Salmon River Restoration Council and US Forest Service

Management Assessment: Roads Crossing Inventories

Using GPS and GIS

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Abstract:

The Salmon River Restoration Council and the Klamath National Forest (USDA - Forest Service) work together within the Salmon River Subbasin to gather information and foster ecosystem management. The Salmon River Subbasin is a 751 Square Mile watershed that is 98.7% federally owned and 45% Wilderness. Under California Fish and Game Funding, the Salmon River Restoration Council and the Klamath National Forest have conducted a road sediment source inventory and risk assessment on a portion of the Salmon River Subbasin. Using Trimble GPS equipment and ESRI GIS software, the cooperators have collected and analyzed information in order to make sound decisions on current and future road management plans.

BACKGROUND

The road network in National Forest watersheds is considered by many to be the most important, the most costly, and potentially the most damaging component of Forest land use. Roads are generally considered to contribute the highest per acre sedimentation rate of all watershed disturbances (e.g., Amaranthus, et al., 1985; de la Fuente & Haessig, 1994; de la Fuente & Elder, 1998; Elder, 1998;Flanagan, Furniss, et al., 1998a & 1998b; Pacific Watershed Associates, 1997; Rieman & Clayton, 1997; U.S. Environmental

Protection Agency, 1998; U.S. Forest Service, 1989)In addition, they can alter hydrology, habitat connectivity, and routing of wood and sediment. These combined effects have the potential to strongly influence downstream aquatic environments critical to anadromous salmonids. As the availability of road maintenance funds allocated to the Forest Service decreases, down nearly 50% in the past six years, the necessity to evaluate and implement measures which reduce the risk of road related impacts to aquatic systems is greater than ever. In the Klamath National Forest *The Flood of 1997: Klamath National Forest Phase I Final Report* (de la Fuente and Elder, 1998) it is estimated that over half of the large road repair sites that were caused by the " New Years" flood were at stream crossings. An estimated 22% of sites resulted in diversion around plugged culverts. A secondary concern to stream diversion is the risk of the stream crossing itself being washed out which could damage downstream habitats and trigger additional failures of crossings downstream, or it could initiate a large debris flow that would scour the channel. Although it is difficult to predict culvert failure, indicators of such failure were assessed in this study in order to assign some level of hazard to each crossing based on debris flow risks. The hydraulic capacity as well as capacity to pass woody debris and sediment was also assessed.

Often the roads with the least stringent design standards are abandoned **non-system roads**, including "temporary" logging and some private roads. Many of these are abandoned and/or unmapped with no attributes known, and have therefore been referred to as "ghost" roads.

The assessment accomplished here is critical for identifying, prioritizing, and getting the most watershed benefit for our restoration dollars and efforts. The Klamath National Forest annually allocates funds for watershed restoration. Restoration projects that have been identified through a comprehensive survey and prioritized through risk and cost analyses receive the highest rating for funding. Performing these surveys and analyses is the purpose of this restoration planning.

COOPERATIVE BACKGROUND

The Salmon River Restoration Council (Council), and the USFS (Cooperators) have joined forces on several coordinated watershed education and improvement projects. The Cooperators signed a Memorandum of Understanding (MOU) in 1997, which establishes common goals in the Salmon River Watershed. As a part of the MOU, the Cooperators meet regularly and generate opportunities for Council involvement in resource management planning. Community participation and sharing of knowledge is a major component of the Council mission. This project is a direct outcome of a Council - USFS meeting. In the spirit of cooperative management, the Salmon River Restoration Council and Klamath National Forest have joined forces to perform the Lower South Fork Road/Stream Crossing Risk Assessment and Restoration Planning.

LAND USE

The Klamath National Forest has recognized the need to reduce mileage of Forest system road. Decommissioning is taking place and the KNF has completing a Forest wide roads assessment. A more detailed access analysis has been done by the Salmon River District interdisciplinary team for the remaining subwatersheds in the Salmon River that are in the District. Those two analyses considered existing road condition data and road needs for legitimate land use. The access analyses for Upper South Fork and North Fork/Main Stem subwatersheds recommended roads where the management strategy should change, and where opportunities exist for road-related restoration. This project provides essential information on road-stream crossing conditions as needed to complete a prioritized list of recommended actions to treat the remaining roads on the District. Sample actions would include elimination, repair or upgrade, increased maintenance and closure.

OBJECTIVES

This project consists of four components:

1. update of the Forest transportation mapping which will locate <u>all</u> roads in GIS
2. conduct stream crossing inventory and erosion hazard assessment on all roads except the main River Road
3. provide support to private landowners interested in formulating transportation management strategies which may include road restoration opportunities
4. plan for road-related restoration needs on public land

The objective for **updating transportation maps** is to more accurately account for the effect of all roads on various resources in the Lower South Fork watershed, and thereby facilitate management of these "ghost" roads consistent with salmonid habitat protection.

The primary objective of the **crossing inventory and assessment** is to identify risk road-stream crossings which pose the greatest threat to aquatic resources, especially sedimentation of anadromous fish habitat. Some or all of the following has characterized high-risk stream crossings:

- large fills at or adjacent to the crossing
- potential for stream diversion
- inadequate culvert capacity to pass water, woody debris or sediment
- unstable geology above site (high debris flow potential) or downslope (high potential for additional erosional effects if crossing fails or diverts streamflow)
- high value beneficial uses that would be adversely impacted if crossing failed.

A secondary objective is to provide education to residents within the watershed on the road crossing designs and risks and how this can affect aquatic habitat, and provide the design principles that landowners can apply to their own roads

The primary objective for supporting **strategic transportation planning** of private roads is to lay the ground work for long term restoration where opportunities might otherwise be limited due to lack of expertise to make informed decisions. A secondary objective is to reach out to landowners in order to educate and interest them in cooperative watershed restoration planning.

The primary objective of the **restoration planning** component is to identify stream crossings which pose the most risk to aquatic resources. The goal is to recommend the most economically and ecologically cost-efficient solutions.

PROJECT METHODS

Analysis of Debris Flow Potential

The susceptibility of certain channels to debris flow events is an important element of crossing hazard. Twenty-seven percent of stream crossing failures involved debris flows during the 1997 New Year's event (de la Fuente and Elder, 1998).Field evidence from older events is often subtle and difficult to recognize in the field. The following approach was used:

1. field identification of obvious and very recent events (e.g. debris flows from the 1997 Flood)
2. consult with road maintenance crews to identify chronic "problem" crossings
3. use existing aerial photo interpretive studies, i.e. the Salmon Subbasin Sediment Analysis (de la Fuente and Haessig, 1993)
4. accomplish additional photo and/or geological map interpretive work where needed, with limited ground truthing.

Non-system Roads Assessment

All roads, including abandoned and used temporary roads and private roads were identified and accurately located using office and field techniques. Office techniques included location of potential roads from Orthophotoquad (Council) and Aerial Photo interpretation (USFS). In the field, the Council crew mapped roads identified from the office exercises and additional roads directly located in the field (see Field Methods below). Old, overgrown roads without hydrologic connectivity may have been identified but were not completely mapped. Detailed information was collected on each road, in the form of a road summary. In the event the crew was not able to GPS all or part of a road, it was mapped by hand in the field. These maps, along with the GPS positions collected, allowed the crew to heads-up-digitize (HUD) the roads in the office using Trimble Pathfinder Office Software. A "HUD" comment was then added to the note section of the attribute table. Road summary information was also collected on System Roads and entered in a field book. This information was spatially linked by heads-up-digitizing a short section of each system road.

Road/Stream Crossing Inventory and Assessment

Sites are defined as Crossings, Cross-Drains and in-between sites ("Tweeners" are failure sites along roads in between crossings and cross-drains. These failures include slumps, landslides, cracks, gullying and loss of fill. They may have the potential to deliver sediment to fish-bearing streams).

Methodology and procedures used for this section of the project were developed by the Cooperators from the works of Flanagan, Furniss, et al. (1998a & 1998b) and Pacific Watershed Associates (PWA) (1997).Details of field procedures are covered in *Field Guide: Explanation & Instructions for Klamath National Forest Road Sediment Source Field Inventory Form* - *May 14, 1999* (USFS, 1999).Field and office-generated data was analyzed to assess the **hazard** of stream crossing failure in each subwatershed. A **risk assessment**, the sum of the hazard and its potential environmental impact, was then performed by an ID team to prioritize sites for repair. The high risk sites were field evaluated to develop potential solutions and rough costs. This will also enable a cost benefit analysis that can direct managers to areas with the most potential benefit for the least amount of effort and money. Locations of each Site were given site numbers as described in the document mentioned above. The ID team worked with high priority sites that included a combination of high "risk" and "consequence". The model for prioritization was field check by the ID team to see if the model worked.

Common Field Methods

The Council crew mapped roads identified from the office exercises and additional roads directly located in the field. When practicable, a Trimble Pathfinder Pro XL GPS was used to accurately map each Crossing, Cross-Drain, 'Tweener and "Ghost" road. Attributes for Sites and Roads were keyed into a Trimble GPS datalogger on site. As a necessary part of project evolution, the data dictionaries for each Site and the Road summaries were developed in several stages. All "Ghost" roads and Sites were also hand-placed on field maps (1:24,000 USGS topographic map). The crew logged any extra notes and drawings in a field notebook for latter clarification. When GPS was not possible, attribute information for Roads and Sites was collected on the datalogger without position information for data continuity purposes. This information was then downloaded into a GIS for further analysis in the office. At the end of each field day technicians would correct GPS-collected information and attributes and verify location information on paper maps for filing and backup. Even if we could collect GPS position at all Sites in the field, some attribute data cannot be collected at the Site. As an example, the Cumulative Ditch Length field (CDL) for Site “X” requires the recorder to move on, maybe to two or more Sites before entering the CDL value for Site “X”. Since the crew cannot go back to a previous Site on the datalogger in the field, the recorder has to make a note in the field book and enter the data into the feature attribute information table in Trimble Pathfinder Office software.

Risk Assessment - Methods

With limited resources, it becomes necessary and desirable to prioritize sites for treatment. Although treatments may vary from site-specific recommendations to all inclusive road segment proposals, from minor maintenance fixes to major crossing re-design and reconstruction, all site are subjected to the same initial prioritization scheme. Site information is taken from data collected in the field and drawn from information available from air photos and existing Forest GIS layers. The priority setting of individual sites combines three general elements: (1) site condition - risk & consequences, (2) potential impacts, and (3) opportunity. A high priority site would be high risk, high consequences, with high potential impacts and high opportunity. (see Figure 1)

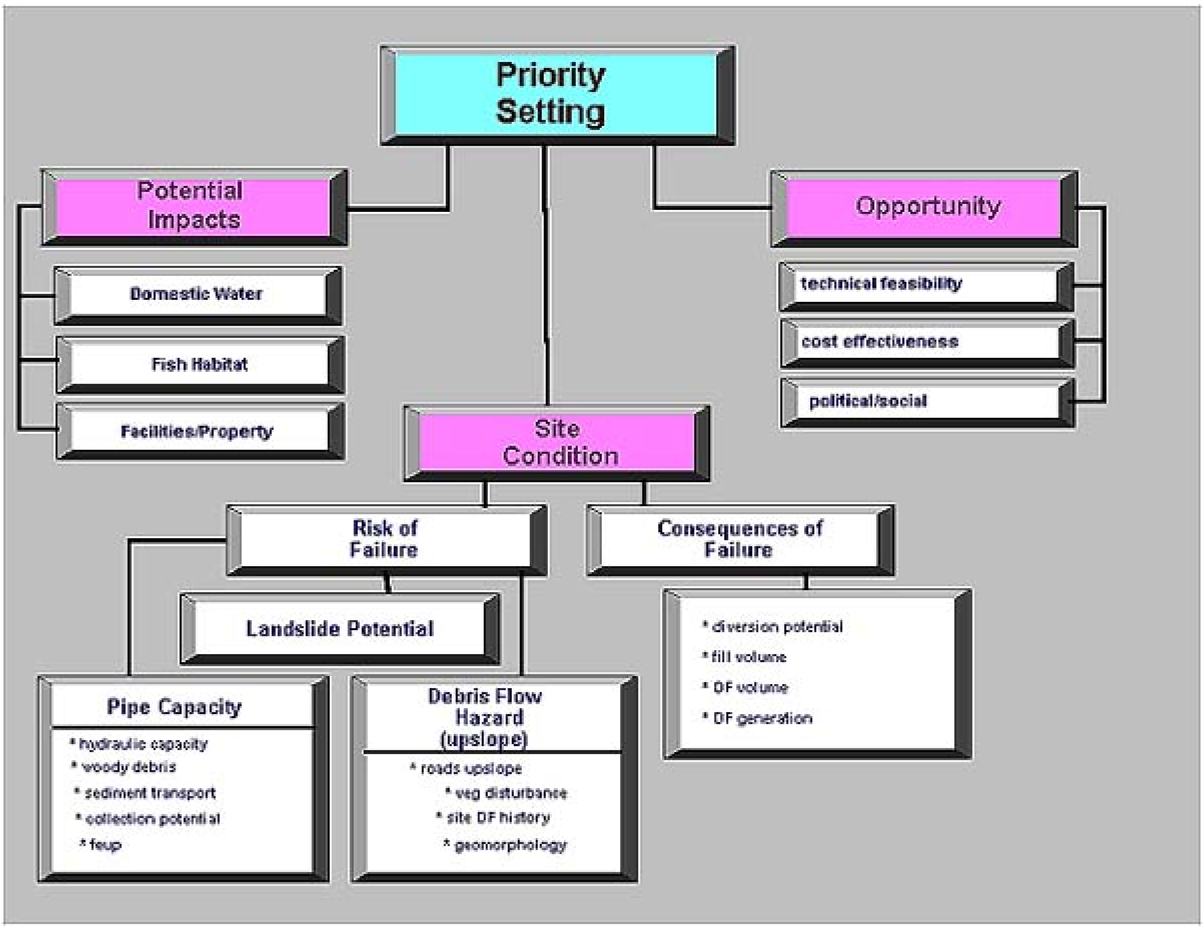

Figure 1

Site Condition:

Site condition is composed of two major elements - risk of failure and consequences of failure. Each of these major components is subdivided further. In general, "risk" characterizes upslope and site conditions that measure the probability of failure; "consequences" characterize the downslope results of a failure. When all elements are combined an overall "site condition" rating is obtained. For example, the highest rated crossing sites would be those with high risk of failure from severely undersized culvert pipe, lengthy contributing ditch, high upslope debris flow risk from past history, large upslope vegetative disturbance and/or unstable geology and high consequences of failure from diversion potential, large fill volume, and high potential for generation of debris flow.

Site risk is the combination of two major elements and a lesser component. The major elements consist of pipe capacity and upslope debris flow hazard. Pipe capacity is a measure of how well individual culverts are designed to handle watershed products, principally, water, woody debris and sediment. Hydraulic capacity of culverts is determined using an empirical culvert-sizing model (developed by US Geological Survey) that takes into account catchment basin area, differences in elevation between site and ridge top, and local precipitation. Required culvert cross-sectional area was calculated using GIS-generated data and a USGS culvert sizing equation to compare actual culvert size with predicted recurrence interval for 25- 50- and 100- year flood flows. This was then compared with the actual pipe cross-sectional area. The equation is detailed in Magnitude and Frequency of Floods in California (USGS, 1977). The GIS-generated data was derived using the ESRI Spatial Analyst "Watershed" command and determining the distance between high and low elevations of the catchment area.

Crossing culvert ability to pass woody debris is based on a ratio between culvert diameter and upslope channel width. A culvert's ability to transport sediment is based on a ratio between slope of the culvert and upslope channel. Field evidence of undersized pipe and large collection potential of upslope in-board ditch add to the three factors cited above to raise the risk of failure for culvert crossings.

Risks associated with upslope debris flow hazards are based on a combination of several elements. Assessment of these risks relies in part on Forest GIS layers. Stability of upslope geomorphology and nature and extent of upslope vegetative disturbances (such as fire and timber harvest) are determined from these GIS layers. Debris flow history at individual sites is obtained from field inventory, historic air photos, and personal accounts. Number and density of upslope roads are considered. Landslide potential at the site is a lesser component that affects a site’s overall risk of failure.

Consequences of failure are the second major element that defines site condition. This important element is composed of four unequally weighted factors - fill volume, diversion potential, potential debris flow generation and volume. Of highest importance (weighting) is fill volume. Fill volume is sediment at-risk that is delivered to the stream system if the crossing fails and is therefore very important when considering adverse road-related sediment impacts on aquatic environment. Another major consequence of crossing failures is the diversion of stream from its natural channel and down the road. This diversion can produce gullies and landslide failures. Crossing failures in the steeper headwaters areas of drainages can generate debris flows, many with significant volumes. Potential for generation and subsequent estimation of volume are based on channel and slope steepness, slope position, and stability of geomorphology at the site.

Potential Impacts:

This general component characterizes the potential adverse impacts to aquatic habitat should failure occur. " Potential impacts” is the combination of adverse impacts to three beneficial uses - domestic water sources, fish habitat, facilities/property. Impacts must be direct and imply proximity or “closeness." Domestic potable water sources are rated by number of users - municipal, >5 households, < 5 households and none. Sites at perennial streams are rated by whether or not anadromous or resident fish species are present. Sites are rated depending on whether or not they are within Riparian Reserves. Sites are rated by whether or not facilities (buildings, campgrounds, trailheads, etc.) or other roads are directly downstream/downslope.

Opportunity:

Opportunity rates the “do-ability” of the recommended treatment and is based on three general criteria - technical feasibility, cost effectiveness, and political/social considerations. These elements are based on subjective professional judgment in inter-disciplinary setting. Technical feasibility rates how effective a given treatment will be in reducing risk, consequences, or impacts. Cost effectiveness rates a proposed project on cost necessary to control an estimated volume of sediment at risk and is usually expressed in “$ per cubic yard saved." Political/social considerations include such things as land use, land ownership, access needs, etc.

Data Analysis and Restoration Planning

The USFS provided road and watershed specialists and the Council provided a field assessment crewmember to do the analysis for approximately 5 person days. They queried the data and categorized all sites into high, medium and low risk. Selected high-risk sites were field visited and alternative conceptual designs formulated. The rough costs associated with these designs were calculated, along with the benefits, in order to develop a cost-benefit ratio. Recommendations will be made to fix high priority sites. The resultant product is a prioritized list of problem sites, their proposed repair actions, and associated cost-benefit ratio.

RESULTS

- This Assessment produced the following Data for the Lower South Fork Area:
- Previously-Identified System and Non-System roads are calculated at 238 Miles
- Over 800 Sites (Crossings, Cross-Drains and ‘Tweeners) were identified and mapped
- Over 32 Miles of “Ghost” Roads were mapped
- Sites were ranked by overall rating and divided into 5 categories
- GIS products were made which showed problem areas and categories of attributes:
    1. Plugged pipes
    2. Diversion Potential
    3. Collection Potential
    4. Fill Volumes
    5. Pipe Capacity Ratings
    6. Treatment Immediacy (see Figure 2)

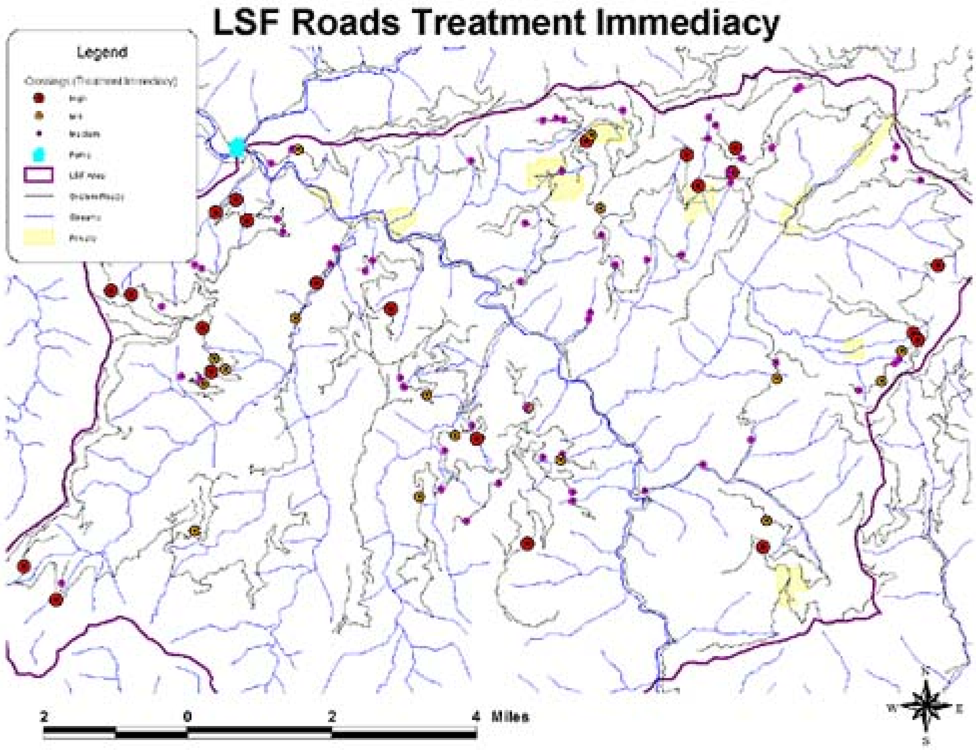

Figure 2

The Trimble GPS allowed a high level of mapping accuracy. Although satellites were not always cooperative, approximately 90% of the Sites were accurately GPSed (within one meter). GPSed Sites helped accurately position the manually located sites (see Fig. 3).

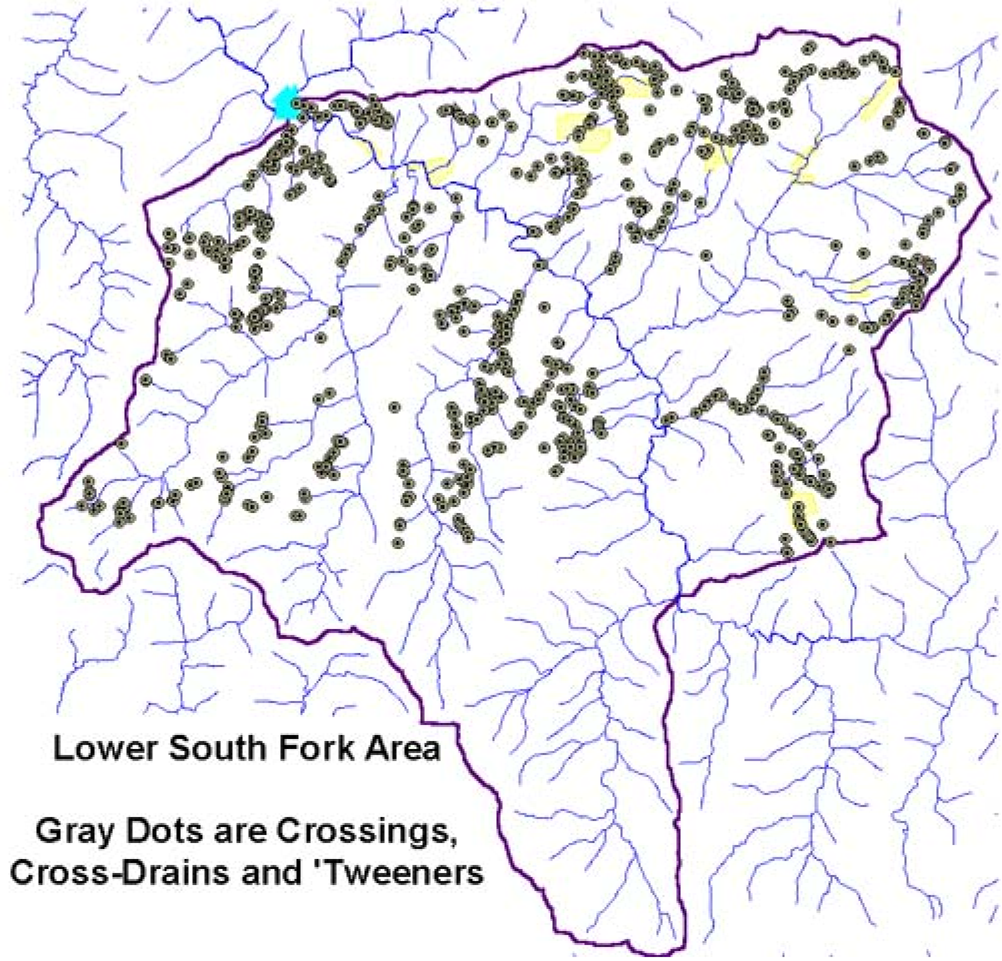

Figure 3

The evolution of the Data Dictionaries created a complicated data handling situation. Sequential Data sets had to be manipulated to match before they could be combined into a single coverage. The advantages to using a combination of GPS and GIS to perform this assessment and analysis are: