NetMap's Road Analysis Tools in Action, A Step Wise Guide: Clearwater River, Western Montana (CFLRP)





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1.0 Introduction

The application of NetMap in the Clearwater River watershed of western Montana (1016 km², 250,000 acres) represents a demonstration analysis of how the NetMap community science system can be applied to restoration planning. Funded by the South West Crown Collaborative Forest Landscale Restoration Project (CFLR) and the Clearwater Resource Council (CRC), this NetMap application utilized a 10-meter digital elevation model, a road layer provided by the Ecosystem Management Research Institute (EMRI), information on fire risk, watershed function and anticipated habitat condition from the Lolo Forest (USFS) and distribution of cutthroat and bull trout by Montana Fish Wildlife and Parks (MTFWP) to explore the potential utility in road related restoration and conservation management.

The objective of this analysis is to evaluate the road network in the Clearwater basin in support of restoration planning to demonstrate a process of prioritization for: 1) improving road drainage and reducing surface erosion to valuable stream habitat (e.g., high quality fish habitat); 2) improving fish passage at road crossings; 3) stratifying roads for effectiveness monitoring; and 4) extrapolating and/or forecasting basin wide effects of road restoration programs.

Although NetMap can be used to inform vegetation management (e.g., pre fire planning, fuels treatment) that topic is not covered here; to view examples of how NetMap is used in pre and post fire planning go to <u>http://netmaptools.org/Fire_Management</u>.

2.0 NetMap Overview

<u>NetMap</u> is a community-based watershed science system consisting of uniform digital databases of common numerical structure and shared analysis tools. Although community science systems are being adopted in various academic disciplines (<u>http://www.cuahsi.org/</u>, Famigietti et al. 2008), NetMap represents the first of its kind community system in the applied watershed sciences (Benda et al. 2009) but with a current focus in the western United States.

NetMap's shared digital landscapes and analysis tools are technically and economically efficient because it leverages the expertise, ideas and funding of a diverse set of stakeholders. NetMap's dual architecture is comprised of a suite of 70 analytical tools and 100 parameters that work within ESRI ArcMap (9.3/10) and 'QuickMaps' - a browser based system of easily accessible maps and data on various landscape attributes. The dual set of tools are designed to provide decision support for a variety of resource management, restoration and conservation activities and thus they address various aspects of hillslope and fluvial geomorphology, aquatic habitats, erosion, watershed disturbance, road networks, wildfire, hydrology, large wood in streams, and climate change, among other processes and attributes.

In the NetMap system, cooperating agencies (USFS, BLM, EPA, NOAA etc.) share in database and tool development and cost, thus engaging in a powerful form of community leveraging (<u>Benda et al. 2009</u>). NetMap's uniform digital <u>watersheds</u> extend across most of Washington, Oregon and northern California as well as southern coastal Alaska. Over

500 pages of web based technical help materials (and counting) that can accommodate contributions from users, making NetMap a networking and learning experience. The menu driven NetMap tools require little GIS experience, making them ideal for many stakeholders. For additional information on NetMap tools, see <u>www.netmaptools.org</u> and <u>video demonstrations</u>.

3.0 Analyzing the Road Network in the Clearwater Basin, Montana

The analysis of roads using NetMap is illustrated below. The NetMap database for the Clearwater watershed and the associated analysis tools are now available to all stakeholders in, or interested in, the basin and can be obtained at: <u>www.netmaptools.org</u>.

3.1 Objective I – Prioritizing roads for improving drainage and for reducing surface erosion.

Surface erosion on roads is governed by road gradient, length of road that is hydrologically connected (e.g., length of overland flow on a road surface), road width, road surfacing (native, gravel), traffic level (high to low), and time since grading (Luce and Black 1999, Sugden and Woods 2007). Using the WEPP road surface erosion model (Elliot et al. 1995, <u>http://forest.moscowfsl.wsu.edu/fswepp/docs/wepproaddoc.html</u>), the necessary parameters include road width, drainage length, road gradient, surface material and traffic level. Since WEPP predicts sediment delivery to streams (t/yr), the intervening hillslope distance (and gradient) between individual road segments and the nearest streams influences the amount of sediment delivered to channels. If the road drains directly to a stream channel, no buffer is considered.

The objective of the NetMap analysis of road surface erosion is to identify road segments that have a high likelihood of producing large amounts of fine sediment and delivering that sediment to high value streams and fish habitat. Road surface erosion can be reduced by increasing the number or frequency of cross drains (thereby reducing the effective length of overland flow on a road surface) and improving road surface materials (such as placement of gravel on a native soil surface). Reducing road surface erosion can be reduced by placement of rolling dips and other secondary drainage structures such as 'open tops'' (Fig. 1). Continuing road maintenance can be expensive and in recent years managers have seen budgets severely limit their capacity for that work. In some cases managers are abandoning, storing, or decommissioning roads in efforts to remove their long-term impacts in critically important areas. Because road restoration, including obliteration and recontouring, also can be very expensive (though it does limit long term maintenance) it is increasingly important to be able to focus limited restoration funds where they can be most useful.



Figure 1. (Top) Long stretches of road can be hydrologically connected, via overland flow. In the Clearwater River basin that can lead to considerable surface erosion and the delivery of both fine sediments and other materials (nutrients) to streams. (Bottom) The use of cross drains (a form called 'open tops' in the photo) can be used to decrease the length of overland flow and thus decrease the amount of surface erosion and the volume of sediment and other materials reaching stream channels. Arrows illustrate the accumulation of flow and its disruption due to the cross drain (during conditions of light rain, October 5, 2011).

The use of NetMap in evaluating road surface erosion for the purpose of prioritizing mitigation efforts or road restoration activities is presented in a step-wise methodology below. However, NetMap is a flexible analysis tool and users can create their own approach and methodology.

Step 1: Map the distribution and values of streams and fish habitat

The MTFWP has identified the distribution of cutthroat trout and bull trout in the Clearwater basin and developed habitat ranking scores for each (Fig. 2). The GIS layers were imported into NetMap and the habitat value for cutthroat (1-10) and for bull trout (1-10) were combined to create a composite index of habitat suitability (Figure 3).



Figure 2. Habitat distribution and values for cutthroat and bull trout in the Clearwater basin (source: MTFWP; Rieman et al., 2012).



Figure 3. The stream habitat values for cutthroat and bull trout (Fig. 2) were combined into a composite score for use in NetMap.

Step 2: Analyze road drainage diversion potential.

To predict road surface erosion using WEPP requires knowledge of the hydrologic connectivity of roads or the potential length of overland flow on roads (e.g., Fig. 1). Typically, GIS road layers contain road segments that are kilometers long and are not delineated by specific physical attributes. Thus, in NetMap, GIS road layers are first broken at pixel cell boundaries thereby creating a linked population of road segments of approximately 10 m in length (when using a 10-m DEM). Next, road overland flow directions are determined for each small road segment (based on road gradient and orientation) and the small road segments are re-aggregated to create hydrologically connected road segments based on hillslope topography . In other words, road drainage (pour) points are determined based on topographic highs (ridges) and lows (swales) and further constrained by roads intersections with stream channels (in this analysis all road-

stream crossings are assumed to have functioning drainage structures [bridges, culverts]). In the current version of WEPP in NetMap, secondary drainage structures are not included in the analysis, although a user can set a fixed flow accumulation distance in the tool (for example, if the user knows that a specific stretch of road has secondary road drainage structures [Fig. 1] every 400 feet, they can specify that constraint when running the tool). Road hydrologic connectivity at the scale of the entire watershed is predicted to range between 10 and 2500 m (Fig. 4).



Figure 4. Predicted road hydrologic connectivity ranged between ten and 2500 meters (average 133 m). This parameter, during large storms or following fires when secondary drainage structures may be compromised, could be viewed as an index of 'road drainage diversion potential'. The drainage diversion index could be used to identify locations where field crews could check on drainage efficacy during or after storms or following fires.

Step 3: Analyze road surface erosion potential, point sources to streams.

The WEPP road analysis tool in NetMap can be run at any spatial scale, ranging from a single road segment (average 130 m in the present analysis) to the entire watershed encompassing 16,418 individual segments. In this demonstration analysis, WEPP was run across the entire road network in the Clearwater basin.

The following parameters were used in WEPP within NetMap: a) road hydrologic connectivity (Fig. 4); b) climate, using Seeley Lake (in the Clearwater basin) [obtained from WEPP's stochastic climate generator, Cligen]); c) road width = 4 m; d) native rock surfacing (personal communication Shane Hendrickson, U.S.F.S., Lolo National Forest); e) high traffic (assumed constant); f) inslope, vegetated and rocked ditch; g) fill gradient and slope of 50% and 5 m; h) soil type sandy loam and i) hillslope buffer length and slope (e.g., the hillslope located between individual road segments and channels) determined for each road segment (ave. 130 m) using NetMap's analytical capabilities. Users can change these parameter settings in subsequent runs of the model within NetMap.

Predicted annual road surface erosion ranged from near zero to 4.7 t (metric tons, 1000 kg) per year. The average predicted erosion to streams was 0.04 t/yr with a standard deviation of 0.13 t/yr (Fig. 5). The road segments (total 16,418) with the highest predicted sediment yields to streams having some combination of long road segments that are hydrologically connected (Fig.4, e.g., several hundred meters plus), steeper gradients, and close proximity to channels (limited buffers).



Figure 5. Road surface erosion (as delivered to streams) in the Clearwater basin ranged from very low (near zero) to a maximum of 4.7 tons/year. In the figure, individual road segments are color coded according to predicted annual sediment yield. Predicted

sediment yields to streams are sensitive to the hillslope distance and gradient (e.g., buffer) from individual road segments to streams, as illustrated in the figure (upper right).

Because WEPP within NetMap is used in the context of remote sensing data (DEMs, road layers, modeled precipitation etc.), it is informative to compare model predictions to field measurements of road surface erosion. A recent study of road surface erosion in western Montana (geology: Belt Supergroup and glacial till materials) by Sugden and Woods (2007) is used to evaluate the WEPP erosion prediction in NetMap. Study sites targeted roads of 6-7% slope and segments were freshly graded. Plot measured road surface erosion (hillslope buffer is not considered and hence total sediment is not limited by partial delivery to streams) ranged from 2.1 to 9.9 t/ha/yr (average 5.4 t/ha/yr), to a maximum plot value of 97 t/ha/y r (Sugden and Woods 1997).

Using an average road segment length in NetMap of 133 m and an average road width of 4 m (0.05 ha) produces a WEPP average sediment yield from roads of 0.8 t/ha/yr with a maximum of 67 t/ha/yr. Since WEPP predicts sediment delivered to stream channels, the results between the two approaches are not directly comparable. For instance, the WEPP predictions are less (average factor of 6) than the measured erosion rates. The measured results do not consider delivery to streams and thus do not account for the length or slope of a vegetated buffer that would tend to limit sediment delivery to streams. In WEPP, the inclusion of an approximate 100 m vegetated buffer (between the road and the stream) can reduce predicted erosion (delivered to the stream) by a factor of eight (Elliot et al. 1999).

Other factors that could contribute to disparities between predicted and observed road erosion include the climate (WEPP that used Seeley Lake RS average annual precipitation of 535 mm/yr compared to field measured winter (May-October) precipitation of about 180 mm/yr [2002-2004] in the study of Sugden and Woods [2007]), traffic levels and time since grading. Nevertheless, considering the sediment reduction effect of buffering (that acts to reduce WEPP predictions by at least several fold), the results between the predicted erosion to streams (WEPP) and that measured in the plot studies (both as a mean and maximum) are reasonably close (Table 1), particularly in the context of erosion modeling accuracy (Reid and Dunne 1996); moreover, the median values between the two studies are quite similar [NetMap-WEPP 0.18 t/ha/yr compared to Sugden and Woods 0.16 t/ha/yr]). This indicates that WEPP, as applied within NetMap in the Clearwater basin, provides a practical screening tool to identify road segments that are potentially important contributors of eroded sediment (and other materials) to streams (Fig. 5).

In NetMap, there are no zero value WEPP road surface erosion predictions, although many values are very low and close to zero. It is likely that many road segments will have road surface erosion values of zero, because many segments are hydrologically disconnected from streams including having wide buffers (hundreds of meters). Based on field knowledge, predicted road surface erosion could be manually truncated at zero based on certain physical conditions in a GIS.

Source	Average	Median	Maximum
WEPP in NetMap	0.8 t/ha/yr^1	0.18 t/ha/yr	67 t/ha/yr
(Clearwater basin)			
Sugden and Woods	5.4 t/ha/yr^2	0.16 t/ha/yr	96.7 t/ha/yr
(2007)			
(western Montana)			

Table 1. Comparison between WEPP prediction of surface erosion and field measurements (Sugden and Woods 2007).

¹ Includes the effect of buffering from road segments to nearest stream channel that can reduce the amount of predicted erosion (sediment delivery) by a factor of 8 in 100 m buffer width. ² Does not include the effect of buffering, based on plot studies only.

There can be several sources of error in NetMap's application of WEPP. One of the most significant is the misalignment of roads in the GIS. Road lines in GIS are typically digitized from aerial photography or from other map products. An error in road placement in a GIS and on a corresponding digital elevation model can lead to spuriously high road gradients, since road gradients in NetMap are derived from elevations of the grid cells located at each end of a road segment (road gradient = the difference in elevation/road segment length) (Fig. 6). In the Clearwater, approximately 10% of the road segments have slope gradients in excess of 12%, a likely upper limit for roads with mixed duty in timber harvest and recreation. Exaggerated road gradients can lead to exaggerated road surface erosion predictions in WEPP.

In NetMap's WEPP tool, a user can specify a maximum road gradient to reduce some of the road gradient error due to misalignment problems. Ideally, however, it will be important to verify the correct alignment of roads in a GIS and correspondingly on the DEM so that the most accurate predictions of road surface erosion can be produced in NetMap. In addition, road layers should be updated to reflect the most current status of the road use (active, decommissioned, storage).



Figure 6. Colored lines represent GIS roads draped onto a Google Earth image in the northeastern corner of the Clearwater basin. Dashed white line overlays upon exact road locations on the satellite imagery. Road misalignments are highlighted by the circles. Exaggerated road gradients (considerably in excess of 12%) can lead to exaggerated road

surface erosion predictions using WEPP. Another issue is that some of the roads contained within the GIS layer used in this analysis are already decommissioned but are not indicated as such in the GIS road layer.

It is feasible to use the results of the road erosion predictions in isolation to identify potential hotspots of road surface erosion to streams. Using Fig. 5, one could search for the road segments with the highest predicted road erosion given the caveat about road alignment issues in the GIS (Fig. 6). An analyst could create a table in ESRI ArcMap (in the NetMap watershed database) that ranks road segments by the predicted erosion contribution. Such as list could be used to prioritize road restoration activities (including increasing road drainage structures [Fig. 1], road reconstruction efforts [move road away from streams and floodplains – see later in the report], road abandonment or decommissioning and road storage). The field component of this analysis (recommended) would need to verify road parameters (that were used in the WEPP predictions) in addition to observations or measurements of road surface erosion and sediment delivery to streams to validate the predictions.

Step 4: Examine overlaps between road surface erosion potential and fish habitat.

Given the spatial variability of habitat value and sensitivity in the Clearwater basin (Fig. 3), it could be effective to couple road erosion predictions with indices of habitat condition. This is done by using the automated tool in NetMap that searches for spatial overlaps between user specified thresholds for erosion magnitude and habitat quality.

Using the WEPP interface in NetMap, an analyst aggregates predicted road surface erosion into stream channels (individual road segment detects which individual channel reach it drains into, either through a vegetated buffer or because the road directly intersects a stream). In some cases more than one road segment will drain into any individual stream segment. The results are shown in Fig. 7.



Figure 7. In NetMap, predicted road surface erosion (Fig. 5) is routed into individual stream segments.

In this illustrative example, three thresholds of road surface erosion (in streams, e.g., Fig. 7) are used: the mean (0.11 t/yr) and the mean plus one and two standard deviations (0.38 and 0.65 t/yr). The threshold of habitat value (combined cutthroat and bull trout) was chosen to have a value of 10. A user can select whatever values they wish in NetMap. The program searches across the Clearwater watershed for matches. The number of overlaps between high surface erosion potential and high habitat potential using the three erosion thresholds yielded 392, 117 and 43 locations in the channel network that met the criteria (Table 2).

Table 2. Using NetMap's "overlap" tool with thresholds for road surface erosion combined with a habitat score of 10 yielded spatial matches ranging in number between 392 to 43, representing 2% to 0.2% of the total stream network of 19,889 individual stream segments; see Fig. 8. Using these (illustrative and arbitrary) thresholds would identify a similar number of particularly problematic road segments that might focus prioritization of road restoration (or refinement of information)

Road surface erosion (t/yr)	Combined habitat score (Figure 3)	Number of matches
>= ave. (0.11)	>=10	392 (2%)
>= ave. + 1SD (0.38)	>=10	117 (0.6%)
>= ave. + 2SD (0.65)	>=10	43 (0.22%)

The identified channel segments that contain both high surface erosion potential and high habitat quality (using the thresholds in Table 1) are identified within NetMap (Fig. 8).

An alternative approach is to display the map of predicted road surface erosion potential using categories of sediment thresholds (the three in Table 1) and then identify road segments (with high erosion potential) that are in close proximity to or are in spatial relationship with high quality or sensitive habitat (Fig. 9).



Figure 8. NetMap's overlap tools are used to identify stream segments where high road surface erosion potential (>=ave. + 1 SD, Fig. 5) overlaps with high quality habitat (>=combined score 10).



Figure 9. An analyst creates maps of road surface erosion using specific thresholds and then visually relates those to specific fish habitat segments. In this approach multiple road segments can be isolated for treatment or further field based refinement and validation.

Step 5: Analyze cumulative road surface erosion potential.

The preceding analysis targeted individual road segments as the appropriate scale for road restoration. However, users may wish to consider the effects of entire road networks (but circumscribed by specific sub watershed boundaries) with respect to erosion and impacts to fish habitat or other issues such as downstream nutrient loading linked to erosion. In this approach, NetMap aggregates the stream segment scale road erosion (Fig. 7) downstream revealing spatial patterns of road erosion at any spatial scale in a watershed as defined by the stream network (Fig. 10).

The map of cumulative road erosion potential in streams can be viewed in the context of the road segments that produce the cumulative sediment supply, and thus entire road networks within individual subbasins can be considered in terms of a road restoration program (Fig. 10).



Figure 10. (Upper) Road surface erosion (delivered to streams) is aggregated (routed) downstream revealing patterns of cumulative road erosion at any spatial scale in a watershed defined by the stream network. Analyses such as this could help clarify and test questions about cumulative downstream loading associated with nutrients or other materials that could be linked to road erosion. (Lower) Cumulative patterns of road erosion (in streams) can be considered in the context of the road segments that create those patterns. The white lines (Lower) circumscribe entire road networks within individual contributing subbasins that are responsible for cumulative road surface erosion, particularly for cumulatively high values. Within individual subbasins, a

restoration program could target groups of road segments that have the predicted highest road erosion potential.

Step 6: Consider other potential road impacts and management questions

Predictions of road surface erosion to streams and the juxtaposition of road related sediment supply to sensitive aquatic habitats (Fig. 4-10) can be usefully applied to the objective of prioritizing where, in a watershed, road upgrades, restoration or road storage should occur. However, an analyst might wish to include other road related factors. Several possibilities are considered as examples below.

Roads in Floodplains

Roads in floodplains represent another type of potential impact to fisheries if a road interferes with natural channel migration or if a road delivers fine sediment directly to the channel. NetMap contains a tool for mapping floodplains in which a user specifies a height above the channel that would define the area of periodic flow inundation (in units of bankfull depths). For illustrative purposes, the floodplain in the Clearwater basin was mapped using three bankfull depths. The intersection between the floodplain and road network is shown in Fig. 11. A particular focus could be placed where roads of high surface erosion potential (or high road drainage diversion potential [Figs. 4-5]) intersect the floodplain.



Figure 11. NetMap is used to map floodplains and then roads that intersect floodplains are identified. Roads with predicted high surface erosion potential that intersect floodplains and streams could be highlighted for field validation and prioritization of restoration efforts.

Roads on Potentially Unstable Terrain

NetMap contains a tool for classifying individual road segments (pixel scale, 10 m) based on the potential instability of the underlying hillslope (shallow failure, gully). This tool was not applied in this analysis.

Roads at Risk from Debris Flows

NetMap contains a tool for classifying individual road segments (pixel scale, 10 m) based on the debris flow risk of individual headwater streams. This tool was not applied in this analysis.

Calculating Road Density at the Subbasin and at the Stream Segment Scale

Road density (mi/mi², km/km²) is often used as a surrogate for road related impacts in a watershed (disruption of drainage, increased erosion, fish migration barriers etc.). Typically, road density is calculated at the scale of entire watersheds or subbasins (Fig. 12). However, road density in NetMap can be calculated at the scale of individual stream segments, or at any scale defined by the stream network.

Calculating road density at the stream segment scale provides a much higher resolution mapping of variations in road density. For example, road density in the Clearwater Basin that is calculated at the scale of HUC 6^{th} field subbasins ranged between 0.5 km/km² and 4 km/km². In contrast road density measured at the stream segment scale ranged between zero and 100 km/km² (Fig. 12).



Figure 12. Road density in NetMap can be calculated over a range of scales including subbasin (HUC 6th field shown in upper left) and individual stream segments (lower right). Notice that the variation in road densities at the channel segment scale is significantly larger compared to the subbasin road densities.

Step 7: Develop Prioritization Strategies for Road Programs

One potential use of road analysis tools in NetMap is developing prioritization strategies. Prioritization strategies could be used for allocating finite resources to improve road infrastructure and or to mitigate potential road impacts to aquatic systems. For example, an agency user can use a spatial join feature in NetMap to link NetMap outputs with his/her agency's Road Segment Number (or ID). This would allow individual NetMap road segments to be prioritized by road segment number relative to all other road segments. The specific prioritization method that is ultimately applied is up to users and their objectives. For example, indices for surface erosion, proximity to sensitive habitats, and roads in floodplains could be combined to create a composite index of road risk to inform road maintenance, road rehabilitation or road restoration activities. Many other combinations are also possible. Thus, a cumulative risk ranking by road ID can be created from high to low for road networks in a project area, by HUC boundary, or for a management unit such as Ranger District in the National Forest System.

NetMap is a robust screening tool that can be used to identify (and prioritize) areas where more detailed field evaluation of conditions might be warranted, since the GIS information used in the predictions lacks specificity regarding road surface and drainage conditions, use and maintenance.

3.2 Objective 2: Prioritizing Road – Stream Crossings for Improving Fish Passage Watershed restoration can include activities designed to improve fish passage at road crossings. Roads-stream crossings involving culverts built before the early 1990s often represent velocity barriers to fish and to other organism movement upstream and poorly designed crossings can also have vertical displacement that also disrupt movement (personal communication, Shane Hendrickson, U.S.F.S.).

It could be informative to have information of the length of available habitat upstream of every road-stream crossing in a watershed, combined with an index of habitat quality above every crossing. NetMap contains a tool for rapidly calculating both the cumulative habitat length and quality upstream of every road crossing (using the habitat distribution and quality scores in Fig. 3).



Figure 13. A user calculates the cumulative habitat length above each road crossing in a watershed to help prioritize where road-crossing restoration and maintenance could occur. In addition to cumulative road length above each road-stream crossing, NetMap was used to calculate the average habitat value score above each road crossing (Fig. 14). An analyst could multiply the two parameters to get a combined score involving cumulative habitat length and quality. Such an analysis could be used to establish priorities about where to consider road-stream crossing upgrades or for removing road crossings altogether.



Figure 14. An analyst calculates the cumulative habitat value above each road crossing in a watershed (shown here as the average quality). This index could be combined with the cumulative habitat length upstream of each road crossing (Fig. 13) to help prioritize where road-crossing restoration and maintenance could occur.

3.3 Objective 3: Design and Support for Effectiveness Monitoring

Road restoration and management can be expensive and understanding its effectiveness is important to refine the methods and demonstrate an appropriate use of limited funds. . Following road restoration activities, it may be desirable to monitor the effectiveness of erosion reduction activities. Because monitoring is also expensive it likely will not be possible to consider every segment of road that is treated. Monitoring could either take the form of pre and post activity at selected locations or a space for a time substitution approach could be applied where similar road segments are identified and one or more treatment sections are mirrored or "controlled" (and monitored) by a set of non treated road segments.

Road surface erosion is significantly influenced by road gradient, road segment length that is hydrologically connected, road surfacing and road use (among other factors, see Luce and Black 1999). To identify a provisional set of road segments that are similar physically (particularly road length and gradient), NetMap's road tools could be used to identify potential monitoring pairs (treatment, no treatment). NetMap's data output includes road length of hydrologic connectivity (e.g., Fig. 4) and road gradient (but note the caveat discussed in 3.1, Step 3 about errors in road alignment in a GIS that results in spurious road gradients). Of course field observations and measurements would be needed to validate any predictive modeling or screening.

If a pre and post action monitoring design was implemented, NetMap's road parameters (such as road hydrologic connectivity or road surface erosion potential) could be used to identify the best sites for detailed erosion monitoring. For example, NetMap could be used to identify a provisional set of road segments that have both high connectivity and associated high erosion and sediment delivery to streams. These types of road segments might show the greatest effect of road restoration activities such as the placement of additional cross drains (e.g., Fig. 1). The monitored road segments would need to drain directly to streams, since monitoring flow and sediment movement through vegetated buffers would be extremely difficult.

In a space for time substitution approach to monitoring, NetMap could be used to help identify similar types of road segments in terms of hydrologic connectivity (length), road gradient and discharge to streams.

3.4 Objective 4: Site Selection for Extrapolating Effects of Restoration Activities

If a road restoration plan was implemented in the Clearwater Basin as part of the CFLRP, it might be important to forecast the effects of a multi-year or multi-decade road restoration plan. This could be done with or without a coordinated effectiveness monitoring.

With Effectiveness Monitoring

Effectiveness monitoring may reveal benefits (reduction of sediment delivery to streams) of improved road drainage structures or road storage programs. To evaluate how a road restoration program that extends across entire watersheds (e.g., the Clearwater basin) would create a cumulative positive effect on water quality, the results from effectiveness monitoring could be extrapolated to other road segments in the basin that have had treatment or results could be forecasted to yet untreated sections of roads. Such extrapolation at the watershed scale would require use of GIS, and the stratification of roads based on their physical properties (connectivity length, gradient, width, surfacing etc.). At least some of these physical road properties could be obtained from NetMap, thereby supporting a program of extrapolation or forecasting effects of a road restoration program both in time and space.

Without Effectiveness Monitoring

In the absence of effectiveness monitoring, there are tools available to forecast effects of road restoration activities, such as increasing the number of drainage structures (such as dips or 'open tops'). One of these is called "Cross Drain", a subroutine in the WEPP family of surface erosion models that can be used to determine optimum cross drain spacing and to estimate the amount of sediment that will be removed from the channel system.

The 'Cross Drain' model (Elliot et al. 1999) is not presently part of NetMap but could be added in the future and coupled to the existing suite of road tools. Application of 'Road Drain' (http://forest.moscowfsl.wsu.edu/fswepp/docs/xdrain2doc.html) within NetMap (and informed by NetMap parameters such as road hydrologic connectivity length, gradient and buffer dimensions) could be used to forecast the effects (sediment saving to streams) of a road restoration plan administered at the scale of entire watersheds, such as the Clearwater or any subbasin within it. The 'Cross Drain' tool could be run using different restoration scenarios (timing and placement) to search for the optimum application of a road restoration program that would achieve the greatest sediment savings in the most biologically important areas of a watershed within the constraints of the overarching restoration rogram. A key question that could be explored is whether anticipated restoration can be expected to have a significant (or measurable) influence on the total sediment budget for the watershed in question.

3.4 Objective 5: Stratify Road Segments for More Intensive Road Erosion Monitoring (GRAIP)

Some national forests are implementing an intensive field based road surface measurement (and prediction) program called GRAIP (Geomorphic Road Analysis and Inventory Package) (Cissel et al. 2011). In it's traditional application GRAIP has been used to provide a complete inventory of a road network. Because of the intensive field based approach and its associated expert modeling framework, the ultimate costs might limit the application of GRAIP spatially. One alternative that is being applied throughout the western states as part of the "Legacy Roads" program, is to use the GRAIP protocols and model to evaluate the benefits of site level road restoration through "before and after" sampling. Conceivably NetMap could be used to identify treatment and monitoring sites as outlined above.

It should also be feasible to combine aspects of GRAIP with NetMap to produce a robust tool for addressing issues related to forecasting road surface erosion to streams at the scale of an entire watershed, particularly if field measurements are available to help constrain predicted road surface erosion values (in the absence of local field measurements of road surface erosion, the GRAIP manual [2011] recommends that WEPP be used to inform the erosion rate parameter [kg/yr] in the GRAIP sediment production equation).

If GRAIP depends on field based estimates of road parameters such as gradient, hydrologically connected road length and location of drainage points, its application

across large watersheds may be hindered by the lack of such site specific data. In that case, NetMap's parameters for gradient, hydrologically connected road length and location of drainage points could be used to apply GRAIP at the watershed scale, such as in the Clearwater basin or subwatersheds within it. However, GRAIP does not account for the effects of varying buffer dimensions (hillslopes located between individual road segments and drainage outlets and stream segments). Thus, whether to couple GRAIP and NetMap and how to apply such a hybrid model may depend on the specific needs and capabilities of a set of analysts in any particular watershed.

3.4 Objective 6: Integrating Aquatic Considerations into Pre and Post Fire Management Planning

Pre fire vegetation management (commercial and pre-commercial thinning, controlled burns) could be informed by adding an aquatic component. For example, where in a watershed would fuels reduction that leads to a reduction in fire intensity have the largest effect on reducing the potential for post fire erosion and its negative effects on fish habitat? Tools in NetMap have been used to address this question in other landscapes and they could be used in several different ways to integrate water quality and fisheries concerns within fire planning or vegetation management in the Clearwater basin.

This topic is beyond the scope of the present analysis in the Clearwater basin. For additional information about how NetMap can be used to inform pre and post wildfire planning, see <u>http://www.netmaptools.org/Fire_Management</u>.

4.0 NetMap Coverage and Additional Information

NetMap's community-based digital watershed databases, that work with the NetMap family of shared analysis tools, are focused in the Pacific Northwest with coverage extending throughout most of Washington, Oregon, northern California (and soon southeast Alaska). In Region 1 of the National Forest System (Northern Region, western Montana and portions of Idaho), NetMap has only very limited coverage, including portions of the Panhandle NF and in the Clearwater basin of Montana, as described in this report.

ESI is seeking collaborative opportunities to increase NetMap coverage across all of western Montana and Idaho. One advantage of a widespread and consistent watershed database is that analyses, such as those described in this report, would be available for all 26 million acres of the national forests of Region 1. In this context, NetMap could be applied to various types of activities: (1) road restoration; (2) minimum roads analysis; (3) channel and aquatic habitat typing; and (4) pre and post (BAER) fire planning, among other programs.

For additional information, please contact <u>Earth Systems Institute</u> or visit the <u>NetMap</u> <u>website</u>.

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