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Off the Charts:
Roads Outnumber Streams in Developed Flathead Watersheds

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Executive Summary

Road and stream data prepared for pending revision of the Flathead Forest Plan indicate the miles of road outnumber the miles of stream in roaded sub-watersheds within the Forest boundary. Only 23% of the sub-watersheds remain roadless.

Ninety-two percent of the roaded sub-watersheds have road densities in excess of levels where most strong bull trout populations occur and in excess of recommended standards for grizzly bear recovery. Fifty-eight percent of the roaded sub-watersheds have road densities in excess of levels which significantly displace grizzly bear from otherwise preferred habitats.

This report details these findings and explains why these indicators are important for maintaining and restoring watersheds for the wildlife habitat, water quality and fish habitat they provide. Companion spreadsheets allow others to explore the data further and provide a template for investigating similar data on other Forests.

The findings point clearly to the need to consider departures from historic watershed regimes more important than departures from historic fire regimes in assessing and restoring watershed integrity and resiliency.

Introduction

This report summarizes road and stream data prepared by the U. S. Forest Service for pending revision of the Flathead Forest Plan. It is intended to provide the layperson lacking access to Geographic Information Systems with two indicators of the degree to which watersheds within the Forest boundary have been roaded.

The Road/Stream Ratio (road miles/stream miles) provides a measure of the degree to which roads compete with native streams in determining the hydrologic function of the watershed. Ratio values greater than zero indicate the hydrology of the watershed has departed from its historic roadless regime. A threshold value of 1.0 is used to determine whether there are more miles of road than stream.

Road Density (road miles/square miles) is commonly used in the scientific literature. A threshold value of 0.45 mi/mi^2 is taken from the literature as the watershed road density at or below which most strong bull trout populations occur. This value is also used to approximate the 0.32 mi/mi^2 recommended as a maximum road density standard to accomplish grizzly bear recovery. A threshold value of 2.0 mi/mi^2 is taken from the literature as the road density above which grizzly bear are significantly displaced from otherwise preferred habitats.

This report will firstly summarize the data and compare it to the Road/Stream Ratio and Road Density indicators and thresholds. It will then provide a brief discussion of the scientific literature that gives meaning to these indicators and how they can be used. It will conclude with a discussion of the data sources, the methods by which the data was summarized, how similar methods may be applied to data on other Forests or land areas, and make suggestions for further study.

Findings

Flathead Forest Plan revision data provides road and stream information for 169 sub-watersheds of various land ownership within the Flathead National Forest boundary, which includes the majority of the headwaters of the Flathead River Basin. Of these sub-watersheds, 77% (130) contain roads and 23% (39) remain roadless.

On the whole, there are 1.2 times more road miles than stream miles in the roaded sub-watersheds (9,092/7,607). More particularly, 55% of the 130 roaded sub-watersheds have more miles of road than stream - often considerably more, 6% have equal miles, and 38% have fewer miles of road than stream. The particulars are shown in Table 1.

Table 1: Road/Stream Ratio Categories* for 130 Roaded Sub-Watersheds

Road/Stream Ratio	**<1.0**	**1.0**	**>1.0**	**(1.1-2**	**2.1-3**	**3.1-4**	**4.1-5**	**5.1-6**	**6.1-7)**
# **Sub-Watersheds**	50	8	72	(49	15	6	0	1	1)
% **Sub-Watersheds**	38	6	55	(38	12	5	0	<1	<1)

* ( ) include categories >1.0

On the whole, 92% of the roaded sub-watersheds have road densities often well in excess of 0.45 miles/square mile, inferring those that are or once were bull trout watersheds are now less likely to contain strong bull trout populations. Indeed, Table 2 reveals the majority of the sub-watersheds (58%) have road densities in excess of 2 miles/square mile. As will be discussed further, this has negative implications not only for fish, but for threatened grizzly bear habitat security.

Table 2: Road Density Categories* for 130 Roaded Sub-Watersheds

Road Density (mi/mi^2)	**<=.45**	**>.45**	**[.46-.99**	**1-1.99**	**(2-2.99**	**3-3.99**	**4-4.99**	**5-5.99)]**
# **Sub-Watersheds**	11	119	[14	31	(35	27	10	2)]
% **Sub-Watersheds**	8	92	[11	24	(27	21	8	2)]

*[ ] include categories >0.45 mi/mi^2, ( ) include categories >2.0 mi/mi^2

Scientific Basis for the Indicators

The scientific literature contains a wealth of information concerning the many ways in which roads damage terrestrial and aquatic ecosystems. Indeed, over the past decade both scientists and land managers have come to view roads as "the major impact" leaving "the most lasting imprint on the landscape." (Johnson 1995 and Dombeck 1998, respectively, emphasis in original). Basin-wide studies have found "60 percent of the healthiest aquatic habitats occur in roadless or very low road density areas on federal land in the Columbia River Basin." (Dombeck 1998). Indeed Interior Columbia River Basin Ecosystem Management Project (ICBEMP) documents summarize the damaging effects of roads as follows:

> "High road densities and their locations within watersheds are typically correlated with areas of higher watershed sensitivity to erosion and sediment transport to streams. Road density also is correlated with the distribution and spread of exotic annual grasses, noxious weeds, and other

> exotic plants. Furthermore, high road densities are correlated with areas that have few large snags and few large trees that are resistant to both fire and infestation of insects and disease. Lastly, high road densities are correlated with areas that have relatively high risk of fire occurrence (from human caused fires), high hazard ground fuels, and high tree mortality." (USFS 1996, parenthesis in original).

In layperson terms, this means not only do the roads themselves impact watersheds and streams, but the logging they provide access for has removed the largest trees and left the more flammable logging slash and smaller trees behind for ignition by humans using those roads. In other words, roads and the management they provide access for, particularly logging, are the primary root of the "forest health crisis," not the suppression of wildfire.

Indeed, studies conducted on landscapes where recent large fires have burned conclude these ecosystems and their fish are well adapted to fire but not to roads.

> Fire and the associated hydrologic effects can be characterized as pulsed disturbances as opposed to the more chronic "press" effects linked to permanent roads or extended timber harvest activities. . . Arguably the recent fires might be viewed as a badly needed "house cleaning" for overstocked forests as well as an infusion of materials critical for the maintenance of productive [fish] habitats. . . It also is not clear that attempts to manipulate the structure and processes of whole ecosystems (i.e. beneficially manipulate the fire regime) can ever be successful. . . The perpetuation or expansion of existing road networks, and other activities might well erode the ability of [fish] populations to respond to the effects of large scale storms and other disturbances that we clearly cannot change. (Rieman et al, 1995, parenthesis in original).

In other words, fish evolved with large scale disturbances such as wildfire but did not evolve with roads. Retaining or building roads in a likely futile attempt to counter wildfire or restore fire regimes through logging will instead make watersheds less resilient and self-healing following inevitable natural disturbances.

In a nutshell, roads compromise watershed integrity and resiliency by altering how water flows. As subsurface water flows downhill in a watershed, it encounters roads cut horizontally into the hillside. Here it bleeds to the surface, meets with exposed soil, picks up sediment, and warms as it follows roads, ditches and culverts before finally reaching a stream. Subsurface water that once may have welled up cold and clean from beneath bull trout spawning gravels instead reaches the stream as warmer and muddier surface water, smothering eggs and fry with sediment and warming the stream to temperatures less productive for spawning. (Johnson 1995 and Brinckman 1996).

ICBEMP and other studies indicate these negative effects cannot be eliminated simply by building better roads.

> Increasing road density is correlated with declining aquatic habitat conditions and aquatic integrity . . . An intensive review of the literature concludes that increases in sedimentation [of streams] are unavoidable even using the most cautious roading methods. (USFS 1996).
>
> Roads, through their interception and re-direction of sub-surface runoff, have had a major contributing emphasis. Restoration of the normal drainage phenomenon can be achieved through the use of road removal and obliteration. (Johnson 1995).

Indeed, road obliteration/decommissioning/reclamation is required for the conservation and recovery of threatened bull trout.

> Bull trout are less likely to use streams in highly roaded areas for spawning and rearing, and where found in highly roaded areas are less likely to be at strong population levels. . . The average road density in bull trout strongholds was 0.45 mi/mi^2, which is considerably less than the standard of 2-3 mi/mi^2 reported as adequate for populations of anadromous salmonids. Bull trout populations classified as "depressed" had an average watershed road density of 1.4 mi/mi^2 and bull trout typically were absent at an average road density of 1.7 mi/mi^2. . . Reduction of total miles of forest roads is an important component of watershed restoration. . . Many miles of roads must be "put to bed" by pulling culverts, resloping road beds, pulling fill and replanting. (USFWS 1998).

The removal of culverts during road reclamation is indeed of primary concern to protect aquatic resources. As noted by Johnson (1995) the Flathead National Forest investigated why it was having culverts "consistently over-topped and blowing out," finding that subsurface water flow intercepted by roads and channeled to streams was contributing to the problem. Hammer (2000) documents a number of culverts that have blown out on the Flathead and cites a single Montana Department of Fish, Wildlife and Parks survey finding 52 partially plugged culverts and 13 culverts blown out in bull trout rearing and spawning streams in the Flathead's South Fork alone. Fish and Wildlife Service (2002) has found "[w]hatever the design life, any crossing structure would have a 100% chance of failure over its installation life if it is not removed after the road is abandoned. Hence, Flathead Forest Plan Amendment 19's road reclamation program wisely requires that all stream-bearing culverts and bridges be removed from reclaimed roads to protect aquatic resources while securing grizzly bear and other wildlife habitat. (USFS 1995).

While Flathead Forest Plan Amendment 19's road reclamation program integrates some requirements for protecting and restoring aquatic resources, it was developed largely to establish road management standards for threatened grizzly bear habitat security. Fish and Wildlife Service cites South Fork Flathead River Grizzly Bear Project findings that grizzly bear displacement from otherwise preferred habitats becomes significant when total road densities exceed 2.0 mi/mi^2 and that, on the whole, female grizzly bears prefer roadless lands and tolerate total road densities in excess of 2.0 mi/mi^2 in only 19% of their home range.

From this finding, a precise total road density standard was established to allow no more than 19% of a Bear Management Sub-Unit, which approximates a 50 square mile female home range, to exceed 2.0 mi/mi^2 when calculated using a pixel-by-pixel Geographic Information System "moving window" analysis. (FWS 1995 citing Mace and Manley 1993). Other analyses of the South Fork grizzly bear data indicate an average total road density standard should be on the order of 0.32 mi/mi^2. (Metzgar 1998). Application of this threshold value to the revision data yields results very similar to application of the 0.45 mi/mi^2 bull trout threshold.

Hence, the Road/Stream Ratio and average Road Density indicators described in this report can be used as the layperson's rule of thumb indicators for watershed health, but should not be thought of as being necessarily equal to more complex indicators, standards or thresholds in the scientific literature. They are intended, however, to provide reasonable insight into agency data for those without GIS resources.

Using the Data and Indicator Thresholds

To summarize, a Road/Stream Ratio greater than zero indicates the hydrology of the watershed has departed from its historic roadless regime. A Ratio greater than 1.0 means there are more miles of road than native stream in the sub-watershed and chances are the hydrologic regime has been significantly altered by the interception of subsurface flow and the contribution of sediment to streams. One must not imply, however, that Road/Stream Ratios less than 1.0 are adequate for maintaining or restoring watershed integrity.

Indeed, conservation groups used the Flathead Forest Plan revision data discussed in this report to challenge the Flathead's Moose Post-Fire Project and to secure press coverage favorable to their cause.

> Big Creek is considered a key bull trout spawning stream, but has been listed by the state of Montana as "impaired" since 1992 due to logging and road building. Big Creek is also listed by the Flathead National Forest as "functioning at unacceptable risk" due to too many roads in the drainage, where land managers have yet to meet Flathead Forest plan road density requirements for wildlife. . .
>
> During the public comment period for the salvage logging project, the groups, the Environmental Protection Agency and others urged the Flathead to decommission more than 57 miles of roads in order to better restore the Big Creek watershed.
>
> "Big Creek has 171 miles of road and only 113 miles of streams," Hammer said. "The decommissioning of 57 miles of road will barely make those numbers even in Big Creek." (Jamison 2003).

In their appeal of the Project, the groups compared the revision data's 3 mi/mi^2 road density in Upper Big Creek and 2 mi/mi^2 in Lower Big Creek to the 0.45 mi/mi^2 threshold at or below which most strong bull trout populations are found to occur. They then cited FWS's 1998 *Bull Trout Interim Conservation Guidance*, which urges land management agencies to reduce road densities that are above 0.45 mi/mi^2. (Swan View Coalition and Friends of the Wild Swan, 2003).

Various Road Density thresholds can be used to infer how well a watershed is likely to support strong bull trout populations or provide adequate grizzly bear security. To recap, most strong bull trout populations are found in watersheds with road densities of 0.45 mi/mi^2 or less, bull trout populations classified as "depressed" had an average road density of 1.4 mi/mi^2, and bull trout were typically absent at an average road density of 1.7 mi/mi^2. When total road densities rise above 2.0 mi/mi^2, grizzly bear are significantly displaced from otherwise preferred habitats while road densities as low as 0.32 may still be too high to achieve population recovery.

These threshold values should be regarded as rule of thumb generalizations that can help indicate watersheds that are in trouble and in need of further and more sophisticated analysis. As will become evident in the following section of this report, the sub-watersheds used in the revision data are not necessarily of the same scale used in the research determining road density relationships to bull trout population strength, nor are they consistent in either size or location to the Bear Management Sub-Units used on the Flathead to calculate precise road densities.

The threshold values and indicators described in this report are of great value to public discourse in providing a bridge between science and the layperson's need for simpler terms and less technical relationships. Current public debate makes it hard to see the forest watershed for the trees amid the rush and rhetoric to return fire regimes and too-thick forests to historic, pre-settlement conditions. Virtually absent is public debate about the need to return watersheds to nearer their pre-settlement roadless conditions.

The Road/Stream Ratio provides a simple and common sense measure of the degree to which roads have moved watersheds away from their historic and native hydrologic function. Road Density provides a more precise measure of whether threatened bull trout or threatened grizzly bear are likely to persist in a roaded watershed containing otherwise suitable or historic habitat. Identified by the Forest Service as indicator species, bull trout and grizzly bear provide a glimpse of whether other species requiring clean, cold waters and security from human disturbance are likely to persist under similar conditions.

Data Sources and Methods

The data used for this report was generated by the U. S. Forest Service in March 2000 for pending revision of the Flathead, Lolo and Bitterroot Forest Plans, the start of which was subsequently delayed for several years. Geographic Information System map and database layers for NRCS (Natural Resources and Conservation Service) 6th Code Hydologic Unit Codes (HUC6, hereafter HUCs), all roads, streams, and land ownership were used to create Lotus database files. These files include data about the miles of road and miles of stream in each HUC, as well as information about road density, the number of stream crossings by roads, road miles and road density within 125 and 300 feet of streams, miles of stream within 300 feet of a road, size of the HUC, and so forth. HUCs are the individual "sub-watersheds" referred to earlier in this report.

While the database files provide a wealth of useful information, the purpose of this report is to boil the data down to the two indicators already discussed: Road/Stream Ratio and Road Density. The Lotus database files were converted to Microsoft Excel spreadsheets and data for HUC number, HUC name, road miles, square miles, road density, and stream miles were retained. All other data was deleted from the working version of the spreadsheets and a new column was added to calculate the Road/Stream Ratio by dividing road miles by stream miles.

A hard copy map of the NRCS HUCs, streams, and land ownership GIS layers was obtained from the Forest Service in order to assign common stream and watershed names to HUCs that were nameless (only HUCs in the Flathead's Middle, North and South Forks had been assigned names). A clear overlay of the all roads layer was also obtained.

The March 2000 GIS data was generated from an early version of the NRCS HUCs as the Forest Service was making the transition from use of Columbia River Basin HUCs used in the ICBEMP analyses. Consequently, it took several tries to obtain a map which matched the database files – in the end with the exception of a few HUCs that had essentially been integrated into others as the NRCS HUCs were being refined. These few adjustments were made with the help of a Flathead Forest fisheries biologist familiar with the HUC maps and database. (VanEimeren 2003). Only one HUC remains nameless in the final spreadsheet because it could not be determined which map HUC it had been absorbed into.

The original database contained 198 HUCs. Some of the HUCs were outside the perimeter Flathead National Forest boundary, largely in the neighboring Glacier National Park, Kootenai National Forest, and Flathead Indian Reservation. These 27 HUCs and 2 that represented Hungry Horse Reservoir and Flathead Lake, rather than land areas, were dropped from the spreadsheet. By then dropping 39 roadless HUCs, the data set and spreadsheet were whittled down to the 130 roaded HUCs of various land ownership within the Flathead National Forest boundary. Similarly note, however, the data includes all inventoried roads within the Forest boundary and GIS database, not just those managed by the Forest Service.

Spreadsheets and Maps

As companion to this report are four spreadsheets which, in electronic format, are included in an Excel Workbook. Electronic copies of both the report and workbook are available on Swan View Coalition's web site at www.swanview.org.

Sheet 1 of the Workbook, "Roaded Land HUCs Within Flathead National Forest Boundary and Totals," shows the results of the methods and process described above. It is divided into six major Flathead Basin "tributaries" and sorted by HUC number.

Each of the six can be sorted to display the data in different orders of priority, such as from highest to lowest Road/Stream Ratio or Road Density.

It is wise to sort using a copy of the spreadsheet file. In the event improper sorting techniques scramble the data, one can then revert to the original, undamaged file. If one prefers, the data for the six tributaries can be combined in another working spreadsheet so it all sorts together. Sorting by HUC number will regroup the six tributaries, although in a different order than presented in Sheet 1.

Sheet 2 of the Workbook, "Number of HUCs by Category and Road/Stream Ratio," displays how the 198 HUCs were whittled down to the 130 roaded HUCs within the Flathead Forest boundary and displays the number of those HUCs in various Road/Stream Ratio categories. Subtotals are provided for each of the six tributaries.

Sheet 3 of the Workbook, "Number of HUCs by Category and Road Density," displays the number of roaded HUCs in various Road Density categories. Subtotals are provided for each of the six tributaries.

Sheet 4 of the Workbook, "Comparison of Totals by HUCs Included," displays for each of the six tributaries and their grand total data for all 198 HUCs, the 169 HUCs within the Flathead Forest boundary, and the 130 roaded HUCs. This allows one to look at the changes in overall road miles, stream miles, land area, Road Density, and Road/Stream Ratio when roadless HUCs and those outside the Flathead Forest boundary are excluded.

Common stream and watershed names are included with the HUCs to allow reasonable identification of sub-watersheds without a HUC map, although a HUC map certainly makes it easier and more certain. The GIS HUC map provided by the Flathead National Forest is at 1:200,000 scale and is likely the smallest scale useable, making it impractical to reproduce for inclusion with this report. It is, however, of excellent display scale at 3' by 4' and, by having the all roads layer on a clear overlay, keeps the underlying streams and HUCs from always being obscured by the roads.

Indeed the map and overlay provide a visual metaphor for how roads in many areas dominate the landscape and watersheds. The Flathead cited costs of $44 to produce the map and overlay, which it may or may not waive pursuant to Freedom of Information Act requests. If the map and overlay are requested and intended to match the data used in this report, be certain to ask for use of the same GIS layers used to produce them for Swan View Coalition.

The NRCS HUCs have changed considerably since March 2000, when the data for this report was generated. The Flathead's difficulty in reproducing a map to fit the data was resolved only by using an older HUC GIS layer. This has understandably prompted an in-house request for the data to be rerun, hopefully in the next year, using current NRCS HUCs for the Flathead, Lolo and Bitterroot Forest Plan revisions that are finally getting underway. (VanEimeren 2003). For those with GIS capabilities, such problems can perhaps be bypassed by requesting the most current GIS layers and by using them to generate the desired data and maps.

Summary and Suggestions for Further Study

This report has introduced the Road/Stream Ratio as an indicator of the degree to which roads compete with native streams in determining the hydrologic function of the watershed, with values greater than zero indicating the hydrology of the watershed has departed from its historic roadless regime. Such an indicator for watershed regimes is sorely needed to move roads to the forefront of the watershed restoration debate, which is currently dominated by talk about fire regimes and too-thick forests as though they are the primary determinants of watershed integrity and resiliency. Consequently, logging, thinning, and biomass harvesting solutions are being proposed as though retention and expansion of the necessary road infrastructure is an acceptable and forgone conclusion – all in the name of watershed restoration and sustainable forestry.

This report has also provided rule of thumb Road Density thresholds by which to gauge whether watersheds warrant further and more sophisticated analyses to determine their ability to support bull trout, grizzly bear and the host of species and habitat conditions for which they are health indicators. This report has also provided a template by which similar data for other National Forests or land areas can be analyzed and reported in layperson terms, whether obtained in tabular database format or generated using GIS technology.

Further analysis is warranted to investigate the relationship between the indicators described in this report and agency determinations regarding the health of individual streams. The Montana Department of Environmental Quality, for example, maintains a listing of streams and water bodies considered "impaired" in the ability to support beneficial uses such as aquatic life support, cold water fisheries, drinking water, recreation, etc.. This list is called the 303(d) list after the section of the Clean Water Act that requires all states to keep such a list and to develop restoration plans for those streams and water bodies listed.

Federal agencies like the Forest Service must also make determinations in biological assessments on whether streams are Functioning at Unacceptable Risk, Functioning at Risk, or Functioning Appropriately in supporting fish species like bull trout listed under the Endangered Species Act. These determinations are made relative to road density and road locations in the watershed, among others. It would be very informative to summarize the miles of stream "impaired" and/or "at risk" in the upper Flathead River Basin and compare those streams to the indicators discussed in this report.

Finally, not to be overlooked are the many other key indicators contained in the GIS data but omitted from this report. The Bitterroot National Forest, for example, determined its few surviving bull trout populations are located in watersheds with the least roads, stream crossings by roads, and timber harvest. The Bitterroot found bull trout are absent in watersheds with the most roads, stream crossings by roads, and timber harvest. (Decker 1992). It's not rocket science and the data is there for the asking.

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