal fluctuations in light, temperature and humidity, being typically drier and hotter than forest interiors, with elevated tree mortality, numerous canopy gaps and a proliferation of disturbance-adapted vines, weeds and pioneer species. In such a situation, the impacted area is likely to be at least 100 m wide along roads (even higher in wider roads, highways, and tourist roads with viewlines). An average width of 100 m of impacted zone along roads implies that **in Bandipur, direct road-related habitat loss and degradation covers around 8000 hectares or 80 km² (~10% of the total park area)**. **In other words, each kilometre of road directly and detrimentally affects at least 10 ha of habitat** (comparable figures for federal highways in the US are 13.5 ha per km of road, Goosem 1997, 2007).

Eagle's eye-view of Bandipur Tiger Reserve dissected by linear intrusions such as roads, viewlines, and powerlines (Courtesy: Google Earth)

Indirect impacts of habitat loss also include displacement of individuals that may eventually die from predation or the greater competition and less resources for each animal in the adjacent habitats into which animals are forced. Some species with high fidelity to home range will be detrimentally affected as they resist shifting and are forced to continue in the same cleared or degraded location. In an example from Australia, the fate of several tree kangaroos was dramatically affected by clearing as described by Newell (1999). During his study of radio-collared individuals in a rainforest fragment, half of the study area was unexpectedly cleared. All of the individuals returned to their original home range shortly after the clearing and continued to reside amongst the fallen debris for up to a year. In the long-term, only those individuals whose home range was largely unaffected survived, while canine predators gradually killed the others.

In forest areas, road-related clearing may also result in higher wind-speeds that may negatively affect trees, increase stress due to desiccation and damage and mortality from wind-throw. Goosem *et al.* (2010) note that increased wind speeds can generate greater wind shear damage to trees, especially those which are no longer supported by the canopy interconnections found in intact forest (Laurance *et al.* 2000). Recent research has shown similar reductions in large trees near highway edges in the Wet Tropics World Heritage rainforests of Australia (Pohlman 2006).

Tall dipterocarp and other trees windthrown along a road through rainforest in Western Ghats (Photos: NCF)

A serious related concern in terms of habitat degradation is also **off-roading by vehicles** in sensitive habitats, including the use of off-road vehicles (ORVs) such as mountain bikes and sports-utility vehicles (SUVs). In locations ranging from montane grasslands of the Western Ghats to various forest types in the plains, beaches, and cold deserts of Ladakh, off-roading is emerging as an 'outdoor sport', leading to much destruction of vegetation, soil erosion, and destruction of habitat such as feeding and nesting grounds. Roads provide access and delivery of people and vehicles to such locations where off-roading occurs.

A recent review of the effects of roads and other infrastructure on populations of 234 mammal and bird species (from 49 studies) showed that density declined with their proximity to infrastructure. **The effect of infrastructure on bird populations extended over distances up to about 1 km, and for mammal populations up to about 5 km. Mammals and birds seemed to avoid infrastructure in open areas over larger distances compared to forested areas, which could be related to the reduced visibility of the infrastructure in forested areas (Benítez-López *et al.* 2010).**

Roads as barriers, and cause for habitat fragmentation

While the effects of large-scale land-use change such as agriculture on habitat fragmentation are widely recognised, the impacts of "**internal fragmentation**" of remaining continuous and remnant forests subdivided by internal clearings for highways, roads, railways, powerlines and pipelines is often overlooked (Goosem 1997, 2007). Roads and their verges can be barriers to the movements and seasonal migration of wildlife. The factors contributing to barrier effects are: loss of habitat; avoiding the altered habitat in the road corridor and on the edge of the forest; road clearing width; physical barriers such as fences, cuttings, fill batters and culverts with drop structures; and altered light, temperature and humidity regimes (Goosem *et al.* 2010).

If wildlife-friendly design considerations are not incorporated, the building of culverts, fencerails, barricades, chain-link and barbed-wire fences, and other concrete and metal structures along roads makes the crossing even more difficult for many species. Parapet-like walls running without a break for hundreds of metres or kilometres along roads, especially on hill roads, become insurmountable obstacles for species such as porcupines, pangolins, turtles, young birds and mammals, to name just a few. On hill slopes where such roads exist, even large animals such as sambar and elephants have to negotiate the upper slope, cross the road, and try to somehow step or jump over roadside walls and culverts to step or land safely on the steep lower slope.

As roads become wider and busier, the number of animals crossing and the rate of roadkill usually increases, but beyond a point it may actually begin to decrease (Seiler 2003). This usually happens when roads become four-laned highways or expressways catering to tens of thousands of vehicles every day. The reduction may be due to the decimation of wildlife populations along the road as well as a 'barrier' effect, where many animals actively avoid the road and avoid crossing it. A road like this passing through a forest or key natural habitat

Top: The highway and sidewall can be an insurmountable barrier for this turtle; middle: long sidewall on a hill road; bottom: busy 4-laned highways act as barriers and fragment habitats essentially cleaves it into two pieces. For many species, this is an added fragmentation of an already fragmented habitat (Goosem 2007).

Roads and genetic effects on animals

The effect of roads as a barrier to individual movements may add another indirect impact: the genetic alteration due to reduced exchange between populations (Goosem *et al.* 2010). A recent review by Holderegger and Di Giulio (2010) reported that, although most roads and highways have only recently been built and only few generations might thus have passed since road construction, several studies have found negative effects of roads on genetic diversity and genetic differentiation in animal species, especially for larger mammals and amphibians. Roads may thus rapidly cause genetic effects and wildlife crossing or passage structures may be required to stave off such population genetic effects.

Roads as conduits for invasive alien species

The increased light levels, exposure, and micro-climatic effects of roads such as heating and drying, produce conditions that favour the establishment of alien (exotic) weed species. A road also provides a movement corridor for the dispersal of weeds. This often results in the development of exotic grasslands or shrubby swathes of woody weeds along verges which enables the penetration of more weeds and animal pests alien to the surrounding forest habitat (Goosem and Turton 2002).

Roads and roadside clearing helps weeds to spread; top: Mikania micrantha *and other weeds along a rainforest road; bottom:* Lantana camara *along a road in dry forest*

Maintenance practices along road verges such as herbicide spraying, burning, mowing, grading and removal of overhanging branches can act as ongoing habitat disturbance which encourages weed colonisation (Goosem *et al.* 2010). Invasive alien weed species may spread into adjoining natural ecosystems and affect the natural recruitment of native plant species. Roadside weeds, including species such as *Lantana camara, Chromolaena odorata (Eupatorium)* may also increase fuel loads, resulting higher risk or intensity of fire. Fire can strongly alter plant composition by allowing greater infestation of species that are more prone to burning (Milberg and Lamont 1995, Goosem *et al.* 2010). In moist forests, these effects may be more pronounced and accompanied by the proliferation of smothering vines and creepers, including invasive alien species such as *Mikania micrantha*, which can suppress plant regeneration (Laurance *et al.* 2009, Goosem *et al.* 2010).

A combination of higher road width and greater infestation by invasive alien species (*Lantana camara*) in Bandipur Tiger Reserve has been shown to have an impact both on tree death as well as tree community composition (Prasad 2009). Road 'improvements' such as widening, improved surface, paving, and grading, carried out without attention to ecological aspects, often result in greater invasion by alien species and declines in native vegetation in a range of ecosystems from grasslands and semi-arid habitats to forest (Gelbard and Belnap 2003, Prasad 2009).

Besides plants, many animal species of other vegetation types, including feral and domestic species may spread along roads into natural ecosystems (Goosem 2007).

Roads as cause for landslides and soil erosion

Road construction is associated with increased frequency of landslides and other forms of erosion in steep forested landscapes (Goosem *et al.* 2010). Road drains divert water from the normal processes of overland runoff and underground seepage, which instead passes into the substrate of the road zone perched on the hillslope (Jones *et al.* 2000). Therefore, slopes and verges need to be protected from concentrated flows and erosion.

In a review, Sidle *et al.* (2006) point out that **roads contribute the largest surface erosion and landslide losses (per unit area disturbed) compared to other land uses**. **Along roads on steep hillslopes, landslide and surface erosion fluxes are typically ten to more than 100 times higher compared to undisturbed forests.** High storm runoff from roads is caused by the generation of infiltration-excess overland flow on compacted surfaces and the interception of subsurface flow at road cuts. These altered pathways increase surface erosion and accelerate the delivery of storm runoff to streams.

Research from the Indian Himalaya also corroborates the increase in erosion that results from road-building and repair (Heimsath 2000, Anonymous 2010). In reserved forest areas, natural vegetation on either side of the road helps in slope-stabilisation, resulting in negative correlation between forest cover and landslide activity (Haigh *et al.* 1995). Road construction and dumping of resulting debris result in the loss or reduction of this forest cover, increasing erosion, thereby creating a need for additional repair work (Haigh *et al.* 1995, see also **Annexures 2, 3**).

In another 2-year study on hillslopes, grass cover, pebbles, and sand content were shown to increase runoff and erosion; whereas slope value, tree cover percentage, structural stability and organic matter content were negatively correlated with runoff and soil losses (Descroix *et al.* 2001). Road construction and maintenance work, especially in forest areas, often results in the creation of the more surface area prone to erosion. In forest areas, slashing of all vegetation, including regenerating trees and saplings, on either side of the road (ostensibly for widening, clean appearance, or better visibility), and removable of overhanging branches, results in the tree canopy cover breaking over the road, and colonisation of roadsides by grasses and rank growth of weeds (Raman 2009). Besides loss of natural vegetation and native species typical to each area, this causes increased soil erosion and landslides. This also leads to further expenditure in road maintenance—providing further opportunity for ecological damage—a vicious cycle leading to considerable wastage of public money due to lack of ecological understanding in road planning, contruction, and maintenance.

From left to right: Widening and earth dumping on road to Tawang near Pakke Tiger Reserve (Photo: Shashank Srinivasan); landslip on E-W Road in Great Nicobars (Photo: Manish Chandi); hard engineering methods are poor replacement for natural vegetation to prevent erosion and slips (Photo: NCF)

Roads through closed-canopy forests: effects on arboreal animals and vegetation

Closed canopy forests (tropical and sub-tropical forests such as semi-evergreen and wet evergreen rainforests) are particularly affected by roads and other linear clearings (Laurance *et al.* 2009) because of:

1. their high biodiversity and complex structure,
2. diversity of species that depend exclusively on presence and connectivity of high tree canopy, and
3. more drastic alteration of environment due to roads when compared to intact forest interiors.

Slender loris killed while crossing road (Photos: Kalyan Varma)

The roadkill threat is particularly acute for many tree-dwelling species that do not normally cross on the ground. When roads slice through our forests and government departments and road contractors widen roads and slash all vegetation, including regenerating trees and saplings on either side, the tree cover breaks over the road. Besides habitat loss, degradation, invasion by weeds and other changes , this destroys the tree canopy connectivity that would have allowed many species to safely cross the road overhead.

Unable to cross overhead using the overlapping branches of intact forest canopies, the animals now face a permanent problem—a serious, life-threatening challenge—of a gap caused by the break in tree cover over the road. In the absence of tree cover, arboreal animals are sometimes forced to use electric wires of powerlines to cross, leading to the double jeopardy of electrocution deaths for species such as lorises and lion-tailed macaques (Radhakrishna and Singh 2002). The roads and powerlines through our forests are increasingly turning into graveyards of tree-dwelling species such as monkeys, lorises, civets, squirrels, and tree shrews (Raman 2009).

Maintaining canopy cover over roads, at least periodically is thus considered critical for roads passing through closed canopy forests. **Besides benefits to wildlife, maintaining canopy cover over the road may benefit the road itself and reduce maintenance costs.** A study of erosion on unsealed rainforest roads (Bacon 1998) found that less erosion and road damage occurred where canopy cover was maintained above the road surface. Erosion was probably reduced because rainfall was intercepted by the multilayered canopy and funneled away from the road along branches and trunks (Goosem and Turton 1999, 2000). Maintaining canopy overhead also reduces costs as it suppresses dense growth of shrubby weeds (thereby reducing the need for roadside vegetation clearing), temperature (reducing energy use for air-conditioning for passing vehicles), and favours growth of favourable native plants such as ferns and herbs. Studies have shown that roadside fern growth plays important ecological roles in reducing road runoff, mitigating splash and surface erosion, trapping sediment where plant seeds can germinate, providing nutrient-enriched throughfall, and moderating harsh surface temperature environment (Negishi *et al.* 2006). When opened-up roadsides are colonised by invasive plants, such benefits are lost leading to ecological and economic costs.

When roads break the forest canopy, threatened species like the Nilgiri langur can jump small gaps but risk death when the canopy is broken completely and they have to cross the road on the ground (Photos: NCF)

Road impacts on aquatic ecosystems

The impacts of roads on aquatic ecosystems is seldom recognised, with roads being considered a mainly terrestrial feature. Adjoining aquatic habitats may, however, be affected by erosion and landslides, sedimentation, flow patterns and channelisation, with subsequent impacts on aquatic and stream bank life both up- and down-stream from the clearing (Eaglin and Hubert 1993, Brown 1994, Trombulak and Frissell 2000, Goosem *et al.* 2010). Alteration of stream flow, siltation and sediment loading, and pollution are some main degradation concerns. Alteration of stream flow regime is both caused and indicated by stream siltation (Harris 1995).

Pollution and sedimentation of rivers due to roads often begins from the first-order streams itself (Photo: Robin Abraham)

Goosem *et al.* (2010) note that run-off from roads also can create turbid water that enters existing waterways. Turbidity reduces the process of photosynthesis in aquatic plants and algae. This, in turn, limits the supply of dissolved oxygen which is essential for fish, tadpoles and other aquatic life. The sediment suspended in turbid water has also been found to irritate the gills of fish. In extreme cases, chronic fine sediment loads can alter the diversity and composition of invertebrate species and dramatically change food web structure within streams (Luce 2002). Runoff from hot rainforest roads can also significantly alter the water temperature in nearby streams with an immediate reduction in the amount of dissolved oxygen in receiving waters.

Considerable deposition of solids into rivers and streams may occur during road construction and repair work. It is also a common sight to see stream and river waters used for consumption, letting-out of wastewater, washing of vehicles and machinery. Improper design of embankments and drain channels may lead to increased water and sediment entering into some stream catchments, corresponding declines in other catchments, and changes in groundwater infiltration and retention. There is a need to reduce such impacts through proper design. Also, the use of buffers of native vegetation along all water courses and sediment and pollutant traps for drain channel waters is essential to minimise negative impacts of roads on aquatic ecosystems (Zeigler *et al*. 2006).

As noted by Goosem *et al.* (2010), when cut through hillslopes or wetlands, roads can intercept shallow ground water flow, potentially causing death of vegetation upstream through ponding and downstream due to reduced availability of groundwater. Groundwater can be concentrated through the compaction of the road base and fill batters, and by trenching for roadside drainage and stabilisation of cut batters. Water that is redirected into surface streams may potentially remove a source of water that was originally destined for a wetland or a spring. Hard bitumen surfaces increase runoff compared to unhardened surfaces, and this additional water can result in channelisation of streambeds and increasing erosion and sedimentation within other sections of the waterway. Road and the kind of road network in mountain landscapes may also affect floods and debris flows and thereby disturbance dynamics in streams and rivers (Jones *et al*. 2000).

Roads built across wetlands often create a barrier or affect flow regimes leading to wetland fragmentation, and other changes including the spread of water weeds. Other associated impacts of roads are the loss of aquatic habitat area and diversity, obstruction of free movement for aquatic life, and degradation of the riparian (stream bank) vegetation. Even when road crossing structures exist, they may impede or prevent fish movement if (Goosem *et al.* 2010) the:

- Water velocity or turbulence is too great;
- Culvert is too dark, long or narrow;
- Water is too shallow;
- Crossing is full of debris; and/or
- Stream has a drop on the upstream or downstream side of the crossing (Cotterell 1998).

In India, during the monsoon, many first order streams come alive from the mountain slopes and provide nurseries for frogs, many insects and certains species of fish. Many forest roads (mostly mud-roads) and firelines have been made along the slopes of the mountains and they cut across several such first order and occasionally second-order streams. In places where the stream order is higher, rock bridges have been constructed to prevent the road from being washed away. But, the lower order streams would definitely be affected by (i) presence of the roads and firelines by increasing silt and sediment load input into these small streams, hence decreasing dissolved oxygen crucial for many specialist fish and tadpoles and (ii) by vehicular traffic (transporting labourers who clear trek roads and firelines, workers in plantations inside some Protected Areas (PAs), Forest Department personnel, and eco-tourists), which cause mortality of many organisms that use these first and second order streams (R. Abraham, pers. comm.).

Roads as ecological traps

In most cases, the road surface and verges are of little use to most animals. Some species, usually common and commensal species such as doves, mynas, and rodents, may be attracted to roads for scraps of food. Some reptiles such as lizards and snakes may be attracted to bask on the hot road surface, as to a rock on a sunny day. Dragonflies and mayflies may be attracted to the polarized light emanating from the asphalt, a form of light pollution that fools them into believing that they are over the surface of a water body. As they fly around to feed or defend territories or even try to lay eggs on the 'water-road', they imperil their own survival. In these cases, the road becomes an ecological death-trap, where the very adaptations evolved over millenia to enable these species to locate their food and thrive in their environment now propel them to their death (Raman 2009).

Roads and change in animal behaviour

Most of the animals that are killed on roads are, like the proverbial chicken, merely trying to cross to the other side. Yet road crossing can be a perilous affair, and many species are behaviourally predisposed to avoiding roads and road-crossings (e.g., Goosem 2001, Laurance *et al.* 2004). Animals may also be seriously stressed or change their behaviour in the vicinity of roads. Studies from Africa on elephants and chimpanzees, have shown how they tend to avoid roads and change their behaviour, due to the associated risks as one would expect from such highly intelligent species (Hockings *et al.* 2006, Blake *et al.* 2008). In areas where hunting of wildlife is frequent and roads are used to gain access, many species whose populations are affected by hunting also show high avoidance of roadsides (Laurance *et al.* 2006). Weekly spurts in vehicle movement over weekends as people leave urban areas for the countryside may also cause change in the activity/movement cycles of birds of prey resulting in their decreased occurrence over weekends in certain areas (Bautista *et al.* 2004). In African rainforests, Laurance *et al.* (2008) also found that the species richness and abundance of several nocturnal primates, smaller ungulates, and carnivores, many of which are affected by changes in forest structure, were significantly depressed within approximately 30 m of roads.

Roads, people and pollution

Another long-term aspect is the issue of increased access: people visiting, passing through, or settling in otherwise remote or inaccessible natural areas. This results in various forms of pollution (solid waste, chemicals and heavy metals from vehicles and road construction, garbage from tourists, noise pollution, air pollution with vehicular exhaust). Waterways may also be polluted by storm water runoff from roads (heavy metals and other contaminants). Burgeoning tourism, including nature-oriented tourism, is increasing the entry of vehicles and people into many protected areas in the country, bringing with it several concerns related to human disturbance and pollution. Laurance *et al.* (2009) note in a review:

"Roads and highways can be a large source of chemical pollutants. Dust, heavy metals, nutrients, ozone and organic molecules are often elevated within 10–200 m of road surfaces. Lead pollution from car exhausts can be especially problematic, particularly in developing nations that still allow leaded gasoline. Effects of chemical pollutants and nutrient runoff are likely to be especially serious for streams and wetlands near roads, with major pulses of waterborne pollutants and nutrients entering aquatic ecosystems with heavy rains at the onset of the wet season. Such contaminants can have wide-ranging effects: for example, many aquatic invertebrates and vertebrates are sensitive to water pollution; waterborne nutrients can promote harmful eutrophication; and heavy metals are often biomagnified in aquatic food chains."

The role of labourers who are staying within protected areas during road construction is also a serious concern. In the Himalaya, roads are sometimes made in a way or in such an alignment that labourers have to permanently stay there for maintainence (e. g. Maling, many passes). The impacts of labour camps (hunting, disturbance, erosion, garbage) can be severe. In Hemis NP, a 20 km stretch to Rumbak village has been under construction for over 10 years now and labourers are semi-permanently resident in the park. Similar problems are rife in the Eastern Himalaya and north-east hill states (Y. V. Bhatnagar, S. Srinivasan, pers. comm., and pers. obs., see **Annexures 2 and 3**).

Roads bring people and pollution into natural areas. Top row: tourists, vehicles, and garbage along road in Anamalai Tiger Reserve (Photos: NCF)
Bottom: Chital in Nagarahole with plastic bag in its mouth (Photo: P. Bhargav); construction work and labour camps (Photo: Y. V. Bhatnagar) add to disturbance and pollution in natural areas.

Road impacts on local and indigenous peoples

Roads can also lead to negative impacts on local and indigenous peoples, as well as social imbalances resulting from market penetration or inequitous distribution of benefits. Proponents of roads take it as 'given' that any road is a beneficial road, yet proper assessments of benefits are rarely carried out. A road leading into a village, for instance, may benefit a small number of traders or merchants, without substantial benefits to agriculturists, or a road through the hills, may primarily benefit distant tourists for motor vehicle-based access, without bringing benefits to local populations *en route*.

In the case of indigenous peoples who have established self-sustaining local communities in remote areas, roads can also lead to many negative effects as seen in the case of roads in the Andaman and Nicobar islands.

Andaman Trunk Road (ATR)

The 340 km long ATR was constructed across the three main Andaman islands between the mid 1970s and 1989, but became fully operational only by the early 1990s (Sekhsaria and Pandya 2010). The indigenous people, Jarawa (known as the 'Ang' amongst them), who were a hostile community until the last decade, are today in peaceable contact with villages neighbouring the forested region they inhabit. Their livelihood based on hunting and gathering is under influence by the cultural contacts. Today they number close to 325 people, and over this decade have experienced the ATR as a means of contact with contact missions as in the past, with large numbers of people who travel on the ATR on a daily basis, as well as of their own free choice. Incidents of transfer of food items from tourists and passers-by to Jarawa have been noticed, there is risk of disease spread as noticed in a measles outbreak. Disturbance to forest habitat by road presence and maintenance, spread of feral animals along the road (leading to additional environmental impact), contact with road labourers, are other serious issues. Despite recognition of these issues and **despite orders by the Supreme Court for the closure of the Andaman Trunk Road, it continues to remain open for daily traffic** (Sekhsaria and Pandya 2010).

Jarawa contact with people and traffic on ATR, despite Supreme Court order

Great Nicobar Island East – West road

A multiethnic population of largely ex-service men and their families were settled on Great Nicobar Island by the early 1970s, where the elusive Shompen live in the interior forests. While a north – south road is constructed for the use of those in the settlements from Campbell bay on the east coast to Shastri Nagar closer to the southern tip upto a distance of 35 km, another road, the east – west road runs right through the Great Nicobar Biosphere reserve virtually dividing two National Parks: Campbell Bay and Galathea. This road was never used in full with no real reason for its use except for the few inhabitants who used to inhabit the west coast before the 2004 tsunami, though more often boats and canoes were used to reach the settlement. Today no settlement exists along the west coast and the reconstruction of the E – W road was initiated, ostensibly for defence purposes. While this road has been subject to yearly landslides, during every heavy downpour of rain, it has only fuelled construction work and financed contractors with the

A shompen after bartering with a road labourer in Great Nicobar (Photo: Manish Chandi) road virtually being never put to use by vehicles for defence or administrative purposes. The road has been a means of contact between road labourers who barter with the Shompen, a shy and elusive hunter-gatherer population spread in small clans across the thick rainforests of Great Nicobar Island. The labourers in exchange for articles such as honey and lemons from the Shompen barter chewing tobacco and alcohol, affecting their health and negatively influencing their otherwise self-sufficient lives (M. Chandi, pers. comm.).

Roads as a drain on public money and economic valuation of roads

A widespread view about roads is that they are synonymous with progress and development. Yet, in cases where social benefits of roads are themselves debatable (previous sub-section), if environmental impact and costs of annual maintenance and repair (e.g., following landslides) are taken into account, the economic value of roads may in fact be negative and represent a drain of public money. For instance, the Andaman Trunk Road is estimated to use Rs 45 crores (Rs 450,000,000) on annual maintenance with an additional Rs 3.5 crore worth of firewood (some cut illegally), and involving 38 tonnes of bitumen and considerable movement of workers and labourers in otherwise undisturbed forests (Sekhsaria and Pandya 2010). At considerable cost to indigenous people and rainforest environment, this road primarily benefits outside traders and tourists, in effect representing a public subsidy of select private interests and unsustainable tourism.

Another similar scenario of wastage of public money in road maintenance is seen in many hill roads passing through closed-canopy forest types of the Western Ghats (Raman 2009). Here, the clearing of vegetation on either side, leads to canopy breakage and openings, leading to proliferation of undesirable invasive weed species. This creates need for additional labour periodically for clearing the weeds. As the workers and managers are unable to distinguish useful native vegetation from invasive weed speices, all vegetation is cleared and the removal only creates open, disturbed conditions for weed proliferation in a self-sustaining, ecological and financial loop. Also, erosion-related landslips and landslides are becoming more frequent due to such clearing of vegetation on either side of roads; again leading to additional cost of repair, including expensive and ecologically undesirable stone and concrete revetments to replace the 'green-revetments' of natural native vegetation that earlier protected the soil from erosion but have been whittled away by inappropriate roadside clearing. **The lack of attention to regeneration of native plants, need for canopy closure, and appreciation of the role of native plant species in safeguarding soils along roads through such forest areas, has resulted in this unhappy situation of considerable annual loss of money to the public exchequer.**

At present there appears to be no national or commonly-used method to assess the total economic value of roads, taking into account social and environmental valuation, incorporating the multiple known and emerging aspects highlighted in this document. As Aldo Leopold remarked in a famous essay 'Marshland Elegy' in *The Sand County Almanac* (Leopold 1949)*: To build a road is so much simpler than to think of what the country really needs.*

Clearing all vegetation on roadsides (left) favours growth of invasive alien weeds (right, photos: NCF)

4.2 Railway lines

The effects of railway lines on wildlife habitats has received attention due to the death of large animals such as Asian elephants, rhinos, tigers, and gaur. The recent report of the Elephant Task Force has analysed salient aspects related to elephant deaths and provided useful recommendations (Rangarajan *et al.* 2010).

Railway lines are linear intrusions, and like roads, cause a multiplicity of ecological problems that deserve attention besides direct mortality of wildlife. In natural areas, these include, besides animal kills, habitat and population fragmentation, habitat loss and degradation, spread of invasive alien species, pollution and garbage accumulation.

Although there are fewer studies on the effects of railway lines on these aspects, the alteration of habitat and the inadequate attention paid to ecological aspects during construction and maintenance, create many conditions similar to roads with resultant similar impacts, including:

- Canopy-breakage when passing through closed canopy forest areas
- Higher light penetration and desiccation
- Higher daytime temperatures, greater diurnal fluctuation in temperatures
- Spread of invasive alien species
- Higher wind speeds and resultant windthrow
- Cutting of all trees and vegetation on either side resulting in second growth and weeds
- Pollution (noise, air, and solid wastes, including food waste from trains along the tracks)
- Steep embankments with stones and concrete (artificial substrate avoided by many species)
- Construction- and maintenance-related disturbance and movement of people

The Elephant Task Force report notes that since 1987, 150 elephants have died due to train hits. These deaths are distributed in the states of Assam (36%), West Beengal (26%), Uttarakhand (14%), Jharkhand (10%), Tamil Nadu (6%), Uttar Pradesh (3%), and Orissa (2%). Many more have died since the submission of the report, including the ghastly tragedy where seven elephants were killed in a single incident near Binnaguri, Jalpaiguri district, West Bengal, on 23 September 2010.


Top to bottom: railway line cleaving through Gibbon Wildlife Sanctuary (Assam) and kills of capped langur and python along the tracks (Photos: Narayan Sharma); elephant killed along rail track.

The report identifies various contributing factors to train hit deaths: ecological (food, water, shelter, vegetation and movement routes), physical (steep embankments and turnings), technical (train speed, frequency and time, unmanaged disposal of edible waste), and lack of awareness among drivers, passengers, and planners. It also provides specific recommendations (Rangarajan *et al.* 2010). In Rajaji National Park, scientific study (Singh *et al.* 2001, Menon *et al.* 2003) followed by joint implementation of recommendations has resulted in reducing train hit deaths to zero since 2002, indicating the opportunity for similar efforts nation-wide.

Internal fragmentation: railway track through Gibbon wildlife Sanctuary, Assam (Courtesy: Google Earth)

An illustrative case of other effects of railway lines is seen in the Hollongapar Gibbon Wildlife Sanctuary that was split into two unequal halves by a railway line constructed in the 1930s. The line has fragmented the tropical wet evergreen forest, the home of threatened tree-dwelling primates such as the hoolock gibbon, capped langur, stump-tailed macaque, and slow loris. While train-hit deaths of capped langurs have been noticed on the line, species such as gibbons, stump-tailed macaques, and loris probably never cross the line resulting in habitat fragmentation and population isolation (Sharma 2009). It may be necessary to create passageways for willdlife species in areas where railway lines pass through natural areas. One would need to assess the efficacy of existing non-widlife passages as well as the distribution and provision of natural vegetation and substrate cover in the vicinity of and within passages (Yanes *et al.* 1995, Rodriguez *et al.* 1996).

4.3 Transmission powerlines

With the Government of India instituting the *Power for All by 2012* program there has been a renewed emphasis on power generation, transmission, and distribution in India. Power generation, and distribution and related aspects including maintenance are guided by the Electricity Act (2003, with amendments as on 2007), and the Indian Elecricity Rules 1956 (amendments up to 2000). **The Electricity Act of 2003 has among its stated objectives the 'promotion of efficient and environmentally benign policies'.**


Transmission lines double up with a road through forests in Karnataka (Photo: NCF)

For the present purpose, we are concerned primarily with overhead transmission lines that are part of the national grid. These are primarily alternating current (AC) lines, although some long-distance high voltage direct current (HVDC) lines are also operational. Based on voltage under normal conditions, the lines are classified as:

- **Low:** voltage does not exceed 250 volts,
- **Medium:** voltage above 250 V up to 650 volts,
- **High:** voltage above 650 V and up to 33,000 volts (33 kV),
- **Extra high:** voltage above 33 kV to at least 800kV
- **Ultra high:** voltage greater than 800 kV

In natural areas from grasslands and wetlands to forests, it is mostly high and extra high voltage lines that are established along long linear clearings.

The main ecological problems associated with these linear intrusions are:

Ecological concerns shared with other linear intrusions such as roads

- Canopy-breakage when passing through closed canopy forest areas
- Higher light penetration and desiccation
- Higher daytime temperatures, greater diurnal fluctuation in temperatures
- Spread of invasive alien species
- Higher wind speeds and resultant windthrow
- Cutting of all trees and vegetation on either side resulting in second growth and weeds
- Construction- and maintenance-related disturbance and movement of people

Ecological concerns unique to transmission powerline

- Risk of electrocution
- Clearance of vegetation even when very distant from lines (when passing over valleys)
- Cutting through very inaccessible areas (as straight lines even over difficult terrain)

A transmission powerline fragmenting rainforest in Vazhachal, Kerala; weeds spreading along powerline clearing; double trouble of road and powerline each cutting its own swath through the forest (Photos: NCF)

Electrocution: Large animals such as elephants have suffered electrocution deaths due to sagging of powerlines (86 elephant deaths in the last 10 years, B. Mohanty, pers. comm.). Where canopy is broken due to powerlines and roads, arboreal mammals such as primates may use the powerlines to cross from one side to another; this has also lead to animal mortality.

The Elephant Task Force has noted this problem and proposed recommendations (Rangarajan *et al.* 2010). Powerlines are also known to be a big hindrance for large birds such as cranes resulting in bird collisions and deaths (P. Trivedi, K. S. Gopi Sundar, pers. comm.). Bevanger (1994) traces problems related to bird deaths from powerlines with useful recommendations.

A lion-tailed macaque electrocuted while trying to use a powerline to cross a canopy gap across a road through a rainforest fragment in the Anamalai hills (Photo: M. Ananda Kumar)

According to Bevanger, **route planning should include careful mapping** of:

(1) topographical features which are leading lines and flight lanes for migrating birds and/or are important for local movements of resident species,
(2) topographical elements such as cliffs and rows of trees that force birds to fly over power lines,
(3) primary ornithological functions or uses of the area to avoid key areas for birds and avoid separating these areas and
(4) local climatic conditions (including seasonal variations) like fog frequency and prevailing wind direction.

The outcome depends largely on a combination of these factors. Objective assessment of the effects of mitigating measures, in particular wire marking, is required.

Vegetation clearing: Another main reason for impacts on natural habitats (loss, degradation, fragmentation) is the clearing of vegetation below and on either side of these powerlines along their entire length. This is particularly the case where the powerlines pass through forest areas. In practice, vegetation below these lines is completely clear-felled annually over a wide swath ranging from 30 m to over 50 m width. This creates serious negative effects due to habitat fragmentation, disturbance, degradation, spread of invasive species, fires etc. The presence of multiple lines passing through an area accentuates the 'internal fragmentation' effects (Goosem 2007, Laurance *et al.* 2009).

Wide swaths of vegetation are cut below high tension lines, even when the lines go high overhead across valleys. Besides fragmenting forest, these are often overrun by invasive alien weeds (Photo: T. R. Shankar Raman)

Electricity Act and Rules: The Electricity Act 2003 has provision for the Government to make rules specifically for 'the avoidance of public nuisance, environmental damage and unnecessary damage to the public and private property by such works' (Section 67-2-k). Rule 29(1) generally stipulates attention to safety for humans, animals, and property, and rules have been also framed for vertical clearance of lines above buildings and streets and other powerlines. **No rules have been framed so far related to environmental aspects for construction and maintenance by government authorities or licencees.** Such rules, which may be incorporated into Chapter VIII of the Electricity Rules of 1956 are urgently required.

4.4 Canals and lift irrigation

Impacts of canals and lift irrigation schemes are probably underestimated as few reports or studies carried out exist for freshwater systems in India. This is in addition to the effects of other linear disturbances in the proximity of aquatic ecosystems (described in section on roads), diversion canals, or water abstraction mechanisms. Many dams and reservoirs have interlinking tunnels running between them and transferring water resources. Such interlinking, in the case of existing links as well as many proposed links, probably affect the natural distribution of species and aquatic ecosystems. Noting the high diversity of aquatic fauna, including 230 endemic fishes (31%) of a total of 750 species found in India, Daniels (2004) notes:

> Interlinking of rivers will affect, besides other aquatic life, fish diversity throughout the project area and beyond, by changing the depth, flow and turbidity of water, creating barriers to those species that migrate upstream to spawn, encouraging the spread of alien invasive species such as tilapia (*Oreochromis mossambica*), permitting the invasion of the hardier species of carps from the northern rivers that tend to out-compete the endemic ones or even hybridize with them and carrying disease-causing parasites and pathogens through water.

Large scale water-abstraction projects such as the Dholpur Lift Irrigation Project, aimed at supplying water to Bharatpur (75 km away) and to 999 other villages, like many earlier projects are likely have severe repercussions to the river (and the life it supports) during the annual dry season, as water is diverted at large scale. The effects of such projects on river water availability and endangered species in the system are yet to be studied. Postel (1998) notes

Canals cleaving through forests. Top to bottom: Chilla power channel and Malayatur canal (Photos: A. J. T. Johnsingh), Canal from Bhoothathankettu (Thattekkad) to Kalady (Photo: James Zacharias)

"Large dams and river diversions have proven to be primary destroyers of aquatic habitat, contributing substantially to the destruction of fisheries, the extinction of species, and the overall loss of the ecosystem services on which the human economy depends. Their social and economic costs have also risen markedly over the past two decades." Diversion canals from irrigation dam reservoirs can turn ponds and lakes from being a source of water to a drainage sink, a process that has killed many traditional ponds (*kulams*) in southern India.

Canals, specifically can also impact natural river tracts negatively by:

- introduction of exotic plants, animals, toxins
- create avenues for riverine species and their young to disperse to unsuitable habitats
- extraction of ecologically unsustainable quantities of water

As a consequence of excessive water use or diversion, many species may be affected by the resultant low flow with impacts such as:

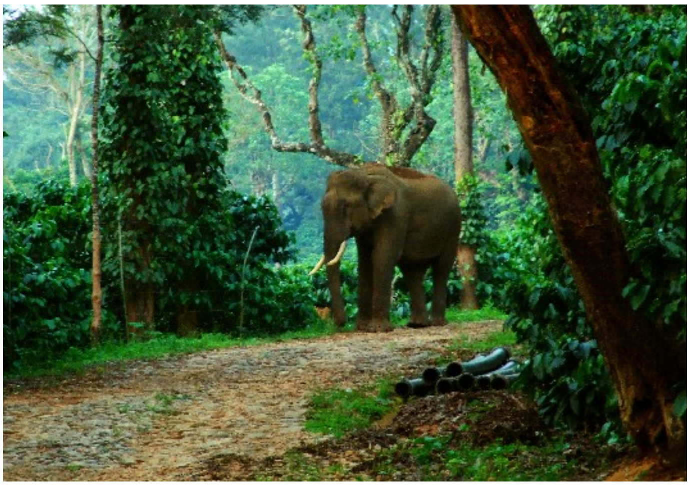
- Habitat fragmentation for aquatic species (species affected: dolphins, gharial, larger fish species)
- Creation of isolated pools vulnerable to netting, dynamiting (species affected: Fish, turtles, crocodilians)
- Fish stocks limted bty low water carrying capacity of deep pools (species affected: Fish and fish predators)
- Increased access to people for river crossing by foot and tractor, fishing, sand mining (species affected: all)
- Reduced number of inaccessible islands (species affected: Indian Skimmer, gharial, turtles, terns, pratincoles)

Steep-sided canals can also be a significant barrier to animal movement and cause of animal mortality. This is known from areas such as the Segur flume channel in Mudumalai Tiger Reserve or the 52 km long (with 4 tunnels) contour canal in the Anamalai Tiger Reserve in Tamil Nadu. In the former case, collaborative effort between the Tamil Nadu Forest Department and the TN Electricity Board was required to ensure that sections were not repaired or made more steep in order to facilitate crossings (A. Udhayan, pers. comm.). An expert committee noted that "*Obstructions to free movement of elephants occur in the shape of penstocks and trolley. Lines loading to the Singara and Moyar power houses and the flume channel connecting the two and patta lands*." (http://www.forests.tn.nic.in/graphics/Expert_Committee_Report.pdf).

4.5 Electric fencing and trenches

Thousands of kilometres of electric fencing (power fences) and trenches have been established across India in efforts ostensibly geared to reduce the incidence of human-wildlife conflict. The fences or trenches are usually meant to keep out species such as elephants, gaur, wild pig etc. from agricultural fields. While the cost of establishment is substantial (around INR 100,000 per km for trenches and INR 125,000 per km for power fences), these often do not have the desired impact due to faulty creation, poor design, or lack of maintenance (Fernando *et al.* 2007). The Elephant Task Force in its report has recommended that there is a need to evaluate past efforts in terms of costs, quality of application, and effectiveness and develop a best practices manual whose guidelines must be mandatory for erection of any barrier (Rangarajan *et al.* 2010). Taking cognisance of these pervasive problems, the report suggested a moratorium on trenches and on expensive electric fences established without community involvement in maintenance.

While such fences and trenches may or may not work for the target species depending on the above factors, they remain a major influence on the landscape in many other ways. They may act as barriers and causes for electrocution deaths of various non-target species (e.g., some ungulates, small mammals, reptiles). In landscapes such as tea and coffee plantations adjoining or within protected areas, extensive deployment of fences can accentuate habitat fragmentation. Cordoning- off large areas of estates, including water sources, although a common practice is inadvisable (Rangarajan *et* al. 2010). This may lead to increase in conflict by deflecting or concentrating animal movements in vulnerable, unprotected areas.



An Asian elephant at an electric fence along a road through plantations (Photo: Nisarg Prakash)

Extensive digging or vegetation slashing along trenches and fences are also forms of disturbance that lead to proliferation of invasive alien species and weeds.

4.6 Firelines

Very little research has directly addressed the effects (positive or negative) of firelines in forest areas, despite the fact that this is considered an important task and one that demands substantial annual labour and fund allocation in many protected areas in India. Firelines can occupy considerable stretches in Indian protected areas. For example, the 334 km^2 Wynaad Wildlife Sanctuary in Kerala, has about 400 km of fireline (excluding an equal length of roads, Moosvi and Mutch 2000). As these are also long linear intrusions, involving clearing of vegetation for anywhere between 10 m to 40 m width and burning of piled-up biomass in the early dry season, they can have several negative effects on adjoining vegetation as noted in the case of roads and powerlines.

In Bandipur Tiger Reserve, for example, there is a total length of 2000 km of firelines, requiring an annual cost of Rs 37,00,000 for maintenance plus another Rs 37,37,400 for fire watchers, supplies, and tower maintenance (more than 10% of the entire Park budget as per the 2010 – 2011 Annual Plan of Operations and sanction order available on the Project Tiger website, http://projecttiger.nic.in/sanction/S2010/Sanction_Bandipur_2010_11.pdf). Fires, nevertheless, affect anywhere up to 25% of the protected area iin bad years, with higher incidence and impacts in and around the tourism zone (Somashekar *et al.* 2009). In Mudumalai Wildlife Sanctuary, which has seen a 3-fold increase in fire frequency in recent times compared to the historical past (Kodandapani *et al.* 2004), a GIS-based study by Srivastava (2006) suggested that firelines may not be the most effective factor to consider in fire management strategies. This study showed the main factor that may help in reduction of fire incidence was the deployment of manned fire-watching camps, with riverine forest areas being the next best (natural) means.

Firelines are also sometimes cut through closed-canopy evergreen forests where the risk of fire is low or absent, and where alternative approaches would be preferable. Over 30 m wide firelines have been established cutting through the rare low-elevation wet evergreen dipterocarp forest in Chimmony Wildlife Sanctuary, for instance, leading to habitat fragmentation and weed invasion effects (T. R. S. Raman, pers. obs.).

4.7 Other structures

A number of other linear structures may exist in terrestrial and aquatic ecosystems ranging from rubble walls and embankments, dykes and groynes, to various kinds of fencing. There has been little research on the impacts of these, although common principles and effects may apply. Attention is drawn here to one such intrusion, seawalls, in the case of coastal and marine ecosystems for which some research input and policy implications are presently available, and a few other linear structures.

Seawalls: Seawalls, touted as a hard-engineering solution to problems of coastal erosion, are constructed with extensive deployment of stone and concrete structures. However, available evidence suggest various negative effects (Shareef 2007, Rodriguez *et al.* 2008) including:

- altered littoral and estuarine dynamics: resultant change in configuration of shoreline and estuarine banks
- obstruction of natural littoral drift of sand and sediment, leading to erosion on the one side and accretion on the other
- loss of beach space for indigenous fishing communities

Tetrapods along the coast in Lakshadweep (Kartik Shanker)

In contrast to suggestions, including from the Swaminathan Committee and recommendations in the Coastal Regulation Zone (CRZ), hard engineering options like seawalls are often the preferred first option over more natural and eco-friendly options. The seawall option is also the more expensive. The state of Kerala has already built seawalls along its coast—for 386 km of the total 560 km coastline of Kerala. The government has sought funding assistance to wall the remaining 92 km and demanded INR 2,16,000,000 from the centre (Rodriguez *et al.* 2008).

Bridges and pipelines: when established across rivers, these need to address environmental impact from the perspective of the entire spectrum of riparian taxa that may be affected including plants, fish, reptiles, mammals, birds in all categories of which are Threatened, Endangered, and Critically Endangered species (IUCN Red Data Book) and many species on Schedules I to III of the Wildlife Protection Act. The impacts may include (R. Whitaker, pers. comm.):

a) construction in an ecologically-sensitive or species-specific optimum habitat for basking, nesting, feeding, reproduction
b) pollution via erosion/siltation and chemicals during construction
c) alteration, erosion, accretion due to the placement, size and design of the construction
d) obstruction to natural movement/migration of riverine animals
e) permanent disturbance in the case of road/railway bridges

Atli river bridge and underpass on Panjim - Belgaum highway (Photo: A. J. T. Johnsingh)

Pipelines in Anamalai Tiger Reserve (Photo: A. J. T. Johnsingh)

Trek paths: Created ostensibly for facilitating patrolling and access for tourists, these are usually maintained at a width of around 4m (2 m path, 2m clearing for visibility). In most areas, including in sensitive habitats such as evergreen forest and shola-grasslands, the width can be brought down to say 1.5 m. Moreover, only regular paths need to be maintained. Trek paths should not be created in primary grasslands like Grass hills and Eravikulam National Park or alpine meadows as intensive use results in soil erosion, spread of invasives, and loss of aesthetic and biotic attributes. Options such as minimising width, avoiding creation of new paths, maintaining natural native vegetation on either side, ground cover and canopy overlap, establishment of board walks (using wood from plantations of alien tree species such as *Eucalyptus, Acacia,* or planted pines) should be considered.

Trek paths in grasslands can become severely eroded and conduits forspread of invasive alien species (Photo: T. R. Shankar Raman)

Chain-link fencing and rubble walls: Often established at high cost (e.g., around protected areas, shola patches), these can act as barriers for a wide-range of species. In the vicinity of villages, domestic dogs often chase wild prey toward fences for a kill. However, due to poor maintenance, some may also be ineffective, representing a wastage of funds.

Chain-link fencing and road through plantation and rainforests in Nelliampathy hills (Photo: NCF)

5 LINEAR INTRUSIONS: CURRENT POLICY AND LEGAL ENVIRONMENT AND LIMITATIONS

Presently, in terms of legal and policy environment, linear intrusions in natural areas primarily come under the purview of the following:

- Forest Conservation Act (related: Forest Advisory Committee)
- Wildlife Protection Act (related: National Board for Wildlife and its Standing Committee)
- Forest Rights Act (provisions related to road construction, implications not explored)
- Supreme Court (forest cases and orders, Central Empowered Committee)
- High Courts (specific cases and orders)
- Park management (occasionally in Management Plans, impacts often overlooked)

The Supreme Court in an important order dated 25 November 2005 in I. A. No. 1220 (interim report of CEC in I. A. No. 548) and I. A. No. 994 stipulated various activities that may be permitted in protected areas including the following related to linear intrusions:

- Maintenance of fair weather non-tar forest roads not exceeding 3 m width
- Clearing and burning of vegetation for firelines
- Weed removal
- Digging
- Laying underground drinking water pipelines up to 4 inches in diameter
- Laying of 11 kV power transmission lines
- Laying of telephone lines and optical fibre cables

It however, stipulated, that the order of 14 February 2002 would not be applicable to the above activities if they are undertaken as per management plan, are consistent with the Wildlife Protection Act and National Wildlife Action Plan, in conformity with the guidelines issued for PA management, and that the construction and related activities merge with the natural surroundings. However, no specific instructions or guidelines were provided on practice or on minimising environmental impact of these construction and maintenance of linear intrusions.

In practice, proposals for linear intrusions are sent for clearance to the Central Committees mentioned above and based on various considerations these are either rejected or permitted with specific conditions imposed on a case by case basis (for an example, see **Annexure 4**). Various other Supreme Court and High Court orders exist on forest cases that may have a bearing on linear intrusions policy and management; these are yet to be compiled.

Lacunae, Loopholes, and Limitations

The above system has several severe lacunae, limitations, and loopholes. This has resulted in the continuation of various negative impacts and undesirable practices in natural areas in the country. There has been widespread criticism of the system of the clearances for projects, inadequacy of environmental assessment, poor planning and illegal installation or expansion of linear intrusions in many cases. Some of the salient aspects are:

- There is no national policy yet on linear intrusions (the present effort is the first of its kind). Although a publication by the Wildlife Institute of India has addressed issues related to roads, in particular, and suggested environmental guidelines (Rajvanshi *et al.* 2001), this has been virtually ignored in most ongoing road projects.
- The strategy of forcing a *fait accompli* by starting work on sections of roads or linear intrusions outside Protected Areas and invoking already incurred expenditure as a reason for completion of project (the Concorde fallacy) needs to be addressed. Policy and legal provisions are required to prevent such situations and deal with existing situations. A current example, is the attempt by the National Highways Authority of India (NHAI) in forcing a *fait accompli* by commencing land acquisition proceedings for four-laning NH 13 outside Kudremukh National Park.

- There are cases of *ex post-facto* approvals that have been granted by the Ministry in the past, which has aggravated the matter. This system must be stopped and all serious cases must be re-opened and investigated for environmental impact under the proposed policy and in relation to issues raised here.
- There are cases of road construction, widening, black-topping or concrete-topping, or other linear intrusions established in protected areas without National Board for Wildlife approval. These need to be investigated and suitable action devised. No such violations have been prosecuted including, for example, a clear case of widening of NH 212 through Bandipur on which a complaint was lodged in 2008 by NBWL member, Wildlife First.
- Often, projects are steam-rollered and stipulations set are ignored or strongly resisted by project proponents or construction proceeds even without necessary permissions. An example is the current stand-off between the Forest Department and District Administration against the National Highway Authority regarding NH 38 that slices through the important Golai elephant corridor. The NHAI is pressurising to push the road through without the modifications recommended by the commitee set up by D. C., Tinsukia, in June 2009. Other examples include road through reserved forests of Kadamakal within the limits of the Pushpagiri Wildlife Sanctuary (2008), NH 212 through Bandipur Tiger Reserve, roads through Anamalai Tiger Reserve, to mention just a few examples.
- The metrics used in proposals seeking diversion for projects require to be changed and clarified. Besides the extent of land in hectares (which may appear insignificant), the distance through the Protected Area, length of the new edge, and the width of the intrusion must be insisted upon. Also, the assessment of impact needs to consider potential edge effects on the ecosystem in order to quantify the actual impacted area.
- Applications for maintenance or enhancement of existing linear intrusions should also include details of the legal status of the original intrusion (e.g., availability of legal and environmental clearance in case of road-widening projects).
- The present system of marking linear intrusions on topo sheets is insufficient for analysis of fragmentation or other impacts. This needs to be supported by high-resolution satellite imagery with elevation and site photographs as standard supporting evidence so that the Standing Committee of the National Board for Wildlife (NBWL) can obtain a better understanding of the impact.
- Inadequate justification is provided for the specific alignment chosen. Details of alternative alignments that do not pass through natural areas are neither considered nor provided for deliberation.
- Although black-topping is not permitted in roads through protected areas, as it was not specifically stipulated that this is meant to include surfacing by other means such as using concrete, some roads in protected areas have been constructed with cement/concrete.

A section of road concrete-topped through montane shola in Anamalai Tiger Reserve (Photo: NCF)

- No project should be cleared without a field assessment by members of the NBWL or Standing Committee of NBWL and site inspection report. Projects are sometimes executed without such assessment.
- It has been suggested that proper screening of proposals has not been effected as members of the Standing Committee of the NBWL are 'overwhelmed' by the proceedings wherein proposals are presented at the last minute, are provided little time for detailed assessment, and that there is a lack of an indepth understanding of legal issues involved. There have been allegations of attempts to hustle the members through proposals that have already been agreed upon by senior Government officials during Track II negotiations.
- In cases where prevention and realignment are deemed impossible, specific mitigation measures are not proposed as part of the project conception and design. These are usually imposed as conditions, which are rarely complied with by project authorities or independently verified.
- When permission is given with conditions (e.g., **Annexure 4**) it is not clear how some aspects will be verified or enforced such as: 'tree felling will be to the barest minimum', 'speed limit within the Sanctuary shall be restricted to 20 kmph', 'collection of firewood shall be prohibited'. Others conditions are also vague (and open to varied interpretation by project proponents and enforcers) such as: 'The agency should ensure that no damage to any flora or fauna is caused during the course of the execution of the work' or 'all the trees along the road shall be protected'.
- There is usually no system of subsequent field assessment or monitoring to ensure that conditions laid down are actually implemented. In case of new problems discovered, there should be scope for revision of implementation.
- There is no system of positive incentives for wildlife-friendly implementation or of punitive sanction in cases of damaging structures or poor implementation.

6 THE 'ROAD' AHEAD: PREVENTION, RESTORATION, REALIGNMENT, MITIGATION

Given the over-arching evidence for the range of deleterious impacts that linear intrusions have on natural areas, policy and rules for practice should ideally emphasise prevention and the precautionary principle. This is particularly because the effects on natural ecosystems such as forests and grasslands are long-lasting and virtually irrevocable. The past approach to deal with this, of levying compensation amount (Net Present Value estimation of lost forest) or compensatory afforestation efforts (mostly using few non-native species), fail to address the real loss of high quality, diverse, native vegetation and animal populations and communities. Efforts at mitigation should therefore really be the last resort and not serve as an excuse to push projects through.

It is therefore proposed that the policy on linear intrusions adopt the following **schema for evaluation of projects in order of priority:**

6.1 Prevention

The first option should be to prevent linear intrusions: the 'Primacy of Prevention' principle. Prevention of projects through Protected Areas or other designated critical habitats should be the foremost option. Until all issues raised by this background paper are comprehensively addressed, there should also be a moratorium on any new linear intrusions such as roads and powerlines in these areas.

- Prevention should have primacy over permission or sanction-with-mitigation, where alternatives including realignment have not been explored or considered for implementation.

New projects that disregard this should be prohibited and not treated as a site-specific project.

- Linear intrusions such as open canals and low powerlines should be banned in wildlife areas.
- Use of underground power cables along existing road alignments must be carefully considered, which may avoid opening up an intact area.
- Off-roading should be strictly banned in all Protected Areas and critical habitats, grasslands, meadow habitats, including open habitats (e.g., Kas plateau, montane grasslands of Western Ghats, thorn forest and semi-desert, and hot and cold desert areas)
- Complete ban on night traffic can be achieved in Tiger Reserve as there are existing provisions in the law for this (Section 38V of the Wildlife Protection Act, 1972).
- Projects that do not explicitly incorporate wildlife-friendly designs and required crossing structures should not be permitted in designated protected areas and critical habitats. These should be included in main budget of project at planning stage itself.
- Ban on certain kinds of activities (cutting of old trees such as banyan and other native species, planting of alien species, pollution and waste dumping, burning, cutting of firewood etc). As far as new roads are concerned, it must be made clear to not allow destruction of any native standing tree that is mature (say, more than 20 yrs old) and list protected plant and animal species, species useful for local and village communities as reserved, so that these cannot be destroyed in road-construction and widening operations.
- Prevention of labour residing in wildlife areas during construction and repair work. Transport may be provided to bring worforce to site everyday from outside camps.

6.2 Restoration

A nation-wide effort is required to identify linear intrusions that are disused, defunct, abandoned, or particularly harmful for conservation, and begin the process of ecological restoration. The restoration should follow international principles (Society for Ecological Restoration International Science and Policy Working Group 2004) and use local and diverse species native to the corresponding vegetation type and proper guidelines.

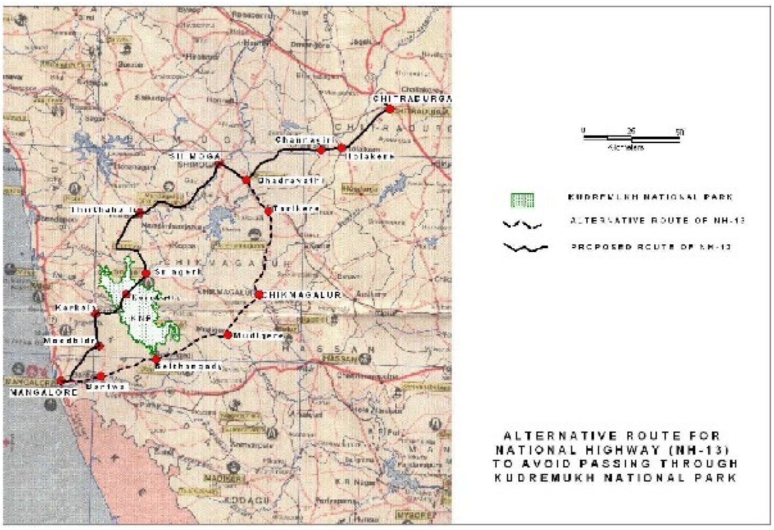
- Road removal and restoration is known to have many ecological benefits in wildlife protected areas (Switalski *et al.* 2004). Removal/ripping and restoration of defunct and disused roads, tramways, powerlines, and other disused structures should be undertaken on a nationwide basis. Currently, while no cases of targetted restoration are known, there are many abandoned roads, particularly unsurfaced roads (e.g., old logging coupe roads) that are gradually regenerating and recovering their wildlife and conservation values.
- During the planning and Environmental Impact Assessment (EIA) phase, mitigation efforts and improvements to the Protected Area or critical habitat need to be addressed in terms of the Compensatory Afforestation fund Management and Planning Authority (CAMPA) requirements.
- Ecological restoration and natural recovery of native tree species or other natural vegation by roadsides and along other kinds of linear clearings is an important aspect that needs to be encouraged
- Rehabilitation guidelines, including slope stablisation using native species, after roadworks and other linear infrastructure installations is an important consideration. Priority should be given to natural 'green' methods, rather than hard engineering 'cement and stone' approaches.

- There needs to be a reevaluation of the existing roads and railway lines in Protected Areas and realigning/closure of these detrimental structures after necessary studies. For example, in Gir National Park existing studies have noted that linear intrusions have lead to animal deaths, smuggling of timber, poaching and habitat disturbance, and recommended closure and realignments. This may be followed by natural regeneration and ecological restoration.
- All roadside, canal-bank plantations could have clear guidelines regarding proportion of native species to be planted with suggestions on which native species should be used in the different ecoregions / biogeographic zones of India.

6.3 Realignment

Realignment is the second choice to be considered after prevention. As deliberated at the National Board for Wildlife meeting chaired by the Honourable Prime Minister, projects passing through or impacting any Protected Area or identified critical habitat should perforce consider realignment to avoid these areas.

- Presently, few proposals contain a detailed analysis or exploration of alternative alignments and credible justification as to why the alignment proposed is the only option.
- A new mandate is needed that ensures that highways departments and authorities such as the National Highways Authority of India (NHAI) can and should try to deviate to save critical wildlife areas. For example, when a national highway of 3000 km is aligned, there should be flexibility to deviate by a few hundred kilometers around critical sites, as suggested in the case of NH7 and the Kanha – Pench corridor. If this policy change is effected, upgradations can follow alternate alignments that already exist outside PAs and critical habitats.
- The wildlife conservation community should be involved in planning alignments where least damage occurs for putting in linear infrastructures. Once this is done and such areas are identified, all linear formations such as roads, gas pipes, power lines should use the same alignment, wherever possible. At the moment each type of the linear intrusion is cutting its own swathe through areas like Western Ghats, quite independently of one another. The impact is magnified multiple times over that of a single alignment.
- The cumulative impact of the various prohects fragmenting a particular Protected Area or landscape must be carefully factored in while considering the alignment.



An example of alternate alignment of National Highway to prevent passing through Kudremukh National Park (Courtesy: Wildlife First)

6.4 Mitigation

Mitigation should be considered, subject to requisite approvals from the MoEF and NBWL, only for existing roads and other linear intrusions and new cases where the above options have been comprehensively considered and overruled with adequate justification. 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.

Given the serious consequences, such mitigatory measures are now increasingly incorporated in infrastructure projects worldwide, leading to many examples. A recent publication synthesises examples of mitigating roads and wildlife (Beckmann *et al.* 2010) and websites such as <http://www.wildlifeandroads.org/> also provide additional useful information. **An excellent model** of science-based planning and practice in various infrastructure projects is available from the Australian World Heritage Management Authority publications specifying the scientific basis, codes of practices, field guides, and detailed implementation guidelines for roads, powerlines, and water infrastructure in the region, including through tropical rainforests, available from: <http://www.wettropics.gov.au/media/med_cop.html> (and) <http://www.wettropics.gov.au/media/med_Library.html>. Other mitigation related to railways and transmission lines appears in the primary scientific literature (references cited earlier).

While some general principles of design are gradually emerging, it is noted that **case-specific considerations** emerge due to the variations of each particular landscape and the ecological requirements of the component plant and animal species. Therefore, **while implementing mitigation, technical inputs from ecologists and wildlife scientists may be required for each area in all stages of the project process.** In the Indian context, a few good recent examples of the joint engagement of conservation biologists, administrators, and managers in this process are from Rajaji National Park (railways: Singh *et al.* 2001), Assam (railways: Sarma *et al.* 2006), Nagarahole National Park (Mysore – Manathavadi road: Hosmat and Gubbi 2009), and Lumding Reserved Forest, Assam (NH 54E, Singh *et al.* 2010). Some possible general considerations for mitigation are provided here:

Identifying relevant mitigation

- Carry out environmental impact assessment by competent independent agencies or personnel familiar with the ecology, natural vegetation and wildlife of the region
- Addition of adjoining forest blocks to the same PA or other PAs/corridors in the landscape by the State Government must be made a pre-condition for grant of permission.
- Carry out field survey to identify specific locations requiring interventions

Reducing human presence and disturbance

- The construction of the linear intrusions should be in a manner (quick, with minimum disturbance) and with adequate design and technology to minimise the long-term impacts.
- Prefabricated and special methods to reduce the time taken in the erection/construction of the intrusions should be adopted.
- Work during the nights must totally be avoided as the movement of many species, especially large mammals and carnivores, is greater during the nights.
- The camping of people/workers must also be avoided. No domestic animals to be allowed. Waste must be carried away from site and not dumped on site. Fuelwood collection and use from the site should not be permitted. Such measures should also be implemented for roads through non-forest ecosystems, such as in the Himalaya, montane grasslands, alpine meadows, etc.

Reducing animal fatalities

An overpass above a busy highway used by forest birds in Brisbane (Jones & Bond 2010) many roadkills (Photo: A. J. T. Johnsingh)

- In case of road vehicles, **speed reduction is a key measure** that will definitely reduce the number of accidents and these are being implemeted in several cases (e.g., speed breakers on the Mysore – Ooty road passing through Mudumalai Tiger Reserve). This needs to be accompanied by measures to prevent unauthorised stopping within Protected Areas.
- Specify height of powerlines through new Rules (Central Electricity Authority) to prevent deaths of species such as elephants.
- For powerlines, removing earth wires (and modifying earthing methods), modifying line, pole and tower design, installing underground cables and conspicuous marking of lines, poles and towers are important measures (Bevanger 1994). Marking of powerline wires with reflectors or other items that will prevent bird collisions and deaths must be attempted and effectiveness monitored.
- For railway lines, existing recommendations such as those of Sarma *et al.* (2006) and Rangarajan *et al.* (2010) may be adopted and implemented. The speed of trains can however be reduced in crucial sections to minimise the accidents.

Wildlife crossing structures

A lion-tailed macaque crosses on an canopy bridge over a road through a rainforest fragment (Photo: Kalyan Varma)

Effectiveness of exsiting underpasses such as this one below Dudhsagar railway track should be evaluated (Photo: A. J. T. Johnsingh)

- **Natural crossings:** wherever possible natural crossings existing across linear intrusions should be retained or encouraged. For instance, overlapping tree canopy in closed canopy evergreen forests is an essential attribute that is a low-cost, efficient and durable solution for the movement of arboreal species. One can also encourage ground, shrubby, or tree growth at periodic, designated points (say, every 100 – 200 m) along linear intrusions to provide for habitat cover and facilitate animal crossings.
- **Underpasses:** well-designed tunnels, culverts, pipes, and other structures can function as underpasses below roads and bridges, for a wide-range of terrestrial and aquatic species, especially frogs, turtles, fish etc. It is important to also have underpasses below penstocks in wildlife areas. Underpasses can also be deployed below railway lines (e.g., as has been suggested in the Raiwala – Haridwar section).
- **Overpasses** and flyways: structures that go above the linear intrusion (besides natural ones such as tree canopy cover) can be considered. These tend to be expensive and

may be applicable in limited areas. (For instance, Jones and Bond 2010 report on the effectiveness of such a vegetated overpass across a busy highway in Brisbane used by many bird species that rarely cross over the open road). Construction of overpasses and overhanging vegetation at periodic intervals along penstock and other pipelines should also be mandatory.

- **Canals:** As far as possible, canals should be covered and made to run underground through pipes to avoid disrupting the habitat of wildlife. Else, canals could be aligned to act as the demarcation line of the PA wherever feasible. Canals should be shallow to allow wildlife to wade through. The side slope of the canal should be gentle to allow wildlife to climb up. There should be a limit on the water speed of the water being discharged. Even with the existing canals, provisions like over and underpasses to help animals cross the canal more frequently needs to be constructed. To help animals that fall into the canals, steel nets at intervals with less steep banks needs to be constructed to reduce accidental deaths. Grill mesh across canals and bridges may also allow crossing of some wildlife species.

Management options

- Along roads through Protected Areas and critical habitat promote public transport, and work to reduce influx of private vehicles, including tourist vehicles.
- Strong regulations controlling timing and traffic volumes need to be built in from the outset for all roads through Protected Areas and critical habitats. Although convoy systems have been suggested for movement of vehicles, these have tended to fare poorly both in wildlife mitigation as well as in locations like the Andaman Trunk Road, where they have not helped prevent environmental and social problems.
- High differential toll during late evening and early morning hours (along with night closure) may be added as a disincentive for use of roads passing through critical areas.
- For trains, automatic speed detection stations should be installed at important areas known to be crossing points of species such as elephants. Regular monitoring of the data downloaded would help monitor and prevent overspeeding by train drivers.
- For seawalls, policy and management recommendations related to seawalls proposed by Rodriguez *et al.* (2008) may be adopted.
- Management strategies to detect and prevent encroachments or construction of new structures and homesteads along linear intrusions need to be adopted. In the case of existing structures such as households and lands, possibilities of using CAMPA and other funds to purchase these should be explored as has been suggested for areas such as the Kotavasal – Thenmala corridor along the Shencottah pass, or along the Golai corridor in Assam (just to give a couple of examples).
- Minimise width of vegetation clearings along roads and powerlines, firelines and other linear intrusions. Explore options to restore connectivity by natural means.
- Speed restrictions and other guidelines that spell out rules and avoidance of disturbance to wildlife and habitats along roads in natural areas must be prominently conveyed through well-designed signboards at entry and exit points and all other relevant locations.

7 CONCLUDING RECOMMENDATIONS

Consultations and drafting of policy

Based on the present background paper, the NBWL could work towards a draft National Policy on Linear Intrusions in Natural Areas. Besides the goals and mission statement proposed here, the policy can adopt the broad principles and precautionary approach ranging from prevention as the primary choice, through realignment, and mitigation. Where possible or imperative, ecological restoration should also be carried out.

A sub-committee of NBWL with invited subject experts may be constituted, and hold stakeholder consultations around India to identify and frame the policy and appropriate guidelines and rules after visiting sites and interacting with Forest Department officers,NGOs and local communities.

Rules for linear intrusions through Protected Areas and Critical Habitats

A key suggestion is that all roads and linear intrusions passing through any designated Protected Area and critical habitats (defined as Wildlife Sanctuary, National Park, Reserved Forests, Tiger and Elephant Reserves, and a 10-km radius around their boundaries, as well as designated community and conservation reserves, wetlands, and grasslands of conservation value) should have special and specific rules that supersedes and supplements existing rules for roads, powerlines, railways, and other linear intrusions, in all other areas. Chief among these are:

ROADS:	Rules involving Ministry of Shipping, Road Transport, & Highways Specifications for road and bridge works (Indian Roads Congress) Upgradation, 4-laning, 6-laning of highways etc
POWERLINES:	Rules under the Electricity Act Location of overhead / underground powerlines Height and design criteria and specifications regarding vegetation clearing
RAILWAYS:	Rules for railway sections passing through Protected Areas and critical habitats Wildlife crossings Speed limits in designated sections Waste disposal from trains

Guidelines for field assessment (and checklist)

There is a need for a comprehensive set of guidelines and a handbook for use in assessments of linear intrusions. This could include:

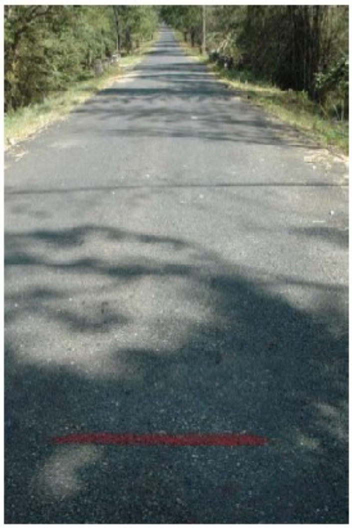
- A full set of relevant Supreme Court orders and MoEF order on linear intrusions collated for use. Proposals must be deliberated upon to see whether and how each order applies.
- A detailed, well-designed checklist for use in field assessment prior to sanction of any project and for subsequent monitoring

Tolls, sanctions, and incentives

- Punishments/sanctions against managers and black-listing of contractors for failures
- All roads, railway lines and other linear structures that go through a protected area could charge a small contribution from the user/traveller (so that it either discourages the use or helps the PA raise funds). This could be called a Conservation Contribution Charge (not tax or toll). For pipelines and powerlines, it could be taken from the developer (including other Government Departments) for specific period with scope for revision.
- System of incentives for innovations and management measures to reduce road-related animal mortality, garbage and plastic regulation, deployment of speed breakers and provisions for wildlife crossings

Legal

- Amending the Electricty Act and Rules to include guidelines for powerlines in protected areas to prevent electrocution deaths of wildlife, and reduce habitat fragmentation and degradation threats.

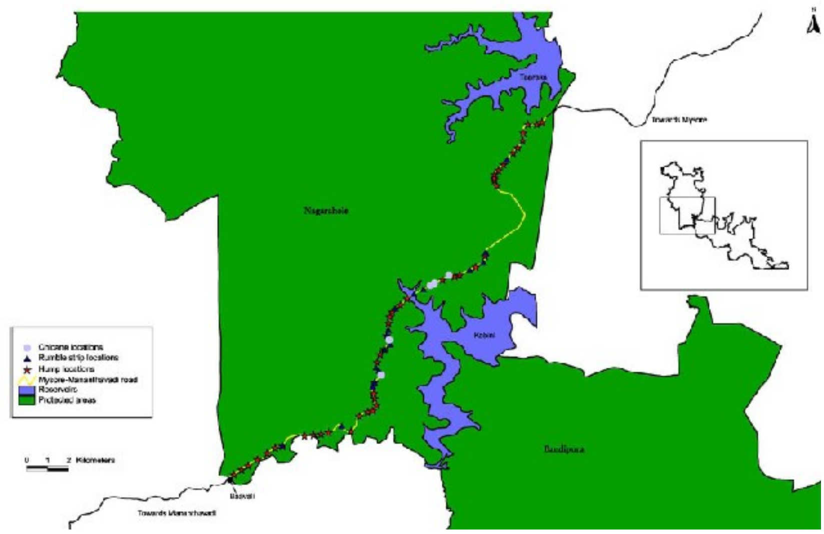


- Establishing rules for implementation of appropriate mitigation such as speed-breakers, width and wildlife crossings including maintenance of natural vegetation on either side and overhead canopy cover in closed canopy forests for roads, in particular.
- Identifying and enacting suitable provisions under other Acts related to Railways and Water diversion stipulating criteria for establishment of these other kinds of linear intrusions.
- A new system where draft affidavits of the Ministry must be placed/circulated to the non-official members of the NBWL before they are filed before the Supreme Court or other courts in various cases of linear intrusions.
- A system of public consultation may be instituted for large linear infrastructure projects (e.g., recent Karnataka High Court decision related to infrastructure projects in urban areas in WP 13241/2009). Provision may be made for constitution of local committees for each natural area with scientists, civil society and community representatives for overseeing linear intrusion establishment, maintenance, and management.
- Establish rules under the Forest Rights Act (FRA) that provides for permission at the level of the DFO for activities like electric and communication lines, drinking water supply and water pipe lines, minor irrigation canals and roads (Sec.3(2) (e), (g), (i) and (l)). Under the FRA, it is preferable to use alternatives like decentralised renewable energy sources (instead of powerlines from the main grid), developing local health traditions and clinics (rather than emphasise road connectivity to access distant health centres). For forest-dwelling communities, especially in remote areas, these will be more useful and will be under their own control and management to a greater extent, besides being less ecologically damaging.
- Cases need to be brought to NBWL attention through consultation with Forest Departments, civil society groups, and others. If deemed necessary, for all such intrusions the NBWL must be empowered to order the ecological restoration of those sections or modifications established illegally (e.g., removal of linear intrusion, road-ripping and regeneration of native vegetation). In cases of determined violations, all further proposals from the respective State seeking permissions for other projects should be held in abeyance till ecological restoration is complete. To monitor such violations, the NBWL must constitute committees under Section 5B (3) of the Wildlife Protection Act and to "carry out or causing to be carried out impact assessment …" as provided for under Section 5C (2)(c).

Framing guidelines documents

In view of the fact that negative impacts of linear Intrusions have been scientifically established, projects such as roads, highways, pipelines, power transmission lines must be diverted or re-aligned to avoid Protected Areass, Reserved Forests, wetlands and such other ecologically sensitive areas and the **'primacy of prevention' principle must be strictly adhered to**. Such projects in other less sensitive areas outside these protected areas may be considered only if the user agency agrees to follow the guidelines and implement best practices.

Around the world, case studies and examples are emerging of better practices related to linear intrusions (e.g., Beckmann *et al.* 2010, Goosem *et al.* 2010a,b, Singh *et al.* 2010, Codes of Practice related to power and water infrastructure of the Wet Tropics Management Authority, Australia). A brief set of guidelines have also been issued under the Governance for Sustaining Himalayan Ecosystems (G-SHE) program (Anonymous 2009, **Annexure 3**). Therefore it is reiterated



An example of targetted planning and implementation of interventions using inputs from wildlife research and management. Map of locations where interventions are required (left) and marking on the road for deployment of speed hump (right; From Hosmat and Gubbi 2009)

that while it is sometimes useful to have guidelines for certain aspects of linear infrastructure projects, it is worth noting that the preparation and availability of these guidelines:

1. should not be misued for approval of projects that agree to adhere to guidelines, when such projects should not be allowed in the first place, under the 'primacy of prevention' principle or for other reasons related to anticipated negative impacts on wildlife areas
2. should not be applied in a blanket fashion to diverse ecosystems and locations without considering that site-specific measures may be necessary and may require separate technical advice or attention of experts familiar with the natural ecosystem and native species (e.g., Hosmat and Gubbi 2009, Singh *et al.* 2010).

Keeping the above factors in mind, the following guideline documents may be developed in future under the auspices of the NBWL:

- Recommendations for wildlife-crossing structures
- Design and deployment of power fences and elephant-proof trenches
- Vegetation maintenance and restoration guidelines along roads and linear intrusions
- Prevention of erosion and sedimentation and mitigation of impacts on aquatic habitats
- Ecological restoration of defunct and unwanted roads and other linear intrusions
- Environmental impact assessment of roads and estimation of total economic value

8 ACKNOWLEDGEMENTS

A number of wildlife scientists, managers, students, and persons experienced with infrastructure projects contributed photographs, references, and suggestions. While the responsibility of the statements made here rests with the author, the contribution of the following list of people, although incomplete, in the preparation of this document is gratefully acknowledged: Robin Abraham, M. O. Anand, Rohan Arthur, Ramana Athreya, Vidya Athreya, Praveen Bhargav, Yash Veer Bhatnagar, Ravi Chellam, Manish Chandi, R. J. Ranjit Daniels, Shekar Dattatri, T. Ganesh, Sanjay Gubbi, K. V. Gururaja, C. R. Jayaprakash, P. Jeganathan, A. J. T. Johnsingh, K. Ullas Karanth, Kashmira Kakati, Ashish Kothari, M. Ananda Kumar, M. D. Madhusudan, Biswajit Mohanty, Divya Mudappa, Nisarg Prakash, Suhel Quader, A. R. Rahmani, Mahesh Sankaran, Pankaj Sekhsaria, Kartik Shanker, Hari Sridhar, Shashank Srinivasan, K. S. Gopi Sundar, H. S. Sushma, Pranav Trivedi, A. Udhayan, Kalyan Varma, Nimesh Ved, Romulus Whitaker, A. Christy Williams, James Zacharias. A special thanks to Miriam Goosem, Steve Goosem, S. Gubbi, K. Kakati, and A. C. Williams for contributing detailed inputs based on field research and models for development of policy and practice based on science.

9 REFERENCES

Anonymous (2009) *Governance for Sustaining Himalayan Ecosystem (G-SHE): Guidelines and Best Practices.* Ministry of Environment and Forests and the G. B. Pant Institute of Himalayan Environment and Development, India. <http://gbpihed.nic.in/G-SHE_Book.pdf>

Bacon, T. (1998) Erosion on unsealed roads in Queensland's Wet Tropics World Heritage Area. M. App. Sci thesis, Tropical Environment Studies and Geography, James Cook University, Cairns.

Baskaran, N. and D. Boominathan (2010) Road kill of animals by highway traffic in the tropical forests of Mudumalai Tiger Reserve, southern India. *Journal of Threatened Taxa* 2(3): 753-759.

Bautista, L. M., García, J. T., Calmaestra, R. G., Palacín, C., Martín, C. A., Morales, M. B., Bonal, R. and Viñuela, J. (2004) Effect of Weekend Road Traffic on the Use of Space by Raptors. *Conservation Biology* 18: 726–732

Beckmann, J. P., Clevenger, A. P. Huijser, M. P., Hilty, J. A. (Eds) (2010) *Safe passages–highways, wildlife, and habitat connectivity*. Island Press, Washington, D. C.

Behera, S., & Borah, J. (2010) Mammal mortality due to road vehicles in Nagarjunasagar-Srisailam Tiger Reserve, Andhra Pradesh, India. *Mammalia* 74: 427–43.

Benítez-López, A., Alkemade, R., and Verweij, P. A. (2010) The impacts of roads and other infrastructure on mammal and bird populations: a meta-analysis. *Biological Conservation* 143: 1307-1316.

Bera, S. K., Basumatary, S. K., Agarwal, A. and Ahmed, M. (2006) Conversion of forest land in Garo Hills, Meghalaya for construction of roads: a threat to the environment and biodiversity. *Current Science* 91: 281–284.

Bevanger, K. (1994) Bird interactions with utility structures: collision and electrocution, causes and mitigating measures. *Ibis* 136: 412–425.

Blake, S., Deem, S. L., Strindberg, S., Maisels, F., Momont, L. Isia, I., Douglas-Hamilton, I.,Karesh, W. B., and Kock, M. D. (2008) Roadless wilderness area determines forest elephant movements in the Congo Basin. *PLoS ONE* 3(10): e3546.

Brown, K. J. (1994) River-bed sedimentation caused by off-road vehicles at River Fords in the Victorian Highlands, Australia. *Water Research Bulletin* 30: 239-250.

Chhangani, A. K. (2004a) Killing of Hanuman Langur (*Semnopithecus entellus*) in Road Accidents in Kumbhalgarh Wildlife Sanctuary, Rajasthan, India. *Primate Report* 69:49-57.

Chhangani, A. K. (2004b) Frequency of avian road-kills in Kumbalgarh Wildlife Sanctuary, Rajasthan, India. *Forktail* 20: 110-111.

Cotterell, E. 1998. *Fish passage in streams: Fisheries guidelines for design of stream crossings.* Queensland Department of Primary Industries, Brisbane.

Daniels, R. J. R. 2004. Interlinking of rivers: ecologists wake up! *Current Science 87*: 1030-1031.

Das, A., Ahmed, M. F., Lahkar, B. P., and Sharma, P. (2007). A prelimnary report on reptilian mortality on road due to vehicular movements near Kaziranga National Park, Assam, India. *Zoos' Print Journal* 22(7):2742-2744

Descroix, L., Viramontes, D., Vauclin, M., Barrios, J. L. G., and Esteves, M. (2001) Influence of soil surface features and vegetation on runoff and erosion in the Western Sierra Madre (Durango, Northwest Mexico). *Catena* 43: 115-135.

Eaglin, G.S. and Hubert, W.A. (1993) Effects of logging and roads on substrate and trout in streams of

the Medicine Bow National Forest, Wyoming. *North American Journal of Fisheries Management* 13: 844 846.
Eigenbroda, F. Hecnarb, S. J., and Fahrig , L. (2008) The relative effects of road traffic and forest cover on anuran populations. *Biological Conservation* 141: 35–46.
Fahrig, L., and Rytwinski, T. (2009) Effects of roads on animal abundance: an empirical review and synthesis. *Ecology and Society* 14(1): 21.
Fernando, P., Kumar, M. A., Williams, A. C., Wickramanayake, E., Aziz, T. and Singh, S. M. (2008) *Review of human - elephant conflict mitigation measures practised in South Asia.* AREAS technical support document submitted to World Bank. World Bank—WWF Alliance for Forest Conservation and Sustainable Use, AREAS, Centre for Conservation and Research, Nature Conservation Foundation.
Forman, R. T. T., Sperling, D., Bissonette, J., Clevenger, A., Cutshall, C., Dale, V., Fahrig, L., France, R., Goldman, C., Heanue, K., Jones, J., Swanson, F., Turrentine, T., and Winter, T. (2003) *Road Ecology: Science and Solutions.* Island Press, Washington, D. C.
Gelbard, J. L. and Belnap, J. (2003) Roads as conduits for exotic plant invasions in a semiarid landscape. *Conservation Biology* 17: 420–432.
Gibbs, J. P. and Shriver, W. G. (2005) Can road mortality limit populations of pool-breeding amphibians? *Wetlands Ecology and Management* 13: 281–289 .
Goosem, M. (1997) Internal fragmentation: The effects of roads, highways and powerline clearings on movements and mortality of rainforest vertebrates. In: Laurance, W.F. and Bierregaard Jr, R.O. (eds.) *Tropical Forest Remnants*. University of Chicago Press., Chicago, Illinois.
Goosem, M. (2001) Effects of tropical rainforest roads on small mammals: Inhibition of crossing movements. *Wildlife Research* 28: 351-364.
Goosem, M. (2007) Fragmentation impacts caused by roads through rainforests. *Current Science* 93: 1587-1595.
Goosem, M. and Turton, S. (1999) I*mpacts of roads and powerlines on the Wet Tropics World Heritage Area: Stage I*. Cooperative Research Centre for Tropical Rainforest Ecology and Management (Rainforest CRC), Cairns.
Goosem, M. and Turton, S. (2000) *Impacts of roads and powerlines on the Wet Tropics World Heritage Area. Stage II Report.* Wet Tropics Management Authority and Cooperative Research Centre for Rainforest Ecology and Management, Cairns, 210 pp.
Goosem, M. and Turton, S. (2002) *Weed incursions along roads and powerlines in the Wet Tropics of Queensland World Heritage Area: Potential of remote sensing as an indicator of weed infestations.* Report to the Wet Tropics Management Authority published by the Cooperative Research Centre for Tropical Rainforest Ecology and Management, Cairns.
Goosem, M., Harding, E. K., Chester, G., Tucker, N. and Harriss, C. (2010) *Roads in Rainforest: Science Behind the Guidelines.* Guidelines prepared for the Queensland Department of Transport and Main Roads and the Australian Government's Marine and Tropical Sciences Research Facility. Reef and Rainforest Research Centre Limited, Cairns (76pp.).
Gubbi, S. (2010) Are conservation funds degrading wildlife habitats? *Economic and Political Weekly* 45(26&27): 22-25.
Haigh, M. J., Rawat, J. S., Rawat, M. S., Bartarya, S. K., and Rai, S. P. (1995) Interactions between forest and landslide activity along new highways in the Kumaun Himalaya. *Forest Ecology and Management* 78: 173-189.
Harris, J. (1995) The use of fish in ecological assessments. *Australian Journal of Ecology* 20: 65-80.
Heimsath, A. M. 2000. Himalayan erosion. *Seminar* http://www.india-seminar.com/2000/486/486%20heimsath.htm
Hels, T. and Buchwald E. 2001. The effect of road kills on amphibian populations. In: *Proceedings of the 2001 International Conference on Ecology and Transportation.* Irwin C. L., Garrett P., and

McDermott K. P. (Eds) Center for Transportation and the Environment, North Carolina State University, Raleigh, NC: pp. 25-42.

Hockings, K. J., Anderson, J. R., and Matsuzawa, T. (2006) Road crossing in chimpanzees: A risky business. *Current Biology* 16: R668-670.

Holderegger, R., and Di Giulio, M. (2010) The genetic effects of roads: A review of empirical evidence. *Basic and Applied Ecology* 11: 522-531.

Hosmat, B. J. and Gubbi, S. (2009) I*nterim report for implementation of speed calming measures on the Mysore-Mananthavadi road in Nagarahole National Park.* Submitted to Principal Secretary (Forests, Ecology and Environment), and Chairperson, Mysore-Mananthavadi Road Monitoring Committee, Government of Karnataka, Bangalore.

Jones, D. N., and Bond, A. R. F. (2010) Road barrier effect on small birds removed by vegetated overpass in South East Queensland. *Ecological Management and Restoration* 11: 65-67.

Jones, J. A., Swanson, F. J., Wemple, B. C. and Snyder, K. U. (2000) Effect of roads on hydrology, geomorphology and disturbance patches in stream networks. *Conservation Biology* 14: 76-85.

Kodandapani, N., Cochrane, M. A., and Sukumar, R. (2004) Conservation threat of Increasing fire frequencies in the Western Ghats, India. *Conservation Biology* 18: 1553-1561.

Kumara, H. N., Sharma, A. K., Kumar, M. A., and Singh, M. (2000) Roadkills of wild fauna in Indira Gandhi wildlife sanctuary, Western Ghats, India: implications for management. *Biosphere Conservation* 3: 41-47.

Laurance, W. F., Delamonica, P., Laurance, S. G., Vasconcelos, H. L. and Lovejoy, T. E. (2000) Rainforest fragmentation kills big trees. *Nature* 404: 836.

Laurance, S. G., Stouffer, P. C. and Laurance, W. F. (2004) Effects of road clearings on movement patterns of understory rainforest birds in Central Amazonia. *Conservation Biology* 18: 1099–1109.

Laurance, W. F., Croes, B. M. , Tchignoumba, L., Lahm, S. A., Alonso, A., Lee, M. E., Campbell, P., and Ondzeano, C.(2006). Impacts of roads and hunting on Central African Rainforest mammals. *Conservation Biology* 20: 1251–1261.

Laurance, W. F., Croes, B. M., Guissouegou, N., Buij, R., Dethier, M., and Alonso, A. (2008) Impacts of roads, hunting, and habitat alteration on nocturnal mammals in African rainforests. *Conservation Biology* 22: 721-732.

Laurance, W.F., Goosem, M. and Laurance, S.G. (2009) Impacts of roads and linear clearings on tropical forests. *Trends in Ecology and Evolution* 24: 659-669.

Leopold, A. 1949. A sand county almanac: and sketches here and there. Oxford University Press, USA.

Luce, C.H. (2002) Hydrological processes and pathways affected by forest roads: What do we still need to learn? *Journal of Hydrological Processes* 16: 2901-2904.

Menon, V., Easa, P. S. and Johnsingh, A. J. T. (Eds) (2003) *Securing Chilla – Motichur Corridor - A Status Report*. Wildlife Trust of India, New Delhi.

Milberg, P. and Lamont, B.B. (1995) Fire enhances weed invasion of roadside vegetation in Southwestern Australia. *Biological Conservation* 73: 45-49.

Moosvi, A. H. and Mutch, R. W. (2000) Global voices, village choices: fire management strategies for people and wildlife in Wyanad, Kerala, India. In: Watson, Alan E.; Aplet, Greg H.; Hendee, John C. (Comps.) *Personal, societal, and ecological values of wilderness: Sixth World Wilderness Congress Proceedings on research, management, and allocation. Volume II.* October 24–29 1998, Bangalore, India. Proc. RMRS-P-14. U. S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Ogden, UT.

Negishi, J. N., Sidle, R. C., Noguchi, S., Nik, A. R., and Stanforth, R. (2006) Ecological roles of roadside fern (*Dicranopteris curranii*) on logging road recovery in Peninsular Malaysia: preliminary results. *Forest Ecology and Management* 224: 176-186.

Newell, G.R. (1999a) Responses of Lumholtz's tree-kangaroo (*Dendrolagus lumholtzi*) to loss of

habitat within a tropical rainforest fragment. *Biological Conservation* 91: 181-189.
Parasharya, B. M. and Tere, A. (2007). An observation of common Indian monitor lizard (*Varanus bengalensis* Schreiber) mortality on Anand-Ahmedabad highway, Gujarat, India. *Zoos' Print Journal* 22(10):2872.
Pohlman, C.l. (2006) *Internal fragmentation in the rainforest: Edge effects of highways, powerlines and watercourses on tropical rainforest understorey microclimate, vegetation structure and composition, physical disturbance and seedling regeneration.* PhD thesis, James Cook University, Cairns.
Postel, S. L. (1998) Water for food production: Will there be enough in 2015? *BioScience* 48: 629–637
Prasad, A. E. (2009) Tree community change in a tropical dry forest: the role of roads and exotic plant invasion. *Environmental Conservation* 36: 201-207.
Radhakrishna, S. and Singh, M. (2002) Conserving the Slender Loris (*Loris lydekkerianus lydekkerianus*). Pages 227-231, National Seminar on Conservation of Eastern Ghats, March 24-26, 2002, held at Tirupati, Andhra Pradesh.
Rajvanshi, A., Mathur, V. B., Teleki, G. C., Mukherjee, S. K. (2001) *Roads, sensitive habitats and wildlife: environmental guidelines for India and South Asia.* Wildlife Institute of India, Dehradun.
Raman, T. R. S. (2009) Death on the highway. *The Hindu Survey of the Environment* 2009: 113 – 118
Rangarajan, M., Desai, A., Sukumar, R., Easa, P. S., Menon, V., Vincent, S., Ganguly, S., Talukdar, B. K., Singh, B., Mudappa, D., Chowdhury, S. Prasad, A. N. 2010. *Gajah: Securing the future for elephants in India.* The Report of the Elephant Task Force, Ministry of Environment and Forests, Government of India, New Delhi.
Rao, R. S. P. and Girish, M. K. S. (2007) Road kills: Assessing insect casualties using indicator taxon. *Current Science* 92: 832-837.
Rodriguez, A., G. Crema, and M. Delibes. (1996) Use of non-wildlife passages across a high speed railway by terrestrial vertebrates. *Journal of Applied Ecology* 33:1527-1540.
Rodriguez, S., Subramanian, D., Sridhar, A., Menon, M. and Shanker, K. (2008) *Policy Brief: Seawalls.* UNDP/UNTRS, Chennai and ATREE, Bangalore, India.
Rytwinski, T., & Fahrig, L. (*in press*). Reproductive rate and body size predict road impacts on mammal abundance *Ecological Applications* http://dx.doi.org/10.1890/10-0968.1
Sarma, U. K., Easa, P. S., and Menon, V. 2006. Deadly tracks: a scientific approach to understanding and mitigating elephant mortality due to train hits in Assam. Wildlife Trust of India, New Delhi.
Seiler, A. (2003) *The toll of the automobile: wildlife and roads in Sweden*. PhD thesis. Swedish University of Agricultural Sciences, Uppsala. Link accessed 11 Feb 2009.
Sekhsaria, P. and Pandya, V. (Eds) (2010) *The Jarawa Tribal Reserve Dossier: Cultural and biological diversities in the Andaman Islands.* UNESCO, Paris.
Society for Ecological Restoration International Science and Policy Working Group (2004) *The SER International Primer on Ecological Restoration.* Society for Ecological Restoration International, Tucson.
Seshadri K. S., Amit, Y. and Gururaja K. V. (2009). Roadkills of amphibians in different land use areas from Sharavathi river basin, central Western Ghats, India. *Journal of Threatened Taxa* 1(11): 549-552.
Shareef, N.M. (2007) Disappearing beaches of Kerala. *Current Science* 92: 157-158.
Sharma, N. (2009). Wildlife under wheels. http://conservation.in/blog/wildlife-under-wheels/
Sidle, R. C., Ziegler, A. D., Negishi, J. N., Nik, A. R., Siew, R., and Turkelboom, F. (2006) Erosion processes in steep terrain—Truths, myths, and uncertainties related to forest management in Southeast Asia. *Forest Ecology and Management* 224: 199-225.
Singh, A. K., Kumar, A., Menon, V., and Mookerjee, A. 2001. *Elephant mortality in train accidents—A scientific approach to understanding and mitigating this problem in Rajaji National Park*.

Wildlife Trust of India, New Delhi.
Singh A. P., Singh A. K., Mishra D. K., Bora P., Sharma A., 2010. *Ensuring safe access to wildlife in Lumding Reserve Forest, Assam, India: Mitigating the impacts of up-gradation of Doboka-Silchar National Highway (NH54E).* WWF-India, New Delhi.
Somashekar, R. K., Ravikumar, P., Mohan Kumar, C. N., Prakash, K. L. and Nagaraja, B. C. (2009) Burnt area mapping of Bandipur National Park, India using IRC 1C/1D LISS III Data. *Journal of the Indian Society for Remote Sensing* 37: 37-50.
Spellerberg, I. F. 2002. *Ecological effects of roads.* Science Publishers, Enfield, New Hampshire.
Srivastava, S. K. (2006) *A Geo-Information System approach for strengthening conservation measures in protected area with reference to forest fire.* MSc thesis, International Institute for Geoinformation Science and Earth Observation, Enschede, The Netherlands.
Sundar, K. S. G. (2004). Mortality of herpetofauna, birds and mammals due to vehicular traffic in Etawah district, Uttar Pradesh, India. *Journal of the Bombay Natural History Society* 101: 392-398.
Switalski, T. A., Bissonette, J. A., DeLuca, T. H., Luce, C. H. and Madej, M. A. 2004. Benefits and impacts of road removal. *Frontiers in Ecology and the Environment* 2: 21-28.
Trombulak, S.C. and Frissell, C.A. (2000) Review of ecological effects of roads on terrestial and aquatic communities. *Conservation Biology* 14: 18-30.
Yanes, M., Velasco, J.M. and Suarez, F. (1995) Permeability of roads and railways to vertebrates: the importance of culverts. *Biological Conservation* 71:217-222.
Vijayakumar, S. P., Vasudevan, K. and Ishwar, N. M. (2001) Herpetofaunal mortality on roads in the Anamalai Hills, southern Western Ghats. *Hamadryad* 26: 265–272.
Ziegler, A. D., Negishi, J., Sidle, R. C., Preechapanya, P., Sutherland, R. A., Giambelluca, T. W., Jaiaree, S. (2006) Reduction of stream sediment concentration by a riparian buffer: filtering of road runoff in disturbed headwater basins of Montane Mainland Southeast Asia. *Journal of Environmental Quality* 35: 151-162.

10 ANNEXURES

Annexure 1. Some recent studies on roadkill mortality of fauna from India.

Annexure 2. Roads construction in montane forests (observations of R. Athreya in Eastern Himalaya)

Annexure 3. Guidelines for ecologically safer roads provided in the report *Governance for Sustaining Himalayan Ecosystem (G-SHE): Guidelines and Best Practices* by the Ministry of Environment and Forests and the G. B. Pant Institute of Himalayan Environment and Development.

Annexure 4. Example of conditions prescribed at time of approval of a road project (for repair of black-topped road and construction of bridge in Orcha Wildlife Sanctuary, Madhya Pradesh, which was to involve felling of 115 trees). From the Minutes of the 20th Meeting of the Standing Committee of the National Board for Wildlife held on 13 October 2010.

Annexure 1. Some recent studies on roadkill mortality of fauna from India.

Source	Study period	Location	Target taxa	Important findings and	Recommendations
Baskaran & Boominathan (2010)	Dec 1998 - Mar 1999	Mudumalai WLS	Vertebrates	Amphibians most affected, followed by reptiles and mammals	Flyovers at animal crossing points, speed limiters, diversion of proposed state highway
Chhangani (2004a)	Dec 1995 - Dec 2000	Kumbalgarh WLS	Hanuman Langur	Male langurs die more often, might lead to female-biased troops	Speed breakers, limiters, signboards, prohibit feeding
Chhangani (2004b)	Dec 1995 - Aug 1999	Kumbalgarh WLS	Birds	Frequently killed were abundant species such as Eurasian collared and Laughing Dove. Critically endangered scavengers like White-rumped and Indian Vultures were often found killed near mammal carcasses	
Das *et al.* (2007)	May 2004 - Sep 2004	Kaziranga National Park	Reptiles	Almost 90% of road kills were snakes, followed by lizards (10%). Higher percentage of snakes in road kills maybe because snakes used roads for thermoregulation. The particular road (NH 37) is also the only high ground available during floods. Arboreal reptiles most affected, followed by terrestrial reptiles.	
Rao and Girish (2007)	Aug 2005 - Nov 2005	Bandipur and Nagarhole National Park	Insects	Mortality highest in dragonflies (61%) and butterflies (35%), all diurnal species. Nocturnal insect casualties mabe much higher. Higher diversity among road kills in roads through protected areas than those outside.	Speed limit of vehicles passing through national parks, construction of overbridges and underpasses, awareness programmes for drivers and general public on road ecology.
Parasharya & Tere (2007)	2007	Anand-Ahmedabad	Monitor lizard	9 individuals observed killed on a 65 km stretch	Tunnels /culverts across highways

Source	**Study period**	**Location**	**Target taxa**	**Important findings and**	**Recommendations**
Vijayakumar *et al.* (2001)	May 1998 - Jun 1998	Anamalai hills	Herpetofauna	Higher number of roadkilled reptiles associated with forests. Greater mortality of amphibians in coffee plantations compared with other vegetation. Lowest mortality of amphibians and reptiles with tea plantations. More roadkills on rainy days compared to dry days.	Closing heavy vehicle traffic at night hours on certain sections
Seshadri *et al.* (2009)	2008	Sharavathi river basin	Amphibians	32 % of roadkills in agriculture section, 22% in waterbody section and 46% in forest section. Roadkill encounter rate highest in forest followed by agriculture and waterbody. High road kill encounters, upto 40/km.	
Kumara *et al.* (2000)	Apr 1995-Dec 1998	Anamalai hills	Reptiles & mammals	Most reptilian roadkills during rainy season in the wet, forest region and most roadkills caused at night. Bonnet macaques followed by porcupines the most frequently killed mammals.	Tourist traffic to be minimised during rainy season and at night. Steps should be taken to maintain canopy contiguity beside the road. When constructing any further roads within the sanctuary, the sensitive rainforest areas must be avoided.
Sundar (2004)	2-year period	Etawah, Uttar Pradesh	Herpetofauna, birds, mammals	133 kills of 33 animal species, amphibians killed more during monsoon, medium-sized birds and omnivores more prone	While some bird species may not perceive road as barrier, their flying across puts them at risk of collision with vehicles
Behera and Borah (2010)		Nagarjuna-Srisailam Tiger Reserve	Mammals	Not available	Not available

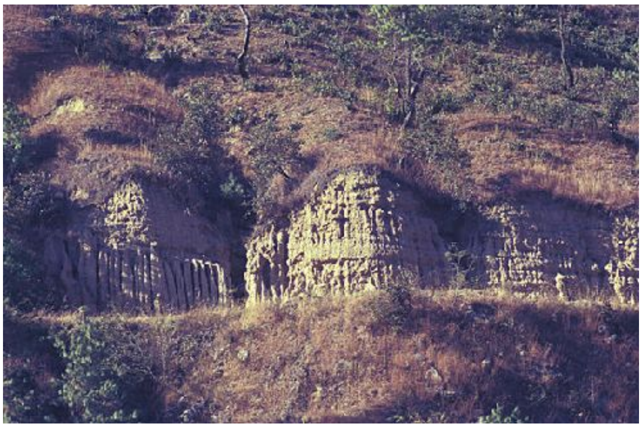
Annexure 2

Road Construction in Montane Forests

Ramana Athreya
Associate Professor, Indian Institute of Science Education & Research, Pune
Member, Arunachal Pradesh State Wildlfe Board
Coordinator, Biodiversity Research & Conservation, EcoSystems-India, Guwahati
Email: rathreya@iiserpune.ac.in Phone: +94235-72434

These suggestions are from my experience with roads in montane regions in Arunachal Pradesh. The issues are in red and suggestions are in black.

1. The debris from dynamiting the slopes is cleared by shovelling it down-slope. Since the debris consists of large boulders and huge amounts of soil, this destroys the vegetation on the entire slope below the road ... often in a strip up to 500m wide.
    a. The debris must be disposed of in specific locations to minimise the damage to the slopes below
    b. Boulders excavated by blasts should be "processed" for stone chips required to layer the road. Often, large amounts of rocks are disposed as waste at one location while stone quarries are opened up on roadside cliffs elsewhere to extract stone chips.
2. The fuel and timber requirements of road construction are usually met from forest trees.
    a. Timber for road construction should either be transported in from outside or should use the least important trees in the area, if such exist. For example, in Arunachal Pradesh the preferred fuelwood trees are oak, rhododendron and fir. All these are very slow growing trees which constitute the primary forest species at different elevations.
    b. Pine grows in extensive mono-specific stands and host a considerably diminished diversity of species. Pine is a coloniser which often prevents the regeneration of other native species. If at all local timber has to be used it should be based on a proper plan and should comprise species like pine ... even if it is less efficient.
    c. The proposed strategy of resource utilisation and the actual execution as per plan must be filed with and certified by the local Forest Department and available for public scrutiny.
3. The road construction work force cause havoc in the wilderness. They cut trees for fuel and building temporary shelters and hunt animals for the pot. It is understandable that the poorly paid workers in those remote areas indulge in these activities.
    a. Workers must be billeted outside the wilderness areas even if it involves an expensive daily commute.
    b. Workers must be supplied with adequate fuel for cooking and warmth, and construction materials from outside ... all these should be included in the price of the road – that is what it takes to build roads in wilderness areas, and on no account should the forest itself be made to bear the cost.
    c. Modern technology and proper logistical planning must be used in wilderness areas to greatly increase the pace of road construction to minimise the time spent by the work force in the area.
4. The greatest damage happens because of the poor standard of construction which requires continuous repairs – i.e. the above ills plague the road all through the year, for decades on end. For instance, the Tezpur-Tawang road is under maintenance with a work force billeted on the surrounding forest throughout the year, for the last 30 years.
    a. Can there be limits on how often roads can be repaired in wilderness areas? Quality HAS to be improved. This may translate into higher initial costs for better quality construction ... anyway, even now this extra cost is being borne in the form of repeated repairs over the years and by the forest itself as workers are billeted for longer periods.
    b. Good drainage to keep water away from the road, proper stability of the slopes along the road, and low level maintenance will minimise road damage and the consequent frequent repairs with a large work force.



The exposed retaining walls have been heavily eroded by rainwater run-off (aggravated by deforestation). During the monsoon large sections of the water-logged walls regularly collapse across the road. There is no effort at stabilising the road walls or the slope. Bad drainage and bad slope maintenance are a general feature of roads causing widespread road surface damage and landslides ... which necessitate perpetual maintenance and pressure on the forest.

Road construction is very slow and labour intensive, and so imposes a heavy burden on the natural resources of the area. While employment generation is a laudable aim, the focus while constructing roads in wilderness areas should be on rapid completion of work.

Also visible in the photo is the lack of any effort at slope stabilisation.

Above-left: forest timber being used to melt tar for the black-top road. Above-right: Stones being quarried on the roadside which causes damage to an existing road. On the one hand, rocks exposed while dynamiting for the road alignment are simply rolled down-slope which destroys the vegetation below. On the other, good sections of the road are destroyed to extract rocks for layering the road.

One of the major problems is the poor quality of construction and poor planning which necessitates perpetual repair work by a large work force. The asphalt surface in some places barely lasts a few months and almost never the rainy season.

If necessary, the extensive secondary pine forests should be utilised for road construction fuel and timber and then the exposed land should be used for mixed species plantations





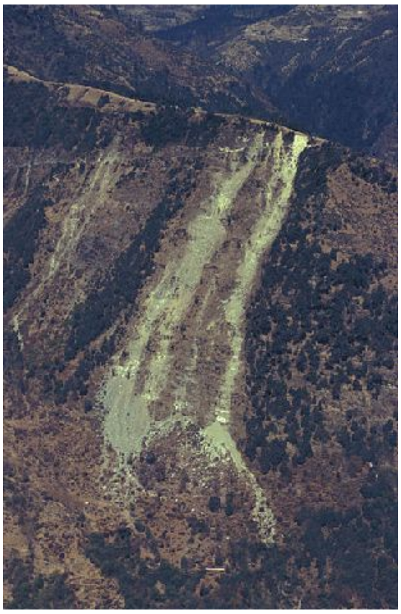


Devastation around road construction camps (at Debrabu, Mandala and O-naga camps; all in Dirang area in West Kameng district). These are not traditional Arunachali settlements but colonies of road construction workers in otherwise uninhabited areas. All these camps are surrounded by extensive tree felling for construction and fuel, and hunting (takin skin on left, and wire snare above-right).

Above-left: Secondary forest on the road slope. Above-right: Untouched primary forest on the slope away from the road.

Left: Deforestation along the road near Bomdila. For one reason or another deforestation tracks road construction. Some of it is because of Arunachali communities opening up new areas for agriculture along the road. More often it is because of deforestation associated with the construction work force. Most of the deforested areas in the Bomdila image have no cultivation.

Huge landslides extending many hundreds of metres, in both forested and deforested slopes. Roads are cut with little thought to slope stabilisation. Given the very loose soil even the presence of trees does not always guarantee soil stability. Above: slides along a small track in Eaglenest sanctuary. Below: slides along the highway in Dirang and Jang.



Annexure 3. Guidelines for ecologically safer roads provided in the report *Governance for Sustaining Himalayan Ecosystem (G-SHE): Guidelines and Best Practices* by the Ministry of Environment and Forests and the G. B. Pant Institute of Himalayan Environment & Development.

Ecologically Safer Roads

- For construction of any road in the Himalayan region of more than 5 km (including extension/widening of existing roads) length where the same may not be tarred roads and environmental impact assessment is otherwise not required, environmental impact assessment should be carried out in accordance with the instructions to be issued for this purpose by the State Governments.
- Provision should be made in the design of the road for treatment of hill slope instabilities resulting from road cutting, cross drainage works and culverts using bio-engineering and other appropriate techniques by including the cost of such measures in the cost estimate of the proposed road.
- Provisions should also be made for disposal of debris from construction sites in appropriate manner at suitable and identified locations so as not to aff ect the ecology of the area adversely; further, the dumped material should be treated using bio-engineering and other appropriate techniques and the cost of such measures should be included in the cost estimate of the proposed road.
- Wherever hot mix plants are used, they should be set up at least 2 km away from settlements and a minimum area of 200 sq. m. surrounding the site should be devoid of vegetation.
- No stone quarrying should be carried out without proper management and treatment plan including rehabilitation plan and fi nancial provision for rehabilitation of the site should be included in the cost of the management plan.
- All hill roads should be provided with adequate number of road side drains and these drains shall be kept free from blockage for runoff disposal; in the event that this is not done and this fact leads to damages that could otherwise have been prevented, the persons responsible should be liable for prosecution/damages; further, the cross drains shall be treated suitably using bio-engineering and other appropriate technologies so as to minimise slope instability.
- The runoff from the road side drains should be connected with the natural drainage system in the area.
- Fault zones and historically land slide prone zones should be avoided during alignment of a road, where for any reason it is not possible to do so, notice should be given providing full justifi cation and the construction should be carried out only after suffi cient measures have been taken to minimize the associated risks.
- Notice should be given about all fault zones and land slide zones along the roads indicating the beginning and the end of such areas.
- Ridge alignment should be preferred to valley alignment.
- Alignment should be selected so as to minimise loss of vegetal cover.
- South or South-west alignment should be preferred to avoid moist areas.
- Appropriate design standards should be followed while designing the roads including mass balancing of cut and fill and avoidance of unnecessary cutting.
- Encouragement should be provided for use of debris material for local development.

Annexure 4. Example of conditions prescribed at time of approval of a road project (for repair of black-topped road and construction of bridge in Orcha Wildlife Sanctuary, Madhya Pradesh, which was to involved felling of 115 trees). From the Minutes of the 20th Meeting of the Standing Committee of the National Board for Wildlife held on 13 October 2010.

Conditions imposed:

1. 5% of the project area falling with the Sanctuary would be paid by the user agency for the development of Orcha Wildlife Sanctuary
2. No new road would be constructed. Only the existing road would be repaired.
3. There shall be no widening of the existing road. The overall width of the road should not be more than existing width including shoulders on either side of the road.
4. The tree felling would be to the barest minimum.
5. No material including earth should be used from the sanctuary area. It will affect flora as well as fauna, particularly the micro fauna.
6. There should be provision of speed breakers at every 400 m of the road inside the sanctuary so that the speed is regulated within the sanctuary so as to avoid accidental death of wild animals.
7. Speed limit within the stretch of road passing through the Sanctuary should be restricted to 20 Kms/hr.
8. Apart from mandatory sign boards along the road, boards depicting wildlife safety instructions and cautions relating to it should also be placed at every 500 m using good material and having proper font size and pictures.
9. The agency should ensure that no damage to any flora or fauna is caused during the course of the execution of the work.
10. All construction materials should be brought from outside the sanctuary area including earth.
11. There should not be any labour camps permanent or temporary, in the sanctuary area during the course of construction of the road. Collection of firewood shall be prohibited.
12. All the trees along the road shall be protected by the user agency.
13. All quarry for metal/sand/moorum shall be informed by user agency and previous sanction to Revenue Department (mining) collector is mandatory. If any Private party found to violate rules or involved in illegal mining during contruction, than [sic!] user agency will be made responsible for it.
14. Heavy vehicular traffic should be avoided as it may cause permanent disturbance inside the sanctuary.
15. All vehicles shall pay prescribed entry fees.
16. All vehicles will enter sanctuary area after sunrise and shall exit the sanctuary before sunset.
17. No camping of vehicles shall be allowed inside the sanctuary..
18. NPV and Compensatory afforestation Funds will be paid by the user agency to the Chief Wildlife Warden as per norms.
19. The user agency should also abide by any other conditions that may be prescribed by the Chief Wildlife Warden.
20. The Chief Wildlife Warden would submit a compliance report on implementation of the conditions specified, before the Standing Committee of NBWL after completion of the project.