TECHNICAL APPENDIX

ENVIRONMENT CANADA COMMENTS

ON

SOUTH FRASER PERIMETER ROAD ENVIRONMENTAL ASSESSMENT

19 NOVEMBER 2007

Outline

1. Introduction

Environment Canada is participating in the cooperative Canada-British Columbia environmental assessment of the South Fraser Perimeter Road Project as a federal authority pursuant to the *Canadian Environmental Assessment Act* (CEAA). In this capacity, Environment Canada (EC) is contributing specialist information and advice to Transport Canada and the Department of Fisheries and Oceans (DFO)[1] as the responsible authorities for the federal environmental assessment of the Project.

In previous correspondence, Environment Canada commented on the SFPR Project Environmental Assessment Application and associated Technical Volumes (Dec 21/06 letter from K. Trainor to L. Sullivan; Dec 22/06 letter from V. Au to L. Sullivan). The Department also sought and transmitted the opinion of the Burns Bog Scientific Advisory Panel (Jul 6/07 letter from L. Walls to L. Sullivan, C. Hainsworth and A. Silverstein). Subsequently, Environment Canada provided detailed comments on supplemental documents submitted by the British Columbia Ministry of Transportation (MoT) in response to technical review comments on the Project Application (Aug 14/07 letter from L. Walls to L. Sullivan).

MoT responded to concerns expressed in Environment Canada's letter of August 14, 2007 with a proposed realignment of the roadway near the southwest corner of Burns Bog and updated mitigation, monitoring, compensation proposals and owner's commitments, as described in the following documents:

- Letter to Lisa Walls, Environment Canada, from Geoff Freer, Ministry of Transportation regarding the South Fraser Perimeter Road Assessment, dated September 21, 2007;
- Technical Memorandum - Ministry of Transportation Responses to Environment Canada Comments on South Fraser Perimeter Road, dated September 21, 2007;
- Tracking Table entitled, 'Environment Canada Response Table', dated September 21, 2007;
- Appendix E (Version 14) South Fraser Perimeter Road: Owner's Commitments and Assurances, dated October 29, 2007; and,
- Alignment drawings titled, 'Relocated South Perimeter Road', dated September 2007.

At the request of MoT, Environment Canada staff also met with MoT on October 9th, 2007, to discuss technical clarifications pertaining to wildlife issues, including as these relate to MoT's cumulative effects assessment.

Environment Canada's comments, advice and recommendations contained in this submission are based on the Department's review of this additional information provided by MoT prior to November 16, 2007.

This submission is based on matters related to Environment Canada's mandate pursuant to the *Department of the Environment Act*, the *Species at Risk Act* and the *Migratory Birds Convention Act, 1994*. Environment Canada's comments are also influenced by the Department's

[1] The scope of project for DFO's environmental assessment of SFPR includes stream crossings that require authorization under section 35(2) of the *Fisheries Act*, none of which are in Burns Bog. As DFO's review does not include examination of the effects of the Project on Burns Bog, many of Environment Canada's comments may not be applicable to the environment assessment being conducted by DFO.

commitment to the conservation and restoration of Burns Bog and its supporting ecological functions, as set out in the Conservation Covenant held by Canada under section 219 of the British Columbia *Land Title Act* (March 2004) and in the Burns Bog Ecological Conservancy Area Management Plan (April 2007).

In this submission, Environment Canada focuses on outstanding concerns related to potential effects of the proposed SFPR alignment along the northern and southwestern margins of Burns Bog on wildlife and wildlife habitat, hydrology, aerial deposition, cumulative effects and the ecological integrity of Burns Bog. For each of these issues, Environment Canada comments on the environmental baseline conditions or context relevant to the SFPR Project, offers a scientific opinion on the environmental effects of the Project, and provides recommendations where applicable.

2. Wildlife and Wildlife Habitat

The Canadian Wildlife Service (CWS) of Environment Canada has focused its review of wildlife and vegetation issues on seven Valued Ecosystem Components (VECs), as follows.

(A) PACIFIC WATER SHREW (*Sorex bendiri*) (small mammal)
(With consideration for other small mammals)

(1) <u>Present Status of the Population</u>
The Pacific water shrew (*Sorex bendiri*) (hereafter 'PWS') is currently listed as Threatened on Schedule I of the *Species at Risk Act* (SARA). In April 2006 the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) up-listed the PWS from Threatened to Endangered, and has recommended to the Minister of Environment that the species' status be changed accordingly on Schedule 1 of SARA. The change in status to a higher risk category is based on the continued decline and fragmentation of habitat of this rare species – confined to the Lower Mainland/Fraser Valley region of British Columbia – as a result of development. COSEWIC noted there is little chance of rescue for this species. The PWS is extremely rare throughout its range.

The Pacific Water Shrew Recovery Team (PWS Recovery Team), in developing a Recovery Strategy for the PWS (currently in draft), undertook an exercise to identify critical habitat, which is described in the document titled, 'Preliminary Partial Critical Habitat Identification for Pacific water shrew (*Sorex bendiri*) – DRAFT (October 19, 2007).

Under the Canada/BC Bilateral Agreement on Species at Risk, BC is the lead jurisdiction for this species; CWS is the SARA responsible agency.

Other small mammal species of concern, for which MoT has proposed that their PWS mitigation, monitoring, and compensation measures apply to, include:

a) Provincially red-listed Red-backed Vole (*Clethrionomys gapperi ssp occidentalis*); and,
b) Recently identified Olympic Shrew (*Sorex rohweri*), which EC considers to be 'data deficient'.

(2) Baseline Information on the Population

The PWS is known to occur adjacent to Burns Bog, and Project baseline studies confirmed the presence of PWS along the alignment, specifically at Fraser Heights.

More recent information obtained as part of the Project environmental assessment has identified a new occupancy area along the alignment in addition to Fraser Heights.

Recommendations

Additional and more comprehensive survey monitoring is needed to determine population distribution and density within Burns Bog. This is a challenging undertaking due to the sensitivity of the species to current survey techniques. Consultation with BC and the PWS Recovery Team is recommended.

(3) Issues Related to the Project

Habitat loss, reduced habitat effectiveness, impaired population dispersal, and mortality have been identified as the major effects of the Project on this species. Based on recent PWS Recovery Team work, the SFPR Project passes through two wetland complexes that have been identified as 'critical habitat' (based on the draft document referenced in Section 1 above). These areas are known occupancy areas for this species. Further, high and moderate suitability habitats (as mapped by the Proponent) will be impacted.

MoT is proposing various mitigation measures, including wildlife crossings, drift fences, and elevated highway structures, at specific sections of the alignment to address negative effects. The refined alignment along the southwest side of Burns Bog will increase habitat impacts to this species, as it encroaches into previously avoided areas rated as high suitability habitat. (Refer to the following for more information: Figure 10, titled 'Distribution of the Pacific Water Shrew' (June 08, 2006), and Figures S40, S43, and S44 (November 2007), which show the original and subsequent alignment shifts). MoT's proposed Habitat Compensation Plan (HCP), which is a strategic-level framework, identifies some conceptual habitat compensation options. Compensation proposals identified thus far are primarily aligned with habitat compensation requirements required by the Department of Fisheries and Oceans in the issuance of *Fisheries Act* authorizations for the Project.

Recommendations

EC recommends that MoT consult the PWS Recovery Team for advice on the following items as they relate to the draft Recovery Strategy:

a) Accuracy of Project PWS habitat suitability mapping, in particular in and around Burns Bog;
b) Assessment of overall loss of PWS habitat along the entire alignment;
c) Effectiveness of proposed mitigation and compensation measures;
d) Monitoring requirements to inform the proposed Monitoring Mitigation Plan (MMP) and HCP; and,
e) Implications of (a) - (d) for the success of the draft Recovery Strategy.

EC advises that, in the absence of a detailed engineering design and supporting hydrological information, the extent to which proposed wildlife crossings will function effectively for mitigating direct impacts to movement of small mammals is uncertain.

(4) <u>Conclusions</u>

COSEWIC has up-listed the PWS from Threatened to Endangered due to on-going habitat loss and degradation within its extremely confined range within British Columbia, and specifically the Fraser Lowlands.

The Project will, as noted in Section (3) above, result in the loss of habitat of this species situated along the perimeter of Burns Bog and at Fraser Heights. Even with the implementation of MoT's proposed mitigation and compensation measures, EC is of the opinion that Project effects to PWS habitat, habitat effectiveness, and population dispersion are predicted to result in significant adverse effects to this species.

If achievable, EC advises that long-term maintenance and protection of habitats along the perimeter of Burns Bog, including the intact lagg zone habitat on the southwest side of the bog, will likely be consistent with the recovery strategy required by SARA, since:

a) The PWS is known to be associated with Burns Bog;
b) One of the objectives of the Burns Bog Management Plan (BBMP) is to restore lagg zone habitat, which, if executed as planned, will very likely benefit the species; and,
c) Maintaining connectivity between the lagg zone and adjacent areas along the northern perimeter of the bog, in particular all the way to the Fraser River, will provide critical dispersal opportunities for this species. Maintaining connectivity would also benefit other species, including landbirds, and be consistent with the BBMP.

EC recommends MoT commit to participating on the Recovery Team or in SARA action planning to address project-specific and region-wide recovery efforts for this species.

EC recommends that the Responsible Authorities consult the Ministry of Environment (MoE) as the lead jurisdiction for this species. EC recommends that the Recovery Team be considered the expert scientific body for the PWS and be consulted by the Responsible Authorities for advice on the SFPR Project's effects on the potential for PWS recovery, as described and recommended above.

The above analysis does not include consideration of the potential hydrological and particulate matter deposition effects of the Project on Burns Bog, and the subsequent effects these would in turn have upon PWS habitat and the population. The anticipated negative effects of the Project upon bog hydrology are predicted to result in alterations to bog habitat for which the net effect upon the PWS is presently uncertain.

(B) SANDHILL CRANE (*Grus canadensis*) (Waterbird)
(With consideration for Great Blue Heron)

(1) <u>Present Status of the Population</u>

The Greater Sandhill Crane is a federal migratory bird under the *Migratory Birds Convention Act* (MBCA). COSEWIC designated the species in April 1979 as Not at Risk, based on significant population increases since the late 1940s and current relatively high numbers. Nonetheless, the Greater Sandhill Crane (*Grus canadensis* pop. 1) in the Georgia Depression has been classified as a red-listed population by the BC Conservation Data Centre (South Fraser Perimeter Road Vegetation and Wildlife Impact Assessment, Technical Volume 1, September 2006). The Burns Bog breeding population has declined from about 8 pairs in 1945

(Biggs,1976) to 2 or 3 breeding pairs and 3 or 4 non-breeders in 1994 (Gebauer,1995). The Crescent Slough area is the only known fall staging area for Sandhill Cranes in the Lower Fraser Valley. Larger than expected numbers in recent years suggest the staging population is a mixture of local (resident) nesting and migrant birds.

Another large waterbird of concern is the Great Blue Heron (*Ardea herodius fannini*), which is a federal migratory bird under the MBCA. COSEWIC lists this species as Special Concern and it appears on Schedule 3 of SARA. The reasons for its COSEWIC listing is as follows: the limited number of colonies of this subspecies indicates a highly clumped distribution; disturbance from human activities and eagle predation of nestlings are causes of concern for the population. Based on Breeding Bird Survey trend data, this species could be in decline. The next COSEWIC assessment will be in April 01, 2008.

(2) <u>Baseline Information on the Population</u>
Baselines studies confirmed the presence of Sandhill Crane on the southwest side of Burns Bog. Studies have not confirmed the extent of staging population movements between agricultural fields and Burns Bog. However, based on previous work, the Sandhill Crane is likely roosting within the bog.

(3) <u>Issues Related to the Project</u>
The Project presents a high risk to this staging population being displaced from preferred forage grounds, specifically along the west and southwest side of Burns Bog. Noise disturbance effects upon roost sites within the bog are also a concern. However, this is less of a concern given the observed distribution of cranes from previous studies (Hebda et al, 2000 for example).

During construction, MoT is proposing to avoid conflict with Sandhill Cranes during the sensitive fall forage period where possible and practical. During operation, MoT is proposing hedgerows, noise attenuation (i.e. quiet pavement), and strategic planting of cover crops as mitigation based on the proposed MMP.

Recommendations
EC advises that avoiding construction activities during the staging period (approx. mid-Aug to mid-Oct) would likely reduce negative adverse construction-related effects to non-significant.

EC advises that hedgerows are an incomplete solution to addressing negative effects during Project operation. This assessment is based on the following:

a) Hedgerows will take a period of time (in the order of 5-10 years) before functioning as effective visual barriers;
b) Noise *may* pose a less harmful effect to cranes than visual effects; nonetheless, hedgerows will not function as effective mitigation to reduce noise levels. It is recognized that large trucks will form a significant proportion of project traffic volume, in the order of 24-36% (SFPR Project Environmental Assessment Application);
c) Depending of plant species used, Hedgerows are not likely function effectively to reduce mortality rates for many years;
d) Hedgerows could likely function as habitat sinks (i.e., habitats that are not capable of self-sustaining a bird population and which require continual recruitment of new individuals into the habitat) for sensitive bird species. This is a particular concern for the southwest side of the bog where high species diversity has been observed (refer to the Landbirds section below for more information); and,

e) Planting hedgerows will negatively affect the hydrological functioning of the lagg zone of the bog.

(4) <u>Conclusions</u>

Available literature indicates that large roads may have negative effects extending more than 300 m from the road. Buffer widths of 500-800m from roost and forage sites where new roads are proposed are recommended (refer to attached bibliography for more information).

Based on (a) – (e) above, to reduce significant adverse effects to non-significant for this species, EC recommends the installation of Solid Sound Barriers (SSBs) on both sides of the alignment in ecologically sensitive areas, such as. Burns Bog, to reduce visual and noise effects during Project operation. SSBs must be of a sufficient height to force birds to fly over container and other truck traffic, which suggests structures approximately 4-6m in height.

Notwithstanding proposed MoT mitigation and advice and recommendations offered above, EC advises that the Project poses a high risk to the local nesting/staging Greater Sandhill Crane population found within and immediately adjacent to Burns Bog. The use of sound walls or hedgerows are unproven mitigation. EC advises that a considerable level of uncertainty accompanies this recommendation.

Notwithstanding this recommendation, SSBs will not address negative effects arising from the transport of mineral material, as described in Section 3. <u>Hydrology and Aerial Deposition</u>.

(C) BARN OWL (*Tyto alba*) (Raptor)
(With consideration for other raptors)

(1) <u>Present Status of the Population</u>

The Barn Owl is listed as Special Concern by COSEWIC, and is listed on Schedule I of SARA as Special Concern. The last COSEWIC assessment was November 01, 2001; the next assessment will be April 01, 2011. Provincially, the Barn Owl is a blue-listed species, which means that the species is not immediately threatened, but is of concern because of characteristics that make them particularly sensitive to human activities or natural events. The Barn Owl's preferred habitat of agricultural fields and pastures is being lost to agricultural intensification and urban developments. The Barn Owl is particularly susceptible to road-related mortality; declines in Lower Mainland breeding populations appear to be occurring.

The Project study area lies within the core BC breeding habitat for this species (South Fraser Perimeter Road Vegetation and Wildlife Impact Assessment, Technical Volume 12, September 2006 citing Fraser *et al*. 1999).

Under the Canada/BC Bilateral Agreement on Species at Risk, BC is the lead jurisdiction and CWS is the SARA responsible agency.

Other raptor species susceptible to road mortality include:

a) Short-eared Owl: COSEWIC/SARA Special Concern. This species is still relatively common in Canada. The main cause of concern is an important and well-documented decline in the past resulting from the loss of its preferred habitat; provincial Blue List;
b) Western Screech-Owl: COSEWIC/SARA Special Concern. This species prefers open forest for foraging and requires cavities in old, large trees for nesting and roosting. Modern forestry practices have created large areas of dense young

forests that have very few suitable nesting snags. Populations have apparently declined in southern Vancouver Island and the Lower Mainland concurrently with the recent arrival of the Barred Owl, which likely predates on this species; provincial Blue List;

c) Northern Saw-whet Owl. Wintering populations are very susceptible to road-related mortality; most common breeding raptor in the bog (Materi & Blood (1999).

On the southwest side of Burns Bog a very large Bald Eagle roost is located approximately 100-200m from the proposed refined alignment.

(2) Baseline Information on the Population

Baseline studies confirmed the presence of Barn Owl at Burns Bog. A Simon Fraser University (SFU) M.Sc. student (supervised by Dr. David Green) is presently conducting research on this species, which in turn is helping inform the Project environmental assessment.

Recommendations

In consultation with the MoE, EC recommends that MoT continue to consult with the SFU graduate student to inform the proposed MMP, including monitoring roost sites during pre-construction, construction, and operation.

(3) Issues Related to the Project

Habitat loss, reduced habitat effectiveness, impaired dispersal, and mortality are seen as the major negative effects of the Project to this species.

The literature is clear that major roadways pose a major mortality risk to Barn Owl populations (for example, refer to Ramsden 2003 and the attached bibliography for more information). A preliminary EC assessment suggests current road density around the bog is approximately 2.4-2.8km/km^2; with the addition of the SFPR Project, density increases to approximately 2.7-3.3km/km^2.

Any analysis of the potential negative effects of increasing road density upon ecological processes should include an evaluation of road distribution across the landscape. In accommodating increased road density and to reduce ecological effects of roads, the literature includes various recommendations, including twinning new roads to existing roads, and re-routing roads to reduce fragmentation effects. (Refer to Jaeger & Fahig, 2005 and Reed *et al*, 1996, and to the bibliography for more examples and information.)

MoT is proposing hedgerows, quiet pavement, nest boxes and (possibly) increasing prey density on agricultural lands to mitigate negative effects to this species.

Recommendations

EC advises that roost sites adjacent to farm fields in the Crescent Slough area are likely to be abandoned due to significant construction-related and operation-related effects. As previously noted, trucks will make up a significant proportion of anticipated traffic volume.

EC advises that there appears to be little scientific evaluation on the effectiveness of structures, including hedgerows, to reduce Barn Owl-vehicle interactions. The generally held belief is that structures such as hedgerows, that force owls to fly up and over on-coming traffic, will reduce collision rates.

To address mortality risk, EC recommends that:

a) SSBs be installed along the Corporation of Delta segment of the alignment. If this is determined to be not feasible, a second option is a combination of tall fencing and hedgerows, except adjacent to Burns Bog (for the reasons stated previously); and,
b) SSBs be installed along the alignment adjacent to Burns Bog.

(4) Conclusions
EC advises that hedgerows in Barn Owl nesting and roosting habitat would likely reduce the mortality risk for the Barn Owl; however, the effectiveness of this mitigation is unproven.

EC advises that declines or local extirpation of the already likely depressed Delta Barn Owl population should be anticipated. This is based on MoT's proposed mitigation and current alignment, in particular around Burns Bog. As mentioned under (3) above, negative Project effects related to increasing road density will likely act cumulatively with existing roadways upon this species. The likelihood of extirpation of local Barn Owl populations needs to be considered in the context of the development of a SARA management plan for the species.

The literature is not clear on whether Barn Owls will avoid flying over a major road way in close proximity to forage and roost areas. EC advises that the nature and duration of negative effects upon dispersing Barn Owls around Burns Bog are uncertain.

EC recommends installation of SSBs on both sides of the alignment in more ecologically sensitive areas, in particular Burns Bog and South Delta, to reduce visual and noise effects during Project operation. SSBs must be of a sufficient height to force birds to fly over container and other truck traffic, which suggests structures approximately 4-6m in height.

EC recommends that the Responsible Authorities consult MoE as the lead jurisdiction for this species.

SSBs will not address negative effects arising from the transport of mineral material, as described in Section 3. Hydrology and Aerial Deposition.

(D) WATERFOWL (Ducks, Swans and Geese)

(1) Present Status of the Population
Northern Pintail appears to be in decline. Within BC, the Trumpeter Swan BC breeding population segments of both the Rocky Mountain Population and the Pacific Coast Population have consistently grown in abundance and distribution in the province since1985 (Breault *et al*, 2005).

(2) Baseline Information on the Population
Farmland habitats within the Corporation of Delta area provide critical foraging habitat for a number of waterfowl species including Mallard, Green-winged Teal, American Wigeon and Trumpeter Swan. Large flocks of these species have been observed in the Crescent Slough farm fields immediately adjacent to the proposed SFPR Project alignment. Gulls, raptors, shorebirds, and songbirds have been observed in these same fields.

(3) <u>Issues Related to the Project</u>
Habitat loss, reduced habitat effectiveness, and, to a lesser extent mortality, are seen as the major negative effects of the Project to waterfowl.

MoT is proposing hedgerows, quiet pavement in strategic locations, the MMP, and the conceptual HCP to address negative effects to waterfowl.

Recommendations
The use of roadside buffer such as hedgerows, or an SSB, is likely to be effective in reducing the Zone of Influence (ZOI) of the highway. Some species such as Trumpeter Swan are more sensitive to road-related noise and traffic irrespective of roadside buffers, and are considered less resilient than dabbling ducks to negative Project effects.

EC recommends that MoT:

a) Install SSBs along the Corporation of Delta segment of the alignment. If this is not feasible, a second option is a combination of tall fencing and hedgerows, <u>except adjacent to Burns Bog</u> (for the reasons stated previously)
b) Install SSBs along the alignment adjacent to Burns Bog;
c) Link the MMP and HCP to address the Trumpeter Swan low resilience characteristics; and,
d) Consult with EC and the Delta Farm and Wildlife Trust on mitigation.

(4) <u>Conclusions</u>
EC advises that, given the high resiliency of most dabbling duck species, and the stability of the less resilient Trumpeter Swan, Project effects will likely be reduced to non-significant adverse effects based on proposed MoT mitigation/compensation and EC recommendations above.

(E) LANDBIRDS

(1) <u>Present Status of the Population</u>
A diverse assemblage of landbirds was observed during Project baseline surveys and subsequent observations made by Martin Gebauer. Species observed include American Pipit, Golden-crowned Kinglet, Hairy Woodpecker, Downy Woodpecker, Pacific-slope Flycatcher, Pine Siskin, Ruby-crowned Kinglet, Red-breasted Sapsucker, Pileated Woodpecker, and Hermit Thrush. Based on Breeding Bird Survey data, which is publically available, these species are showing increasing and decreasing population trends. For example, the Golden-crowned Kinglet shows a 3.7%/year decline over last 10 years (trend non-significant), Pine Siskin a 6.9%/year decline over last 10 years (trend non-significant), and Hermit Thrush a 0.5%/year decline over the last 10 years (non-significant trend, but significant increases in BC generally).

(2) <u>Baseline Information on the Population</u>
In the vicinity of Burns Bog, and in particular along the southwest side of the bog, there is considerable species richness of wintering passerines, woodpeckers, raptors and waders. (For more information refer to the SFPR Vegetation and Wildlife Impact Assessment, Tech. Vol. 12 (September 2006), and EC's Technical Memo (August 14 2007).)

(3) <u>Issues Related to the Project</u>
Habitat loss, reduced habitat effectiveness, and mortality are seen as the major negative effects of the Project to landbirds.

MoT is proposing hedgerows, quiet pavement, sound walls (in residential areas), pre-construction nest surveys, nest buffers, limited land clearing activities during the breeding bird season, monitoring under the MMP, and habitat compensation concepts under the HCP to address negative effects to landbirds.

Recommendations

EC advises that the Project is predicted to result in negative effects upon breeding and wintering bird species utilizing the north and west sides of the bog. Extensive literature supports this conclusion. Breeding and wintering bird populations at the southwest end of the bog are diverse and particularly susceptible to noise effects and other such effects that reduce habitat effectiveness. A reduction in habitat effectiveness will be most pronounced for low resiliency species. The literature indicates that effects will extend into the adjacent forests and fields (refer to MoT's ZOI documented (July 2007) and attached bibliography for more information). High mortality rates are anticipated until typical road side bird populations become established, with residual mortality rates anticipated thereafter for the life of the Project.

EC recommends that MoT:

a) SSBs be installed along the Corporation of Delta segment of the alignment. If this is determined to be not feasible, a second option is a combination of tall fencing and hedgerows, <u>except adjacent to Burns Bog</u> (for the reasons stated previously); and,
b) SSBs be installed along the alignment adjacent to Burns Bog.
c) Apply the ZOI assessment in further development of the MMP and HCP, and that these aforesaid plans include explicit mitigation and compensation options for landbirds.

EC advises that MoT's proposal to protect residual properties adjacent to the alignment to compensate for negative effects will not serve as an effective short or long-term management strategy for retaining landbird diversity and abundance. In ecological terms, adjacent properties could serve as buffers to protect sensitive habitats that are beyond the range of the negative effects of the road.

(4) Conclusions

EC advises that the Project is predicted to result in residual adverse effects to landbirds in the short and long term. These effects will be most readily observed in ecologically rich and sensitive areas, including Burns Bog and Fraser Heights. The proposed MoT mitigation-monitoring and compensation strategies, coupled with the EC recommendations above, will reduce negative effects to non-significant.

Habitat compensation measures must consider the long-term management objectives of the BBMP to reduce the existing conifer/mixed forest in the bog, except for within lagg zones. MoT needs to consult with EC and the Burns Bog Scientific Advisory Panel.

EC advises that the potential mortality of migratory birds or harm to migratory bird nests potentially caused by the Project will require the proponent to undertake appropriate due diligence measures to reduce negative effects and comply with the MBCA.

(F) RED-LEGGED FROG (Amphibians)
(With consideration for the Western Toad)

(1) Present Status of the Population

The Red-legged Frog (*Rana aurora*) is listed as Special Concern by COSWIC, and is listed on Schedule I of SARA as Special Concern. A Recovery (Management) Team does not currently exist for this species. COSEWIC last assessed this species November 01, 2004.

The Canadian range of the Red-legged Frog is restricted to British Columbia. A large proportion of the known Canadian distribution of this species occurs in the densely populated southwestern part of British Columbia (the primary region of occurrence of this species being the Lower Mainland). Habitats are becoming increasingly lost and fragmented due to land conversions and other human activities. Two introduced species, the Bullfrog and Green Frog, which are spreading rapidly, have replaced this species at many sites and appear to adversely affect the use of wetland breeding sites and reproductive success of the Red-legged Frog. Populations of this species, and other amphibian species that require extensive habitat, are inherently vulnerable to habitat fragmentation which can be expected to exacerbate isolation effects and local extirpations.

Another amphibian species that will potentially be impacted by the Project is the Western Toad (*Bufo boreas*). COSWIC has listed this species as Special Concern, and it is listed on Schedule I of SARA as Special Concern. COSEWIC last assessed this species on November 01, 2002. BC is the primary region of occurrence, but it does occur in other regions, including the Yukon, Northwest Territories, and Alberta. This species has suffered population declines and population extirpations, at least one of which is well documented. It is relatively intolerant of urban expansion and conversion of natural habitat for agricultural use.

Under the Canada/BC Bilateral Agreement on Species at Risk, BC is the lead jurisdiction and CWS is the SARA responsible agency for both the Red-legged Frog.

(2) Baseline Information on the Population

A Red-legged Frog egg mass was identified at Fraser Heights. While not identified during Project baseline studies, this species has been documented within Burns Bog and within Delta generally. The Burns Bog Ecosystem Review noted that, ‘The COSEWIC vulnerable-listed Red-legged Frog (*Rana aurora*) was observed in the central heath land habitat of Burns Bog and in the north-eastern mixed forest (Figure 4.27) (Knopp and Larkin 1999). Though native amphibian species in sphagnum habitats are not well known, Red-legged Frogs use lowland bog habitat as well as upland forested sites in the Fraser Valley (Knopp 1996). Breeding sites for the Red-legged Frog could potentially occur in ponds in Burns Bog and adjacent areas (Knopp and Larkin 1999).

Western Toad was not identified during Project baseline studies, but has been identified adjacent to Burns Bog in previous studies (South Fraser Perimeter Road Vegetation and Wildlife Impact Assessment, Technical Volume 1, September 2006).

Recommendations

Comprehensive baseline monitoring is needed for Red-legged Frog and Western Toad to determine population densities and distribution within and adjacent to Burns Bog. Consultation with MoE is recommended to further develop MoT’s proposed MMP.

(3) Issues Related to the Project
Habitat loss, reduced habitat effectiveness, impaired dispersal and mortality are seen as the major effects of the Project on these species.

MoT is proposing various mitigation and compensation measures, including wildlife crossings, drift fences, elevated highway structures (southwest side of Burns Bog and Fraser Heights), and mitigation, monitoring and habitat compensation concepts under the MMP and HCP.

Recommendations
EC advises that further development of the MMP and HCP should adequately mitigate impacts to habitat loss and effectiveness. While fisheries habitat compensation may benefit amphibian species, EC recommends that an assessment be undertaken to avoid negative interactions between fish and amphibian species where habitat restorative/enhancement concepts overlap.

Lagg ponds proposed for the north side of Burns Bog may benefit amphibian populations after water levels and appropriate vegetation have been established. However, lagg ponds as amphibian habitat does not address negative effects to the bog arising from the transport of mineral material, as described in Section 3. Hydrology and Aerial Deposition.

EC advises that the proposed MMP should be further developed, in consultation with MoE, to assess, monitor and mitigate effects upon amphibian dispersion and mortality. The MMP will require an adequate assessment of baseline amphibian density and distribution in order to effectively determine mitigation effectiveness and the need for any additional mitigation, should initial mitigation be inadequate. EC suggests that inclusion of an SSB, guide fences and vegetated, grated culverts along the Burns Bog segment of the alignment would likely result in non-significant adverse effects to amphibians.

(4) Conclusion
EC advises that significant adverse effects can be reduced to non-significant based on proposed MoT mitigation and the EC advice and recommendations above.

The above analysis does not include consideration of the potential hydrological and aerial deposition effects of the Project on Burns Bog, and the effects these would in turn have upon Red-legged Frog and Western Toad habitat and the populations. However, anticipated negative adverse effects upon bog hydrology will result in a change in bog habitat. The net effect of such shifts upon the Red-legged Frog and Western Toad is presently uncertain.

EC recommends that the Responsible Authorities consult MoE as the lead jurisdiction for these species.

(G) STREAMBANK LUPINE (Vascular Plant)
(With consideration for the Vancouver Island Beggartick)

(1) Present Status of the Population
The Streambank Lupine (*Lupinus rivularis*) is listed as Endangered on Schedule I of SARA. COSEWIC last assessed this species November 01, 2002. The species occurs mainly in BC, with very few extant populations and extremely low numbers of plants remaining. These populations are all close to industrial and other development and are at risk from habitat loss, herbicide spraying, and predation by exotic slugs.

The Vancouver Island Beggarticks is listed as Special Concern on Schedule I of SARA. According to COSEWIC, this is an annual species with fluctuating population sizes occurring at about 30 confirmed sites in wetland habitats of restricted extent, with most of the species' global range occurring in southern British Columbia.

Under the Canada/BC Bilateral Agreement on Species at Risk, BC is the lead jurisdiction for both species; CWS is the SARA responsible agency.

(2) Background Information on the Population
The species is known to occur within the Project area, and related baseline studies have confirmed its presence.

(3) Issues Related to the Project
Mortality is seen as the major negative effect of the Project to this species.

Under Appendix E (Version 14) of the Owner's Commitments and Assurances table, (dated October 29, 2007), MoT is committing to, '*make all reasonable efforts to avoid direct impacts to stream bank lupine habitat (including areas considered as seed banks) adjacent to Gunderson Slough during the design and construction of the Project. Where impacts cannot be avoided, the Owner will work with the Ministry of Environment and the Stream Bank Lupine Recovery team to identify and carry out appropriate mitigation measures including, but not limited to, the stockpiling of soil containing Streambank lupine seeds'*.

(4) Conclusions
EC concurs with MoT's mitigation efforts, and recommends the Responsible Authorities consult with MoE for both species as well as with the Streambank Lupine Recovery Team.

3. Hydrology and Aerial Deposition

(A) Ombrotrophic [Raised] Sphagnum Bogs

Burns Bog, a large domed, Sphagnum-dominated bog located within the Fraser River Delta, is the largest of its kind on the west coast of North America, and one of the most southerly (Vitt et al., 1999). Burns Bog is chemically similar to other coastal bogs and distinct from continental bogs (Vitt et al., 1999). Whereas all bogs are Sphagnum dominated, Burns Bog is floristically distinct because of a unique combination of climatic, physiographic and historical factors (Vitt et al., 1999). Burns Bog is more diverse ecologically than any natural bog in Canada (Warner and Asada, 2006). Yet it may have been greater before the present level of disturbance (Hebda and Biggs, 1981). Technically, Burns Bog is an ombrotrophic bog, meaning it receives all of its water and nutrients from precipitation falling directly on its surface. The word literally translates to "cloud-fed." Large ombrotrophic Sphagnum bog ecosystems are relatively rare at this latitude and its ecological analogues will be most commonly found in more northern locations. Due to its morphology, chemistry, flora and size, Burns Bog is of global ecological importance (Vitt et al, 1999; Hebda et al., 2000).

Ombrotrophic bogs are hydrologically isolated from the surrounding landscape and are home to organisms which are tolerant of acidic, low-nutrient environments. The vegetation is dominated by Sphagnum moss. However, this in and of itself fails to capture the complexity of the ombrotrophic bog ecosystem – a complexity dependant on high inputs of water, low inputs of nutrients, a plant community that creates its own chemical environment, and its own hydrology.

Vitt (2006) indicates that peatland persistence depends on a constant, long-term water supply and the origin of this water influences the form and function of peatlands. Peatlands are a generic term for any wetland where partially decayed plant matter accumulates. Many peatlands are a complex of bogs and fens. Klinger (1996) reviews theories of bog succession and concludes that the ombrotrophic bog is the climax ecosystem. Wheeler and Proctor (2000) describe a "bog" as having a pH less that 5.0, with low calcium (Ca^{+2})concentrations, typically dominated by species of Sphagnum species, with ericoids [heather family], and calcifuge Cyperaceae [sedges]. Calcifuge is a term that indicates an inability to grow in alkaline conditions. Acidic wetlands exist across a range of gradients in pH, nutrients, and base cation richness (Wheeler and Proctor, 2000). Økland et al.(2001) suggest ombrotrophic bog sites should be recognized as a separate and unique type. Swedish bogs are distinctly more acid than British ones and have very low Ca concentrations, well below 1 mg/l and pH <4.0 (Sjors and Gunnarsson, 2002). Økland et al. (2001) and Sjors and Gunnarsson (2002) argue that ombrotrophic bogs are separate and the least ambiguous bog classification and are clearly defined from hydrological criteria.

Sphagnum species direct succession through acidification and paludification (Andrus, 1986). Paludification is the process of formation of a peat bog, the steady growth of new peat-forming plants in phase with a steady building of a layer that separates the living Sphagnum from underlying materials. In Burns Bog this has been both the sinking of the peat into the depression in which the bog has formed and the building of a mound creating the domed form. Sphagnum itself plays the major role in creating these wet, poorly mineralized and acidic conditions (Andrus, 1986). Vitt (2006) links ombrotrophy with increased oligotrophy [lack of nutrients], increased aerobic peat column [acrotelm], drier surface conditions, and the dominance of Sphagnum species. In ombrotrophic bogs autogenic factors [those controlled by Sphagnum] are more important than allogenic ones [external to the bog]. Andrus (1986) describes how Sphagnum generated acidification, plus nutrient filtering through cation exchange, allows Sphagnum under some conditions to direct wetland succession.

Bell (1959) demonstrated the ability of Sphagnum to markedly alter its chemical environment. Van Breeman (1995) indicates that the bog environment is created by Sphagnum and this environment helps Sphagnum to out complete other plants for light. Sphagnum is an effective "ecosystem engineer" in that modification to the environment benefits itself in both the short and long term. The great water absorbing capability of Sphagnum is an important factor (Andrus, 1986), as under humid conditions this allows the development of an unusual type of ecosystem, the ombrotrophic bog, with peat surfaces above the regional groundwater table and the nutrient input only from rainwater. Sphagnum plants have the ability to produce and maintain an unusually acid environment given a suitable water supply (Clymo and Hayward, 1982). During drought the plants will become white, increasing albedo and reducing evapotranspiration (Gorham, 1991). Water movement is almost entirely laterally through the highly permeable acrotelm (Bragg, 1995, 2002; Clymo, 2004). Sphagnum stimulates water stagnation by depositing impermeable debris [paludification]. Sphagnum has no cuticle to inhibit water loss (Meininger and Spatt, 1988). The accumulation of peat in the catotelm [bottom layer of peat that is permanently below the water table] through paludification results in a water logged mound with extremely low hydraulic conductivity. While there is lots of water in the catotelm, it does not move.

Peat changes character permanently when dewatered therefore continuously maintaining a high water content is essential for preserving peat (Price and Schlotzhauer, 1999; Schouwenaars, 2007). When peat deposits are drained the permeability of the peat is irreversibly increased. Drainage and other dewatering of peat create a positive feedback leading to increased movement of water increasing the drainage of the bog (Van Breeman, 1995). Trees avoid the catotelm by having shallow roots (Ohlson et al.2001). Low pH and calcium concentrations in the acrotelm exclude calciole plants [those plants living where alkaline condition exist and calcium concentration are high], but pH's are not less than the surface horizons of many mineral soils (Van Breeman, 1995; Malmer, 1988).

In addition to receiving all water and nutrients from rainfall, ombrotrophic bogs lie at the low extreme of the range of base cation richness (Clymo and Hayward, 1982). Vitt and Slack (1984) report concentrations of Ca^{+2} as less than 0.5 mg/l and pH < 5.0 in ombrotrophic bogs, and narrow niche breadth for both pH (0.25±0.12) and calcium (0.33±0.09). [Niche breadth is the range in which those plants will live.] Proctor and Maltby (1998) determined that the pH of 'pristine' ombrotrophic bog in absence of pollutants is 4.40 [with a 95% confidence range from 4.22 to 4.58].

Gorham and Pearsall (1956) showed that raised bogs have low pH and calcium concentrations and Sphagnum species are intolerant of calcium. Shotyk (1988) determined that cation exchange is important to the chemical ecology of Sphagnum. Surface Sphagnum communities are outside the influence of groundwaters because of the convexity of the dome or raised bogs. The reader needs to remember that the pH scale is the –log of the hydrogen ion activity, hence small differences in bog pH [for example, 3.8 to 4.6 is a six fold difference and it is 1000 times more in hydrogen (H^+) activity than the range between 6.5 and 7.0] are ecologically important. Shotyk (1988) demonstrated that some Sphagnum are intolerant of calcium. The more dependent the mosses are on dust and precipitation, the more acidic they need to be to obtain their nutrients. Shotyk (1988) also demonstrated that low pH is found where Sphagnum occurs – not the reverse. Gignac and Vitt (1990) considered a transect of bogs and mires across western Canada and demonstrated that Sphagnum species are limited to those having low cationic contents and conductances. [Conductance is a measure of how well electric current will pass through water, low conductance is associated with a lack of dissolved ions] .Gignac and Vitt (1990) demonstrate that ombrotrophic bogs in Canada have very low concentrations of calcium and magnesium (Mg^{+2}) derived solely from precipitation, and high concentrations of H^+ [low pH] from Sphagnum decomposition and Sphagnum ion exchange processes. Some natural pH variations are expected from variations in the input of terrestrially derived cations (Proctor and Maltby, 1998).

Northern peatlands contain 20-30% of all organic carbon (C) and nitrogen (N) in the world's soils (Van Breeman, 1995). The growth of Sphagnum and paludification processes makes bogs important carbon fixing sinks (van Breeman, 1995). It is estimated that peatlands contain 5,000 tonnes of carbon per hectare and absorb carbon from the air at 0.7 tonnes per hectare per year (Moore et al. 2002). Roehm and Roulet (2003) determined that the growing season uptake of carbon dioxide (CO_2) was 113 g/m^2 and the annual net was 76 g/m$^{2.}$ Frolking et al. (2001; 2002) demonstrate that over thousands of years, peatlands have been a persistent sink for CO_2, so while the annual net primary productivity is low the net amount of CO_2 sequestration is very high. Burns Bog is recognized as playing an important role in the sequestration of carbon dioxide in British Columbia.

(B) Hydrology

(1) <u>Role of the Lagg</u>

The role of the lagg in ombrotrophic bogs is complex. The lagg is a transition zone between the raised bog and the surrounding landscape. In the same conceptual manner that the bog isolates itself from the underlying geology by paludification, the lagg isolates the bog from surrounding influences. Vitt et al, (1990) observed that ombrotrophic bogs are surrounded by lagg that is subject to groundwater influence. It is recognized that the lagg may have different forms, but they all isolate the bog from the surrounding area. The lagg serves as [1] a hydrological barrier acting to support the elevated water levels in the bog, [2] as a hydrochemical barrier where bog water and mineral rich waters mix, and the entry of mineral water into the bog is prevented, and [3] a sharp ecological transition from bog species [the interior of bogs have small stunted trees and irregular pools] to mineral dependent species takes place. Mineral dependent plant species occupy the outermost area of the lagg and serve as sinks for cations.

Whitfield et al. (2006) describe the presumed nature of the laggs that once surrounded Burns Bog. The remaining example of lagg in the southwest (SW) corner of Burns Bog is of the levee type. This is formed over hundreds and perhaps thousand of years from the continual interaction of the bog and the annual flooding of the Fraser River. In this lagg, vertical profiles and cores show there are both layers of peat, and layers of sediment as floods deposit sediment on top of bog plants, and bog growth deposits peat on top of sediment. Ultimately, the lagg becomes a natural levee bog transition that increases the hydrological isolation of the bog. The outer levee portion is dominated by vegetation, such as trees, that require minerals. The demand for minerals by this vegetation effectively excludes minerals from the bog and creates a vegetation barrier between the bog and the surrounding area. This outer vegetation of the lagg also acts as a natural barrier to dust transport hence they capture airborne mineral in the outer lagg and prevent them from depositing in the bog.

The Burns Bog Science Advisory Panel is of the opinion that the long term recovery from the existing damage is dependent upon restoration of the lagg surrounding Burns Bog. The small remaining lagg area that exists in the south-west corner is the prototype of the levee type of lagg that needs to be created during bog restoration. Other lagg types that formerly existed either cannot be created [upslope type at eastern margin], or cannot be adequately maintained [beach types that existed on the southern margin]. While reconstruction of levee type lagg was conceived as a solution to lagg restoration for the bog by the SAP, there has been insufficient measurement and study of the processes within this remnant to adequately understand how its structure and function could be adequately duplicated.

(2) <u>Effect of SFPR on the Lagg</u>

The proposed alignment of the South Fraser Perimeter Road would directly impact the remaining fragment of Burns Bog lagg. The alignment would compress and distort the levee portion of the lag and eliminate its hydrological function. The alignment would also eliminate the vegetative buffer that reduces the existing rate of transport of windblown dust into the bog, and increase the amount of dust being transported into the bog. The long-term restoration of the bog depends on reestablishing lagg function along the entire perimeter, and the alignment is expected to result in the loss of the remaining fragment needed to base a realistic model for remediation.

In EC's August 14th letter, the effects described above were discussed in detail. The proponent's response to the August 14th letter indicated that they believe the SW section of Burns Bog was not a functioning lagg, but that rather "it appears to function like lagg even though it is hydrologically isolated from the Bog" (MoT response table, September 21, 2007). This is simply incorrect. Water levels collected on one day in no way addresses any aspect of lagg functions (hydrochemical, hydrological, or ecological); rather their argument was inappropriately based on water levels. Regardless, MoT's suggested mitigation included (1) a refined alignment, including a reduced right of way and additional vegetation and wildlife mitigation; (2) mitigation to address potential effects on hydrology; and (3) finalizing and implementing a mitigation monitoring program to confirm the long term effectiveness of proposed mitigation. No specific details on how item (2) will be addressed have been provided by MoT.

EC has reviewed MoT's suggested mitigation (September 21, 2007) in detail and offers the following assessment:

(1) EC disagrees with MoT's assessment that the SW section of the Bog margin is not functioning lagg. MoT's assessment is based on a one time sampling event taken in March 2006 that simply captured static hydraulic behaviour on one day that is artificially created by the presence of the roadside ditch along the 72nd street corridor. Static water levels observed on one day do not address the complex hydraulic, hydrochemical and ecological process in the transition between the bog and the surrounding areas that take place entirely within the lagg. Damming the 72nd street ditch, as proposed by the SAP, would raise the water level in the ditch so that in the winter the Bog water would cross the gas pipeline corridor and move westward into Crescent Slough, restoring the bog-lagg zone hydrology on a year-round basis. The MoT proposal to place a double ditch parallel to the road within the lagg will contribute to dewatering of the water mound of the bog, disrupt the hydrological and hydrochemical processes that take place within the lagg, and lead to permanent changes in the local ecology. EC refers the reader to the SAP opinion, page 8: "It is imperative that the SFPR does not encroach on the existing lagg because this Crescent Slough-mixed conifer forest zone is the last remaining lagg area of its type in Burns Bog representing what once extended for many kilometers. The SFPR must be shifted west of this Crescent Slough-mixed conifer forest zone".

(2) EC notes that the refined alignment proposed by MoT still directly impinges on the lagg-mixed conifer swamp forest ecosystem of this lagg system. EC advises that the effects of placing the alignment in this location will result in effects (as described above) that will be permanent, irreversible and of a high magnitude in an area identified from an ecological context as being regionally and/or globally distinct.

(3) EC further advises that MoT has not responded directly to the concern about the loss of the remaining fragment of the prototype lagg needed to base a realistic model for remediation of the bog as a whole. Rather, MoT state that to improve the understanding of hydrological conditions in the vicinity of the Bog's edge, they have completed "initial investigations on water movements along the north side where the lagg has been eliminated, and at the south-western side, where the lagg has been altered" (MoT response table, September 21, 2007).

(3) Effect of SFPR on Bog Hydrology

There is an extensive body of knowledge surrounding the general impact of road construction on local hydrology. Roads change many aspects of ecological importance including hydrology

(Trombulak and Frissell, 2000). Ditches and drainage structures have a negative impact on an ombrotrophic bog since reducing water levels removes water from the bog and creates a positive feedback – accelerating the loss of water from the bog (Schouwenaars, 1988ab, 1993; Schouwenaars and Gosen 2007; Price and Schlotzhauer, 1999; Schlotzhauer and Price 1999; Price and Whitehead, 2001; Price et al., 2003).

MoT has proposed engineered lagg pond complexes along the northern edge and southwestern corner of the bog to mitigate potential hydrological impacts. In its letter of August 14th, 2007, EC asserted that:

(1) there was presently no evidence that the multiple functions and attributes of a natural lagg can be replaced by an engineered structure;
(2) it is unknown to what degree such a structure could contribute to maintaining or restoring bog function;
(3) the design and maintenance of a berm/double ditch (BDD) structure remains unresolved at present given the lack of complete engineering drawings and construction plans;
(4) It is not clear what contingencies would exist should the system fail to function as expected; and
(5) The potential impact of aerial deposition of mineral material into the Bog may ultimately override any intended benefits of a BDD system.

MoT's response to EC's August 14th letter attempted to address EC's concerns. Their response included frequent references to berm double-ditches, and plan views showing lagg pools. However, there are no specific designs that demonstrate mechanisms for maintaining of bog water, or "lagg" pool water levels. The SAP identified that these potential hydrologic remediation measures [Hebda and Jeglum] would have to be maintained within fine tolerance [1 cm]. Such engineered pools, without planned water level control structures would simply drain water from the bog. The original concept provided to Gateway by the SAP was to create pools where the water level could be managed within the fine tolerances needed to enhance Sphagnum regrowth and lead to peat deposition. EC would have expected since this is a key element to bog restoration and for eliminating the hydrological impacts of the road that a more fulsome set of drawings demonstrating how the berm and ponds would be constructed would have been provided. The SAP concept depends on being able to use peat as a construction material and to create peat berms that will support water in pools without drying out. This type of engineering has not been employed in construction previously, never at the scale proposed and has a high likelihood of failure based on existing experience. While it is conceivable that hydrologically sufficient designs could be developed, the impacts of road dust and road spray on the bog cannot be adequately mitigated or adaptively managed.

In response to EC's concerns regarding the efficacy of an engineered structure, MoT has pointed out numerous studies where raised bog restoration efforts have occurred. None of these studies have shown results that would contribute to a high level of confidence in their potential success nor do any of these studies deal with the scale of restoration that is required for Burns Bog.

In response to EC's concerns regarding the lack of detail currently available for review, MoT has acknowledged that the design and maintenance protocols are not finalized (MoT response table, September 21, 2007). MoT further proposes that future development of the BDD concept be an iterative/collaborative process involving EC/BBMPC/BBSAP and other key stakeholders. EC advises that the effects on hydrology would be permanent, irreversible and of a high magnitude in an area identified from an ecological context as being regionally and/or globally distinct. Therefore it is not acceptable from EC's perspective to receive detailed designs after the completion of the environmental assessment process.

EC finds that the concept of engineered components presented by MoT has not been demonstrated to be feasible. Continued degradation of the bog, drainage, and other disturbance of peat may lead to significant off-site water quality problems; oxidation and drying out may lead to release of sulphate and acidity into the drainage waters (Proctor and Maltby, 1998). Water levels cannot be maintained by additional double ditches proposed to replace natural hydrological and hydrochemical processes.

In response to EC's concerns regarding contingencies, MoT has stated that it will include redundancies such as additional drainage and control structures supported by an intensive monitoring program. During the review process, the SAP and Environment Canada have clearly demonstrated that additional drainage structures will have a negative impact on the hydrology of the Bog, and there is no possibility for these impacts to be adaptively managed. A monitoring program is not mitigative in these circumstances as these impacts on Burns Bog are not reversible.

MoT's proposal, in their letter dated Sept.21 to EC, states that "MoT is committed to contributing significant financial resources to support the implementation of the Burns Bog Ecological Conservancy Area Management Plan." As we noted earlier, the published peer reviewed science clearly indicates that the impacts of the roadway will be sufficiently severe that the restoration of the bog hydrology, and the restoration of lagg functions identified in the management plan – Return Burns Bog to an ecological condition shaped by raised bog processes, buffered from disruptive or disturbing adjacent processes on the landscape, within a timeframe of 100 years – will not be attainable. Therefore, EC does not consider MoT's commitment for additional funding to be an effective means to address the hydrologic impacts, particularly on the lagg, of the proposed roadway.

(4) <u>Conclusion</u>

The proposed construction of the road will negatively impact the hydrology of the bog by failing to address drainage issues. EC is of the opinion that the proposed alignment route of the South Fraser Perimeter Road would directly impact the remaining fragment of Burns Bog lagg in the southwest corner. The alignment would compress and distort the levee portion of the lag and eliminate its hydrological function. The long-term restoration of the bog depends on recreation of lagg function along the entire perimeter, and South Fraser Perimeter Road will cause the loss of the remaining fragment of the prototype lagg needed to base a realistic model for remediation.

MoT asserts that the bog has a demonstrative resilience by its ability to continue to function, albeit at reduced capacity and with affected hydrological characteristics, and with natural lagg conditions mostly or entirely absent. EC strongly disagrees with this assessment. The Burns Bog Management Plan and the existing body of Burns Bog specific literature indicates that without restorative interventions the state of Burns Bog will continue to decline. It is inappropriate to look at the bog as a static object and to suggest that the current status is acceptable, that the Bog could accept additional impacts, without reflecting the existing rate of decline in bog function. The average position of the water table in the acrotelm of the most unaffected portion of the bog is about 25 cm lower than it was in the 1930s (Hebda et al., 2000). Further, none of the natural drainage channels and little of the lagg remain. The resulting loss of water storage in the past few decades have contributed to the degradation of the bog. To ensure the Bog's long term viability, substantial restoration of hydrologic function is required.

Any further disruption to the ecological integrity of Burns Bog poses a high risk to its long term viability.

Given the permanent, irreversible and of a high magnitude of these effects, in an area identified from an ecological context as being regionally and/or globally distinct, EC considers the effects of the Project on hydrology to be significant.

(C) Aerial Deposition

In response to EC's concerns regarding the potential impact of aerial deposition, MoT states that "there is very little particulate matter that is generated from a well managed highway system" and suggests the installation of vegetated barriers where possible to further mitigate the "anticipated minimal effects of aerial deposition of mineral material or aerial spray into the bog" (MoT response table, September 21, 2007). EC strongly disagrees with this response and will address the issue of aerial deposition in this section.

(1) Effect of Calcium Deposition

Ombrotrophic bogs are expected to be particularly sensitive to airborne pollutants because they receive all their solutes from atmospheric sources (Proctor and Maltby, 1998). Road dust affects photosynthesis, respiration, transpiration and pollutant transport within plants (Farmer, 1993). Dusts are particles small enough to be carried by wind and are produced by cars and road surfaces. Dusts from road surfaces and concrete are highly alkaline and have high calcium levels. Bryophytes [mosses, liverworts and hornworts] readily trap dust on their surfaces. Spellerberg (1998) reviewed original research and found that the hydrologic and ecological impacts of roads started during construction and persisted long term. These included changes in hydrology, in edge habitats; in physical disturbances extending laterally, and in plant mortality extending from road edge for varying distances. Farmer (1993) identified the most sensitive ecosystems are those dominated by Sphagnum which show decreased photosynthesis rates and fixing of carbon; these changes were detectable where deposition was as low as 0.07 g/m2/day. Sphagnum was increasingly replaced by minerotrophic species. This is so because they are completely intolerant of elevated pH and calcium ions – precisely the conditions that result from the deposition of calcareous particulates (Farmer, 2002).

A series of studies have examined the impacts of a gravel highway on Sphagnum in Alaska. While dust emissions on a gravel road are in excess of what would be expected from a paved highway, the ecological impacts remain a product of the introduction of excess calcium into Sphagnum communities. Spatt and Miller (1981) observed that while dustfall from unpaved road was greatest near the road, it is spread away from the road, and heavy dust accumulation was recognized as a factor affecting Sphagnum health and vitality. At 50m from the road Ca^{+2} concentrations were outside of the optimum range for Sphagnum. Walker and Everett (1987) found decreases in Sphagnum and other acidophilous mosses occurred near the road; and this was coupled with an increase in minerotrophic species. Walker and Everett (1987) identified that the areas with the highest susceptibility to dust impacts were ombrotrophic peat bogs. Some impacts were observed in the first two years following road construction while other impacts require long-term study. Longer term studies confirm those impacts. Moorhead et al.(1996) found that the activities of extracellular enzyme activities were inversely proportional to dust loading from the Dalton Highway, Alaska [gravel]. Reductions were 88% endocellulase, 74% exocellulase, and 45% phosphatase of enzyme activities at 500 m from the road. These impacts occurred with dust loadings of only 0.03-0.6 kg/ha/day. [0.3 - 6.0 mg/m^2/day]. Auerbach et al.(1997) found that effects on vegetation of roadside disturbance from 15 years operation was more pronounced in acidic Sphagnum tundra. At undisturbed sites pH was 4.0 while near to the road 7.3. In the acidic low arctic tussock tundra, the dominant Sphagnum mosses were virtually eliminated, due to higher pH. While road and dust disturbance affected all tundra, acidic tundra is particularly vulnerable. In another study of Alaskan Tussock tundra, Myers-Smith et al.(2006) found that the bog had a pH of 4.0 in 1987; 5.5 in 1989; 6.0 by 2002; these changes were accompanied by an increased graminoid [grasses] biomass and a large decline (130 g/m^2) in moss biomass. They concluded that there was a significant impact on a 200m wide corridor adjacent to the unpaved highway. Meininger and Spatt (1988) argue that since dust can negatively impact on Sphagnum and the tardigrades [water bears] that inhabit Sphagnum environments then it is likely that the potential impacts upon lower trophic levels have been inadequately addressed. Similar results have been reported by Forbes (1992, 1993, 1994, 1997,)

Polluting substances are spread as a consequence of the construction and use of roads. Source oriented mitigation measures have more effect that runoff measures (Van Bohemen and Janssen van de Laak, 2003). Conko et al.(2004) demonstrate that urban road dust is a significant source of mineral material and trace elements to the local environment and cold weather concentrations are more than double those of warm weather. The continual resuspension of road dust by high-volume traffic facilitates local dispersion of the salts. This resuspension by vehicles occurs under both dry and wet conditions. When the roads are dry a certain amount of mass of dust (or its constituents) per cubic meter of air in the vicinity of the road is produced. When the road is wet this process may also occur but it is also important to consider the amount of dust contained in the liquid spray, in mg/l of water, that is injected into the air off the road from the passing vehicles. In this case, the spray droplets likely tend to be larger than the dry dust particles, which may impact their rate of deposition. Clearly, in the case of both dry and spray the highest deposition is in the immediate vicinity of the road, but the level of deposition remains significantly above background for several hundred meters (Van Bohemen and Janssen van de Laak, 2003). Road spray is a much more important contamination route than direct runoff; 57-83% of the dust moves from the road through road dust/spray, and they report that it can be as high as 90% (Van Bohemen and Janssen van de Laak, 2003). Plantings of trees and noise screens restrict the pollution to the immediate vicinity (Van Bohemen and Janssen van de Laak, 2003). However, planting trees in windrows along the margins of bogs results in the dewatering of the catotelm and generates hydrological and hydrochemical effects described previously.

There is considerable literature on the generation of road dust, and road spray, but much of the literature deals with the generation of pollutants directly from the fleet of vehicles, as opposed to the transport of dust from the road. Table 1 (section 7.0, Bibliography and References) lists measurements of road dust generation as concentrations or as emission rates. In either case, the literature indicates that quantities of road dust are quite large in terms of supply (Nicholson, 1988). Resuspension is a function of vehicle size, speed and the number of vehicles (Sehmel, 1973; Nicholson and Branson, 1990). Road maintenance is also an important factor particularly given that the production of road dust is strongly seasonal, predominantly in road spray and enhanced by road cleaning and sweeping. Given that calcium is the 5th most abundant element in crustal materials, an average concentration is 41500 mg/kg could be used to estimate how little dust will be needed to negatively impact Sphagnum ecosystems.

The area over which the road dust/road spray deposits will depend on many aspects that are well reported in the literature and in some instances are summarized in Table 2 (section 7.0, Bibliography and References). Dispersion modelling from a linear feature (“line source”) such as a road, which is needed to calculate average concentrations of dust or spray as a function of distance from the road, is non-trivial. Modelling the dispersion within the bottom of the atmosphere involves complex turbulence and boundary conditions and the different physics of dry particles and road spray. At present, observations are more directly relevant than estimates from models. In most of the published literature, authors detected materials generated at a road way as far as the maximum distance they measured. As an example, Bäckström et al., (2003) demonstrated the lateral transport of trace metals and base cations, including calcium, from roadways in Sweden. Road salt was used on both these roadways. Figure 1 demonstrates that road spray travels large distances laterally from the road surface. In the more heavily travelled route (Norsholm) calcium concentration are never less that 8 mg/l.

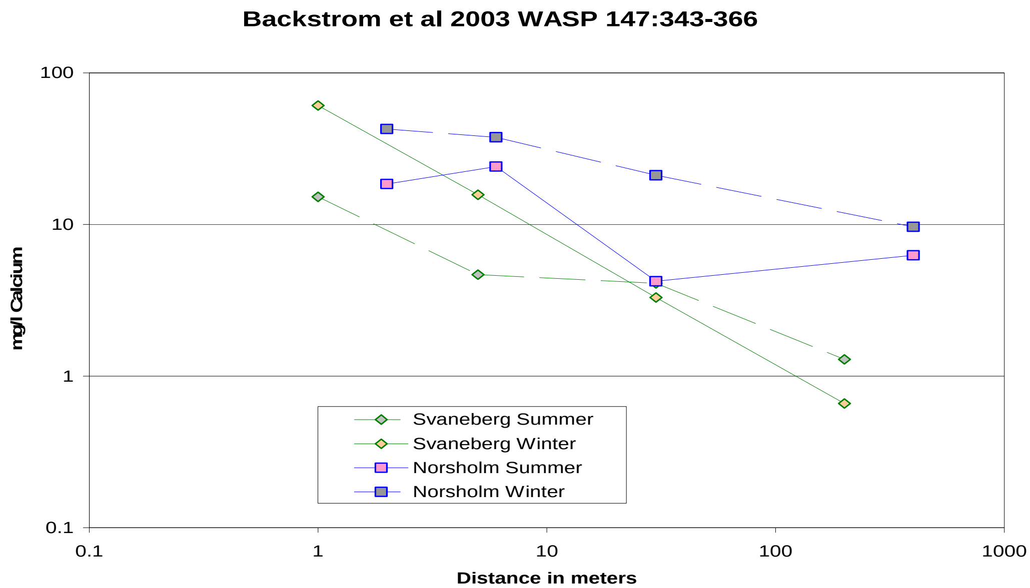

Figure 1. Calcium concentrations in road spray lateral to two highway locations in Sweden; Svaneberg is a more lightly travelled rural area, and Norsholm is a more heavily travelled urban route. Note that both axes use log scales.

Mineral material has accumulated on the forest floor of Burns Bog more than 1100 meters from Highway 91 (Hamish Kimmins, personal communication). This road has been in operation for more than 20 years and this type of material may have been generated during construction or from the period of operation. In addition, the forest growth observed in this area is minerotrophic and the forest may have arisen because water levels were decreased, or the water levels were decreased because there was sufficient mineral material to support tree growth, or there may be sufficient forest to trap this mineral material. Other surveys have revealed that the area of Burns Bog along highway 91 has been reported to have Type 2 water (Hebda *et al*., 2000). Bog water is referred to as Type 1, mineral rich water as Type 3 and the mixture in the lagg as Type 2. A broad area of the eastern zone of Burns Bog has “Type 2” water despite being within the water mound, and not within the lagg. This suggests that the water type is not the product of mixing of Types 1 and 3 but *in situ* generated Type 2 water likely from the continued deposition of mineral material from road dust and road spray. As mentioned above, the area of the bog which will be affected will depend on the dispersion of road dust and road spray away from the road.

Dispersion depends upon meteorological conditions and the nature of the road dust/road spray that will be encountered (i.e., the distribution of particle sizes in this dust/spray). The dispersion of road dust/road spray can be modeled using dispersion models (that also need to account for gravitational settling effects on particulates resuspended from the ground surface) and quantities deposited can be estimated provided we know the resuspension rates for road dust/road spray at the surface to use as a boundary condition for the atmospheric transport models. The predictions from these models are only as good as the accuracy of the resuspension rate provided for the road dust/road spray mixture. From this information, one can calculate surface deposition of resuspended road dust/road spray as a function of distance from the point of resuspension. Using this approach, the critical loading of calcium was calculated based upon a concentration of 0.5 mg/L of Ca^{2+} as the maximum concentration of calcium tolerable by *Sphagnum* (Vitt and Slack, 1984) and an average Vancouver rainfall of 1117 mm. From these we can determine a critical loading of 558.5 mg/year. A background loading of 62.6 mg/yr was used based on an average concentration of calcium in rainfall in Vancouver of 0.056 mg/l.

Table 3. Areas of Burns Bog potentially subjected to increased dry dust and spray deposition from South Fraser Perimeter Road

Dispersion Distance (meters)	Area Affected (ha)	Amount of Burns Bog affected[1]	Basis	Reference
100	65	3.2%	Lead observable in soil	Deroanne-Bauvin *et al.*1987
250	140	6.9%	200 meters considered unaffected	Santelmann and Gorham 1988
500	290	14.3%	Plant damage from road salt observed	Spellerberg and Morison 1998 Beckerman *et al.*2007
1000	650	32.0%	Tundra studies; personal observations[2]	Myers-Smith *et al.*2006; Gillies *et al.*2005

[1]uses the Burns Bog 'ecological boundary' Hebda *et al.*2000.
[2] Hamish Kimmins, personal communication

The impact of calcium on *Sphagnum* from the existence of the road depends on the availability of road dust, the number of vehicles travelling on the road and the area over which it is dispersed, all of which are not known. Consequently, one approach to gain insight and to bound the problem is to evaluate these unknowns for a series of realistic scenarios. Scenarios were calculated for the areas in Table 3; daily vehicle traffic of 10000, 20000, and 45000; and dust emission rates of 0.1 g/km/v, 1.0, 10, 3.0 and 5.9. The later two numbers are the range reported by Etyemezian *et al.*(2003) for summer and winter for high speed and low speed roads in the United States and apply to highways in temperate areas. We have assumed that only one-half of the resuspended material will land in the bog. These figures also assume that there is no road salt application; obviously if $CaCl_2$ is used for snow/ice removal the loading would be higher. They also assume that all of the resuspended dust deposits uniformly within the various dispersion distances considered. The results from these scenarios are shown in Figure 2. Only the lowest volumes of traffic, the lowest emissions of dust, and the widest dispersion areas have loadings below the threshold loading. Both the initial traffic loading (20,000 vehicles per day), and the 2013 traffic levels (45,000) shown in the heavy lines greatly exceed the threshold loading. Our estimates, based upon information reported in the scientific literature and simple assumptions, consider only the impact of calcium and none of the other hazardous compounds that are in the dust.

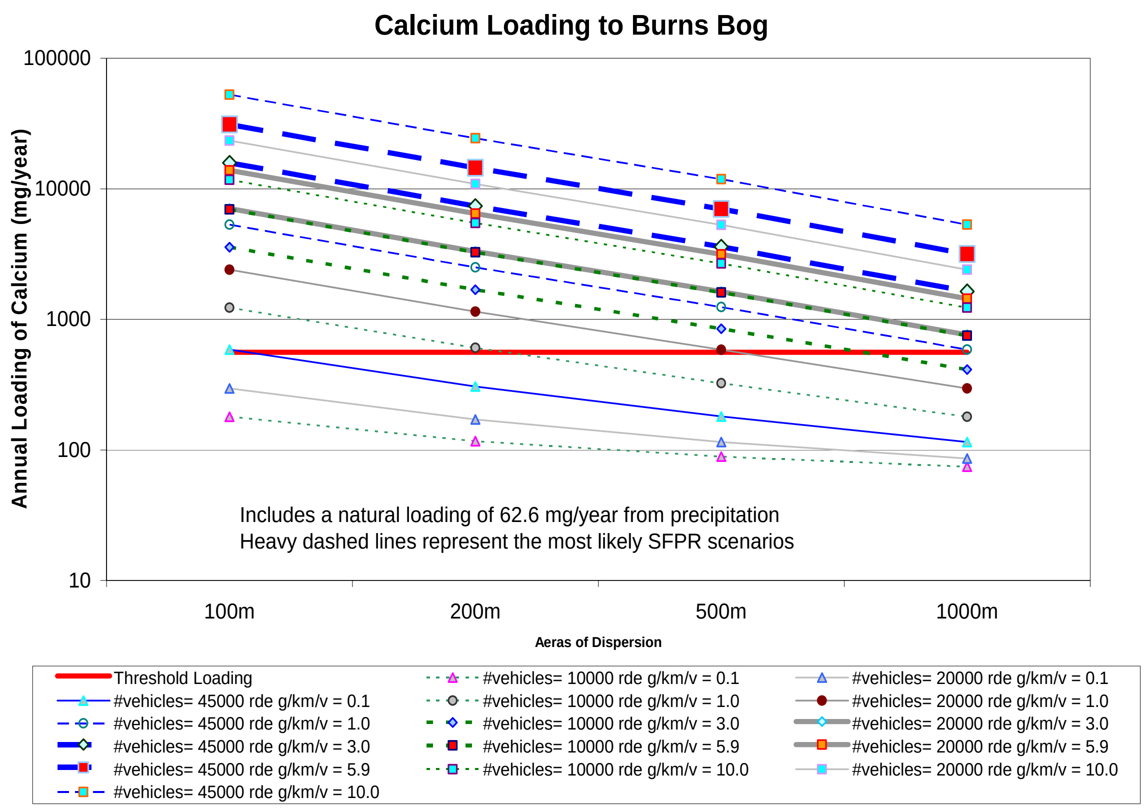

Figure 2. Scenario based calcium loadings to Burns Bog under different availability of road dust [symbols], levels of traffic [line type] and, dispersion area, expressed as distance from the road in meters. Heavy solid lines indicate this expected initial condition, and the heavy dash line the situation in 2031.

In Figure 2, the solid red horizontal line entitled 'Threshold Loading' represents the calcium loading level that will exclude Sphagnum from the ecosystem. As discussed above, the threshold loading value was calculated using a concentration of 0.5 mg/L of Ca^{2+}, based upon the maximum concentration of calcium tolerable by *Sphagnum* (Vitt and Slack, 1984), and an average Vancouver rainfall of 1117 mm. The two heavy dashed lines in Figure 2 indicate anticipated future SFPR scenarios, using #vehicles numbers provided by Gateway (Project Background) and realistic dust emission rates (Etyemezian *et al*., 2003). **Clearly, the anticipated SFPR scenarios far exceed the threshold loading level. In other words, even at 1000m away from the SFPR alignment, calcium loading values are predicted to be unsafe for the Burns Bog ecosystem.**

Trombulak and Frissell (2000) showed that roads change many aspects of ecological importance including adding dust and heavy metals to roadside environments. Studies show exponential decline away from the road; elevated levels of heavy metals often occur 200m or more from the road. Few of the experts building roads or ‘restoring’ them are trained to recognize and address the full spectrum of ecological issues that have been identified. Trombulak and Frissell (2000) offer the broad view of the ecological effects of roads reveals a multiplicity of effects; it also suggests that it is unlikely that the consequences of roads will ever be completely mitigated or remediated.

(2) <u>Effect of Acid [Nutrient] Deposition</u>

Another impact on ombrotrophic bogs comes from nutrients in acid deposition. Such deposition comes from industrial air pollution [SO_4^{2-}] and from automobile exhaust [NO_2^{2-}] (Blancher and McNicol, 1987). Rochefort *et al.*(1990) demonstrated in a boreal bog that while acidification caused an initial stimulation of growth of *Sphagnum*, after 4 years the growth declined or ceased completely. Bobbink and Lamers (2002) demonstrated that an increased N deposition causes a decline in the original bog *Sphagnum* vegetation, together with an increase in more N dependent species. Bragazza *et al.*(2004) estimated a critical load of N of 1 g/m2/year, above which *Sphagnum* communities would change to plants that are co-limited by potassium (K) and phosphorus (P). Bubier *et al*. (2007) fertilized bog with 6 treatments of N and K. In the initial 5-6 years *Sphagnum* species were lost first, followed by other mosses and an increase in vascular plants. In natural ombrotrophic bog ecosystems few vascular plants can compete with *Sphagnum*.

(3) <u>Assessment of Aerial Deposition Effects on Burns Bog</u>

MoT has proposed the installation of vegetated barriers where possible to mitigate the effects of aerial deposition of mineral material or aerial spray into the bog. In its letter of August 14th, 2007, EC asserted that:

(1) measureable impacts from aerial deposition on plant communities and soil communities are anticipated at least 200-300 metres away from the proposed SFPR alignment;
(2) the evidence of impact along Highway 91 indicates that local negative effects are both detectable and considerable; and
(3) aerial deposition of mineral material will subsequently promote the development of a wide margin of forest, which would contribute to dewatering of the acrotelm and ultimately threaten the viability of the Bog.

MoT’s response to EC’s August 14th letter states that: (1) MoT anticipates minimal effects from aerial deposition of mineral material or aerial spray into the bog; (2) MoT suggests that the volume of road dust associated with highway operation is insignificant relative to that from atmospheric deposition of PM material in the regional watershed; and (3) MoT suggests there is no evidence to support EC’s assertion that vegetation changes in the vicinity of Highway 91 are related to aerial deposition of mineral soils. Such opinions are clearly not supported by the scientific literature, nor by observations that have been made in the vicinity of Highway 91.

Further mitigation measures suggested by MoT in their September 21, 2007 response include:

(1) vegetated barriers where possible;
(2) intensive monitoring and mitigation of construction related dust emissions adjacent to the Bog;
(3) a pre-construction assessment of the effects of Highway 91 on Burns Bog; and
(4) Monitoring of particulate matter deposition during construction with established exceedance thresholds.

EC stresses that the likelihood of MoT's mitigation measures being effective in reducing the predicted effects is improbable.

(1) vegetated barriers where possible. This is not an acceptable solution and the type of vegetation needed would be of insufficient height to prevent the aerial transport of mineral materials. The vegetation itself would itself negatively impact on the bogs water budget.

(2) intensive monitoring and mitigation of construction related dust emissions adjacent to the Bog; Monitoring is not part of a solution when no adaptive management options exist.

(3) a pre-construction assessment of the effects of Highway 91 on Burns Bog. Such a study would confirm the existing observations and provide additional information that is expected to confirm the existing science.

(4) monitoring of particulate matter deposition during construction with established exceedance thresholds. These thresholds have not been identified. In this case too, monitoring is not part of a solution when no adaptive management options exist.

Ultimately, EC concludes that the aerial deposition impacts associated with the proposed SFPR alignment will result in certain, permanent, irreversible impacts of a high magnitude. This impact alone will lead to the extirpation of *Sphagnum* and the loss of the existing Burns Bog ecosystem.

(4) Conclusion

EC advises that the effects associated with building a road adjacent to Burns Bog will result in certain, permanent, irreversible impacts of a high magnitude that EC considers to be significant. The ombrotrophic ecosystem of Burns Bog will not tolerate the input of road dust and road spray. Both road dust and road spray transport into the bog would be greatly increased by the construction and operation of the road. The peer-reviewed scientific literature clearly indicates the range of ecological impacts of roads and the impacts of road generated mineral material on *Sphagnum* and in particular ombrotrophic bogs. EC has found no scientific evidence that a road can be constructed adjacent to the bog that will not contribute to the degradation of the *Sphagnum* ecosystem of Burns Bog.

The amount of additional mineral material one would expect to be introduced into the bog from the construction and operation of SFPR, using both the evidence of mineral material dispersion from the construction and operation of Highway 91, and the peer-reviewed literature on the topic of road dust dispersal, would eliminate species of *Sphagnum* from predominance of the ecosystem. This would contribute to the conversion of the bog to forest and create a positive feedback with respect to negatively reducing Burns Bog water levels. The existence of the *Sphagnum* community within the bog is critical to the persistence of the ombrotrophic bog ecosystem, which both the Conservation Covenant and the Burns Bog Ecological Conservancy Area Management Plan seek to protect and restore.

4. Cumulative Effects

EC's August 14, 2007 submission raised concerns regarding MoT's Project Cumulative Effects Assessment (CEA), as it relates to the wildlife Valued Ecosystem Components (VECs). MoT provided its responses to these concerns on September 21, 2007. EC subsequently met with MoT on October 9, 2007, to discuss wildlife issues, including those related to assessing cumulative effects.

MoT contends that the effects of past and present projects and activities are so large or confounding as to render the incremental contribution of the SFPR to these effects as negligible. EC's view is that the effects of the Project will not be small in comparison to current conditions, but rather will have a proportionally more damaging impact in ecologically sensitive areas such as Burns Bog. As a consequence, EC and MoT have reached different conclusions regarding both the stand alone and cumulative contributions of the SFPR Project upon certain VECs.

In EC's analysis, the Project will likely result in residual adverse effects after mitigation for the following VECs:

1. Pacific Water Shrew (PWS);
2. Barn Owl;
3. Hydrology; and,
4. Ecological Integrity of Burns Bog (Ecological integrity of the bog was not identified as a VEC, *per se*, during the review. EC has, however, identified that the Project will likely result in significant adverse effects for the ecological integrity of the bog.)

EC predicts that the direct negative effects of the Project upon the PWS, bog hydrology, and ecological integrity of the bog will likely result in significant adverse effects. It follows that any Project CEA will also be significant for these VECs. Consequently, the following CEA analysis considers only the single VEC (the Barn Owl) for which, with currently proposed MoT mitigation, the direct negative, residual, effects of the Project will not be significant, but are likely to act cumulatively with the negative effects of past, present and foreseen projects.

EC's primary concern for the Barn Owl (and in consideration of other raptor species – Western Screech Owl and Short-eared Owl – as identified by EC in the review of this VEC) is that the residual negative effects of the Project will likely act cumulatively with existing transportation corridors, including Highway 99, Highway 17, and secondary road networks, such that an increase in Barn Owl-vehicle conflicts will occur. However, EC anticipates that should MoT include SSBs as Barn Owl mitigation, the direct effects of the Project on Barn Owl mortality will likely not result in significant negative effects. Based on MoT's proposed mitigation, supplemented by EC's recommendations, the negative effects of present-day projects when combined with the residual effects of the Project will likely be:

- Medium-to-low magnitude;
- Local in extent;
- Continuous;
- Permanent; and,
- For a species with low resiliency.

EC concludes that, with mitigation measures proposed by MoT, in combination with EC's recommendations, the cumulative effects to Barn Owl arising from SFPR and existing highways will likely be non-significant. However, because the effectiveness of hedgerows, tall fences and sound walls as mitigation measures is unproven, EC advises that a considerable level of uncertainty accompanies this particular conclusion.

5. Ecological Integrity of Burns Bog

Burns Bog is more diverse ecologically than any natural bog in Canada (Warner and Asada, 2006). It supports a complex and highly interdependent ecosystem comprised of insects, amphibians, reptiles, migratory birds, raptors, small to large size mammals and plants. The maintenance of ecological integrity and the preservation of the bog as a healthy and viable ecosystem is a focus of the Burns Bog Management Plan (BBMP) approved by the Greater Vancouver Regional District (GVRD) in May 2007. Consequently, in addition to assessing the effects of South Fraser Perimeter Road (SFPR) on individual species or environmental components, it is important to holistically consider the interaction and combination of the environmental effects of the Project on Burns Bog and the wildlife habitats it supports, i.e., the bog's biodiversity.

Canada is a signatory to The Convention on Biodiversity. According to Article Eight of this Treaty signatories 'shall regulate or manage biological resources important for the conservation of biological diversity whether within or outside protected areas, with a view to ensuring their conservation and sustainable use'. Signatories are to, 'promote the protection of ecosystems, natural habitats and the maintenance of viable populations of species in natural surroundings, ' and, 'rehabilitate and restore degraded ecosystems and promote the recovery of threatened species'.

Vitt *et al*, 1999, as a contribution to the Burns Bog Ecosystem Review, and on behalf of the Delta Fraser Properties Partnership and the British Columbia Environmental Assessment Office, described the global and regional distinctness of Burns Bog in the context of its biodiversity values. Vitt et al, 1999, also noted international and national obligations to be considered in the face of public-sector decisions potentially affecting Burns Bog, including:

- North American Waterfowl Management Plan;
- The Ramsar Convention;
- Convention of Biological Diversity; and
- Federal Policy on Wetland Conservation.

These obligations were considered by the government partners when acquiring the Burns Bog lands, and in part they led to the commitments that BC, the GVRD and the Municipality of Delta made in the Conservation Covenant held by the Government of Canada (as represented by Environment Canada).

In Environment Canada's view, the SFPR poses risks to key ecological functions required for the long term viability of Burns Bog. Generally, roads are known to impart various environmental effects that act at different spatial and temporal scales on the local landscape. Forman (1991, 1995) describes corridors, including roads, as potentially exhibiting five primary ecological functions that, depending upon the circumstances, can act in a positive or negative way: barriers, conduits, habitats, sources and sinks. (Refer to wildlife bibliography for more information on the effects of roads on wildlife and wildlife habitat).

The proposed SFPR alignment is expected to impact bog-associated wildlife in two primary ways:

a) The alignment passes through the lagg zone habitat located on the southwest side of the bog that supports a diverse assemblage of wildlife species; and,
b) The alignment along the bog perimeter will affect bog hydrology, which in turn will result in changes to wildlife habitat and consequently to wildlife.

With respect to (a) above, a long-term objective of the BBMP is to restore the lagg required to achieve and maintain fully functioning raised bog processes. The terrestrial habitat associated with the lagg on the southwest side is unique and ecologically sensitive. MoT indicates in its September 21, 2007 response that the proposed refined alignment will result in an 80% reduction in footprint impacts to red-listed plant communities in the lagg zone. The refined alignment nonetheless passes through the agricultural field – riparian forests/shrubland – transitional swamp forest – bog forest complex which Environment Canada has identified as being of regional significance for a variety of wildlife species (refer to Environment Canada's Technical Appendix, dated August 14, 2007, for information on the ecological values associated with this area). The Burns Bog Ecosystem Review also noted the value of this area in terms of restoring hydrological function (for more information, refer to Hebda, R.J., K. Gustavson, K. Golinski and A.M. Calder (2000)).

With respect to (b) above, hydrologic changes and deposition of particulate matter resulting from the Project are predicted to contribute to the advance of woody shrubs and tree growth into the bog. This would in turn result in a re-distribution of wildlife abundance and species diversity found within and along the margins of the bog. Whether these effects will positively or negatively impact wildlife species will depend entirely on each species' habitat requirements and their ability to adapt to a changing environment. For example, in general terms, a reduction in aquatic habitat would likely negatively affect amphibian breeding habitat, while an increase in forest habitat could possibly benefit some landbird species. Regardless, Environment Canada notes that any further encroachment of forest habitat toward the core bog area is counter to the BBMP's long term objective of maintaining such habitat within the lagg zone only.

To address the anticipated negative effects of the Project upon plant and wildlife VECs, MoT has proposed various strategic-level mitigation and compensation measures, and commitments to ensure their implementation. Nevertheless, the residual effects of the Project – that is, those that will remain after mitigation and compensation measures have been applied – are predicted to lead to a further diminishment in the bog's ability to support habitats that in turn support the diverse and rare wildlife populations associated with those habitats today. The more sensitive species are predicted to become less resilient to chronic and/or stochastic environmental effects, such that local declines or even local extirpation is a real possibility in the long-term.

The establishment of Burns Bog as an Ecological Conservancy Areas was intended to protect against further degradation of the bog's fragile ecosystem. Forty percent of the original Burns Bog area has been alienated by agricultural, residential and industrial development. Past activities have disturbed the hydrology and ecological processes of more than half of the remaining bog area and these disturbances continue to affect the bog today (*Burns Bog Ecosystem Review*, *Synthesis Report March 2000*). None of the natural drainage channels and little of the original lagg remains. Loss of water storage capability has contributed to the degradation of bog hydrology with only about 29% of the original surface of the bog's water mound remaining intact (BBMP, April 2007). The average position of the water table in the acrotelm of the most unaffected portion of the bog is about 25 cm lower than it was in the 1930s (Hebda et al., 2000). Several feet of peat have been lost over the last 100 years due to accelerated decomposition caused by lower water table levels (BBMP, April 2007). While the ecological functioning and integrity of the bog has been altered and diminished as a result of historical activities, restoration objectives of the BBMP aim to reverse this trend.

MoT asserts that the bog has a demonstrative resilience as evidenced by its ability to continue to function, albeit at reduced capacity and with affected hydrological characteristics, and with natural lagg conditions mostly or entirely absent. EC does not agree with this assessment. The Burns Bog Management Plan and the existing body of literature specific to Burns Bog indicate that without restorative interventions the health and integrity of Burns Bog will continue to decline. It is inappropriate to look at the bog as a static object and to suggest that the current status is an acceptable baseline, and that the Bog could accept additional impacts. To favor the Bog's long term viability, substantial restoration of hydrologic function is required. Any further disruption to the integrity of the water mound, the peat that encloses it, and the peat-forming plant communities (sphagnum mosses) increases the risk to the long term viability of the bog.

Based on the above, Environment Canada is of the opinion that the Project will significantly compromise the ecological processes that are fundamental to the long term viability and integrity of Burns Bog.

6. Summary

Environment Canada's comments as documented in this submission focus on environmental effects of the SFPR Project on those matters of greatest concern to Environment Canada pursuant to the Department's mandate and its role in the conservation and restoration of Burns Bog. Environment Canada acknowledges the changes that MoT has made to the Project with additional wildlife mitigation measures and a westward shift of the alignment along the southwest corner of Burns Bog. Despite these proposed improvements, Environment Canada has concluded that the changes are not sufficient to alleviate its concerns related to the impacts of the Project on Pacific Water Shrew (PWS), hydrology, aerial deposition, and ecological integrity of Burns Bog. Environment Canada has offered a number of recommendations regarding next steps to address direct project effects on wildlife and plant species of concern. However, these recommendations will not address outstanding concerns regarding changes to bog hydrology and water chemistry that are predicted to negatively affect the long-term viability and ecological integrity of the bog.

The Pacific Water Shrew (PWS), listed as Threatened on Schedule I of the *Species at Risk Act* (SARA), and the Streambank Lupine, listed as Endangered on Schedule I of SARA, are known to occur within the Project area. Impacts of the Project on PWS habitat, habitat effectiveness and population dispersion are expected to result in significant adverse effects. Environment Canada recommends that MoT consult the PWS and Streambank Lupine Recovery Teams for specific advice on the Project's effects on the potential for recovery of these species. Environment Canada further recommends that MoT commit to participating on the Recovery Team or in SARA action planning to address recovery efforts for PWS.

The Project poses a potential high risk to Barn Owls, waterfowl, landbirds, Red-legged Frog and the local nesting/staging population of Greater Sandhill Crane, due to habitat loss, reduced habitat effectiveness, impaired dispersal and mortality along the alignment, particularly next to Burns Bog (not all effects apply to all species). Various mitigation and compensation measures proposed by MoT, along with recommendations offered by EC, are expected to reduce significant adverse effects for these species to non-significant. Because the effectiveness of hedgerows, tall fences and sound walls as mitigation measures is unproven, EC advises that a considerable level of uncertainty accompanies this particular recommendation.

Under the Canada/BC Bilateral Agreement on Species at Risk, BC is the lead jurisdiction and CWS is the SARA responsible agency for: PWS, Barn Owl, Red-legged Frog and Streambank Lupine. EC recommends that MoE be consulted as the lead jurisdiction for these species. While the residual effects of increased Barn Owl mortality resulting from SFPR will act cumulatively with impacts of existing nearby highways, EC concludes that, with mitigation measures proposed by MoT in combination with EC's recommendations, the cumulative effects to Barn Owl arising from SFPR in combination with existing highways will likely be non-significant. However, because the effectiveness of hedgerows, tall fences and sound walls as mitigation measures is unproven, EC advises that a considerable level of uncertainty accompanies this particular recommendation.

EC has not seen evidence that the proposed berm double-ditches and lagg pools will be effective in preventing adverse effects on the hydrology of Burns Bog. Further, EC is of the opinion that the proposed SFPR alignment is likely to directly impact the remaining fragment of lagg in the southwest corner of Burns Bog and eliminate its hydrological function. The long-term restoration of the bog depends on recreation of lagg function along the entire perimeter, and SFPR is expected to result in the loss of the remaining fragment of the prototype lagg needed to base a realistic model for remediation.

Based on estimates of calcium loadings to Burns Bog resulting from various scenarios for dry dust and spray deposition, the additional deposition of mineral material predicted from the operation of SFPR is expected to exceed safe levels for Sphagnum. The existence of the Sphagnum plant community within the bog is critical to the persistence of the ombrotrophic bog ecosystem, which both the Conservation Covenant and the Burns Bog Ecological Conservancy Area Management Plan seek to protect and restore.

EC concludes that the hydrological and mineral deposition effects associated with constructing and operating the proposed roadway adjacent to Burns Bog will negatively reduce water levels and contribute to degradation of the Sphagnum ecosystem and conversion of the bog to forest.

Forty percent of the original Burns Bog area has been alienated by agricultural, residential and industrial development. Past activities have disturbed the hydrology and ecological processes of more than half of the remaining bog area and these disturbances continue to affect the bog today (Burns Bog Ecosystem Review, Synthesis Report, March 2000). Protecting the long term ecological integrity and viability of Burns Bog requires sustaining and restoring the sensitive balance and interactions between the hydrological, hydrochemical and vegetative processes that support a raised-bog ecosystem. Any further disruption to the ecological integrity of Burns Bog, through changes to bog hydrology, deposition of mineral material or degradation of Sphagnum, poses a high risk to the long term viability of an ecosystem which supports important wildlife habitat. Such changes are likely to be significant and irreversible, with ecological effects that cannot be adaptively managed. Environment Canada acknowledges MoT's commitment for additional funding support the implementation of the Burns Bog

Management Plan. However, EC does not consider compensation to be an effective mitigation measure in these circumstances.

Environment Canada concludes that the management objectives for restoration of Burns Bog, to which the Province of BC, GVRD and Corporation of Delta committed to Canada in the Conservation Covenant, and further articulated in the Burns Bog Management Plan, will not be attainable should the Project proceed as proposed.

7. Bibliography, Tables and References

(A) Annotated Bibliography

Impacts of Linear Corridors on Wildlife – Gateway Projects – South Fraser Perimeter Road and Port Mann Highway 1

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IMPACTS

General

According to Forman (2006), the two overarching principles for road development are minimizing roads in an around large natural patches and maximizing effective habitat connectivity between the large natural patches. Sanz et al. (2001) investigated road-related mortality of mid-sized animals in Spain and recommended several design recommendations of new highways including: 1) take into consideration the arrangement of landscape elements (e.g., strips and patches of vegetation, rivers, the position of hills, etc.) as well as topography as both influence the number of deaths and road permeability; 2) isolate the road from the environment in areas shown to have high road-kill rates, paying particular attention to the perimeter fence design. Wildlife passages should be located in these area as well as other structures that encourage road permeability; and 3) apply corrective measures to sections where there is a high incidence of road-kill.

Jaeger and Fahrig (2005) recommend 'bundling' of roads to keep as large areas as possible free from disturbances due to traffic. This can be accomplished by avoiding construction of new roads by upgrading existing roads and placing new roads close and in parallel to existing roads. Population persistence is generally better when all traffic was put on one road, rather than being distributed on several roads across the landscape. Where this is not possible, the recommendation is to bundle roads close together.

In Massachusetts, the road effect zone for wildlife was estimated at 600 m or 300 m from the edge of the road (Forman and Deblinger 2000). The authors concluded that busy roads should be kept well away from nature reserves and similar protected areas and that nature areas near such roads may be impoverished in species sensitive to road and traffic disturbance.

Opening of a new motorway in France resulted in an immediate demographic depletion and effective population isolation (Lode 2000). Animal mortality exponentially increased with traffic volume (Lode 2000).

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Exotic Vegetation

In Eucolypt forests in Australia, exotic vegetation extended 50 m from a two-lane arterial road (Pocock and Lawrence 2005).

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Amphibians

Road density in proximity to ponds had a negative effect on the occupation probability of Moor Frogs. Roads increase the isolation between ponds and contribute to habitat fragmentation. Exchange of individuals on the landscape will decrease due to mortality on roads (Vos and Chardon 1998). In Denmark, Hels and Buchwald (2001) estimated that the probability of an amphibian dying during a road crossing ranged from 0.34 to 0.61 when crossing a road with a traffic load of 3,207 vehicles/per day, and from 0.89 to 0.98 when crossing a highway. In Ontario, Carr and Fahrig (2001) found that for more vagile species such as Leopard Frogs, traffic mortality can cause population declines.

Fahrig et al. (1995) found a negative effect of roads, with a higher proportion of dead frogs and toads on roads with high traffic density and lower abundance of amphibians near intensively used roads. Gibbs (1998) also observed roads as hindering amphibian movement and Puky (2006) reviewed a number of studies related to this issue.

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Birds

In Eucolypt forests in Australia, core habitat boundary for birds was identified at about 900 m from a two-lane arterial road. The average distance avoided by interior-nesting birds ranged from 150-900 m (Pocock and Lawrence 2005).

In open field habitats in the Netherlands, Van der Zande et al. (1980) documented considerable disturbance effects of roads on breeding shorebirds. Distance effects varied from 480 m for a road with 50 cars and 2,000 m for a highway with 54,000 cars per average weekday. Forman et al. (2002) found that for roadways with heavy traffic volumes (i.e., 15,000- 30,000 vehicles per day), bird presence and breeding in adjacent grassland habitats were reduced for 1,200 m from the road. Another study in Holland that investigated the national impact of roads on birds found that for more than 50% of bird species the impacts were negative (Cuperus and Foppen 2004).

In wetland habitats in Finland, the number of breeding wader birds declined considerably due to a two-lane highway resulting in a disturbance distance of 800 m (Hirvonen 2001).

Reijnen et al. (1997) concluded that sound levels above 50 dBA could be considered potentially deleterious, and that the effect distance was estimated to be an average of 1,000m. It should be noted, that this effect is species-specific and that some bird species do not appear to be affected by road-related traffic or noise (Kaseloo 2006).

In Maine, a four-lane highway resulted in lower populations of interior nesting birds such as Bay-breasted Warbler, Blackburnian Warbler, Blue Jay and Winter Wren near the highway, but higher populations of edge species such as Chestnut-sided Warbler, Common Yellowthroat, White-throated Sparrow and American Robin (Ferris 1979).

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Small Mammals

Small mammal mortality on interstate highways was greatest for those species with highest densities in ROW habitat and did not appear to be detrimental to populations of these species (Adams and Geis 1983).

Highways act as a barrier to small mammal dispersal (Yale Conrey and Mills 2001), although if individuals are displaced across the road, they will return home (Kozel and Fleharty 1979). In Montana, Deer Mice were responsible for the vast majority of highway crossings, while only one vole and no chipmunks crossed four-lane highways (Yale Conrey and Mills 2001). In the Bow Valley, Clevenger et al. (2003) found that road-kills of small vertebrates tended to occur close to vegetative cover and far from wildlife passages or culverts.

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Large Mammals

Within established home ranges, bobcats in Wisconsin crossed paved roads less than expected in proportion to their occurrence, while secondary highways, unpaved roads and trails were crossed in proportion to their occurrence (Lovallo and Anderson 1996).

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MITIGATION

Hedgerows

Fruit-bearing hedgerows can result in excessive bird mortality when planted in close proximity to highways. In Virginia, Watts (2000) described high mortality of Cedar Waxwing along a segment of roadway planted with Thorny Elaeagnus (*Elaeagnus pungens*) a fruit-bearing shrub.

Overpasses

Large overpasses are being used in Switzerland to reconnect the landscape in order to increase exchange of populations and reduce wildlife mortality (see Figure 4)(Trocme 2005).

Underpasses

In Banff National Park, McDonald and St. Clair (2004) found that adding overhead cover to crossing structure entrances enhanced the ability of small mammals to move below the trans Canada highway. Clevenger et al. (2003) suggested that metal culverts be installed at frequent intervals along highways to provide opportunities for animals of all body sizes to avoid crossing roads. In Spain, Yanes et al. (1995) found that culverts were widely used by small vertebrates but that various factors such as culvert dimensions, road width, height of boundary fence, the complexity of vegetation along the route, and the presence of detritus pits at the entrance of culverts were important.

Along a new motorway in France, underpasses reduced road-related mortality of dispersing toads and field mice (Lode 2000).

Buffer Zones

In Florida, a buffer zone of 100 m was suggested as minimizing disturbance of activities including automobiles to most species of waterbirds (Rodgers and Smith 1997).

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MONITORING

Findlay and Scott (2000) provided evidence that the full effects of road construction on wetland biodiversity may be undetectable in some taxa for decades. Such lags in response to changes in anthropogenic stress have important implications for land-use planning and environmental impact assessment.

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Ascensao, F. and A. Mira. 2007. Factors affecting culvert use by vertebrates along two stretches of road in southern Portugal. Ecological Research 22(1): 57-66

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REFERENCE LIST

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- Small mammal community structure and density were both influenced by roads
- Several species did not prefer ROW habitat while many other species did
- Small mammal density (all species combined) was generally greater in interstate ROW habitat than in adjacent habitat
- ROW habitat and its accompanying edge are attractive not only to grassland species but other less habitat-specific species
- Mortality on interstate highways was greatest for those species with highest densities in ROW habitat, and did not appear to be detrimental to populations of these species

Alexander, S.M., N.M. Waters and P.C. Paquet. 2005. Traffic volume and highway permeability for a mammalian community in the Canadian Rocky Mountains. The Canadian Geographer/Le Géographe Canadien 49 (4): 321–331.

- How highway traffic volume changed the rates of movement (habitat permeability) for ten mammalian species in the central Canadian Rocky Mountains was examined
- Traffic volume significantly reduced habitat permeability for the community with habitat permeability significantly reduced for carnivores at high traffic volume and for ungulates at very high traffic volume
- Movement was impaired for carnivores when traffic ranged from 300 to 500 vehicles per day (VPD) and for ungulates between 500 and 5,000 VPD
- The TCH requires mitigation to restore habitat permeability for all species

Andrusiak, L. 1994. Nesting and roosting habitat, and breeding biology of the Barn Owl. M.Sc. Thesis, UBC, Vancouver.

- Barn owl mortalities are regularly reported from Fraser Valley highways
- Barn owl are considered to be at risk from vehicle collision from the following south Delta highways and roads: Highway 99, Highway 17, Deltaport Way, Ladner Trunk Road, 72nd Street and to a lesser degree from other secondary and tertiary roads

Ascensao, F. and A. Mira. 2007. Factors affecting culvert use by vertebrates along two stretches of road in southern Portugal. Ecological Research 22(1): 57-66

- The use of 34 culverts from two roads in southern Portugal, differing in traffic volume, vehicle speeds and configuration, was evaluated by the analysis of terrestrial vertebrate footprint data (408 passage-operative days)

- 901 complete crossings (13 taxa), corresponding to an average of 2.2 crossings/ culvert/ operative day were observed. Animal species included reptiles, small mammals, lagomorphs, carnivores and dogs and cats
- Results suggest that fencing might have a funneling effect, directing larger animals toward culverts and that vegetation covering culvert entrances seems to have a positive effect, particularly on genets
- Longer passages with entrances far from the pavement were, apparently, avoided by smaller animals
- Forest-living species favor passages with low, open land cover nearby; and smaller species, like lagomorphs and small mammals, appear to use more culverts near the pavement, which probably reflects the importance of road verges as refuges for these species
- Constructing numerous passages of different sizes which are distributed along roads might be an important step in mitigating road fragmentation effects on animal populations

Ascensao, F. and A. Mira. 2006. Spatial patterns of road kills: a case study in Southern Portugal. *In* Proceedings of the 2005 International Conference on Ecology and Transportation, Eds. Irwin CL, Garrett P, McDermott KP. Center for Transportation and the Environment, North Carolina State University, Raleigh, NC. pp. 641-646.

- A segment of a main road 26-km long was sampled by car at an average speed of 20 km/h every two weeks for two years (54 surveys) between 1995 and 1997, collecting all road-killed specimens found
- A total of 2421 vertebrate road-killed specimens (80 species) were collected, which corresponded to nearly 46 specimens per 0.5 km per year. Eighty non-domestic species were recorded.
- Results suggested that some road sections should receive particular mitigation actions given that mortality hotspots may arise, particularly sections where montado is the dominant habitat and where stream and other water courses run nearby and parallel to the road

Bank, F.G., C.L. Irwin, G.L. Evink, M.E. Gray, S. Hagood, J.R. Kinar, A. Levy, D. Paulson, B. Ruediger, R.M. Sauvajot, D.J. Scott and P. White. 2002. Wildlife habitat connectivity across European highways. Federal Highway Administration, US Department of Transportation. Report No. FHWA-PL-02-011.

- Fencing, including electrical fencing, is used to keep wildlife off highways in Slovenia
- Also in Slovenia, a public demonstration was held to express the need for action for wildlife on a proposed highway project. The result was a viaduct that was constructed for multiple purposes including wildlife, hydrology, and human access
- Switzerland has a long history of science and actions related to wildlife in its transportation and environmental programs
- GIS-based identification of wildlife habitat and corridors has been completed, and bottlenecks and voids have been identified
- Diverse habitats on green bridges were scientifically identified as important to providing connectivity for the broadest spectrum of species
- The Swiss prefer overpasses (green bridges or ecoducts) of varying widths as a preferred structure for maintaining connectivity for many species
- Overpasses with a width of 50 m or greater are used by the widest variety of species

- Legal requirements in Germany necessitate fencing (because many highway stretches do not have speed limits), signing, underpasses, overpasses (green bridges), and land conservation as mitigation for transportation facilities
- Germany has the largest number of overpasses (32) of countries visited. Overpasses vary in width from 8.5 to 870 m. Eight more are under construction and 20 more are planned
- Germany has many mitigation projects along roads where additional barriers to amphibian movement are provided along fences (more than 100 projects)
- The Germans report that 130 bridges over rivers are designed to accommodate wildlife
- France has taken numerous measures to reduce wildlife collisions, and fencing is required on all federal highways
- Experts indicate that reflectors, deer whistles, and signing do little to reduce wildlife mortality. Culverts, underpasses, overpasses and viaducts have been used in France as structural alternatives
- France was the first European country to try hour-glass overpasses with the narrowest point from 8-15 m. France has many overpasses for wildlife with the widest being 800 m
- For amphibian crossings, a plastic fence is attached to the regular fence to guide amphibians to culverts
- In the Netherlands, an extensive system of culverts (600) is provided for badgers, and retrofits are being conducted on others
- The Netherlands also has a 10 pipe-culvert system designed specifically for amphibians that are strategically located to provide for seasonal movements
- Existing bridges and culverts for waterways have also been modified to provide dry passage on wood or earthen shelves along the inside of structures, primarily for small-mammal movement

Bautista, L.M., J.T. Garcia, R.G. Calaestra, C. Palacin, C.A. Martin, M.B. Morales, R. Bonal and J. Vinuela. 2004. Effect of weekend road traffic on the use of space by raptors. Conservation Biology 18(3): 726-732.

- Traffic load near large cities may show dramatic cyclical changes induced by weekend tourism, and this could induce cyclical changes in the activity patterns of wildlife
- A 19-km-long section of a road that crossed a high-use raptor area near a large city in Spain was studied. Eighteen raptor species were observed along this segment of the road, including some threatened species, such as the Spanish Imperial Eagle (*Aquila adalberti*)
- The number of cars increased dramatically on Saturdays and Sundays, so the effect of varying traffic loads on raptor behavior was recorded
- On weekends, the occurrence of Spanish Imperial Eagles and vultures decreased near the road. The occurrence of other species did not change between working days and weekend days
- Weekly cycles in wildlife caused by human activity are a source of concern in conservation biology

Bettinger, K. and R. Milner. 2000. Sandhill Crane *Grus canadensis*. In E.M. Larsen and N. Nordstrom, editors. Management Recommendations for Washington's Priority Species, Volume IV: Birds. Washington Department of Fish and Wildlife.

- The authors recommend an 800 m buffer between new construction of any type and Sandhill Crane foraging habitat

Biggs, W.G. 1976. An ecological and land use study of Burns Bog. M.Sc. Thesis, Simon Fraser University, Burnaby, BC.

- Report provides a collation and review of existing environmental and land-use information on Burns Bog
- Results of basic vegetation and wildlife inventories as well as a habitat map

Bissonette, J.A. 2002. Scaling roads and wildlife: the Cinderella principle. *In* Jagdwiss. Z. Supplement, 208 – 214. USGS Utah Cooperative Fish and Wildlife Research Unit, College of Natural Resources, Utah State University, Logan UT USA.

- Increased permeability of roaded landscapes can only be achieved by up-front planning and subsequent mitigative actions
- Wildlife overpasses and underpasses, often referred to as ecoducts or green bridges, with associated structures to enable larger animals to exit the road right of way, e.g., earthen escape ramps, various culvert designs for smaller animals including badger pipes and amphibian and reptile runnels, and fish ladders are but a small sampling of the structures already in place around the world.
- Attention to the big picture is needed. Landscapes need to be reconnected and made more permeable. Responsible agencies and organizations need to be aggressive about promoting mitigations and a conservation ethic into road planning.

Breault, A.M., B. Harrison and S. Shisko. 2005. Breeding distribution and abundance of Trumpeter Swans in British Columbia, summer 2005. Unpublished Technical Report. Canadian Wildlife Service, Pacific and Yukon Region, British Columbia.

- Distribution and abundance of swans in the delta area is provided

Brehme, C.S. 2003. Responses of small terrestrial vertebrates to roads in a coastal sage scrub ecosystem. M.Sc. Thesis, San Diego State University.

- Excellent thesis on the barrier effects of roads on wildlife
- Even a simple 2-lane rural highway through coastal sage scrub habitat is sufficient to result in substantial road avoidance behaviour r in many species.
- Avoidance of improved roads may be a beneficial response by many species in that increased mortality from vehicular traffic is avoided or minimized. However, matrices of roads throughout the landscape may divide habitat into fragments that are too small to sustain some populations over the long term
- To reduce the effects of habitat fragmentation resulting from this, the availability of corridors or safe-crossing structures are needed
- For those species which cannot or do not avoid roads, the use of barrier fencing along primary and secondary roadsides would be necessary to reduce road mortality and the possibility of species extirpation from the adjacent natural areas

British Columbia Ministry of Environment, Lands and Parks. 1999. Sandhill Crane: small populations and threats to nesting habitat put this species at risk in British Columbia. Wildlife Branch, Ministry of Environment, Lands and Parks, Victoria, B.C. 6 pgs.

Burger, J. and M. Gochfeld. 2001. Effects of human presence on foraging behavior of Sandhill Cranes (*Grus canadensis*) in Nebraska. Bird Behavior 14(2): 81-87.

- 500,000 Sandhill Cranes roost along the Plate River attracting birdwatchers and photographers
- The potential for bird-human encounters and disturbance could reduce feeding time and interfere with the accumulation of fat at this critical migratory stopover site
- The responses of Sandhill Cranes to stopped cars feeding in flocks of various sizes at varying distances from the road were examined
- Sandhill Cranes within 70 m of a road were almost always disturbed by stopped cars while those >300 m from the road usually showed no response
- Over the 6-week stopover period in the Platte River Valley, cranes may deplete food resources far from roads, and switch habitats closer to the road, subjecting them to more frequent disturbance.

Cain, A.T., V.R. Tuovila, D.G. Hewitt and M.E. Tewes. 2003. Effects of a highway and mitigation projects on Bobcats in southern Texas. Biological Conservation 114(2): 189-197.

- The impacts of a 4-lane divided highway on Bobcats (*Lynx rufus*) in southern Texas was studied
- From June 1997 to May 1999, 25 bobcats were found dead on the 32.2 km section of highway. Mortalities were more likely adjacent to habitat preferred by bobcats and in sections of the highway in which thornshrub had been left in the median
- Bobcats used culverts to cross under the highway and for other activities, such as resting. Culvert use was positively related to the openness ratio (width×height/length) of the culvert and to the amount of thornshrub cover adjacent to the culvert
- Sections of fence 100 m long erected to funnel wildlife toward culverts did not increase bobcat use of culverts in an analysis of all culverts, but may have increased use of high-use culverts

Cairo, S.L. and S.M. Zalba. 2007. Effects of a paved road on mortality of Red-bellied Toads (*Melanophryniscus* sp.) in Argentinean grasslands. Amphibia-Reptilia 28(3): 377-385.

- Effects of a road on the mortality and mobility of the toads was studied
- Fifteen individuals were killed by vehicles in the 2003-04 and ten in the 2004-05 reproductive seasons, representing from 2.5 to 5.9% of the population annually
- Only two of the 76 observations of recaptured toads were made on the opposite side of the road
- Roads can be considered as having a significant impact on this species by augmenting mortality, hindering the mobility of the species and increasing habitat isolation

Carr, L.W. and L. Fahrig. 2001. Effect of road traffic on two amphibian species of differing vagility. Conservation Biology 15(4): 1071-1078.

- Leopard Frog population density was negatively affected by traffic density within a radius of 1.5 km
- There was no evidence that the presence of vehicular traffic affected Green Frog populations
- Traffic mortality can cause population declines and more vagile species may be more vulnerable to road-related mortality

Cavallaro, K. Sanden, J. Schellhase, M. Tanaka and F. Davis. 2005. Designing road crossings for safe wildlife passage: Ventura County Guidelines. A Group Project submitted in partial satisfaction of the requirements for the degree of Master's of Environmental Science and Management for the Donald Bren School of Environmental Science and Management.

- Excellent summary paper of crossing design and success with numerous photos

Clark, W.D. and J.R. Karr. 1979. Effects of highways on Red-winged Blackbird and Horned Lark populations. Wilson Bulletin 91(1): 143-145.

- Highways affect abundance of bird species and the effect varies with species, habitat type, season, and distance from the highway
- Future construction projects for highways should consider effects on wildlife, both in the immediate highway right-of-way and in areas at least 500 m from the right-of-way

Clark, B.K., B.S. Clark, L.A. Johnson and M.T. Haynie. 2001. Influence of roads on movements of small mammals. The Southwestern Naturalist 46(3): 338-344.

- Capture-mark-recapture (CMR), fluorescent pigments, and radiotelemetry techniques were used to assess the influence of roads on movements of rodents
- During CMR, only 5 of 53 (9.4%) individuals captured more than once spontaneously crossed roads, whereas 21 of 51 (41.2%) rodents that were displaced across roads when released returned to the side of their original capture
- Only 1 of 54 (1.9%) rodents powdered with fluorescent pigment moved across the road when released at their capture site. In contrast, 7 of 53 (13.2%) displaced and powdered animals crossed the road
- Six of 12 (50%) radiotagged animals were located on both sides of the road on at least 1 occasion; however, >90% of all locations were on the same side as the original capture for all individuals
- Roads were partial barriers to movements of rodents; however, when displaced, animals exhibited a greater likelihood of crossing a road

Clevenger, A.P., B. Chruszcz and K.E. Gunson. 2001. Highway mitigation fencing reduces wildlife-vehicle collisions. Wildlife Society Bulletin 29(2): 646-653.

- Highway mitigation fencing to reduce wildlife-vehicle collisions was studied along 3, 4-lane sections (phase 1, 2, 3A) of the Trans-Canada highway in Banff National Park, Alberta
- Wildlife-vehicle collisions were distributed non-randomly after fencing and were associated with and close to fence ends. Wildlife-vehicle collisions were greatest within 1 km of fence ends, but proximity to major drainages also likely influenced location of collisions
- post-fencing wildlife-vehicle collisions were reduced effectively as ungulate-vehicle collisions declined 80%

Clevenger, A.P., B. Chruszcz and K.E. Gunson. 2001. Drainage culverts as habitat linkages and factors affecting passage by mammals. Journal of Applied Ecology 38(6): 1340-1349.

- Culvert use by small- and medium-sized mammals was investigated along roads in Banff National Park, Alberta, Canada

- Weasels (*Mustela erminea* and *M. frenata*) and Deer Mice (*Peromyscus maniculatus*) used the culverts for passage most frequently, whereas Red Squirrels (*Tamiasciurus hudsonicus*) and Snowshoe Hares (*Lepus americanus*) were the most common small mammals in the study area according to transects sampled near each culvert
- At all scales of resolution (species, species group and community level), traffic volume, noise levels and road width ranked high as significant factors affecting species' use of the culverts. Passage by American Martens (*Martes americana*), Snowshoe Hares and Red Squirrels all increased with traffic volume, the most important variable
- Weasel passage was positively correlated with culvert height but negatively correlated with culvert openness. Martens preferred culverts with low clearance and high openness ratios. High through-culvert visibility was important for snowshoe hares but not for weasels
- The passage by weasels and Snowshoe Hares was positively correlated with the amount of vegetative cover adjacent to culverts
- To maximize connectivity across roads for mammals, future road construction schemes should include frequently spaced culverts of mixed size classes and should have abundant vegetative cover present near culvert entrances

Clevenger, A.P., B. Chruszcz and K.E. Gunson. 2003. Spatial patterns and factors influencing small vertebrate fauna road-kill aggregations. Biological Conservation 109: 15-26.

- Spatial patterns and factors influencing small terrestrial vertebrate road-kill aggregations in the Bow River Valley, Alberta were examined
- Mammal and bird road-kill indices were consistently higher on a low volume parkway than on the high-speed, high volume Trans-Canada highway
- Road-kills tended to occur close to vegetative cover and far from wildlife passages or culverts
- Simple below road passages (e.g., metal culverts) should be installed at frequent intervals (150-300 m) to provide opportunities for animals of all body sizes to avoid crossing roads. Cover should be provided close to passage entrances to enhance animal use

Coffin, A. 2003. Landscape and road network interactions: a proposal to study landscape and road network patterns in the Florida Panhandle. PowerPoint Presentation, Department of Geography, University of Florida, U.S.A. 15 pgs.

Cooper, J.M. 1996. Status of the Sandhill Crane in British Columbia. Ministry of Environment, Lands and Parks, Wildlife Branch, Victoria, B.C. Bulletin No. B-83. 43 pgs.

- Provides detailed information on Sandhill Crane in BC including comments on the lower Fraser Valley population

Cuperus, R. and R. Foppen. 2004. Impacts of highways on Dutch breeding birds: an analysis by applying national bird censuses. *In* Proceedings of the 2003 International Conference on Ecology and Transportation, Eds. Irwin, C.L., P. Garrett and K.P. McDermott. Center for Transportation and the Environment, North Carolina State University, Raleigh, NC: p. 475.

- The project aimed to describe impacts of highways on the population level for a wide variety of breeding birds in the Netherlands
- Of the 125 species for which analyses could be conducted, negative impacts for traffic (e.g., effects on density and/or presence/absence) could be shown for 25-50% of the

species, depending on the analysis. An integration of these results showed that for more than 50% of the species the highway's impact is negative
- The effects are spread over a wide variety of taxonomic groups
- Species of special conservation concern showed larger negative impacts than average
- In 11% of the species, a positive effect was found, mainly for species of (sub)urban and rural habitats

deMaynadier, P.G. and M.L. Hunter, Jr. 2000. Road effects on amphibian movement in a forested landscape. Natural Areas Journal 20(1): 56-65.

- The effects of a wide (12 m), heavily used logging road were compared to those of a narrower (5 m), less used forest track
- Anuran habitat use and movements were unaffected by even the larger road. In contrast, salamander abundance (i.e., *Ambystoma* spp., *Plethodon cinereus*, and *Notopthalmus viridescens*) was 2.3 times higher at forest control sites than at roadside sites
- Captures in roadside traps (road crossings) were only 25.9% of similarly oriented captures in paired forested controls, suggesting that the larger road significantly inhibited movement by salamanders
- Forest roads apparently can serve as a partial filter to the movements of some amphibian species

Donaldson, A. and A. Bennett. 2004. Ecological effects of roads: implications for the internal fragmentation of Australian parks and reserves. Parks Victoria Technical Series No. 12. Parks Victoria, Melbourne.

- Five primary impacts of roads on ecosystem function and biodiversity have been identified by a review of published literature on the ecological effects of roads and road traffic.
- **Roads are a source of habitat alteration -** Roads alter surrounding habitats in numerous ways, consequently influencing the quality and suitability of roadside areas for plants and animals. Increased edge effects, increased levels of disturbance, and greater input of matter and energy are the primary ways that roads alter conditions in adjacent habitats. Potential effects of these impacts on animal populations include local reductions in population density, altered reproduction and mortality rates, and altered movement and dispersal patterns
- **Roads provide conduits for the movement of plants and animals -** Roads serve as a conduit for the movement of plants and animals. Human use of roads has many impacts on surrounding environments, including the spread of human disturbance and hunting pressure, often in otherwise remote areas. Many other organisms also use roads and roadside habitats as movement corridors, including animals inhabiting road verges and associated edge habitats, and predators or scavengers moving along the road itself. The dispersal of weed propagules, and other alien flora, along roads is another way in which roads can act as conduits. The movement of pest species (including weeds, introduced animals such as foxes and Cane Toads along roads in Australia) has been identified as a problem in some areas.
- **Roads act as barriers to the movement of animals, potentially fragmenting and isolating populations and communities -** Roads may form barriers to the movement of animals. This barrier effect results in one of the more significant ecological impacts of roads: the fragmentation and isolation of wildlife populations. Roads may limit the access of animals to vital resources, therefore decreasing the area of available habitat, and may potentially limit the movement and dispersal of individuals, fragmenting populations and

consequently reducing gene flow. The barrier effect of roads on animal movement depends primarily on road width and the intensity of its use. Wide roads with heavy traffic loads have the greatest impact on animal movement

- **Roads cause wildlife mortality -** The mortality of wildlife on roads may act as a significant demographic sink for some populations and species. Many animals are vulnerable to being killed on roads, with the associated impact on populations differing between species. Most species are not adversely affected by the impacts of road mortality, but for some, road mortality can be a significant threat to the survival of populations. To reduce the barrier effect of roads on the movement of animals due to both movement inhibition and increased mortality, structures facilitating animal movement across roads such as culverts and wildlife underpasses have been used. The success of such structures in facilitating animal road crossings is primarily related to their dimensions and location. However, little is known of the benefits of such movements for the overall status of populations divided by roads; movement of few individuals across such structures, for example, may not greatly benefit a population divided by a long stretch of road
- **Roads are a source of biotic and abiotic effects -** The impacts of roads on plants and animals, as well as other components of the environment such as soil and water, are derived both from their structural characteristics and their use and maintenance. Roads are a source of numerous particulate and chemical pollutants and traffic-related disturbance. Water run-off from road surfaces alters the moisture balance of roadside areas, and potentially affects the local hydrology by altering natural flow regimes. Increased sedimentation of road run-off also alters water flow regimes, and reduces the quality of aquatic habitats. Roads and their traffic alter soil properties and structure, the activity of micro and macroinvertebrate soil fauna, and also leaf litter layers. This influences the structure and floristic composition of roadside vegetation communities. The degree to which these effects of roads impact on surrounding environments depends on a number of factors, including road traffic volume and surfacing material, and frequently varies between locations and through time. It is hypothesised that the ecological road effect zone extends for up to 300 m on either side of roads in the USA, and therefore affects a significant area of land, an area substantially larger than that covered by roads themselves

Dooling, R.J. 2006. Estimating effects of highway noise on the avian auditory system. *In* Proceedings of the 2005 International Conference on Ecology and Transportation, Eds. Irwin, C.L., P. Garrett and K.P. McDermott. Center for Transportation and the Environment, North Carolina State University, Raleigh, NC: pp. 30-31.

- The adverse effects of noise on birds can be considered with regard to four potentially overlapping categories
- First, noise might be annoying to birds. This may cause them to abandon a particular site that is otherwise ideal in terms of food availability, breeding opportunities, etc.
- Second, noise which lasts for very long periods of time can be stressful. Such noise levels can raise the level of stress hormones, interfere with sleep and other activities, etc.
- Thirdly, very intense noise (acoustic overexposure) can cause permanent injury to the auditory system
- Finally, noise can interfere with acoustic communication by masking important sounds or sound components

Erickson, W.P., G.D. Johnson and D.P. Young Jr. 2005. A summary and comparison of bird mortality from anthropogenic causes with an emphasis on collisions. USDA Forest Service Gen. Tech. Rep. PSW-GTR-191. Pgs 1029-1042.

- An estimated 500 million to possibly over 1 billion birds are killed annually in the United States due to anthropogenic sources including collisions with human-made structures such as vehicles, buildings and windows, power lines, communication towers, and wind turbines; electrocutions; oil spills and other contaminants; pesticides; cat predation; and commercial fishing by-catch
- A summary of the literature is provided to give the basis for the mortality projections for many of the apparent significant sources.

Fahrig, L., J.H. Pedlar, S.E. Pope, P.D. Taylor and J.F. Wegner. 1995. Effects of road traffic on amphibian density. Biological Conservation 73(3): 177-182.

- The number of dead and live frogs and toads per km decreased with increasing traffic intensity
- The proportion of frogs and toads dead increased with increasing traffic intensity
- The frog and toad density, as measured by the chorus intensity, decreased with increasing traffic intensity.
- Taken together, our results indicate that traffic mortality has a significant negative effect on the local density of anurans and that recent increases in traffic volumes worldwide are probably contributing to declines in amphibian populations

Ferris, C.R. 1979. Effects of Interstate 95 on breeding birds in northern Maine. Journal of Wildlife Management 43(2): 421-427.

- Influence of a highway may be summarized as a trade-off between loss of the breeding population of forest birds from the area within the RoW boundaries and the eventual repopulation of the RoW and median with species more suited to those habitats
- A 50% reduction in bird populations resulted from construction of a 4-lane highway
- Populations of Bay-breasted Warbler, Blackburnian Warbler, Blue Jay and Winter Wren were lower near the highway suggesting that these birds were disturbed by the highway
- Chestnut-sided Warbler, Common Yellowthroat, White-throated Sparrow and American Robin increased in forest areas adjacent to the highway, likely in response to the forest edge habitat created

Findlay, C.S. and J. Bourdages. 2000. Response time of wetland biodiversity to road construction on adjacent lands. Conservation Biology 14(1): 86-94.

- Populations of some susceptible species are expected to decline gradually after road construction, with local extinction occurring sometime later
- The full effect of road construction on wetland biodiversity may be undetectable in some taxa for decades
- Such lags in response have important implications for land-use planning and environmental impact assessment

Findlay, C.S. and J. Houlahan. 1997. Anthropogenic correlates of species richness in southeastern Ontario wetlands. Conservation Biology 11: 1000-1009.

- Amphibian species richness decreased with an increase in the density of paved roads, particularly roads within 2 km of a wetland
- According to their model, a 2m/ha increase in paved road density within 2 km of a wetland will result in a 19% decrease in amphibian species richness within 2 km of the wetland

Forman, R.T.T. 1991. Landscape corridors: from theoretical foundations to public policy. *In* D.A. Saunders and R.J. Hobbs, eds. Nature Conservation 2: the Role of Corridors. Surrey Beatty, Chipping Norton, Australia. Pp. 71-84.

Forman, R.T.T. 1995. Land Mosaics: the Ecology of Landscapes and Regions. Cambridge University Press, Cambridge, UK.

Forman, R.T.T. 2000. Estimate of the area affected ecologically by the road system in the United States. Conservation Biology 14(1): 31-35.

- Approximately 1/5th of the US land area is directly affected ecologically by the system of public roads
- Several transportation planning and policy recommendations, ranging from perforating the road barrier to wildlife crossings to closing certain roads, offer promise for reducing this enormous ecological effect

Forman, R.T.T. 2006. Good and bad places for roads: effects of varying road and natural pattern on habitat loss, degradation and fragmentation. *In* Proceedings of the 2005 International Conference on Ecology and Transportation, Eds. Irwin, C.L., P. Garrett and K.P. McDermott. Center for Transportation and the Environment, North Carolina State University, Raleigh, NC: pp. 164-174.

- Modeling suggests that in a landscape of dispersed natural patches or corridors, the greatest ecological road effect by far results from a highway that bisects or a highway network that subdivides a large natural patch
- A highway network has a greater effect on habitat conditions in a natural landscape than in an agricultural or suburban landscape
- An ecologically optimum road network contains: a few large roadless areas; a few busy roads rather than many lightly used roads; and, perforated roads (for species movement) between the large roadless areas
- The two overarching principles are minimizing roads in and around large natural patches and maximizing effective habitat connectivity between the large natural patches

Forman, R.T.T. and A.M. Hersperger. 1996. Road Ecology and Road Density in different landscapes, with international planning and mitigation solutions. Harvard University, Cambridge, MA 02138 USA.

Forman, R.T.T. and L.E. Alexander. 1998. Roads and their major ecological effects. Annual Review of Ecology and Systematics 29: 201-231.

- Road avoidance, especially due to traffic noise, has a major ecological impact. The still-more-important barrier effect subdivides populations, with demographic and probably genetic consequences
- Roads by wetlands and ponds have the greatest road kill rates
- The greatest transportation impact on amphibians is likely road kills

- Based on road-effect zones, an estimated 15–20% of the United States is ecologically impacted by roads

Forman, R.T.T. and R.D. Deblinger. 2000. The ecological road-effect zone of a Massachusetts (U.S.A.) suburban highway. Conservation Biology 14(1): 36-46.

- Traffic noise was believed to be the critical factor causing reduced bird densities adjacent to roads near Boston, Massuchusetts
- Road avoidance by birds in grassland areas extends for >1km adjacent to a 4-lane highway
- The average width for the road zone effects is 600 m (300 m on either side of the road)
- Density of forest interior species decreased by 33% within 650 m of a 4-lane highway
- Busy roads and nature reserves should be well separated

Forman, R.T.T., B. Reineking and A.M. Hersperger. 2002. Road traffic and nearby grassland bird patterns in a suburbanizing landscape. Environmental Management 29(6): 782-800.

- Grassland bird data (5 years) for 84 open patches near Boston were analyzed relative to: distance from roads with 3000-8000 to > 30,000 vehicles/day; open-habitat patch size' area of quality microhabitat within a patch; adjacent land use' and distance to other open patches
- For moderate traffic (8,000-15,000), there was no effect on bird presence although regular breeding was reduced for 400 m from road
- For traffic of 15,000-30,000 (two-lane highway), both presence and breeding were decreased for 700 m
- For a heavy traffic volume of >30,000 (multi-lane highway), bird presence and breeding were reduced for 1,200 m from a road

Fraser, D.F, W.L. Harper, S.G. Cannings and J.M. Cooper. 1999. Rare birds of British Columbia. Ministry of Environment Lands and Parks and Resources Inventory Branch, Victoria, B.C.

Friesen, L.E., P.F.J. Eagles and R.J. Mackay. 1995. Effects of residential development on forest-dwelling neotropical migrant songbirds. Conservation Biology 9(6): 1408-1414.

- Neotropical migrants consistently increased in number and abundance as forest size increased
- The number of houses surrounding a forest severely undermined its suitability for neotropical migrants
- Neotropical migrants consistently decreased in diversity and abundance as the level of the adjacent development increased, regardless of forest size
- 4 ha woodlots without any nearby houses had on average a richer, more abundant Neotropical community than did 25 ha woodlots
- Threshold distances for housing developments around forests need to be determined to prevent or minimize adverse effects on features and functions within forests

Gebauer, M.B. 1995. Status, reproductive success and habitat requirements of Greater Sandhill Cranes (*Grus canadensis tabida*) in the lower Fraser River delta in 1993 and 1994. B.C. Ministry of Environment, Lands
and Parks, Wildlife Branch, Surrey, BC. 70pp.

- Report summarizes results of an intensive crane monitoring program in Burns Bog in 1993 and 1994
- Cranes were confirmed breeding in the Bog and the importance of fields in the Crescent Slough area for breeding and migratory cranes was identified

Gibbs, J.P. 1998. Amphibian movements in response to forest edges, roads, and streambeds in southern New England. Journal of Wildlife Management 62(2): 584-589.

- Amphibian movements in response to forest edges, roads and streambeds was investigated in southern Connecticut
- Roads appear an important anthropogenic landscape component hindering amphibian movements
- Forest edges associated with open lands were much more permeable to amphibian movements than were road edges
- Landscape-level conservation strategies aimed at amphibians should account for such filters and conduits to amphibian movements

Gibbs, J. and W. Shriver. 2005. Can road mortality limit populations of pool-breeding amphibians? Wetlands Ecology and Management 13(3): 281-289.

- Road maps, traffic volume data, and pool locations were integrated in a modeling study to estimate the potential effects of road mortality on populations of pool-breeding Spotted Salamanders (*Ambystoma maculatum* Shaw)
- Population projections based on Spotted Salamander life tables imply that an annual risk of road mortality for adults of >10% can lead to local population extirpation; mitigation efforts (tunnels, road closures, and other measures) should seek to reduce road mortality rates to below this threshold
- For central and western Massachusetts, it was estimated that salamanders would be exposed to at least this threshold level of risk at 22–73% of populations (assuming a 100 vs. 500 m migration distance, respectively)
- Road mortality can be a significant source of additive mortality for individual spotted salamanders in many parts of the species' range
- Efforts to prevent such mortality by transportation planners are likely warranted strictly on a biological basis in areas with road densities >2.5 km per km^2 of landscape and traffic volumes >250 vehicles/lane/day within the migration range of a breeding population of spotted salamanders

Groot Bruinerink, G.W.T.A and E. Hazebroek. Ungulate traffic collisions in Europe. Conservation Biology 10(4): 1059-1067.

- To reduce the risk of ungulate traffic collisions, a combination of fencing and wildlife passages for roads and railroads that combine high traffic volume with high speed is recommended
- For secondary roads, seasonal application of intermittently lighted warning signs, triggered if possible by the ungulates is recommended.

Gucinski, H., M.J. Furniss, R.R. Ziemer and M.H. Brookes. 2000. Forest roads: a synthesis of scientific information. U.S. Department of Agriculture Forest Service. 117 pgs.

Hawbaker, T.J., V.C. Radeloff, R.B. Hammer and M.K. Clayton. 2005. Road density and landscape pattern in relation to housing density, land ownership, land cover, and soils. Landscape Ecology 20: Pgs. 609–625.

- Both road density and landscape patterns created by roads in relation to suitability of soil substrate as road subgrade, land cover, lake area and perimeter, land ownership, and housing density across 19 predominantly forested counties in northern Wisconsin, USA was investigated
- Landscape indices showed greater fragmentation by roads in areas with higher housing density, and agriculture, grassland, and coniferous forest area, but less fragmentation with higher deciduous forest, mixed forest, wetland, and lake area
- Results are important for understanding the impacts of roads on ecosystems and planning for their protection in the face of continued development

Hels, T. and E. Buchwald. 2001. The effect of road kills on amphibian populations. *In* Proceedings of the 2001 International Conference on Ecology and Transportation, Eds. Irwin, C.L., P. Garrett and K.P. McDermott. Center for Transportation and the Environment, North Carolina State University, Raleigh, NC: pp. 25-42.

- Diurnal movement patterns of six amphibian species in close proximity to roads was studied in Denmark
- The probability of getting killed ranged from 0.34 to 0.61 when crossing a road with a traffic load of 3,207 vehicles/day and from 0.89 to 0.98 when crossing a motorway
- Population sizes were estimated for all ponds within 250 m of highway stretches being studied. Results indicate that 10% of the adult population of Common Spadefoots and Brown Frogs were killed annually at the site

Hirvonen, H. 2001. Impacts of highway construction and traffic on a wetland bird community. *In* Proceedings of the 2001 International Conference on Ecology and Transportation, Eds. Irwin, C.L., P. Garrett and K.P. McDermott. Center for Transportation and the Environment, North Carolina State University, Raleigh, NC: pp. 369-372.

- The two-lane section of highway was constructed through shore pastures in Finland
- After the highway had been opened for traffic, the mean conservation value of the wetland bird community had decreased by 25% as compared to the control area
- Decline in conservation value was due primarily to the loss of several habitat specialists such as European Bittern, Ruff and Little Gull
- Abundance of breeding wader birds also declined in areas near the highway where the traffic noise exceeded 56 dB
- Population abundance of passerine birds did not show a response to disturbance by the highway regardless of noise level
- The effects of traffic noise could to some extent be mitigated by noise barriers

Irwin, H., K. Brooks and S. Andrew. Regional road density analysis using weighted metrics sensitive to landscape conservation effects. Southern Appalachian Forest Coalition, Asheville, NC and Clemson University, Clemson, SC, U.S.A.

- Road density calculated for analysis of wildlife habitat effects and wildland identification is almost always determined with all roads contributing equally. This method ignores the fact that roads in reality have differing spheres of influence and offer different barriers ranging from busy Interstate Highways to Forest Service roads with closed access. These roads have different effects on wildlife based on width, amount of traffic, and engineering (e.g. fencing and concrete barriers)

- In this study road density is calculated based on a weighted road density measure. Weightings allow characterization of the different effects of roads and a modeling of how these effects would be accumulated on the landscape

Jackson, S.D. 2000. Overview of transportation impacts on wildlife movement and populations. Pp. 7-20 In Messmer, T.A. and B. West, (eds) Wildlife and highways: Seeking solutions to an ecological and socio-economic dilemma. The Wildlife Society.

- As long linear features on the landscape, railways, roads and highways have impacts on wildlife and wildlife habitat that are disproportionate to the area of land that they occupy
- highways and railways are sources of road mortality that threaten wildlife populations
- Indirect effects on wildlife include reduced access to habitat due to road avoidance and human exploitation.
- Transportation infrastructure also undermines ecological processes through the fragmentation of wildlife populations, restriction of wildlife movements, and the disruption of gene flow and metapopulation dynamics.
- A variety of techniques have been used to mitigate the impacts of transportation systems on wildlife movements with mixed success. To make progress on these issues wildlife biologists must: 1) recognize the potential long-term effects of highways and railways on wildlife populations and advocate more strongly for appropriate mitigation measures; 2) document the impacts of transportation infrastructure on wildlife populations; 3) conduct landscape analyses to identify ‘connectivity zones’ and use these analyses to engage transportation planners earlier in the planning process; 4) enlist transportation engineers to help solve technical problems; and, 5) design and conduct good monitoring studies to effectively evaluate various mitigation techniques.

Jacobson, S.L. 2005. Mitigation measures for highway-caused impacts to birds. *In* USDA Forest Service General Technical Report PSW-GTR-191. Pgs. 1043-1050.

- Highways cause significant impacts to birds in four ways: direct mortality, indirect mortality, habitat fragmentation, and disturbance. In this paper, solutions from a highway management perspective are presented.
- Suggested solutions include highway crossing structures, diversion poles on bridges or medians, modified right-of-way mowing regimes, road kill removal, appropriate median vegetation, and modified deicing agents.
- Indirect mortalities caused by highway construction or maintenance include habitat loss and decreased quality; predator attraction or bridges to nesting habitat; increased incidence of invasive species; increased associated lethal structures; and, maintenance practices that disrupt reproduction.

Jaeger, J.A.G. and L. Fahrig. 2005. Effects of bundling of roads on population persistence. *In* Proceedings of the 2005 International Conference on Ecology and Transportation, Eds. Irwin, C.L., P. Garrett and K.P. McDermott. Center for Transportation and the Environment, North Carolina State University, Raleigh, NC.

- Roads act as barriers to animal movement, increase wildlife mortality, and reduce the quality and amount of habitat. To minimize these effects roads and traffic should be bundled because it keeps as large areas as possible free from disturbances due to traffic.
- Bundling can be achieved by upgrading existing roads and placing new roads close and in parallel to existing roads
- Population persistence is generally better when all traffic was put on one road than being distributed across the landscape

Jaeger, J.A., L. Fahrig and K.C. Ewald. 2006. Does the configuration of road networks influence the degree to which roads affect wildlife populations? *In* Proceedings of the 2005 International Conference on Ecology and Transportation, Eds. Irwin, C.L., P. Garrett and K.P. McDermott. Center for Transportation and the Environment, North Carolina State University, Raleigh, NC: pp. 151-163.

- Modeling clearly supports the bundling concept. Populations persistence was generally better when all traffic was put on one road than when it was distributed on several roads across the landscape.
- If traffic can not be put on one road, the model suggests it is better to bundle the roads close together than to distribute evenly across the landscape

Kaseloo, P.A. 2006. Synthesis of noise effects on wildlife populations. *In* Proceedings of the 2005 International Conference on Ecology and Transportation, Eds. Irwin, C.L., P. Garrett and K.P. McDermott. Center for Transportation and the Environment, North Carolina State University, Raleigh, NC: pp. 33-35.

- A series of studies have indicated that road noise has a negative effect on bird populations, particularly during breeding, in a variety of species
- These 'effect distances' can extend two to three thousand metres from the road
- Not all species show this response with some species (edge species) increasing in numbers near roads or utilizing rights-of-way

Katti, M. and P.S. Warren. 2004. Tits, noise and urban bioacoustics. TRENDS in Ecology and Evolution 19(3): 109-110.

- Understanding urban bioacoustics and its effects on animal behavior can provide additional insight into why some species are more successful urban dwellers than others

Knight, R.L., H.A.L. Knight and R.J. Camp. 1995. Common Ravens and number and type of linear rights-of-way. Biological Conservation 74: 65-67.

- Common Raven numbers did not increase with increasing road traffic volume and traffic speed
- Raven numbers did increase with increasing number of linear rights-of-way which ran in parallel

Knopp, D.H. 1996. Fraser Valley Amphibian Survey, Ministry of Environment, Lands and Parks, Victoria, BC.

Knopp, D.H. and L.K. Larkin, 1999. Burns Bog and Adjacent Areas. Amphibian and Reptile Study. Report prepared for Delta Fraser Properties Partnership and the Environmental

Assessment Office in support of the Burns Bog Ecosystem Review. BC's Wild Heritage Consultants, Sardis, BC.

Knutson, M.G., J.R. Sauer, D.A. Olsen, M.J. Mossman, L.M. Hemesath and M.J. Lannoo. 1999. Effects of landscape composition and wetland fragmentation on frog and toad abundance and species richness in Iowa and Wisconsin, U.S.A. Conservation Biology 13(6): 1437-1446.

- The most consistent result across all anuran guilds was a negative association with the presence of urban land
- Upland and wetland forests and emergent wetlands tended to be positively associated with anurans
- Roads are a barrier to amphibian movement

Kobylarz, B. 2003. The effect of road type and traffic intensity on amphibian road mortality. Journal of Service Learning in Conservation Biology 1: 10-15.

- The proportion of frog and toad mortalities increased with increased traffic density

Kozel, R.M. and E.D. Fleharty. 1979. Movements of rodents across roads. The Southwestern Naturalist 24(2): 239-248.

- The capture-recapture method was used in west-central Kansas during summer and fall of 1976 to estimate movements of small rodents across roads
- Grids were established on both sides of two gravel roads, a bituminous two-lane highway, and a divided interstate highway
- Rodents, with the exception of ground squirrels, did not cross roads
- When artificially transported across roads, members of five species returned
- Evidently, roads inhibit normal movements of rodents but, once displaced across roads, rodents will home

Krapu, G.L., D.E. Facey, E.K. Fritzell, and D.H. Johnson. 1984. Habitat use by migrant Sandhill Cranes in Nebraska. The Journal of Wildlife Management 48(2): 407-417.

- Cranes roosted in the shallows and on nearby sandbars of about 111 km of river channel. Cranes usually roosted where the channel was at least 150 m wide and avoided stretches narrower than 50 m.
- Height of woody vegetation along shorelines and on islands influenced where cranes roosted when unobstructed channel width was less than 150 m; bridges or roads adjacent to the channel also reduced use by about half.

Kuhn, J. 1987 (as cited in deMaynadier and Hunter 2000). Strassentod der Erdkrote *(Bufo bufo* L.): Verlustquoten nd Verkehrsaufkommen, Verhalten auf der Strasse. Beih. Veroff. Naturschutz und Landschaftspflege in Baden- Wurttember 41: 175-86.

- Traffic rates of 24-40 vehicles/hour resulted in a 50% mortality of migrating toads

Kuitunen, M, E. Rossi and A. Stenroos. 1998. Do highways influence density of land birds. Environmental Management 22(2): 297-302.

- The road effect zone on passerines in Finland extended up to 200 m from the highway
- No difference in bird densities between 25 and 200 m were detected in the study

Lesbarreres, A. Pagano and T. Lode. 2003. Inbreeding and road effect zone in Ranidae: the case of Agile Frog, *Rana dalmatina* Bonaparte, 1840. C.R. Biologies 326.

- In eleven western France populations of Agile Frog studied, observed heterozygosity was significantly lower than expected in all cases, giving new evidence of such a depression in small populations. It especially occurred in ponds located near an highway rather than in undisturbed populations
- Our results argue for a "road effect zone". Roads are directly involved in inbreeding and in local extinction; thus, road construction ought to consider conservation management.

Lode, T. 2000. Effect of a motorway on mortality and isolation of wildlife populations. Ambio 29(3): 163-166.

- A new motorway in France considerably affected vertebrate populations (14.5 animals/day/100 km) despite compensatory adjustments such as wildlife passages and fences
- A total of 2,266 road-killed animals representing 97 species was found. 8.1% of the animals were Barn Owls
- Mammals represented the greatest proportion of road-kills (43.2%) and several rare and endangered species were also impacted
- Mortality increased exponentially with traffic volume
- Mortality reached almost 100% when no wildlife passages existed. With underground passages, road mortality of two the most common species, Field Mouse (*Apodemus sylvaticus*) and Common Toad (*Bufo bufo*), was reduced to 31% and 23%, respectively
- Traffic severely influenced both wildlife species demography and population exchanges resulting in effective population isolation

Lovallo, M.J. and E.M. Anderson. 1996. Bobcat movements and home ranges relative to roads in Wisconsin. Wildlife Society Bulletin 24(1): 71-76.

- Within established home ranges, Bobcats crossed secondary highways, unpaved roads, and trails in proportion to their occurrence and crossed roads less than expected
- Geographic and behavioral selection appeared to be a function of vehicle traffic levels and juxtaposition of preferred Bobcat habitat to road types

Lovvorn, J.R. and C.M. Kirkpatrick. 1981. Roosting behavior and habitat of migrant Greater Sandhill Cranes. The Journal of Wildlife Management 45(4): 842-857.

- Primary roosting requirements were water generally <20 cm deep and lack of human disturbance.
- Cranes required lesser distances from human activity when roosts were surrounded by trees than when roosts were open and visible from roads.
- Lack of crane use of areas probably results from unfavorable location in the migration path and absence of tradition based on historical habitat availability.

Malo, J.E., F. Suárez and A. Díez. 2004. Can we mitigate animal-vehicle accidents using predictive models? Journal of Applied Ecology 41 (4): 701–710.

- Vehicle collisions with wild animals are a serious problem that justifies the widespread application of mitigation measures such as road fencing and provision of crossing structures
- Road sections with high collision rates were associated with areas having high forest cover, low crop cover, low numbers of buildings and high habitat diversity
- Specific collision points typically had no guard-rails or lateral embankments, were not near underpasses, crossroads or buildings, and featured hedges or woodland near the road
- Predictive models of animal–vehicle collision locations should be used at both a landscape level and a local scale during the process of road design and implementation of mitigation measures
- Modeling of collision risk could inform decisions on road alignment and on the exact location of crossing structures for mammals, to improve wildlife survival and road safety

Massemin, S., Y. Le Maho and Y. Handrich. 1998. Seasonal pattern in age, sex and body condition of Barn Owls *Tyto alba* killed on motorways. Ibis 40: 70-75.

- The Barn Owl (*Tyto alba*) was the most common owl killed on motorways in northeastern France
- The number of birds killed on roads was highest in the period from early autumn to late winter, i.e. during the non-breeding period, and showed a pattern similar to that of the temporal difference between sunset, which varies with day length, and peak of traffic, the occurrence of which is constant throughout the year
- An autumnal mortality peak, concomitant with the post-fledging dispersal, was mainly of immature birds, especially females
- Except for mature females, Barn Owls killed on roads in 1991-1994 were in good body condition. This does not support the idea that only birds in poor body condition were killed
- mortality of Barn Owls on motorways in autumn and winter was probably related to the concomitance between the peak of traffic and the onset of hunting activity and the large number and dispersal of immature individuals during the same period

Materi, J.J. and D.A. Blood. 1999. Burns Bog spring raptor study. Prepared for ENKON Environmental Ltd.

Mazerolle, M.J. 2004. Amphibian road mortality in response to nightly variations in traffic intensity. Herpetologica 60(1): 45-53.

- A total of 4643 amphibian crossing events was tallied during the 37 surveys in eastern Canada
- A decreasing trend in abundance for amphibian roadside populations over the eight year study was not observed
- The number of dead American Toads (*Bufo americanus*) increased with increasing traffic intensity, while the number of ranid frogs (*Rana clamitans*, *R. pipiens*, and *R. sylvatica*) dead on the road was greatest when many individuals were moving on the road and at moderate traffic intensities (approximately 10–18 vehicles/h)
- The number of ambystomatid salamanders (*Ambystoma laterale* and *A. maculatum*) dead on the road, did not respond to traffic intensity

- Subtle variations in traffic intensity (i.e., 5–26 vehicles/h) can increase mortality on the road for certain amphibian species

McClure, H.E. 1951. An analysis of animal victims on Nebraska's highways. Journal of Wildlife Management 15(4): 410-420.

- In Nebraska between 1941 and 1944, the average highway loss was 9.1 animals per 100 miles. Much higher losses have been reported in New England (70.5), Iowa (42.9) and Wisconsin (249.9)
- The greatest losses of animals were in July, likely related to the increased numbers of dispersing young and the increase in highway use by vacationing motorists

McDonald, W. and C.C. St. Clair. 2004. Elements that promote highway crossing structure use by small mammals in Banff National Park. Journal of Applied Ecology 41: 82-93.

- Translocated small mammals returned with higher success across small crossing structures than across larger ones, perhaps because these structures provide more overhead cover from predators
- Adding overhead cover to crossing structure entrances improved return success
- Deer Mice had the highest return success for translocations the greatest distance from the highway
- Wildlife corridors need to offer sufficient cover and be placed with a frequency that corresponds to the movement patterns of targeted species

McGregor, R., D. Bender, S. Derrane and L. Fahrig. 2003. The effect of traffic volume on translocated small mammal movement. John Muir Institute of the Environment, University of California, Davis.

- Traffic volume influenced the return probability of small mammals
- When traffic volumes exceeded 11,000 vehicles/day none of the translocated individuals successfully crossed the road back to their home range
- Small mammals were able to cross roads with moderate (5,000 – 7,000 vehicles/day) and low (<2,000 vehicles/day) traffic volumes

Mensing, D.M., S.M. Galatowitsch and J.R. Tester. 1998. Anthropogenic effects on the biodiversity of riparian wetlands of a northern temperate landscape. Journal of Environmental Management 53:349-377.

- Amphibian abundance was related to land use within 1 km of a wetland

Merriam, G., M. Kozakiewicz, E. Tsuchiya and K. Hawley. 1989. Barriers as boundaries for metapopulations and demes of *Peromyscus leucopus* in farm landscapes. Landscape Ecology 2(4): 227-235.

- Roads are effective inhibitors of movement for mice as opposed to absolute movement barriers, and were not effective barriers to stop recolonization of empty habitats adjacent to roads

Meunier, F.D., C. Verheyden and P. JouventIn 2000. Use of roadsides by diurnal raptors in agricultural landscapes. Biological Conservation 92: 291-298.

- Motorway verges, and to a lesser extent secondary road verges, were used significantly more than adjacent areas by buzzards, kestrels and black kites, but not by harriers
- Raptor abundance along roads was not directly related to the relative abundance of small mammals
- The supply of perching sites and the width of verges appeared important factors in the attractiveness of roadsides for these species

Meunier, F.D., J. Corbin, C. Verheyden and P. JouventIn 1999. Effects of landscape type and extensive management on use of motorway roadsides by small mammals. Canadian Journal of Zoology 77: 108-117.

- Small mammal species richness was greater on roadsides than in cropland and pine plantations
- The three dominant species (94% of captures), Greater White-toothed Shrew, Wood Mouse and Common Vole were generally more abundant on roadsides than in the landscape matrices
- Extensively managed motorway roadsides seem to be favorable to most small mammal species, regardless of the landscape matrix

Nowald, G. 2001. Verhalten von Kranichfamilien (*Grus grus*) in Brutrevieren Nordostdeutschlands: Investition der Altvögel in ihre Nachkommen Journal für Ornithologie 142 (4), 390–403.

- Future landscape planning should avoid new traffic structures, buildings (e. g. wind turbines) or power lines at least in areas of high crane density.

Orlowski, G. 2007. Spatial distribution and seasonal pattern in road mortality of the Common Toad *Bufo bufo* in an agricultural landscape of south-western Poland. Amphibia-Reptilia 28(1): 25-31.

- Between June 2001 and August 2003, 957 Common Toads *Bufo bufo* were recorded killed on 48.8 km road network with various traffic volumes (350-10,500 cars per 24 h), situated in the agricultural landscape of south-western Poland.
- The highest mortality was recorded in April (57% of all road-kills).
- During the whole study period, 73% of all road-kills were recorded on roads (55% of all controlled) with the lowest traffic volume (350-470 cars per 24 h).
- The number of road-kills on 15 road sections was most closely related to the abundance of local populations of *Bufo bufo* and to the size of water bodies situated in the road vicinity.
- The yearly level of local mortality in breeding populations of *Bufo bufo* due to the vehicle traffic ranged from 2 to 18%.

Ovaska, K., L. Sopuck, C. Engelstoft, L. Mathias, E. Wind and J. MacGarvie. 2004. Best management practices for amphibians and reptiles in urban and rural environments in British Columbia. WLAP BMP Series. Unpublished Report prepared for BC Ministry of Water, Land and Air Protection, Nanaimo, BC. 150 pp + appendix.

- Generally, amphibians have been shown to prefer small culvert structures (1 m in diameter) with moist substrates
- The key to success of amphibian underpasses is the correct placement of crossings, low light levels around the opening of the crossing culvert (avoidance of street lighting around underpasses), amphibian friendly vegetation leading to each underpass, amphibian friendly substrate within the underpass, fencing to direct amphibians into the underpass, and barriers to keep amphibians off the road
- Crossing structures should be located at 50 m intervals

Oxley, D.J., M.B. Fenton and G.R. Carmody. 1974. The effects of roads on populations of small mammals. The Journal of Applied Ecology 11(1): 51-59.

- Crossing rates of small forest mammals (e.g., mice) decreased with wider rights-of-way and crossing of 4-lane roads by small mammals was rare
- Increased mortality rates to medium-sized mammals (e.g., hares, raccoon, muskrat) were associated with increases in the width of road rights-of-way

Pocock, Z. and R.E. Lawrence. 2005. How far into a forest does the effect of a road extend? Defining road edge effect in eucalypt forests of South-Eastern Australia. Pp 397-405. *In* On the Road to Stewardship, Wildlife Crossing Structures.

- The study measures the extent of road (2-lane; >1,600 vehicles/day) impacts into a temperate eucalypt forest ecosystem in southeastern Australia
- Exotic vegetation was found to extend about 50 m from the road
- Mammal surveys indicated that there was an increase in species richness once traffic noise reached ambient levels (40dB) and traffic light penetration ceased
- Bird surveys identified four species (90% that only occurred within 150 m of the road (edge species) and 21 species (58%) that only occurred at distances of 150 m or more from the road (interior species)
- A core habitat area for birds was identified at about 900 m from the road, translating to an area of 1.8 km^2 per kilometer of road

Pons, P. 2000. Height of the road embankment affects probability of traffic collisions by birds. Bird Study 47: 122-125.

- The relative probability of bird collision (overall number of carcasses/ km) increases as bank height decreases
- Compared to the highest embankment category (>3 m), the probability of collision when embankment height is 1.5-3 m is 1.5 times, three times when embankment height is 0.25-1.5 m, almost four times in the absence of an embankment, and 2.5 times near buildings.
- A bird crossing a road in a section where the embankment is more than 3 m high would have about a quarter the probability of traffic collision than in a section without embankment. This is likely due to the greater flying heights of birds forced to surpass the embankment when crossing the road
- Results indicate the advantages of installing well-designed vertical barriers on especially sensitive road sections, to force birds to fly higher above the road and thus preclude collision with vehicles

Preston, M.I. and G.A. Powers. 2006. High Incidence of Vehicle-induced Owl Mortality in the Lower Mainland and Central Fraser Valley, British Columbia. Wildlife Afield. 3(1 Supplement): 15-23.

Puky, M. 2006. Amphibian road kills: a global perspective. *In* Proceedings of the 2005 International Conference on Ecology and Transportation, Eds. Irwin, C.L., P. Garrett and K.P. McDermott. Center for Transportation and the Environment, North Carolina State University, Raleigh, NC: pp. 325-338.

- Numerous studies worldwide that have documented road-related impacts to amphibian populations
- Speed of transport and the duration and timing of surveys were decisive factors, causing differences of 5.5-16 times the number of road-killed amphibians recorded, mainly in connection with low visibility and retention time of amphibians on roads
- The spatio-temporal pattern of amphibian road kill is also influenced by habitat and transportation characteristics, and weather conditions
- Technical solutions (e.g., tunnels) have successfully reduced amphibian road kills under different conditions, although lack of maintenance and construction deficiencies are common problems

Ramsden, D.J. 2003. Barn Owls and major roads: results and recommendations from a 15-year research project. The Barn Owl Trust, Ashburton, United Kingdom.

- Individual Barn Owls are often struck by traffic soon after encountering a major highway in the United Kingdom
- Major highways can cause the loss of local Barn Owl populations and the long-term absence of resident Barn Owls within 500 m of a nest site due to collisions reducing populations
- Barn Owls should not be encouraged to nest within 1 km of any major road unless they are bordered by a protective screen > 3m high
- Ideally Barn Owls should not be encouraged to nest within 3 km of a major highway
- Areas of rough grass, which are likely to support small mammals, should only be planted near roads if they can be planted behind vegetation buffers

Ramsden, D.J. and J. A Howells. (publication date not found). 2003 Devon Barn Owl Survey Report. Results from a county-wide survey by the Barn Owl Trust with the Devon Bird Watching and Preservation Society. The Barn Owl Trust, Ashburton, UK. 23 pgs.

Reed, R.A., J. Johnson-Barnard and W.L. Baker. 1996. Contribution of roads to forest fragmentation in the Rocky Mountains. Conservation Biology 10(4): 1098-1106.

- Roads added to forest fragmentation more than clearcuts by dissecting large patches into smaller pieces and by converting forest interior habitat into edge habitat
- Edge habitat created by roads was 1.54-1.98 times the edge habitat created by clearcuts
- Fragmentation due to roads could be minimized if road construction is minimized or rerouted so that its fragmentation effects are reduced

Reh, W. and A. Seitz. 1990. The influence of land use on the genetic structure of populations of the Common Frog *Rana temporaria*. Biological Conservation 54: 239-249.

- Separation by highways reduced average heterozygosity as well as well as genetic polymorphism of local populations of Common Frog (*Rana temporaria)* in the Federal Republic of Germany
- Multiple regression analysis showed that motorways and railways have a significant barrier effect on frog populations within 3-4 km

Reijnen, R. and R. Foppen. 1994. The effects of car traffic on breeding bird populations in woodland. IV. Influence of population size on the reduction of density close to a highway. Journal of Applied Ecology 32: 481-491.

- The acoustic masking of bird songs appears to be the mechanism by which traffic noise impacts passerine density along roads
- Breeding success in male willow warblers within 200 m of the roads in the Netherlands was 50% less than that of males in comparable habitat further from the road

Reijnen, R., R. Foppen and H Meeuwsen. 1995. The effects of traffic on the density of breeding birds in Dutch agricultural grasslands. Biological Conservation 75: 255-260.

- In grasslands, the zone of influence for individual species varied from 20 m (coots) to 1,700 m (European oystercatchers) for roads with 5,000 vehicles/day and 75 (coots) to 3,500 m (European Osytercatchers) for roads with 50,000 vehicles/day
- When all species were combined, the road zone effects ranged from 120-560 m
- The authors predicted that all species within 100 m of the road would have a 40-74% reduction in population density

Reijnen, R., R. Foppen, C. ter Braak and J. Thissen. 1995. The effects of car traffic on breeding populations in woodland, III. Reduction of density in relation to the proximity of main roads. Applied Ecology 32: 187-202.

- Zone effects for birds in woodland areas varied from 40-1,500 m for roads with 10,000 vehicles/day to 70-2,800 m for roads with 60,000 vehicles/day
- Within 250 m of roads, the reduction in species densities varied between 20 and 98%

Reijnen, R., R. Foppen and G. Veenbaas. 1997. Disturbance by traffic of breeding birds: evaluation of the effect and planning and managing road corridors. Biodiversity and Conservation 6: 567-681.

- Traffic noise is believed to be the critical factor in causing reduced bird densities adjacent to roads
- Roads with low traffic noise had almost no effects on bird species density in adjacent habitats
- Bird species density was reduced by 39% in grasslands and 35% in woodlands within the road effect zone

Rheindt, F.E. 2003. The impacts of roads on birds: does song frequency play a role in determining susceptibility to noise pollution? Journal of Ornithology 14: 295-306.

- Bird species richness and diversity decreased towards a road
- The acoustic masking of bird songs appears to be the mechanism by which traffic noise impacts passerine density along roads
- Birds whose calls had a higher frequency than that of the road noise were less susceptible to road noise effects

Rodgers, J.A., Jr. and H.T. Smith. 1997. Buffer zone distances to protect foraging and loafing waterbirds from human disturbance in Florida. Wildlife Society Bulletin 25(1): 139-145.

- Sixteen species of waterbirds in Florida were exposed to four types of human disturbance (walking, all-terrain vehicle, automobile, boat)
- Both intraspecific and interspecific variation was observed in flushing distance
- A buffer of about 100 m should minimize disturbance to most species of waterbirds studied in Florida

Romin, L.A. and J.A. Bissonette. 1996. Deer: vehicle collisions: status of state monitoring activities and mitigation. Wildlife Society Bulletin 24(2): 276-283.

- Nearly all states had used some type of signs, modified speed limits, fencing, over- and underpasses, reflective apparatus, habitat alteration, or public awareness programs, but few agencies had evaluated performance of those techniques
- Approaches that alter deer behavior and movement patterns appear to be the most fruitful for future application and evaluation

Rost, G.R. and J.A. Bailey. 1979. Distribution of Mule Deer and Elk in relation to roads. The Journal of Wildlife Management 43(3): 634-641.

- Deer and elk avoid roads, particularly areas within 200 m of a road
- Road avoidance was greater along more heavily traveled roads

Ruediger, B. and M. DiGiorgio. 2007. Safe Passage: a user's guide to developing effective highway crossings for carnivores and other wildlife. Southern Rockies Ecosystem Project. 20 pgs.

Sanz, L. 2001. Landscape integration of freeways: how does it affect road kill rates? *In* Proceedings of the 2001 International Conference on Ecology and Transportation, Eds. Irwin, C.L., P. Garrett and K.P. McDermott. Center for Transportation and the Environment, North Carolina State University, Raleigh, NC: pp. 522-528.

- High road-kill rates along a highway in Spain are related to the areas in which the topography facilitates wildlife access to the road
- During road design, the arrangement of the landscape elements (e.g., strips of vegetation, rivers, the positon of hills etc.) as well as topography need to be taken into consideration. Both factors influence the number of wildlife deaths and road permeability
- Isolate the road from the environment in stretches of high road-kill rate, paying particular attention to the perimeter fence design. Wildlife structures should also be installed in fenced areas

- Apply corrective measures to sections with a high incidence of road-kill

Seiler, A. 2001. Ecological Effects of Roads – A review. Introductory Research Essay, Department of Conservation Biology, SLU.

- Roads, railroads, and their traffic disrupt ecological processes; increase mortality in animals, lead to a degradation, loss and isolation of wildlife habitat, and cause a fragmentation of the landscape in a literal sense
- Despite the quantity of empirical studies, it is still difficult to draw general conclusions or define impact thresholds that could guide evaluation work
- The increasing public demand on mitigation and prevention of environmental impacts strongly requires the development of evaluation tools for civil engineers and ecologists to apply in the planning and construction of transport infrastructure.
- The scientific literature on the known ecological effects of transport infrastructure, with special focus on roads is reviewed

Seong-Hwan, P. and P. Won. 1994. Wintering ecology of Red-crowned Cranes and White-naped Cranes *Grus japonensis* and *G. vipio* in the Cholwon Basin, Korea. The Future of Cranes and Wetlands: 97-106.

- In 541 hours of observation, 188 disturbances were vehicle (60.1%), noise (25.5%), human (3.7%), aircraft (1.1%), unidentified (6.4%), and others (3.2%)
- Cranes tended to stay more than 500 m away from roads, although they wandered closer when no vehicles were in the area

Shriver, W.G., T.P. Hodgman, J.P. Gibbs and P.D. Vickery. 2004. Landscape context influences salt marsh bird diversity and area requirements in New England. Biological Conservation 119: 545–553.

- We evaluated the contributions of spatial distribution, juxtaposition, and quality of salt marsh habitat to salt marsh breeding birds along the New England coast, USA
- Species richness was at least 20% greater on larger salt marshes
- Response to marsh isolation and human development varied regionally, with bird species more sensitive to marsh isolation and road proximity in the more pristine (Gulf of Maine) than altered (Long Island Sound) region the habitat requirements of salt marsh breeding birds.

Slabbekoorn, H. and M. Peet. 2003. Birds sing at a higher pitch in urban noise. Nature 424: 267.

- Human-altered environments might change the communication signals of wild bird species
- Song plasticity of Great Tits may represent a general behavioral mechanism that allows more bird species to reproduce despite high noise levels
- Species that lack song plasticity or have no room for variation within the conspecific frequency range, might suffer from auditory masking. For those species, noise could affect breeding opportunities and contribute to a decline in species density and diversity

Spellerberg, I.F. 1998. Ecological effects of roads and traffic: a literature review. Global Ecology and Biogeography Letters 7: 317-333.

- Report summarizes data from a number of studies investigating the ecological effects of roads and traffic

St. Clair, C.C. 2003. Comparative permeability of roads, rivers, and meadows to songbirds in Banff National Park. Department of Biological Sciences, University of Alberta, Edmonton, AB, Canada.

- The permeability of roads, rivers, and meadows to songbirds in Banff National Park, Alberta, Canada, where a four-lane highway dissects a wide montane valley was investigated
- Forest-dependent birds were reluctant to cross rivers but not roads or meadows, and they crossed barriers less often when the barriers were noisy
- Results suggest that the response to barriers by montane birds is strongly dependent on their degree of forest dependence. The surprising result that forest birds were less likely to cross rivers than either roads or meadows may stem from evolutionary history and suggests that birds do not perceive the risk of mortality posed by road traffic.

Swihart, R.K. and N.A. Slade. 1984. Road crossing in *Sigmondon hispidus* and *Microtus ochrogaster*. Journal of Mammology 65(2): 357-360.

- The smallest road clearance (<3 m) exhibited a strong inhibitory effect on small mammals
- Movements of Prairie Voles and, to a lesser degree, Cotton Rats were restricted by something as seemingly innocuous as a narrow, seldom-used vehicle path
- The effect of the small road clearance on Prairie Voles was particularly dramatic and has important implications for the maintenance of genetic diversity in spatially fragmented populations of this species

Switalski, T.A. 2006. How Many is Too Many: A Review of Road Density Thresholds for Wildlife. Winter Solstice 2006, Vol. 11, #4.

Trocme, M. 2006. The Swiss defragmentation program – reconnecting wildlife corridors between the Alps and Jura: an overview. *In* Proceedings of the 2005 International Conference on Ecology and Transportation, Eds. Irwin, C.L., P. Garrett and K.P. McDermott. Center for Transportation and the Environment, North Carolina State University, Raleigh, NC: pp. 144-149.

- Fragmentation of natural habitats has become a major conservation concern as vulnerable species become rarer and the red list of endangered species becomes longer
- Many amphibian breeding areas along lakeshores have been cut off from their wintering grounds by roads, with populations then disappearing
- Highways have proven to be an impassable barrier for the lynx
- The Swiss embarked on a defragmentation program to improve connectivity of natural habitats
- Standards have been defined to guide engineers and biologists in the analysis of existing structures and the potential permeability for fauna
- Criteria were developed to facilitate the choice of the optimal type of passage for each given situation

Trombulak, S.C. and C.A. Frissell. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. Conservation Biology 14(1): 18-30.

- A review of the scientific literature on the ecological effects of roads and found support for the general conclusion that they are associated with negative effects on biotic integrity in both terrestrial and aquatic ecosystems.
- Roads of all kinds have seven general effects: mortality from road construction, mortality from collision with vehicles, modification of animal behavior, alteration of the physical environment, alteration of the chemical environment, spread of exotics, and increased use of areas by humans.
- Road construction kills sessile and slow-moving organisms, injures organisms adjacent to a road, and alters physical conditions beneath a road. Vehicle collisions affect the demography of many species, both vertebrates and invertebrates; mitigation measures to reduce road kill have been only partly successful.
- Roads alter animal behavior by causing changes in home ranges, movement, reproductive success, escape response, and physiological state.
- Roads change soil density, temperature, soil water content, light levels, dust, surface waters, patterns of runoff, and sedimentation, as well as adding heavy metals (especially lead), salts, organic molecules, ozone, and nutrients to roadside environments.
- Roads promote the dispersal of exotic species by altering habitats, stressing native species, and providing movement corridors.
- Roads also promote increased hunting, fishing, passive harassment of animals, and landscape modifications.
- Not all species and ecosystems are equally affected by roads, but overall the presence of roads is highly correlated with changes in species composition, population sizes, and hydrologic and geomorphic processes that shape aquatic and riparian systems

U.S. Department of Transportation. 1980. Highway Traffic Noise. U.S. Government Printing Office, Washington, D.C. 20402, U.S.A. 15 pgs.

U.S. Department of Agriculture Forest Service. 2000. Forest Roads: A Synthesis of Scientific Information. Edited by H. Gucinski, M.J. Furniss, R.R. Ziemer and M.H. Brookes. Roads: Science Synthesis, June 14, 2000.

Van der Zande, A.N., W.J. Ter Keurs and W.J. Van der Weijden. 1980. The impact of roads on the densities of four bird species in an open field habitat, evidence of a long-distance effect. Biological Conservation 18: 299-321.

- Disturbance zones of 2 km adjacent to a busy highway was estimated for two European waders
- Distance effects varied from 480 m for a road with 50 cars and 2,000 m for a highway with 54,000 cars per average weekday

van Gelder, J.J. 1973. A quantitative approach to the mortality resulting from traffic in a population of *Bufo bufo* L. Oecologia 13(1): 93-95.

- Mortality rates of 29% were found for migrating female toads crossing paved roads in the Netherlands

Vitt, D.H., L.A. Halsey and J. Doubt. 1999. Global and Regional Distinctness of Burns Bog. Prepared for Delta Fraser Properties Partnership and the Environmental Assessment Office in support of the Burns Bog Ecosystem Review. Department of Biological Sciences, University of Alberta, Edmonton, AB., Canada. 19 pgs.

Voorhees, L.D. and J.F. Cassel. 1980. Highway right-of-way: mowing versus succession as related to duck nesting. Journal of Wildlife Management 44(1): 155-163.

- Mallard nest success was constant in roadside mowed habitats whereas in unmowed areas, representing later successional stages, nesting success declined continually

Vos, C.C. and J.P. Chardon. 1998. Effects of habitat fragmentation and road density on the distribution pattern of the Moor Frog *Rana arvalis*. Journal of Applied Ecology 35: 44-56.

- In the Netherlands, occupation of wetlands by the Moor Frog was positively correlated to wetland size and negatively correlated to road density
- Roads within 250 m of moor frog breeding sites negatively affected population size
- The negative relationship between wetland occupation and roads attribute to the increased isolation of the wetland due to fragmentation
- The higher the traffic density the lower the probability of survival of amphibians crossing the road. Amphibian movement was even affected at very low traffic volumes (i.e., 26 vehicles/hr)

Warner, R.E. 1992. Nest ecology of grassland passerines on road rights-of-way in central Illinois. Biological Conservation 59: 1-7.

- Numbers of nests and species of grassland passerines increased with roadside width
- Frequency of nesting on rights-of-way was affected by seeding type and by mowing regime
- The amount of vehicular traffic along secondary roads did not influence nest densities
- Road rights-of-way are critical in sustaining grassland birds that nest in edges and ecotones

Warner, R.E. and G.B. Joselyn. 1986. Responses of Illinois Ring-necked Pheasant populations to block roadside management. Journal of Wildlife Management 50(4): 525-532.

- Vegetation was developed as breeding habitat on roadsides and mowing was voluntarily delayed to minimize nest destruction
- With management, pheasant abundance increased 2-3 times
- The boom phase in regional pheasant trends was amplified, and subsequent declines related to land use and severe winters were moderated

Watts, B.D. 2000. The impact of highway plantings on bird mortality (briefing paper). Center for Conservation Biology, College of William & Mary.

- A fruit-bearing shrub planted in coastal Virginia along a motorway attracted migrant birds into the path of traffic causing more than 95% of observed mortality

- In spring 2001, 1,600 Cedar Waxwings (*Bombycilla cedrorum*) were collected along two road segments and as many as 350 birds were collected from one location in a single day

White, P.A. Getting up to Speed: a Conservationist's Guide to Wildlife and Highways. 149 pgs.

White, P.A. and M. Ernst. Second Nature: Improving Transportation without Putting Nature Second. Surface Transportation Policy Project, Defenders of Wildlife.

- Numerous ideas on reducing road-related impacts to wildlife

Wildlife Crossings Toolkit: http://www.wildlifecrossings.info/sa015.htm

Wilkins, K.T. 1982. Highways as barriers to rodent dispersal. The Southwestern Naturalist 27(4): 459-460.

- Highways do not completely inhibit dispersal of certain rodent species
- The tendencies of rodents to cross barriers varies not only by species, but other factors such as population densities, resource availability, and various physical parameters of the potential barrier

Willamette National Forest Pilot Road Analysis. 1998. Appendix D. Terrestrial Wildlife Process Paper. 20 pgs.

Yale Conrey, R.C. and L.S. Mills. 2001. Do highways fragment small mammal populations? *In* Proceedings of the 2001 International Conference on Ecology and Transportation, Eds. Irwin, C.L., P. Garrett and K.P. McDermott. Center for Transportation and the Environment, North Carolina State University, Raleigh, NC: pp. 448-457.

- Preliminary results suggest that highways in western Montana inhibit movement of small mammals
- Movement was hindered more by four-lane than two-lane highways
- Deer Mice were responsible for the vast majority of highway crossings, while only one vole and no chipmunks crossed four-lane highways

Yanes, M., J.M. Velasco and F. Suarez. 1995. Permeability of roads and railways to vertebrates: the importance of culverts. Biological Conservation 71: 217-222.

- Culverts in Spain successfully permitted passage of amphibians, lizards, snakes, small mammals and several species of carnivorous mammals
- Intensity of wildlife movement was influenced by factors including culvert dimensions, road width, height of boundary fence, the complexity of vegetation along the route, and the presence of detritus pits at the entrance of culverts
- Adequately designed culverts can aid the conservation of vertebrate populations

(B) Literature Review – Aerial Deposition Summary Tables

Table 1. Selected reported observed concentrations in road dust and PM10 associated with mineral sources

Source	Concentration or Emission	Material Type	Notes and Comments	Reference
Resuspended Road Dust	600/735 mg/km	PM10	Street sweeping increases PM10 re-entrainment rate, strongly seasonal being lowest in summer. 59% is associated with road	Gertler et al 2006
Road dust – HDD (heavy duty diesel vehicles)	2247±617	PM10		Abu-Allaban et al 2003a
Road dust LDSI (light-duty spark ignition vehicles)	224±59	PM10		Abu-Allaban et al 2003a
Sanding		PM10	10% of observed PM10 is from sand applications	Kupianen and Tervahattu, 2004
Road side			11 elements show elevated levels increasing with mean traffic density; some nearly 10 times the background levels.	Ward, 1990
Lead in road dust	1.2ug/m^3 at 120m distance	PM10	Exponential decrease in lead; in first 3 years after road opening	Ward 1990
Paved road	0.03-0.04 g/VMT (grams per vehicle mile traveled)	Urban	Concentration decrease away from road steeper than predicted by dispersion modelling	Lamoree and Turner 1999
Paved Road	0.2 – 0.3 g/VMT	Rural	Concentration decrease away from road steeper than predicted by dispersion modelling	Lamoree and Turner 1999
Transition metals			One order of magnitude higher concentrations in winter than summer; due to more intense wearing of road surface – 90% of the total	Bäckström et al. 2003
Tunnel observations	0.069±0.03 g/km/vehicle	PM10	Crustal elements ~7.8% ; geological elements 12.6%	Gillies et al 2001

Table 1 – Continued

Source	Concentration or Emission	Material Type	Notes and Comments	Reference
Road dust HDD (heavy duty diesel vehicles)	530 – 9100 mg/km	PM10		Abu-Allaban et al 2003b
Road Dust LDSI (light-duty spark ignition vehicles)	90 – 850 mg/km	PM10		Abu-Allaban et al 2003b
PAH	100-200 ug/km/vehicle day		Major part deposited within 100 m of road, almost entirely via air	Lygren et al 1984
Lead	1 mg Pb/km/vehicle day		As dustfall, but within 7m of road, 16.14 @6m ; 1.80@20m ; and 1.06 @100 m	Lygren et al 1984
Ca	3.1 to 30.9 mg/l		In road surface runoff	Lygren et al 1984
Dust			At 95m only 15% pf that at 3m – simulated urban area	Veranth et al 2003
Trace Metals		Pb, Cu, Cd, Zn	The amount of metal deposited via dust greatly exceeds that in runoff**. 15x for Zn 4x for Cu**. Atmospheric deposition is major process; affected by deposition, resuspension and removal by runoff and resuspension.	Hamilton et al 1987
Calcium Hamilton Ontario	100,000 – 150,000 ppm		10-15% DW (dry weight). Variability dependent on source; more diurnal – anthropogenic. Calcium in agricultural soils, but also in cement, bricks, concrete, aggregates and enriched over rural areas	Vermette, et al 1991
Road dust – Summer	5.3 g/vkt (grams per vehicle kilometer travelled) 3.0 g/vkt	Low traffic speed, High traffic speed	While high speed roads are much cleaner, they have the same order of emissions as a low speed road on a vkt basis. Default values at too low by a factor of 1.5 for summer	Etyemezian et al 2003

Table 1 – Continued

Source	Concentration or Emission	Material Type	Notes and Comments	Reference
Road dust – Winter	5.9 g/vkt 4.9 g/vkt	Low traffic speed, High traffic speed	While high speed roads are much cleaner, they have the same order of emissions as a low speed road on a vkt basis. Default values at too low by a factor 3.8 during winter	Etyemezian et al 2003
Calcium	50,000 – 80,000 mg/kg	PM10	5 – 8% DW (dry weight) Messina Italy	Dongarra et al 2003.
Calcium in road dust	140% of unwashed	110 ug/g in washed fruit and vegetables	Food crops as biomonitors	Ward and Savage, 1994
Road dust	60% of that observed at 2m	Vertical 79m	Macao, China	Wu et al 2002
Calcium	1900 ng/m^3	PM10	Coarse fraction predominantly crustal	Koçak et al 2007

Table 2. Measures of distance travelled by road dust and other materials from the literature

Maximum Distance detected	Maximum Observed distance	Material	Notes and comments	Reference
350 m	350m	Road salt (NaCl)	Exponential decay still 50g/m^2 at 350m	Pederson et al 2000
520 m downwind	520 m	Road dust, road spray, road salt, and pollutants	Linear decay against unknown soil background, use of $CaCl_2$ [pH 8.5-9.5] enhanced base-saturation levels, and major effect on vegetation	Bernhardt-Robinson et al 2006
200 m	200 m	Wind born soil dust	Logarithmic decay ; a more than 200 m sample considered uncontaminated	Santelmann and Gorham 1988
100 m	100 m	Lead in soil [fig 3]	Concentration at 100m = 40 mg/kg DW (dry weight) Concentration at roadside = 200 mg/kg DW (dry wt)	Deroanne-Bauvin et al 1987
1000 m	1000 m	Road dust	Impact of unpaved road on adjacent tundra; significant disturbance in 200m wide corridor. Load decreases logarithmically from road	Myers-Smith et al 2006
1000 m	1000 m	0.8 x km/hr to 48	On unpaved roads Resuspension increases with Vehicle size, speed and weight. Injection height effects measurable at 100m	Gillies et al 2005
47 m downwind	47 m downwind	PM10	For both rural and urban sites	Lamoree and Turner 1999
300 m	300m	Ultrafine particles. Black carbon / PM10	Particle numbers at 5 distances down-wind	Zhu et al 2004
228 m	226 m	Lateral – only 7% removed	Macao, China	Wu et al 2002
500m		Road salt	Plant damage	Spellerberg and Morison 1998
100 m	100 m	$Ca^{2+,}$ PAH, pH	Snow for inorganics; moss for organics. Prevailing winds are important;	Viskari et al 1997
100-400m	Literature review	Particulate material	Material characteristics best explain variability- materials formed on road surface have clear gradient	Zhou and Levy 2007

Table 2 – Continued

Maximum Distance detected	Maximum Observed distance	Material	Notes and comments	Reference
200 meters	200 m	Road spray	57 to 80% of the material from road way moves as road spray and dry dust. A case of 90% is reported.	Van Bohemen and Janssen van de Laak 2003
50m	50m	Pt, Rh, Pd,	These metals used in catalytic converters were statistically significantly elevated at all locations near roads. Others have observed this as far as 150m in Germany.	Ely et al 2001
1000 m	1000m	Road dust	Unpaved road measurable deposition	Everett 1980
70 km	70 km	PM10 and other Ultrafine particles	Source dominated by vehicle sources and detected at receptor site.	Kim et al 2002
400 m	400 m	Road salt	Between 20 and 63% of the salt applied left the road and most salt deposited in the first 40-100 meters.	Blomqvist and Johansson 1999
300m			Traffic within 300m used a a predictor of PM2.5	Moore et al 2007

(C) References – Hydrology and Aerial Deposition

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