Recovery Potential Metrics Summary Form

Indicator Name: WATERSHED ROAD DENSITY

Type: Stressor Exposure

Rationale/Relevance to Recovery Potential: Storm drains and roads appeared to be important elements influencing the degradation of water quality with respect to the biota. Fish density, number of intolerant fish species, and invertebrate density are seen to change in association with more roads in watersheds. Studies of Middle Atlantic streams have linked greater road densities to increased conductivity and subsequent impacts on aquatic life. Roads also add to impervious surface and thereby contribute to many secondary effects on flashy flows and related destabilized channels, increased urban pollutant transport, and other effects.

How Measured: Mean road length per watershed square mile.

Data Source: Transportation GIS datasets are widely available and can be used in overlay with an impaired waters dataset where watershed boundaries have been delineated. 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 are widely available and can be used in overlay with an impaired waters dataset where watershed boundaries have been delineated. ESRI offers a free roads dataset that can be opened in ArcMap (http://www.arcgis.com/home/item.html?id=3b93337983e9436f8db950e38a8629af).

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.

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) Under the Wild and Scenic Rivers Act, river segments are assigned wild, scenic, or recreational status based on accessibility by road, and management plans are based on assigned status. Hence, information on road density is useful in the ecological and political assessment process, as well as for future management, should protection be conferred. Furthermore, these findings compel management at broad spatial scales (808).
- (Radwell and Kwak 2005) Our research revealed several insightful findings applicable to river ecology and management. First, we found that physical characteristics were more influential in ranking rivers in terms of ecological integrity, relative to biotic attributes. Among physical attributes, those at the watershed level, including land use, ownership, and road density, were the most influential components, playing a major role in discriminating among rivers. However, fish density, biomass, and occurrence of intolerant fishes were influential biotic factors, as well as invertebrate density and taxa richness (806).
- (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).
- (Grau et al., 2003) Forest recovery tends to occur in areas of marginal agriculture: at high elevations, on steep slopes, within reserve areas, far from roads, in areas with net population out-migration, and in small farm areas located near preexisting forests. Urban areas expand at lower elevations, on flat topography, and closer to roads and urban areas (Thomlinson et al. 1996, Helmer 2003). The landscape features that favor urbanization are the same ones that favor intensive agriculture. For example, between 1977 and 1994, new urban areas replaced 6% of the island's prime agricultural lands (López et al. 2001) (1160).
- (Bressler et al. 2009) Our study showed that a relatively straightforward stressor gradient consisting of human population density, road density, and urban land use is useful in providing a framework for developing relevant biological indicators and evaluating the potential of biological communities as a basis for assessing attainment of designated aquatic life use.
- (Coffin 2007) At the landscape scale, road networks interact with stream networks, increasing the stream drainage density, the overall peak flow in the stream drainage, and the incidence of debris flows in the drainage basin (Jones et al., 2000). Roads extend the drainage network of the stream network when drainage swales along roads directly connect to stream networks (Forman and Alexander, 1998). Faster moving water enters the stream channels increasing the energy of the stream system, eroding channel banks, scouring the channel and can increase the likelihood of flooding downstream (Dunne and Leopold, 1978).
- (Coffin 2007) To the extent that the road network is extended and connected, the landscape becomes more fragmented and less well connected. Reed et al. (1996) found in the Rocky Mountains that roads created more forest fragmentation than clearcut logging by ''dissecting large patches into smaller pieces.'' In numerous studies, densities of species are correlated either with road density (negatively) or with distance from road (positively) (Barnes et al., 1995; Canaday, 1996; Huijser and Bergers, 2000; Develey and Stouffer, 2001; Mech et al., 1988). These tend to be species that require interior forest conditions, require extensive home ranges and are shy, or are hunted.
- (Coffin 2007) Roads are often associated with land uses that can, in tandem, cause changes to erosion and deposition rates of sediments in stream channels. Logging roads and logging are notable because forestry is commonly the first broadscale land use

causing the whole-sale anthropogenic removal of vegetation and exposure of soil in a watershed.

- (DeCantanzaro, Cvetkovic and Chow-Fraser 2009) Road density was the dominant factor influencing many water quality variables, showing positive correlations with specific conductivity (COND), total suspended solids (TSS), and inorganic suspended solids (ISS) and a negative correlation with overall Water Quality Index scores. Road density also showed positive correlations with total nitrate nitrogen (TNN) and total phosphorus (TP)…..Our findings suggest that road density is currently the overriding factor governing water quality of coastal marshes in Georgian Bay during the summer lowflow period.
- (DeCantanzaro, Cvetkovic and Chow-Fraser 2009) Based on the regression model, an increase in road density of just 11.6 m ha-1 would be expected to decrease WQI scores by 1.00 unit, representing a considerable decline in water quality. This water-quality impairment in turn has the potential to alter trophic dynamics and cause a shift toward more degradation-tolerant flora and fauna (Lougheed and others 2001; McNair and Chow-Fraser 2003; Seilheimer and Chow-Fraser 2006; Danz and others 2007).
- (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).
- (Forman et al. 1997) Six major patterns associated with a higher road desnsity have been identified (Forman & Hersperger 1996):...4. On moist slopes road culverts that are inadequate in size, location or number normally cause a higher water table upslope and a lower water table downslope. Also a road with an upslope cutbank and large roadside ditches and culverts may cause a lower water table both upslope and downslope. 5. Roadside ditches typically become connected to the stream network, resulting in significantly higher and earlier peak discharges, which in turn cause floods, damage and floodplain alteration (Jones & Grant 1996). Greater erosion and sedimentation also occurs.
- (Forman et al. 1997) Road density itself is an overall index or measure, which represents several more specific variables producing road density effects. These variables include road network connectivity, road type or width, and traffic density.
- (Trombulak and Frissell 2000) A road transforms the physical conditions on and adjacent to it, creating edge effects with consequences that extend beyond the time of the road's construction. At least eight physical characteristics of the environment are altered by roads: soil density, temperature, soil water content, light, dust, surface-water flow, pattern of run-off, and sedimentation.
- (Trombulak and Frissell 2000) Findlay and Houlahan (1997) found that herptile species diversity in wetlands declined in relation to the density of roads within 2 km of the perimeter. Among streams in the Pacific Northwest, the status or abundance of bull trout populations has been inversely correlated to road density (Rieman et al. 1997; Baxter et al. 1999); these studies used roads as the best available general proxy of cumulative effects associated with land use and human access.