APPENDIX C
HYDROLOGY RELATIVE RISK ANALYSIS

Appendix C
Hydrology Relative Risk Analysis

Baseline road and watershed risk information is important in transportation planning, as road management activities need to consider the current condition and potential vulnerabilities of the areas where future activities will, or are proposed to occur. The result of this analysis is a relative hydrology risk rating that approximates the potential risk of roads to areas, primarily from erosion and sediment transport to streams or sensitive areas. This rating is developed for roads and for each watershed. The hydrology road risk rating is one of eight risk ratings developed to estimate the overall risk potential from roads. This hydrology risk rating is divided into six sub-categories to show the potential effect on areas in general and on certain sensitive areas in particular.

As one component of Steps 4 and 5 of the Road Analysis Process (RAP), information was collected and processed using Geographic Information System (GIS) computer technology. Only roads and watersheds, or portions of them, contained within the Forest boundary were evaluated and categorized. In this appendix, as throughout this document, numbers and mileages are based upon best available BHNF GIS data. Field verification of the data was not completed as part of this analysis. Land use and cover type were not included in this analysis and were assumed to remain relatively constant over the Forest.

The GIS analysis was evaluated for each Forest System Objective Maintenance level 3, 4,and 5 road including those under county jurisdiction. Small campground loop roads and short roads at administrative sites were not included. All subsequent discussions under this roads analysis section refer to this selection of roads unless stated otherwise. The analysis was also evaluated for 6th-order hydrologic units (HUCS), commonly referred to as “watersheds”, on the Black Hills National Forest (BHNF)

In all cases, the individual risk indicators are based on relative amounts of a parameter found on the Black Hills National Forest. The actual or ‘absolute’ risk of roads to the hydrology of an area could not be determined and would likely require site-specific information that is beyond the scope of this analysis. An attempt was made to be conservative in assigning risk conditions to increase the likelihood that high risk areas would be identified. The assigning of these risk conditions and the relative ranking of the results is based, in most cases, on the professional judgment of the specialists involved. It is important to note therefore that the relative risk rankings should only be used as an indicator of the road’s potential risk to the hydrology of an area and as a flag for project level analysis teams to look at a road or area in more detail.

In combining the individual risk factors into the overall hydrology relative risk rating, the factors were weighted equally. It is likely that certain risks would contribute more or less to the overall risk of a particular road, area, or watershed but a valid method of weighting them could not be arrived at. General relative risk categories were assigned as follows:

0 - There are no or relatively low potential hydrology risks.

1 - There are relatively moderate potential hydrology risks.

2 - There are relatively high potential hydrology risks .

The Hydrology Relative Risk Analysis is divided into two parts, Road Relative Risk Analysis and Watershed Relative Risk Analysis. The Road Relative Risk Analysis was performed to provide a relative ranking of individual roads based on their risks to the hydrology of an area. This allows managers to consider hydrology risks when considering management options for individual roads. The Watershed Relative Risk Analysis was performed to provide a more general picture of concentrations of potential hydrology risks throughout the forest and to provide the data at a scale that is frequently used during project level analysis.

Each part was divided into the following related risk factors.

1. **Road Density Risk**
2. **Perennial Stream Crossing Risk**
3. **Stream Proximity Risk (30 feet)**
4. **Stream Proximity Risk (119 feet)**
5. **Highly Erosive Soils Risk**
6. **High Slope Risk**

ROAD HYDROLOGY RELATIVE RISK ANALYSIS

Road Density Risk – by road

Road density is a simple indicator of the concentration of roads in an area and is calculated by dividing the length of roads found within the Forest and within a selected area by the selected area. The larger the area selected, the less precise the density information. For this analysis, the forest was divided into one mile square sections. Road densities were calculated using **all roads** (Forest Service system and non-system, county, state and private) within each section (one mile square) within the Forest Boundary. All roads were used for this calculation because the potential effect of the road density does not really depend on who has jurisdiction or for what reason it was created. The distribution of the section densities was evaluated and the sections were divided into three categories based on a logical break in the distribution. There were 840 relatively low density sections within the forest boundary, 1,139 relatively moderate density sections, and 711 relatively high density sections.

Relatively lower road density: 0 to 2.5 miles per square mile. - (32% of all sections)
Relatively moderate road density: 2.5 to 4.5 miles per square mile - 42% of all sections)
Relatively higher road density: 4.5 to 10.0 miles per square mile - (26% of all sections)

The road density risk indicator for each road was then calculated as the percentage of each level 3,4,5 road that was in a high density section. The distribution of the risk indicators of all 3,4,5 roads was reviewed and roads were divided into three ratings:

0 - Relatively lower road density risk: 0 to 20 percent of the road in high density sections
1 - Relatively moderate road density risk: 21 to 50 percent in high density sections
2 - Relatively higher road density risk: 51 to 100 percent in high density sections

The potential effects of high density road areas on the hydrology of the area primarily relate to the increased opportunities for the road to transport sediment or hydrocarbon or salt based pollutants to sensitive areas such as streams, lakes, riparian areas, and botanical areas. The real effect of a road on these areas depends on such variables as the size of the road, the road surfacing, traffic levels, the proximity to sensitive areas, the erosion potential of the soils, the steepness of the surrounding topography, the grade of the road, the amount and type of precipitation, and effectiveness of the road drainage structures. This risk factor is a general way of taking into account all of these conditions. The other hydrology risk factors represent some of these conditions more accurately.

Because of the importance of road density, maps were prepared showing road density within the Forest Boundary in two ways. One map shows the relative density of all roads at low, moderate, and high intervals using three shades of grey. A second map shows the relative density of just Forest Service System roads, both Forest Service and County jurisdictions. It shows the influence of the non-system roads on our density calculations.

Perennial Stream Crossing Density Risk – by road

Road-Stream crossing density is an indicator of the degree of direct effects related to aquatic habitat loss, sediment input into streams and the potential for aquatic habitat fragmentation due to instream structures, e.g. culverts. Road-stream crossings are the points where roads and streams intersect. The accuracy and currency of the roads and stream data is critical to producing a useful stream-crossing coverage. For this analysis, the BHNF perennial streams GIS coverage (updated for currency using field surveys {2000 to 2005} by Les Gonyer, BHNF and the South Dakota School of Mines & Technology) was used. The overall number of stream crossings may be inflated using this stream layer because the source document is old and the positions accuracies of the streams are not comparable to the more current road position data. The method of relative ranking the results tends to reduce the effect of the poor stream position accuracies. This indicator is reported as the number of road-stream crossings per road. Relative risk ratings used for the stream crossing density indicator are:

0 - Relatively Lower Risk: 0 to 1 stream crossings per road
1 - Relatively Moderate Risk: 2 to 3 stream crossings per road
2 - Relatively Higher Risk: 4 to 14 stream crossings per road

The value of this risk indicator is related to the nature of the stream crossing and the type of road. A native surface road in steep topography and highly erosive soils crossing a stream at an unimproved/wet crossing will likely have significantly more impact on the stream than a paved road in a flat, vegetated area crossing over a bridge. This analysis did not provide such detailed

information however the number and nature of crossings would be a major point in a project level analysis.

Stream Proximity Risk (30 feet) – by road

The 30 foot stream channel proximity indicator is used to address encroachment into floodplains, channel restrictions, and as another indicator of hydrologic connectivity between roads and streams. A hydrologically connected road can be defined as "any road segment that has a continuous surface flowpath to a stream channel" (Williams n.d.). Inboard ditches that drain to road-stream crossings are the most obvious road segments that are connected. Other situations that connect roads to streams are cross drains that create overland flow to stream channels, roads with fill slopes that encroach on stream channels, and landslide scars that create a surface flowpath to a channel. For this factor, connectivity was addressed using a 30-foot buffer of the updated BHNF perennial streams GIS coverage. Thirty feet was selected as the distance generally observed on the Black Hills between the centerline of roads and streams where the road template appears to modify the hydraulics of the stream under normal flood conditions (Williams, n.d.).

Using a buffer. of stream channels to determine the length of road hydrologically connected to streams is only an approximation of connectivity. This risk indicator does not account for variations in hydrologic connectivity resulting from slope position, hillslope gradient, road type, precipitation, soil type or bedrock geology, vegetative buffers, all of which may significantly influence the degree of connectivity. Further development of this indicator would involve field sampling to determine how well the indicator represents actual connectivity. Relative risk ratings for road proximity (30 feet) to stream channels are as follows:

0 - Relatively Lower Risk: 0 to .01 miles of the road within 30 feet of a perennial stream
1 - Relatively Moderate Risk: .>01 to .1 miles of the road within 30 feet of a perennial stream.
2 - Relatively Higher Risk: >.1 to .95 miles miles of the road within 30 feet of a perennial stream.

Stream Proximity Risk (119 feet) – by road

The 119 foot stream channel proximity indicator is used to address general sediment delivery into streams and other sensitive areas. The 119 foot buffer distance is the estimated distance in the Black Hills at which the buffer zone is 97 percent effective in trapping sediment from roads in highly erosive soils, evaluated at large scale for long time periods (Williams no date). Roads within 119 feet of a stream would therefore pose some risk of delivering sediment. The risk would increase as the road gets closer to the stream. The relative risk ratings for stream channel proximity (119 feet) are as follows.

0 - Relatively Lower Risk: 0 to .5 miles of the road within 119 feet of a perennial stream
1 - Relatively Moderate Risk: >.5 to 1 mile of the road within 119 feet of a perennial stream.
2 - Relatively Higher Risk: >1 to 3.6 miles of the road within 119 feet of a perennial stream.

Highly Erosive Soils Risk – by road

The highly erosive soils indicator is used to address potential for damage due to erosion and for sediment transport into environmentally sensitive areas. The Black Hills has numerous different soil types at the surface. Some of them are highly erosive and move quite readily during rain events particularly if they are without vegetative cover and are in steep areas. The potential risk is also related to proximity to sensitive areas. The stream proximity risk and high slope risk are covered by other factors.

The Black Hills GIS layer for severely erosive soils was utilized for this analysis. The soil data was originally collected per county and merged into one GIS layer. Apparent anomalies in the data are due to different standards used to collect the data in different year groups and with different data resolution. Data for Weston, Crook, and Fall River counties was not available. It was approximated using the existing vegetative layer. Data for Lawrence County is very sparse. It is currently being brought up to date by the National Resources Conservation Service (NRCS) but is not yet available. The relative risk ratings for highly erosive soils are as follows:

0 - Relatively Lower Risk: 0 to .05 miles of the road within highly erosive soils.
1 - Relatively Moderate Risk: >.05 to .5 miles of the road within highly erosive soils.
2 - Relatively Higher Risk: >.5 to 8.3 miles of the road is within highly erosive soils.

High Slope Risk – by road

Hill slope gradient, or slope, is one of the primary driving forces in mass-wasting failures, erosion, and non-point source pollution, including sediment delivery to streams and other surface water bodies. High slope areas tend to deliver more sediment onto a road and carry it downslope once it leaves the road. High slope areas can also have a correlation to grade of the road in that area. Roads with steep grades transport sediment more readily and are at greater risk to erosion damage. For this analysis, a 30 meter Digital Elevation Model (DEM) was processed using GIS to generate percent slope gradients throughout the BHNF. The slope classes are, therefore, subject to the accuracy of the DEM. High slope areas were defined as having a slope (in percent) greater than 40 %.This figure is based on specialist professional judgment and is for the Black Hills. The relative risk ratings for highly erosive soils are as follows:

0 - Relatively Lower Risk: 0 to .1 miles of the road within high slope areas.
1 - Relatively Moderate Risk: >.1 to .25 miles of the road within high slope areas.
2 - Relatively Higher Risk: >.25 to 2 miles of the road within high slope areas.

Overall Hydrology Relative Risk – by road

The risk rating for each of the above hydrology risk factors was added for each road. The distribution of these sums was reviewed and a cumulative hydrology relative risk factor was assigned. This factor is used in the overall road risk computation. The cumulative ratings are as follows:

0 - Relatively Lower Overall Risk: 0 to 4 Overall Road Risk Score
1 - Relatively Moderate Overall Risk: 5 to 8 Overall Road Risk Score
2 - Relatively Higher Overall Risk: 9 to 12 Overall Road Risk Score

See Appendix H for maps showing each risk by road. The data is also presented in the following spreadsheet printout.

WATERSHED HYDROLOGY RELATIVE RISK ANALYSIS

Relative watershed risk was evaluated using the same relative risk indicators that were used for roads. The evaluation by watershed was performed to provide a more general picture of concentrations of potential hydrology risks throughout the forest and to provide the data at a scale that is frequently used during project level analysis. Unlike the data for the calculation by level 3,4,5 system road above, the data used for this calculation includes all roads (system and non-system, all jurisdictions). The risk indicators were added up in each 6th order watershed and divided by the square miles in that watershed. Therefore, the units of these risk factors are occurrences or miles per square mile vs the occurrences per road. As with the roads analysis, the risks were summed up for each watershed and an overall relative hydrology risk was assigned to each watershed.

Road Density Risk – by watershed

For this analysis, the forest was divided into watersheds. Road densities were calculated using all roads (Forest Service system and non-system, county, and state) within the Forest Boundary. The distribution of the watershed densities was evaluated and the watersheds were divided into three ratings based on the same distribution used for the road density by section analysis in the

0 - Relatively lower road density: <2.5 miles per square mile
1 - Relatively Moderate road density: 2.5 to 4 miles per square mile
2 - Relatively higher road density: >4 to 5.6 miles per square mile

A map was developed to show the density by watershed. By comparing this map to the two developed for the road risk analysis above, the reader can see how the scale of the presentation can sometimes change how information is perceived.

Perennial Stream Crossing Density Risk – by watershed

This indicator is the number of road-stream crossings per mile of perennial stream within a 6th-level watershed. Relative risk ratings used for the stream crossing density indicator are

0 - Relatively Lower Risk: 0 to .407 stream crossings per square mile.
1 - Relatively Moderate Risk: >.407 to 1.1 stream crossings per square mile.
2 - Relatively Higher Risk: >1.1 to 4.3 stream crossings per square mile.

Stream Proximity Risk (30 feet) – by watershed

Relative risk ratings for stream channel proximity (30 feet) stream channel are as follows:

0 - Relatively Lower Risk: 0 to .01 miles of road are within 30 feet of a perennial stream per square mile.
1 - Relatively Moderate Risk: >.01 to .047 miles of road are within 30 feet of a perennial stream per square mile.
2 - Relatively Higher Risk: >.047 to .18 miles of road are within 30 feet of a perennial stream per square mile.

Stream Proximity Risk (119 feet) – by watershed

Relative risk ratings for stream channel proximity (119 feet) stream channel are as follows:

0 - Relatively Lower Risk: 0 to .05miles of road are within 119 feet of a perennial stream per square mile.
1 - Relatively Moderate Risk: >.05 to .19 miles of road are within 119 feet of a perennial stream per square mile.
2 - Relatively Higher Risk: >.19 to .52 miles of road are within 119 feet of a perennial stream per square mile.

Highly Erosive Soils Risk – by watershed

. The relative risk ratings for highly erosive soils are as follows:

0 - Relatively Lower Risk: 0 to .2 miles of road are within highly erosive soils per square mile.
1 - Relatively Moderate Risk: >.2 to .6 miles of road are within highly erosive soils per square mile.
2 - Relatively Higher Risk: >.6 to 4.7 miles of road are within highly erosive soils per square mile.

High Slope Risk – by watershed

. The relative risk ratings for high slope risk are as follows:

0 - Relatively Lower Risk: 0 to .03 miles of road are within high slope areas per square mile.
1 - Relatively Moderate Risk: >.03 to .1 miles of road are within high slope areas per square mile.
2 - Relatively Higher Risk: >.1 to .27 miles of road are within high slope areas per square mile.

Overall Hydrology Relative Risk – by watershed

The risk rating for each of the above hydrology risk factors was added for each watershed. The distribution of these sums was reviewed and a cumulative hydrology relative risk factor was assigned. This factor was not used in the overall road risk computation but it is useful in showing a relative risk over a large area. A map was generated to show the resulting relative risk of each watershed. The cumulative ratings are as follows:

0 - Relatively Lower Overall Risk: 0 to 3 Overall Watershed Risk Score

1 - Relatively Moderate Overall Risk: 4 to 7 Overall Watershed Risk Score

2 - Relatively Higher Overall Risk: 8 to 12 Overall Watershed Risk Score