Recovery Potential Metrics Summary Form

Indicator Name: CORRIDOR ROAD DENSITY

Type: Stressor Exposure

Rationale/Relevance to Recovery Potential: Riparian corridor roads can affect sedimentation and deposition processes, increase siltation to the detriment of aquatic biota, raise water temperature episodically by heating runoff and displacing riparian shade, compact floodplain substrates and reduce recharge that would help maintain base flow, and increase pollutants such as road salts that raise conductivity and harm stream invertebrates and fish. Because most stream corridor roads are not likely to be removed, their relevance to recovery potential is also linked to whether the degraded conditions can be managed or mitigated for. Although correlated with corridor urban and corridor impervious cover in highly developed areas, this metric plays a potentially important role differentiating among rural waters that have markedly different levels of exposure to the stressors described above.

How Measured: Ratio of road length in corridor divided by channel length. Can be calculated for waterbody segments or for watersheds; in watersheds, corridors are delineated for all channels, channel length is summed, and road length within the corridors of the watershed is summed. An alternative measure is to calculate the ratio of road length over the total area of the riparian corridor.

Data Source: National road and stream data is obtainable through the National Atlas (See: http://nationalatlas.gov/). Landsat data is also often used for road and stream data and can be accessed through the USGS Earth Explorer (See: http://edcsns17.cr.usgs.gov/EarthExplorer/). Transportation GIS datasets (e.g., ESRI transportation http://www.arcgis.com/home/item.html?id=3b93337983e9436f8db950e38a8629af) are widely available and can be used in overlay with an impaired waters dataset with a corridor of set width (e.g., 30M, 90M per side) delineated. 90M is preferable for this metric in order to ensure that roads that generally parallel the channel are detected and counted.

Indicator Status (check one or more)
_______ Developmental concept.
___x__ Plausible relationship to recovery.
_______ Single documentation in literature or practice.
___x__ Multiple documentation in literature or practice.
_______ Quantification.

Comments: Operational and applicable to small to medium-size rivers, streams, and wetlands. Comparisons of multiple waters on the basis of this metric should compare groups of urban and rural waters separately.

Examples from Supporting Literature (abbrev. citations and points made):

- (ourso and frenzel 2002) As contributing factors to a subbasin's impervious area, storm drains and roads appeared to be important elements influencing the degradation of water quality with respect to the biota.
- (DeLuca et al., 2004) Findlay and Houlahan (1997) and Whited et al. (2000) both found that road density at local scales had a pronounced negative effect on wetland bird assemblages and concluded that reduced connectivity between wetland patches caused by development may have restricted wetland bird distribution. Disturbances in close proximity to wetlands also provides habitat for an abundance of generalist birds (Blair

1996). Generalists are then capable of invading the marsh and increasing interspecific competition with marsh birds for available resources (844).

- (DeLuca et al., 2004) Small and Hunter (1988) found that roads, power lines, and edges, all characteristics of developed areas, provide pathways for potential predators to enter undisturbed habitat and depredate bird nests. Pathways or corridors such as these may act in similar ways near marshes to increase nest predation and lower reproductive success. Another explanation for the reduction in marsh bird community integrity may be the transfer of pollutants from adjacent land. Chemical pollutants and nutrients transferred from developed areas through point sources may reduce the food resources of marsh birds (Poulin et al. 2002). For example, aquatic macroinvertebrates might be impacted from such point source pollution. Interestingly, most secretive marsh birds, marsh foraging specialists, feed primarily on aquatic macroinvertebrates, and only three of the 45 lowest scoring wetland sites of our study had secretive marsh birds present (844).
- (Radwell and Kwak 2005) Fish density, number of intolerant fish species, and invertebrate density were important biotic variables responsible for the rankings. Contributing physical variables included riparian forest cover, nitrate concentration, turbidity, percentage of forested watershed, percentage of private land ownership, and road density both in the watershed and in a 100-m buffer (806).
- (Chang and Carlson 2005) As reported earlier in this paper, increases in solute concentrations are associated with increases in urban land cover within a subbasin. As a result of urbanization, impervious covers and nonpoint source pollution increased. The higher concentrations of chloride in urban basins underscore the importance of high road density and concordant overall volume of de-icing salts applied to the roads.
- (Eigenbrod, Hecnar and Fahrig 2008) The necessity of moving between multiple habitats and dispersing to re-colonize breeding sites means that many amphibians are also vulnerable to roads in the landscape. Studies have shown negative correlations between anuran species richness and paved road density (e.g., Findlay et al. 2001); between anuran pond occupancy and road density (Vos and Chardon 1998); and between anuran relative abundance and traffic density (Fahrig et al. 1995; Carr and Fahrig 2001).
- (Forman and Alexander 1998) Roads may alter the subsurface flow as well as the surface flow on wetland soils (116). Compacted saturated or nearly saturated soils have limited permeability and low drainage capacity. Wetland road crossings often block drainage passages and groundwater flows, effectively raising the upslope water table and killing vegetation by root inundation, while lowering the downslope water table with accompanying damage to vegetation (116, 118). Streams may be altered for considerable distances both upstream and downstream of bridges. Upstream, levees or channelization tend to result in reduced flooding of the riparian zone, grade degradation, hydraulic structural problems, and more channelization (17). Downstream, the grade change at a bridge results in local scouring that alters sedimentation and deposition processes (17, 49).
- (Forman and Alexander 1998) Buffer strips between roads and streams tend to reduce sediments reaching aquatic ecosystems (77, 91). Buffers may be less effective for landslides than for arresting water and sediment from culverts and roadside ditches. Good road location (including avoiding streamsides and narrow floodplains for many ecological reasons), plus good ecological design of roadsides relative to slope, soil, and hydrology, may be a better strategy than depending on wide buffers to absorb sediment.
- (Forman and Alexander 1998) Aquatic ecosystems are also affected by road density. Hydrologic effects, such as altered groundwater conditions and impeded drainage upslope, are sensitive to road density (116, 118). Increased peak flows in streams may be evident at road densities of 2–3 km/km2 (62). Detrimental effects on aquatic ecosystems, based on macro-invertebrate diversity, were evident where roads covered 5% or more of a watershed in California (75). In southeastern Ontario, the species richness of wetland plants, amphibians/reptiles, and birds each correlated negatively with road density within 1–2 km of a wetland (38).

- (Opperman et al. 2005) Agricultural and urban land uses and road density were positively associated with embeddedness, while the opposite was true for forest cover. The ability of land use and land cover to predict embeddedness varied among five zones of influence, with the greatest explanatory power occurring at the entire-watershed scale. Land use within a more restricted riparian corridor generally did not relate to embeddedness, suggesting that reach-scale riparian protection or restoration will have little influence on levels of fine sediment.
- (Opperman et al. 2005) In a study relating fish abundance with watershed characteristics, Bradford and Irvine (2000) reported that agricultural land use was associated with declines in coho salmon populations within 40 tributary watersheds of the Thompson River, British Columbia. Similarly, Pess et al. (2002) showed that coho salmon abundance in the Snohomish Basin in Washington was negatively correlated with the percentage of watershed in agriculture, urban development, and roads. The abundance of juvenile Chinook salmon was also negatively correlated with road density in a study in Idaho (Thompson and Lee 2000).
- (Opperman et al. 2005) Much attention and resources have been spent on piecemeal stream restoration and sediment control efforts at the local scale (e.g., bank stabilization). Our data indicate that the effects of such localized efforts will be overwhelmed by processes operating at larger scales and, thus, have little influence on spawning conditions. Rather, to improve spawning gravels, restoration efforts should emphasize protecting riparian corridors throughout entire watersheds and promote programs or policies that ameliorate the influences of roads and agricultural land use. However, even watersheds with relatively low levels of development (e.g., 5% of a watershed) had relatively high embeddedness scores, suggesting a limit to the improvements that restoration programs can hope to achieve.