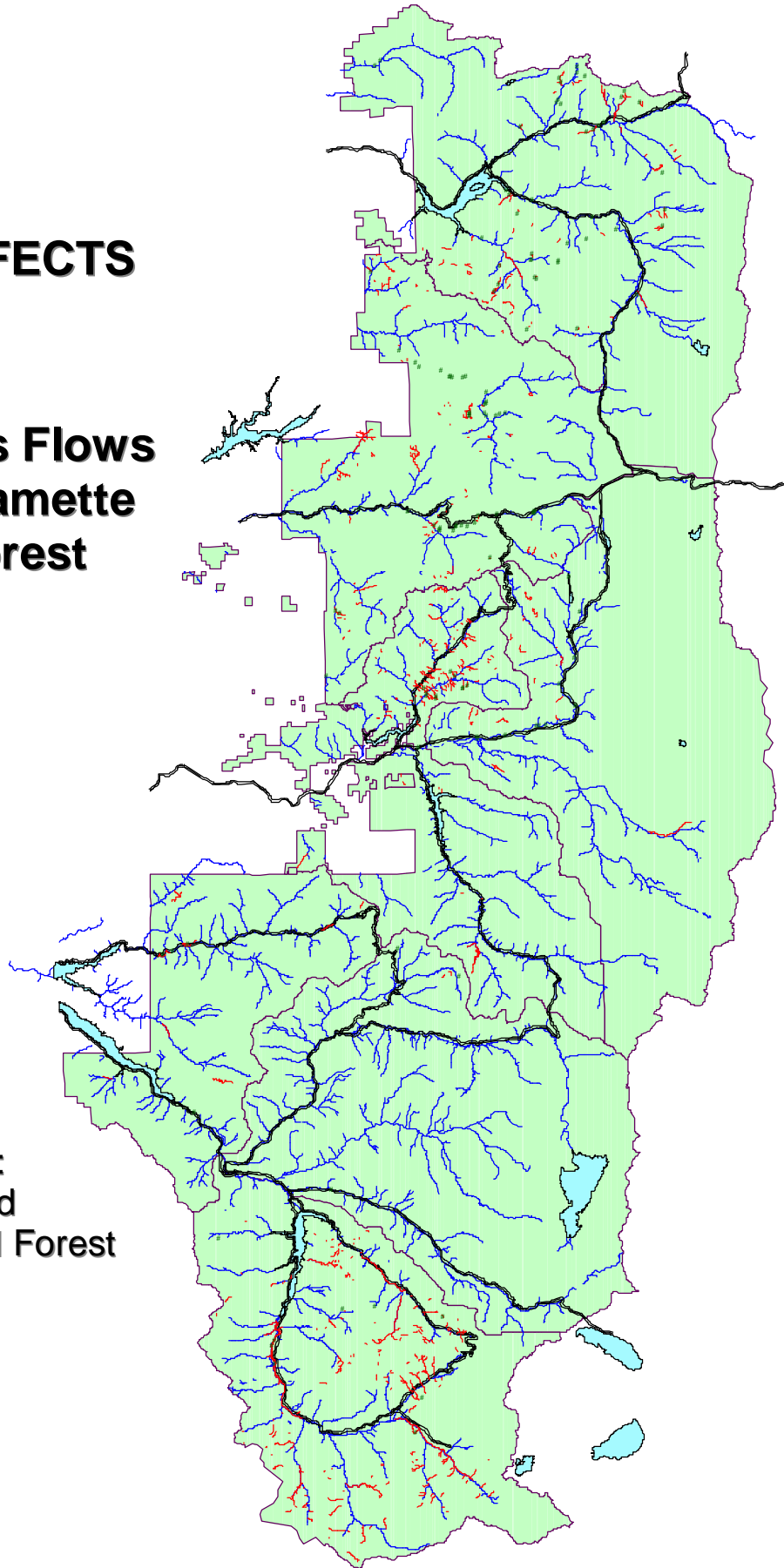


NON-ERFO FLOOD EFFECTS ANALYSIS

1996 Debris Flows on the Willamette National Forest



Prepared by:
Jennifer Lloyd
Willamette National Forest



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INTRODUCTION

The Floods of 1996

Several intense rainstorms during 1996 caused widespread flooding in western Oregon and throughout the Pacific Northwest. Moist, subtropical air masses brought record - setting rainfall on several occasions. Rain, coupled with the significant melting of deep snow pack and/or substantial runoff from saturated soil, pushed some stream levels above all-time crests. In addition, debris flows occurred, destroying roads and causing significant property damage. Greater detail on the impact of these storms to the Willamette National Forest can be found in the Flood Team Report of 1996 (WNF).

This study is primarily concerned with documenting and evaluating storm damage, specifically debris flows, which occurred during the periods of February 5-9, 1996 and November 18-19, 1996 on the Willamette National Forest. During the February 1996 flood event, the portion of the Forest north of the McKenzie River experienced, on average, 11-17 inches of rain in five days. A maximum of 25 inches on the Forest in that time span occurred at Mount Jefferson on the Detroit Ranger District eastern boundary.

The November 1996 flood event brought precipitation amounts of 9-12 inches, on average, to the northern portion of the Forest and between 7-9 inches to the southern end of the Forest in just two days. The rainfall high on the Forest for this event was about 24 inches and occurred in the Three Sisters Wilderness area along the eastern boundary. Precipitation plots depicting both storm events on the Willamette National Forest are included with this report (see Appendix I). Precipitation data was compiled by the Oregon Climatological Service, Oregon State University.

The purpose of this study is to gain learning from where debris flows occurred in the landscape of the Willamette National Forest and why. A comparison between two selected study areas described in the **Analysis** section of this report may help to recognize correlations and provide answers to aid and revise management on Forest lands to limit the acceleration of erosion on the landscape.

Project History

The task of documenting flood damage on the Willamette National Forest during these storm events was initially approached from a fiscal standpoint, that is, only funded flood damage projects were considered. The terms 'ERFO' and 'Non-ERFO' simply refer to the type of funding a project may receive; ERFO is Emergency Relief for Federally Owned Roads. ERFO dollars were appropriated to the Federal Highways Commission and distributed to the Forest Service to repair roads after the floods, where damage costs exceeded the Forest's financial capability to repair. ERFO dollars could only be used to cover the costs of road repair within the road prism. Non-ERFO dollars were appropriated directly from Congress in one-time allocations specific to each flood event. Non-ERFO dollars were spent to repair trails and recreation sites and for stream and soil restoration projects following the floods.

The intent of this project was to map non-ERFO sites in a manner similar to the documentation of ERFO sites. The ERFO database, located on the Willamette NF servers, is found at [/fsfiles/ref/library/gis/wil/erfo1996](#). It contains sites (points) and descriptions where ERFO dollars have been spent within the road system. The non-ERFO database has not yet been placed on the Willamette NF servers.

As progress was made, it was realized that most non-ERFO projects were just extensions of ERFO projects. Non-ERFO dollars were being used to supplement ERFO projects where damage occurred outside of the road prism, such as to revegetate cutbanks and fill slopes, or to perform heavy maintenance over large portions of the road system. Much more could be gained by extending the study beyond projects funded by ERFO or non-ERFO dollars.

Thus, 'non-ERFO' took on a meaning beyond funding--the non-ERFO database provides a more complete picture of how the landscape was affected by the storms of 1996 by showing the actual tracks and initiation points of debris flows, regardless of whether they were projects designated to receive funding for repair or not. The non-ERFO database also shows sites where non-ERFO dollars were used to fund repair projects. More information on the limitations and quality of data can be found within the attached data dictionary for the GIS directory, NONERFO_96 (see Appendix I).

Additional fieldwork was not requested to complete this project in order to create minimal impact to District personnel in the data gathering process. Only existing data was used in analysis, including layers within the Forest's GIS database. The GIS layers used are described in following sections of this report.

METHODS

GIS Limitations

It is important to realize the limitations of using Geographic Information Systems (GIS) as a model for analysis. The accuracy of GIS as a modeling tool is dependent on the quality of the collected data and methods used to compose each layer. Limitations that may affect the quality of the individual GIS layers within the database on the Willamette National Forest include:

- Source of data -- collected within the agency, private, or other outside agency.
- Techniques used to gather data -- sophistication and experience of data collector(s), digital or manual collection and quality of equipment used.
- Currency of data -- history of initial data collection and frequency of updates.
- Error in inputting data -- miscommunication between data collection protocol and input into GIS.
- Data layer registration -- especially if layer is from outside source or projected from another data type. Data may be 'shifted' slightly during translation.

Despite these limitations, GIS is currently the best system available to store and analyze spatial data on the Willamette NF. Details on the generation of each GIS layer can be found within the individual data dictionaries.

Data Capture

All data represented in NONERFO_96 was collected from District personnel, except in the H.J. Andrews Experimental Forest, Blue River Ranger District. Data for this area was obtained through the Pacific Northwest Research Station, Forestry Sciences Laboratory (FSL), Corvallis, Oregon, from Kai Snyder. Debris flow data from the FSL was field-verified by Matt Wallenstein, and was available as an ARC/INFO line coverage (arcs and routes). No translation of FSL data was necessary for use in this study. All other debris flows and non-ERFO project sites were adapted from field maps and/or aerial photographs and digitized into the GIS directory, NONERFO_96 as line and point coverages respectively. Attribute fields for each debris flow and non-ERFO project site are listed and described in the data dictionary for NONERFO_96.

Debris flow data collection in the former Rigdon area of the Middle Fork Ranger District was performed by District employee, Dennis Maupin, during the field season of 1998.

In addition to a field map, a hand-held Global Positioning System (GARMIN™ model 12XL) was used when data was field-verified. The latitude and longitude data obtained from the GPS unit was translated into a point coverage, which can also be found in the NONERFO_96 directory. Greater detail on the data collection for the Rigdon area can be found in the [Inventory of 1996 Landslides](#), Middle Fork Ranger District, Willamette National Forest, October, 1998 (see Appendix I).

Debris flow locations and non-ERFO project sites were entered into ARC coverages by on-screen digitizing in ArcEdit. Layers used as backdrops for the digitizing process included the Forest transportation layer (TRAN), the stream layer (STR), the trail layer (TRAIL) and contour layers generated from the 10-meter Digital Elevation Model (DEM). The TRAN, STR and TRAIL coverages are located in [/fsfiles/ref/library/gis/wil](#). The 10-meter DEM can be accessed at [/fsfiles/unit/gis/sgi/elev/10meter/elev_XX](#), where 'XX' is the quadrangle number for the desired area. Contours were generated with the LATTICECONTOUR command in ARC. In cases where debris flows followed stream channels or portions of road, arcs were copied from the STR and TRAN layers into the NONERFO_96 layers.

Coverages located in the GIS directory, NONERFO_96:

- 'LINES_96' contains arc data representing debris flows, channel, road and trail damage.
- 'POINTS_96' contains point data representing non-ERFO sites and projects.
- 'GPS_96' contains point data converted from GPS data, Rigdon area only.
- 'SURVEY_96' contains arc data representing areas surveyed, still in planning stages; individual repair sites are not yet identified.
- 'DEB_DF96' contains original data from the FSL, limited to the Upper Blue River and Lookout Creek Watersheds, H.J. Andrews Experimental Forest. A finished data dictionary is not yet available for this coverage (see Appendix I).

This report and attached charts were created in Microsoft Word and Excel. Data presented in the **Occurrence of Initiation Points in GIS Layers** section was obtained by using the IDENTITY and FREQUENCY commands in ARC to join the NONERFO_96 coverages with the GIS category coverages accordingly to produce frequency distributions. Initiation point frequency distributions can be observed in tables and charts accompanying this report. All illustrative maps and plots were composed in ArcPlot or ArcView; digital map compositions are available.

ANALYSIS

Portions of the Forest have been covered more extensively with respect to recognizing and realizing flood damage through field study as stated above. This analysis is concentrated in two areas: the Upper Blue River and Lookout Creek subwatersheds on the Blue River Ranger District (Blue River study area) and a selected area within the boundary of the Middle Fork Ranger District (Rigdon study area). The Blue River study area is 60.4 square miles (38,656 acres) in size and covers a portion of the Blue River watershed (fifthfield 12). The Rigdon study area is about five times larger than the Blue River study area at 290 square miles (185,600 acres) and covers portions of the Hills Creek, Upper Middle Fork Willamette and the Middle Fork Willamette Downstream Tributaries watersheds (fifthfields 27, 29, 30).

Comprehensive, field-verified data sets were available because funding was specifically allocated for flood investigation in these areas. The entire extent of land within the boundaries of each study area was covered specifically for the purpose of discovering 1996 flood-related debris flows. This report describes and compares the performance of each study area in reaction to the 1996 debris flows.

Data Interpretation

Debris Flow initiation points within each study area are reported according to where they occurred in these GIS categories: elevation, geologic type, slope percent category, structural stand stage, road density category and soil stability rating. As no further field study was required at the time the project began, only layers existing within the Forest's GIS database were used, with the exception of field reconnaissance performed to obtain the debris flow data. See the GIS directory and data dictionary for 'NONERFO_96' for details on the layers that have been created as a result of obtaining debris flow and other flood damage locations on the Forest.

Results are compared and analyzed by 1) normalizing the number of initiation points as a percent of the total number of initiation points and 2) calculating the ratio of initiation points to area per GIS category.

The first method is independent of area as a factor, which might sway the probability of debris flows occurring within a category. For example, in the Blue River study area, 41.2 % of the initiation points occurred in the old growth category and 42.3% of the area is defined as old growth. One would suspect more initiation points to occur in the old growth category because almost half of the total area falls in that category.

The second method of normalization considers area as a factor in the probability of initiation point occurrence. A ratio value of 1 indicates the number of initiation points is proportional to the study area within the category. Again, the above example illustrates this point: 41.2% of the points occur in 42.3% of the total study area, yielding a ratio

value of approximately 1.0. A ratio value less than 1 indicates an underproportion of initiation points per area, and a ratio value greater than 1 indicates a high number of initiation points per area proportionately. Anomaly high percentages of initiation points and high ratio values (those that exceed 1 or do not follow the trend of values within the set) indicate areas of question and concern, hence the focus of this study.

The following section shows the results of highest initiation point frequency per GIS category, normalized by the methods described above. Several series of charts accompany each subsection to illustrate points and improve the clarity of this written documentation.

OCCURRENCE OF INITIATION POINTS IN GIS LAYERS

Elevation

Elevation ranges with the highest percentage of initiation points (normalization method 1, see charts A1b and B1b):

GIS Category	Blue River Study Area		Rigdon Study Area	
Elevation	2000-2500'	51.0%	4500-5000'	28.1%

Elevation ranges with the highest ratio of initiation points to area (normalization method 2, see charts A1c and B1c):

GIS Category	Blue River Study Area		Rigdon Study Area	
Elevation	2000-2500'	3.3	4500-5000'	2.1

Overall, the Rigdon study area resides at higher elevations; 67.4% of the area is in the 3000-5500' range, whereas the bulk of the Blue River study area lies within the 2000-4000' range (74.6%).

All of the debris flows in the Blue River study area occurred during the February 1996 flood event, a time when snow was elevationally low in the mountains, even below the normal lower transient snow level (1200'). The culprit warm front that accompanied the intense and sudden rainfall relieved the area of snow pack fairly quickly, especially at lower elevations, and thus exposed those areas for failure by supersaturating the soil.

BLUE RIVER STUDY AREA

Chart A1a: Flood Damage Initiation Points by Elevation

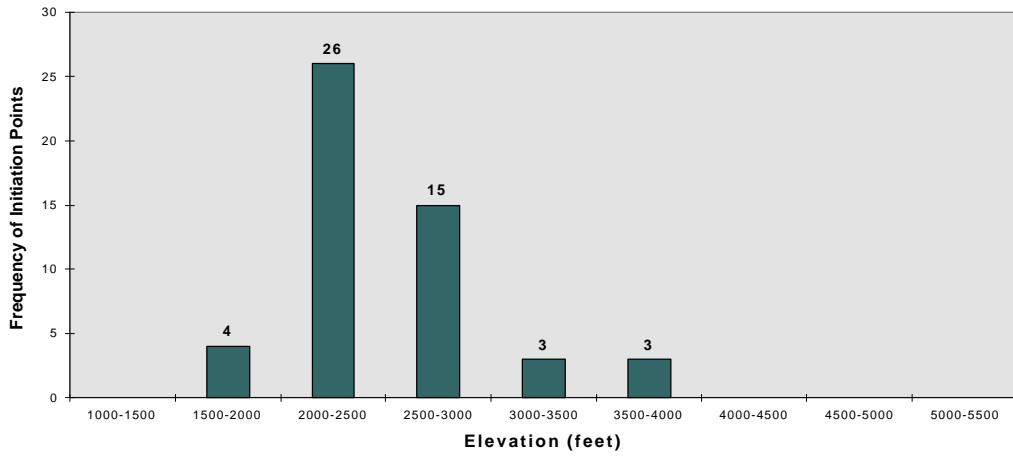


Chart A1b: Study Area and Initiation Point Distribution by Elevation

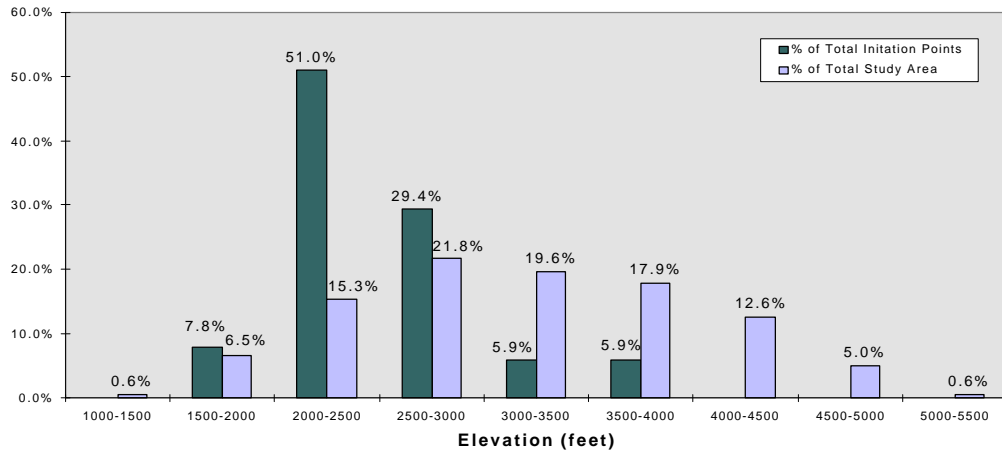
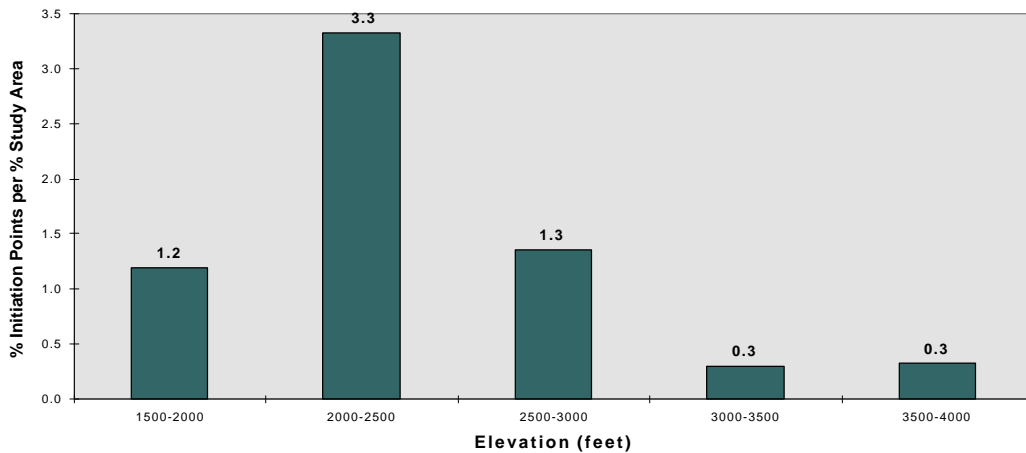


Chart A1c: Ratio of Initiation Points to Total Study Area by Elevation



RIGDON STUDY AREA

Chart B1a: Flood Damage Initiation Points by Elevation

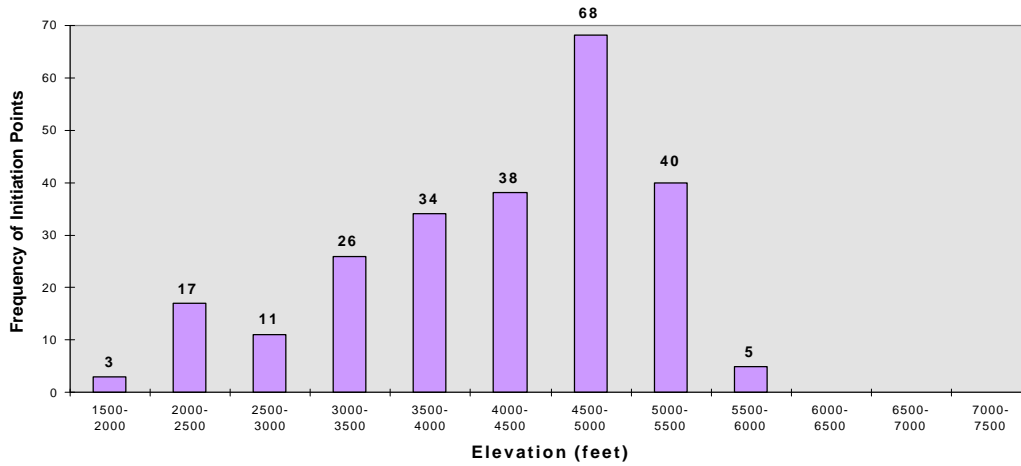


Chart B1b: Study Area and Initiation Point Distribution by Elevation

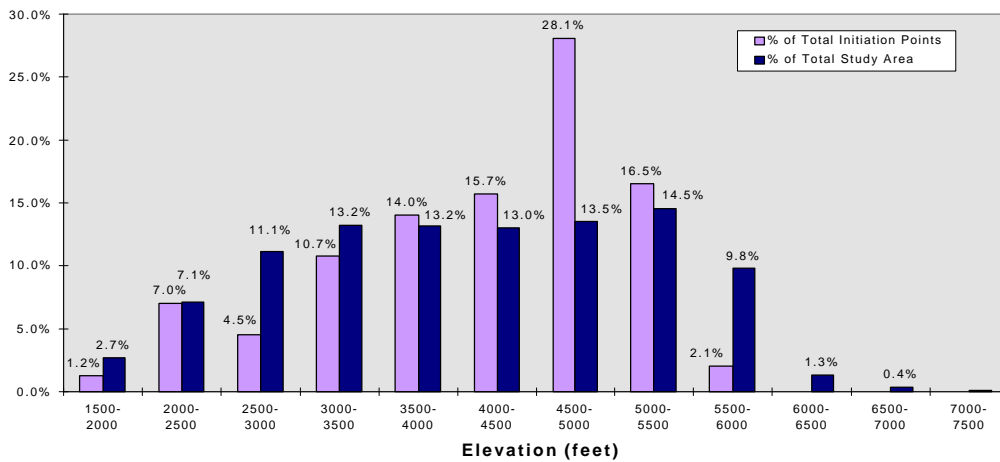
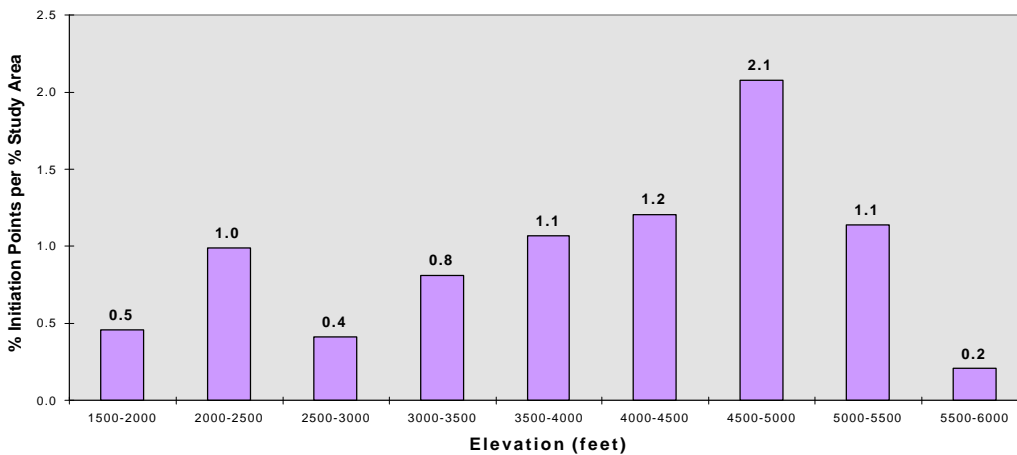


Chart B1c: Ratio of Initiation Points to Total Study Area by Elevation



District personnel have reported that damage was much less in areas that remained under snow cover, as is evident in this study. No initiation points occurred above the upper transient snow level of 4000', in the Blue River study area.

Most of the debris flows in the Rigdon study area occurred during the November 1996 flood event, a time when the snow level was higher in elevation. Although precipitation values were lower than in the Blue River area for both flood events, the November storm was much more intense, spanning a duration of just two days. Soils in the Rigdon study area were not protected by snow pack and were thus more vulnerable to saturation and failure at higher elevations.

The high ratio value of 3.3 in the Blue River study area elevation range 2000-2500', indicates a disproportionately large number of initiation points per a relatively small part of the study area. Approximately 3.3 times as many debris flows were initiated in that range as compared to any other range with a ratio value of 1.

Geology

Both study areas exhibit Western Cascades geology, created by a history of volcanic activity beginning in the Eocene. The Rigdon area borders the High Cascades formation and so contains some younger rocks (Qba and QTba from the Pleistocene and Pliocene) overlying rocks stratigraphically similar to those in the Blue River study area (mostly Miocene, Oligocene). The Blue River study area is touched by some High Cascades geology as well, ridge-capping basalt and basaltic andesite (Trb) from the Pliocene. Most rocks in both study areas are of volcanic origin, the exception being some sedimentary rocks and deposits with volcanic constituents.

The Willamette National Forest's GIS geology layer is titled GEOL and is located in the directory [/fsfiles/ref/library/wil](#). The item name used to define the geologic units represented here is called PTYPE. The United States Geologic Survey is the source of data for GEOL.

Geologic units with the highest percentage of initiation points (normalization method 1, see charts A2b and B2b):

GIS Category	Blue River Study Area		Rigdon Study Area	
	Geology	Tu	78.4%	Tbaa

Geologic units with the highest ratio of initiation points to area (normalization method 2, see charts A2c and B2c):

GIS Category	Blue River Study Area		Rigdon Study Area	
	Geology	Tbaa	3.4	Tub

BLUE RIVER STUDY AREA

Chart A2a: Flood Damage Initiation Points by Geology

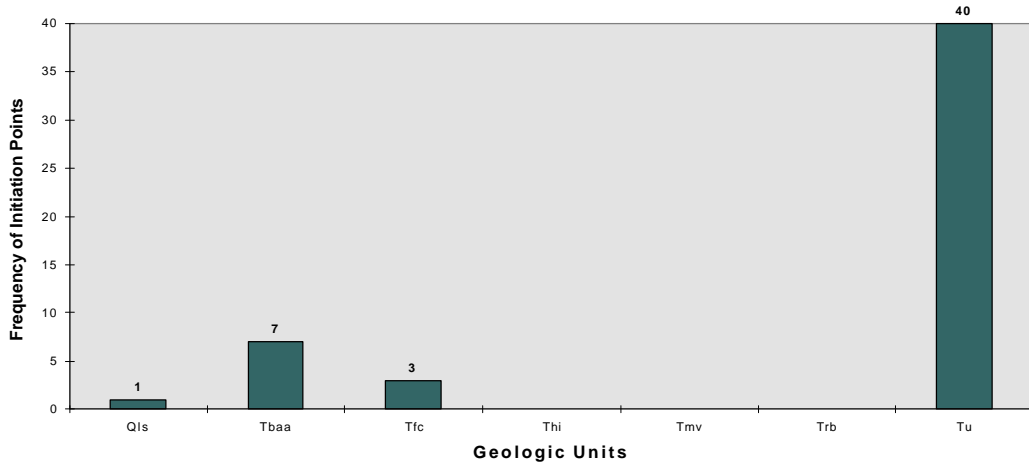


Chart A2b: Study Area and Initiation Point Distribution by Geology

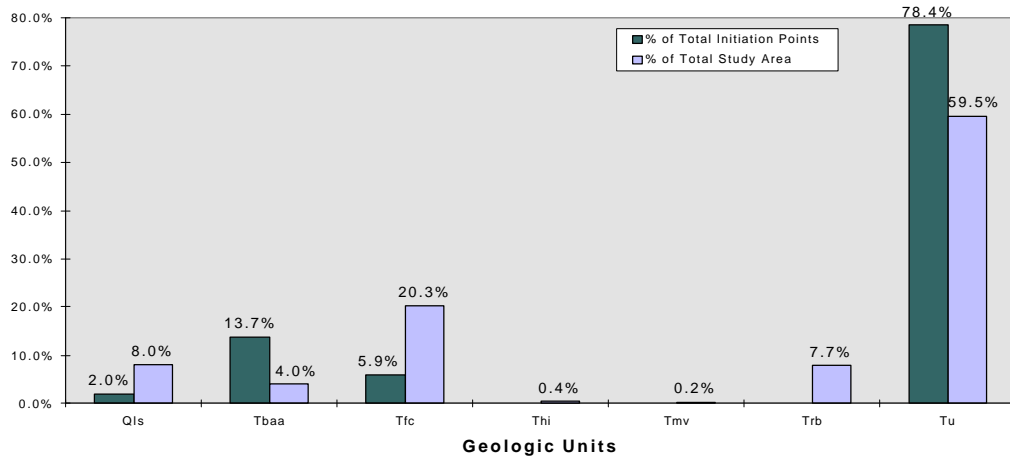
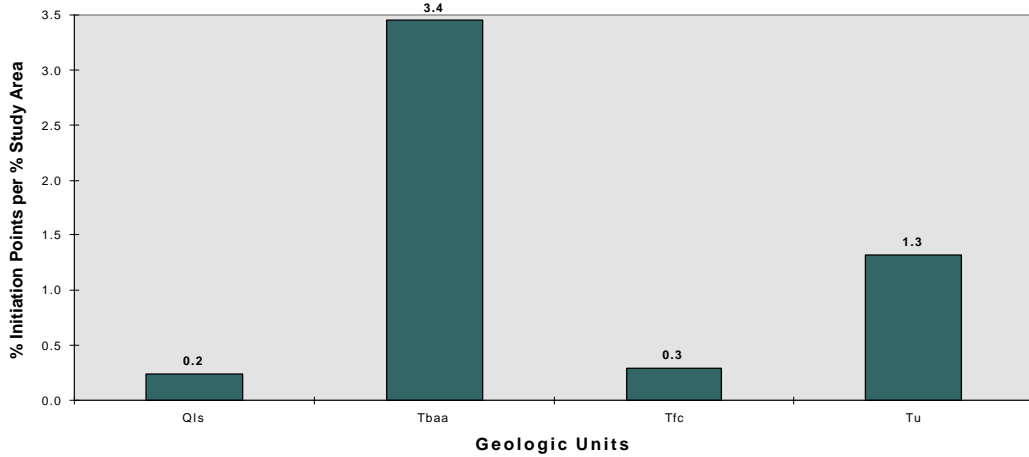


Chart A2c: Ratio of Initiation Points to Total Study Area by Geology



RIGDON STUDY AREA

Chart B2a: Flood Damage Initiation Points by Geology

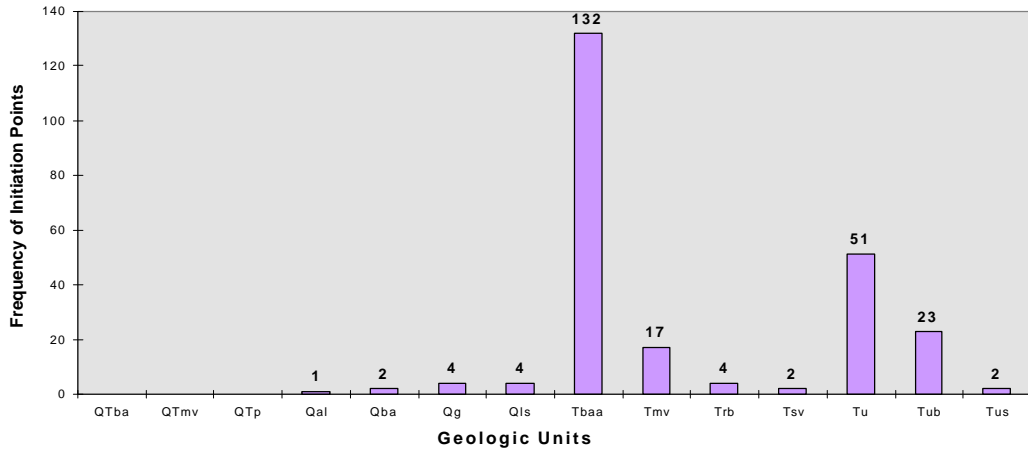


Chart B2b: Study Area and Initiation Point Distribution by Geology

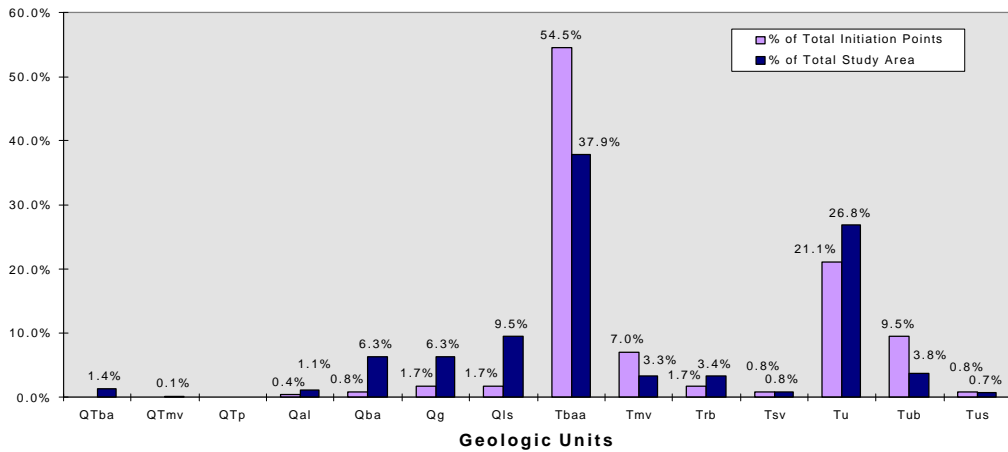
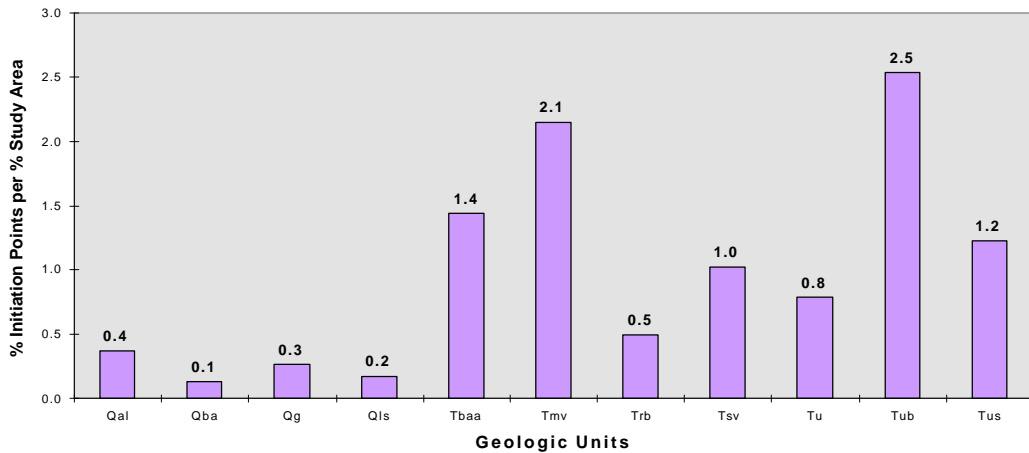


Chart B2c: Ratio of Initiation Points to Total Study Area by Geology



Descriptions of geologic units above* :

- Tbaa Basaltic and andesitic rocks (upper and middle Miocene)**
Lava flows and flow breccia of hypersthene and olivine andesite, basaltic andesite containing plagioclase and pyroxene phenocrysts, and basalt; many flows contain phenocrysts of both hypersthene and augite. Includes interbedded volcanoclastic and epiclastic rocks mostly of andesitic composition, but partly of dacitic or rhyodacitic composition. Includes areally restricted flows of silicic andesite or dacite. Upper part of unit mostly unaltered, although olivine crystals are locally altered to clay minerals. Lower parts commonly altered; secondary minerals include nontronite and saponite chalcedony, calcite and zeolites. Older parts of this unit locally are propylitically altered adjacent to larger intrusions erupted mostly from widespread northwest- and north-trending dikes and dike swarms, and related plugs and lava cones. Tbaa occurs in both study areas.
- Tu Undifferentiated tuffaceous sedimentary rocks, tuffs and basalt (Miocene and Oligocene)**
Heterogeneous assemblage of continental, largely volcanogenic deposits of basaltic andesite, including flows and breccia, complexly interstratified with epiclastic and volcanoclastic deposits of basaltic to rhyodacitic composition. Includes extensive rhyodacitic to andesitic ash-flow and air-fall tuffs, abundant lapilli tuff and tuff breccia, andesitic to dacitic mudflow (lahar) deposits, poorly bedded to well-bedded, fine to coarse grained tuffaceous sedimentary rocks, and volcanic conglomerate. Most ages from basalt and basaltic andesite lava flows are in the range of about 35 to 18 Ma. Locally intruded by small stocks of granitoid rocks and by dikes, sills, plugs and invasive flows of basaltic andesite and basalt; in many places, the intrusions are indistinguishable from poorly exposed interbedded lava flows. Tu is also found in both study areas.
- Tub Basaltic lava flow**
Basaltic and basaltic andesite lava flows and breccia. Tub is found in the Rigdon study area only.

By definition, unit Tu would be most likely suspected to fail because it is composed of less consolidated, sedimentary-type material. It is also the oldest and most extensive rock type found in the Blue River study area and therefore most available to physical weathering.

Tbaa shows up as a high value in both normalizations in either study area. It too, is

* From the data dictionary for the GIS layer, GEOL, of the Willamette National Forest, May 1994. Please refer to the data dictionary for expanded descriptions, credits and references. Descriptions for other units within the study areas can be found in Appendix II.

one of the oldest rocks found in either study area, however less abundant than Tu in the Blue River area. The high ratio value of 3.4 in the Tbaa unit of the Blue River study area illustrates the incompetence of this rock type—13.7% of the initiation points occurred in only 4.0% of the study area. The ratio of initiation points to area of Tbaa in the Rigdon study area is lower at 1.4; even though 54.5% of the initiation points occurred there, 37.9% of the study area lies in the Tbaa rock type.

Age and expanded description for unit Tub was not attainable. Tub appears in isolated extents within the Rigdon study area indicating that it may have been a thin, widespread flow, which has mostly eroded over geologic time. Tub comprises only 3.8% of the total Rigdon study area and contains 9.5% of the initiation points—a fairly high ratio value of 2.5 and the third highest percent of initiation points in the entire area.

Slope Percent

Some argument exists as to the validity of generating slope percent values from the Digital Elevation Model (DEM). It is commonly thought that the generated values are intrinsically lower than actual ground slope measurements, although slope percent is generated from the same 10-meter DEM the USGS uses to generate contoured quadrangles. Some scientists believe the satellite signals used to create the DEM are not readings from the actual ground slope but are signals reflected from treetop levels, road surfaces, etc.. Slope percent generated from the DEM is used here because no other options are available for evaluating slope percent at this time.

Field-verified slope measurements at debris flow initiation sites are available for the Blue River study area only. A study is currently underway to compare field values with generated values by Kai Snyder at the Pacific Northwest Research Station, Forestry Sciences Laboratory, Oregon State University.

Slope percent categories with the highest percentage of initiation points (normalization method 1, see charts A3b and B3b):

GIS Category	Blue River Study Area		Rigdon Study Area	
	Slope Percent	20-30%	39.2%	30-40%

Slope percent category ranges with the highest ratio of initiation points to area (normalization method 2, see charts A3c and B3c):

GIS Category	Blue River Study Area		Rigdon Study Area	
	Slope Percent	40-50%	1.6	90-100%

BLUE RIVER STUDY AREA

Chart A3a: Flood Damage Initiation Points by Slope Percent Category

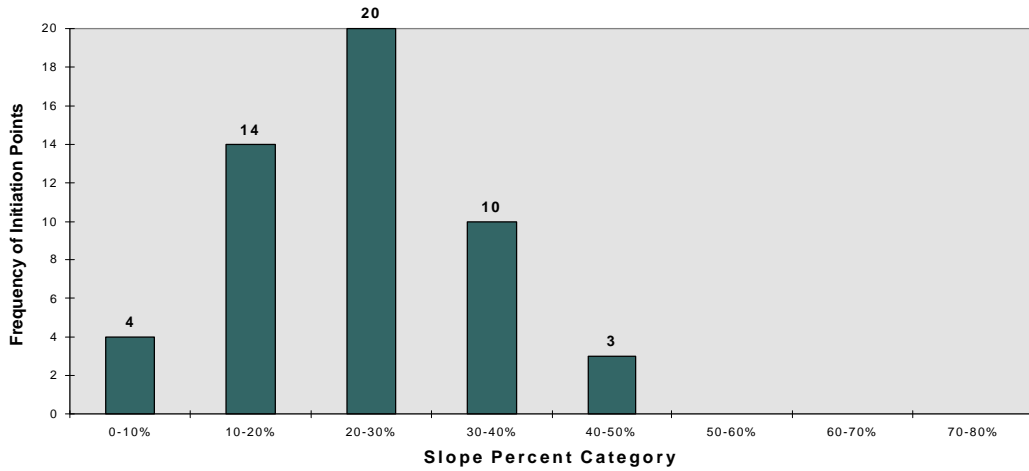


Chart A3b: Study Area and Initiation Point Distribution by Slope Percent Category

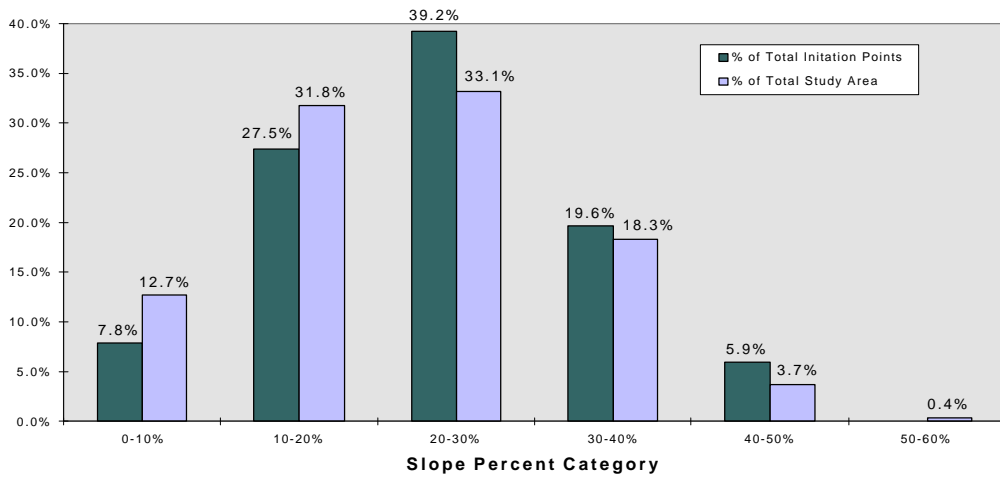
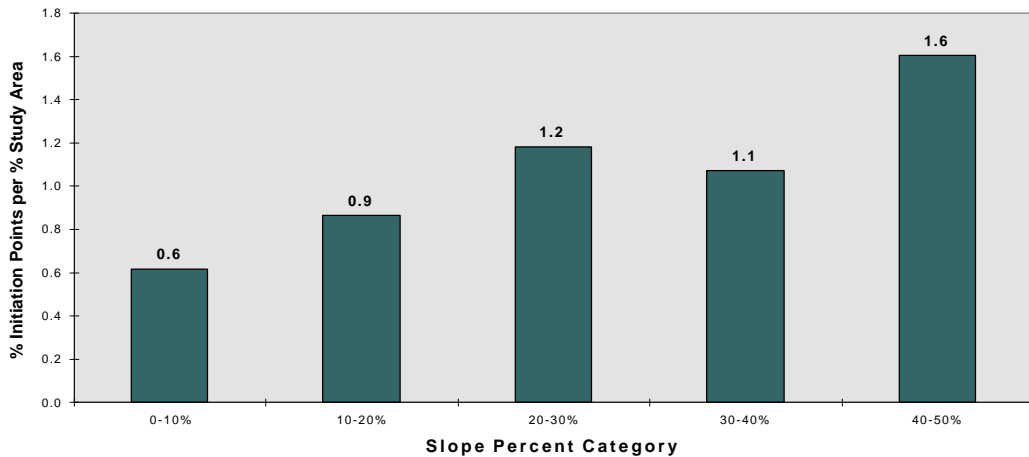


Chart A3c: Ratio of Initiation Points to Total Study Area by Slope Percent Category



RIGDON STUDY AREA

Chart B3a: Flood Damage Initiation Points by Slope Percent Category

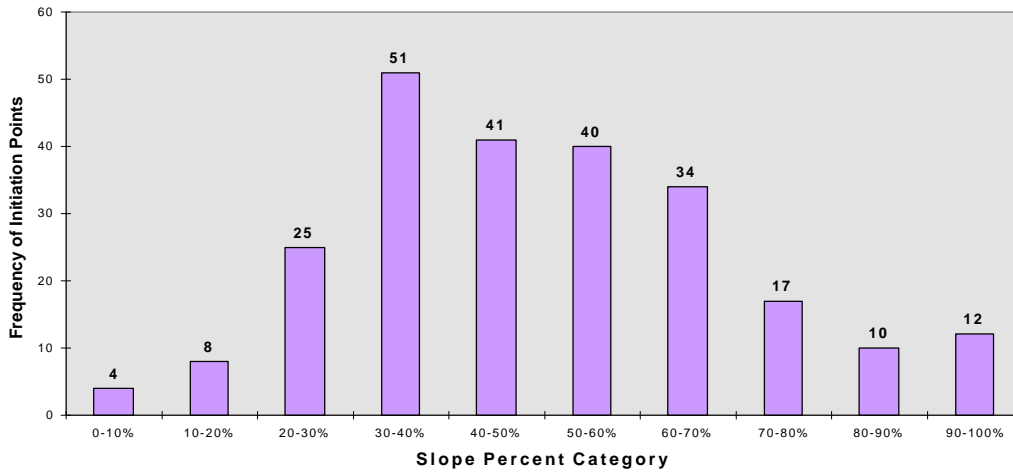


Chart B3b: Study Area and Initiation Point Distribution by Slope Percent Category

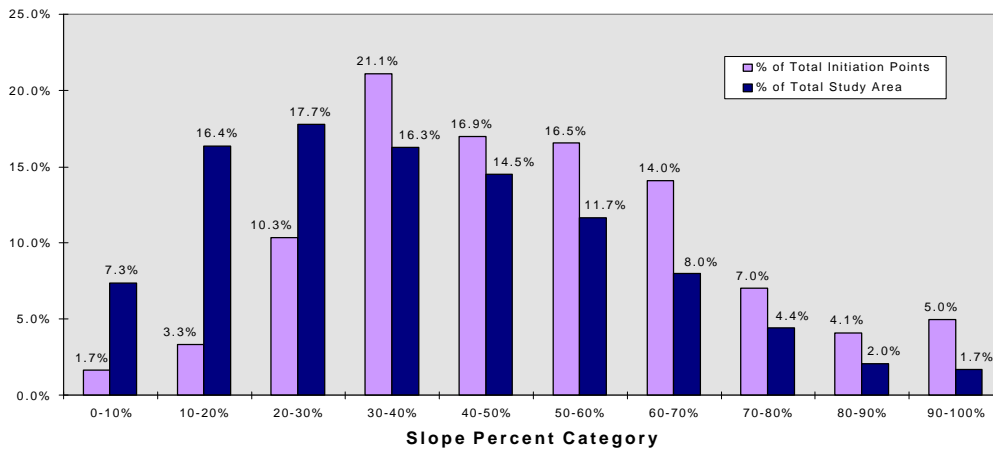
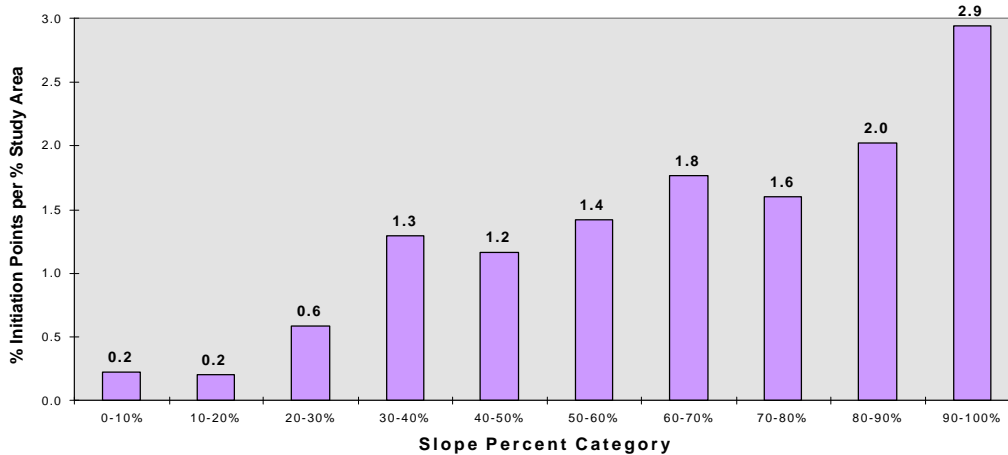


Chart B3c: Ratio of Initiation Points to Total Study Area by Slope Percent Category



Little difference in initiation point frequency occurs between several slope percent ranges within each study area--the percentages presented in the first normalization above are not unique. By observing Chart B3b (Rigdon study area), the reader can see 67.5% of the initiation points lie within four range categories, 30-70%. Observe Chart A3b for the Blue River study area, 66.7% of the initiation points lie in two range categories, 10-30%.

Naturally, one would think steeper slopes would have higher debris flow rates. Often this isn't true because soil can't develop and reside on steep slopes--material is not available to create debris flows. This is dependent on a balance between soil formation and/or vegetation establishment and the recurrence interval between storm events great enough to remove soil and other debris from steeper slopes. A large-magnitude event is usually not required to bring rocks, soil and vegetation down off of steep slopes. It is surprising that 5% of the debris flows were initiated in only 1.7% of the total Rigdon study area at the 90-100% slope percent range. The ratio values are highest in the greatest slope percent category in each study area.

Structural Stand Stage Category

Structural stand stage categories were determined according to the Willamette National Forest Watershed Analysis accepted protocol. General stages of this model are usually the result of some disturbance, either timber harvest or past fires. Stand stages are determined according to the age, degree of management, diameter of trees at breast height, canopy density, and degree of plant diversity present in the stand. Definitions not presented here for each stand stage can be found in Appendix II. They include Stand Initiation (early), Stem Exclusion (early-mid, mid), Understory Reinitiation (late-mature), Old Growth (late-old growth) and Non Forest categories.

The GIS grid used for this portion of the analysis is called LSRVEG and is located at [/fsfiles/unit/gis/sgi/iris_nr/lsr_assm/veg](#). The grid was clipped and translated into a polygon coverage with the ARC command, GRIDPOLY, for both the Blue River and Rigdon study areas. SERAL is the item used in this analysis to categorize the stand stages.

Structural stand stage categories with the highest percent of initiation points (normalization method 1, see charts A4b and B4b):

GIS Category	Blue River Study Area		Rigdon Study Area	
Stand Stage	Old Growth	41.2%	Stand Initiation	56.8%

BLUE RIVER STUDY AREA

Chart A4a: Flood Damage Initiation Points by Structural Stand Stage Category

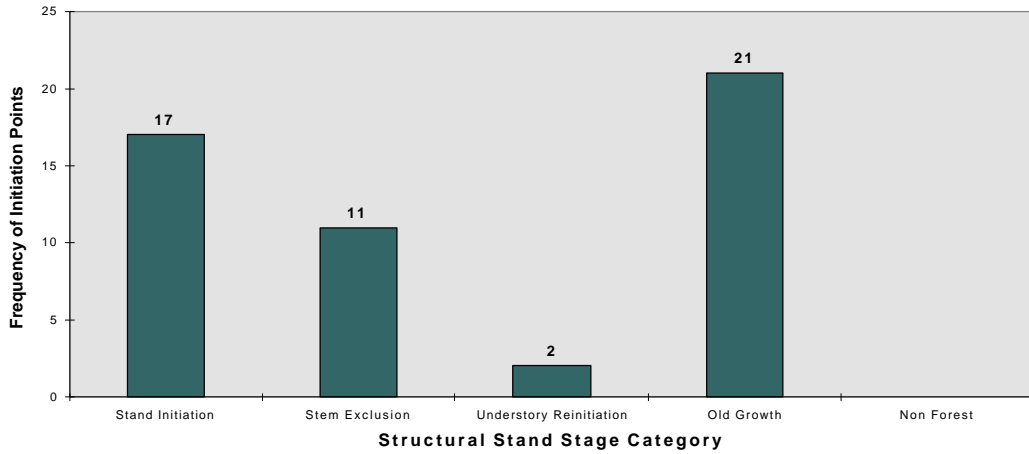


Chart A4b: Study Area and Initiation Point Distribution by Structural Stand Stage Category

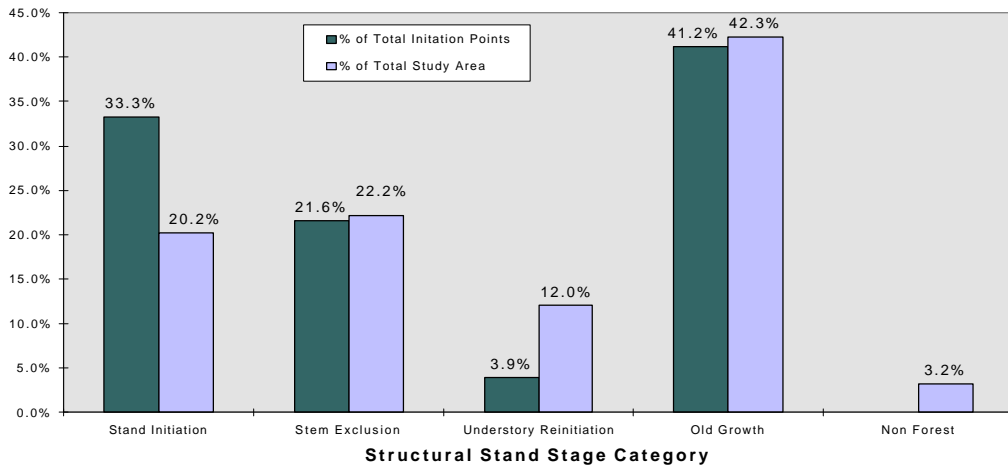
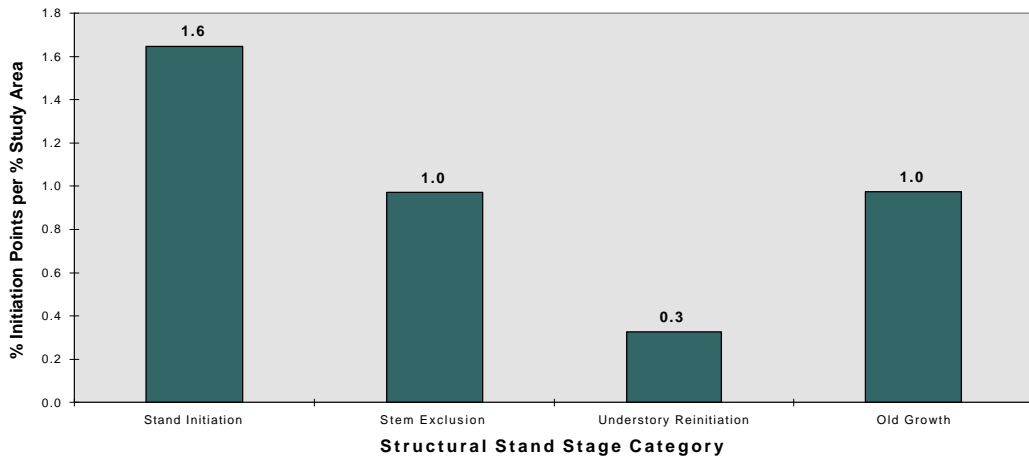


Chart A4c: Ratio of Initiation Points to Total Study Area by Structural Stand Stage Category



RIGDON STUDY AREA

Chart B4a: Flood Damage Initiation Points by Structural Stand Stage Category

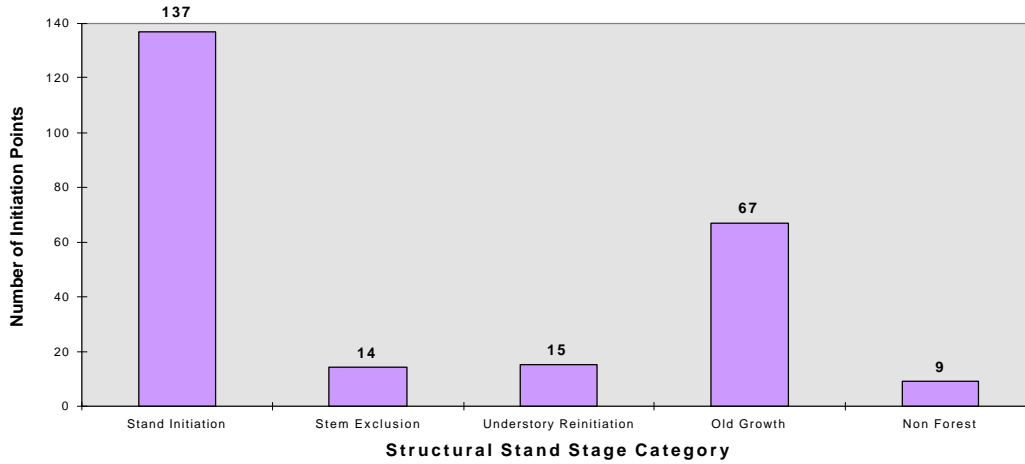


Chart B4b: Study Area and Initiation Point Distribution by Structural Stand Stage Category

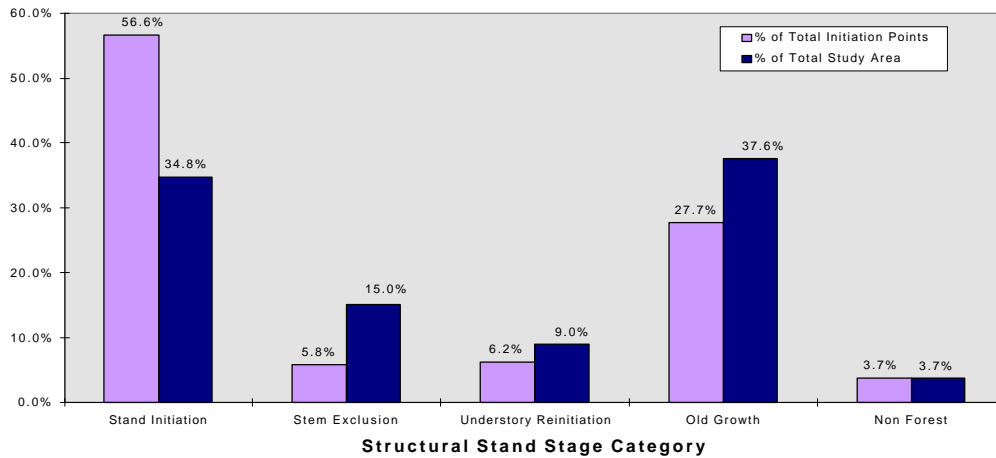
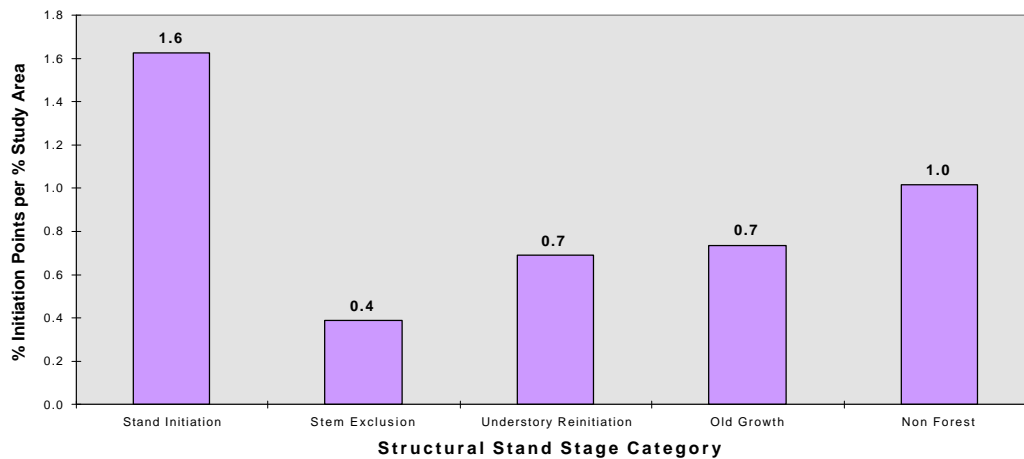


Chart B4c: Ratio of Initiation Points to Total Study Area by Structural Stand Stage Category



Structural stand stage categories with the highest ratio of initiation points to area (normalization method 2, see charts A4c and B4c):

GIS Category	Blue River Study Area		Rigdon Study Area	
Stand Stage	Stand Initiation	1.6	Stand Initiation	1.6

Definitions for structural stand stages found within the above normalizations:

Stand Initiation Stage (early) – In this stage, stand ages range from 1 to 20 years old depending on site conditions and degree to which the stand has been managed. Conifers regenerate and shrubs and herbaceous species that were present in the preexisting plant community are reestablished in abundance; species such as rhododendron and vine maple resprout after timber harvest and broadcast burning. At higher elevations, beargrass also survives timber harvest and burning and may cause severe competition for planted trees. Invasion of harvested sites by non-sprouting plants is highest at lower elevations, <3000 feet, and on southerly and westerly aspects. The degree of plant species diversity declines with increasing elevation and frequency of lower temperatures.

Old Growth Stage (late-old growth) – These stands are generally the largest and oldest found within the watershed. They may range from over 200 to over 600 years old. Second and third canopy layers are usually well developed with shade tolerant species. Other vegetation, primarily shrubs, may reach high levels because of open canopies. Heavy competition from rhododendron, other shrubs or beargrass may reduce replacement of mortality, leaving stands more open.

As stated in the **Data Interpretation** section of this report, the old growth stand stage is listed here as having the highest percent of initiation points in the Blue River study area probably because the greatest portion of the area is located in that stage (42.3%). Old growth stands generally have susceptibility to debris flow occurrence simply because undergrowth cannot survive due to canopy closure. Undergrowth can help to provide root strength to soil as well as curb soil erosion due to precipitation runoff during high rainfall events. Debris flow occurrence in this stage could also be due to high wind—larger, older trees are more susceptible to blow down. With such intense amounts of rainfall experienced by the Blue River study area on pre-saturated ground, it is understandable that supersaturated soil, dislodged roots and debris could quickly and easily have been washed down slope.

The stand initiation stage category fell just 7.9% short of the old growth stage in highest percent of initiation points in the Blue River study area (see chart A4b), even though only 20.2% of the area is in the stand initiation stage. This stage is probably most

vulnerable to debris flow due to soil exposure and loss of root strength from recent disturbance. The soil is capable of becoming supersaturated at an accelerated rate because young vegetation cannot absorb the high amounts of precipitation both study areas received during the flood events of 1996, nor can it provide established root strength to keep the soil in place.

Road Density Category

Road density categories were calculated by running the AML (ARC Macro Language), RDDEN.AML, on the Forest-wide TRAN layer. The study areas were then clipped from the resulting coverage, RD_DEN, located in [/fsfiles/unit/gis/so/road_analysis](#). RDDEN.AML is located in the [/fsfiles/unit/gis/so/road_analysis/aml](#) directory. The AML uses a circular, one-square mile moving window to evaluate road density and creates polygons depicting those densities in one or two mile per square mile increments. RDDEN.AML does **not** correct for watershed boundaries (ridges, valleybottoms, etc.) nor does the evaluation extend beyond the Forest transportation boundary. The size of the moving window is adjustable; it's been noted that using a smaller window increases the number of polygons created and makes areas with zero road density more apparent. A one-square-mile moving window and a two-mile polygon increment were used in this study to be consistent with the recent road analysis that was performed on the Willamette National Forest as part of a nationwide pilot program.

Road density categories with highest percentage of initiation points (normalization method 1, see charts A5b and B5b):

GIS Category	Blue River Study Area		Rigdon Study Area	
Road Density	4-6 mi/mi ²	58.8%	2-4 mi/mi ²	57.0%

Road density categories with highest ratio of initiation points to area (normalization method 2, see charts A5c and B5c):

GIS Category	Blue River Study Area		Rigdon Study Area	
Road Density	4-6,6-8 mi/mi ²	1.6	2-4,4-6,6-8 mi/mi ²	1.1

Both percentages reported here in the first normalization are highly anomalous compared to the other categories--about 25% higher than the next lowest value in each study area. As with slope percent category, ratios between categories in each study area are too similar to be of consequence individually. Refer to charts A5b and A5c, B5b and B5c for illustration.

BLUE RIVER STUDY AREA

Chart A5a: Flood Damage Initiation Points by Road Density Category

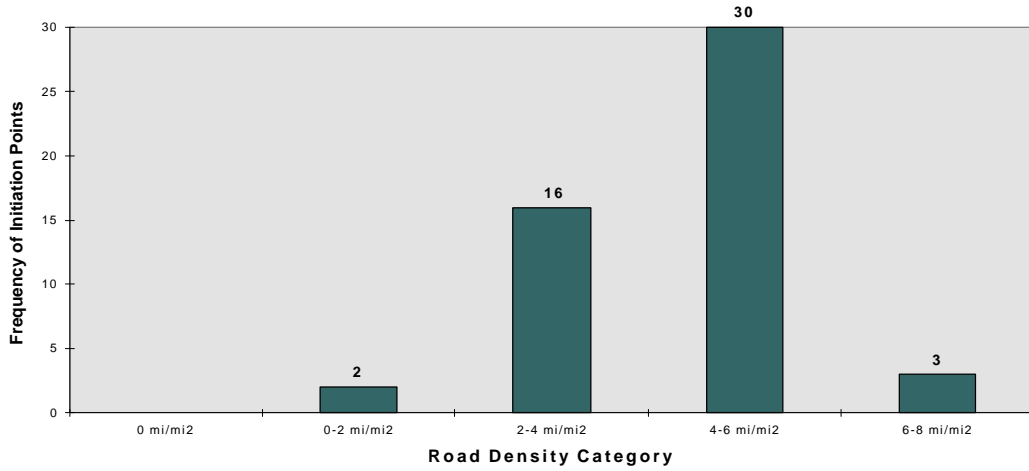


Chart A5b: Study Area and Initiation Point Distribution by Road Density Category

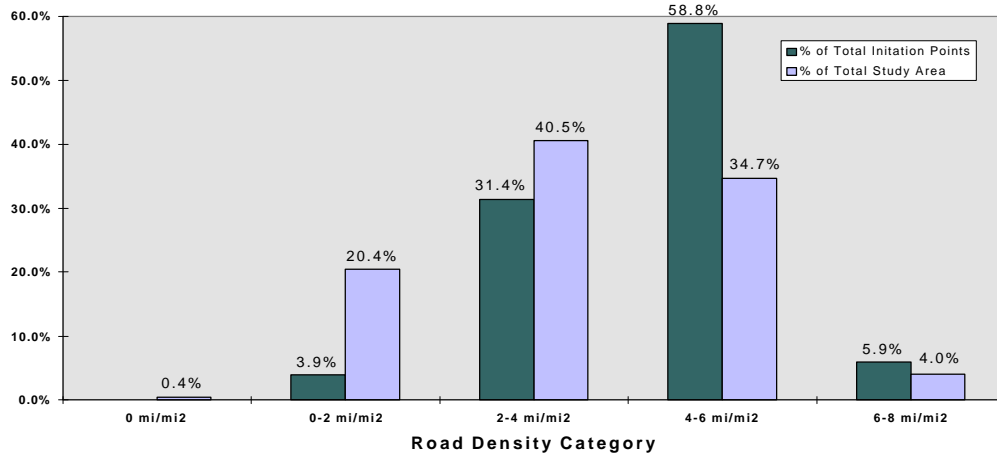
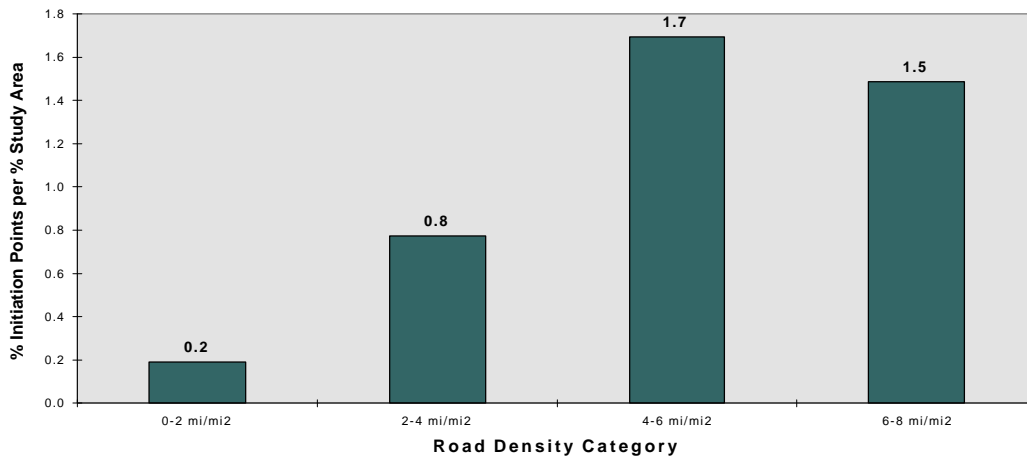


Chart A5c: Ratio of Initiation Points to Total Study Area by Road Density Category



RIGDON STUDY AREA

Chart B5a: Flood Damage Initiation Points by Road Density Category

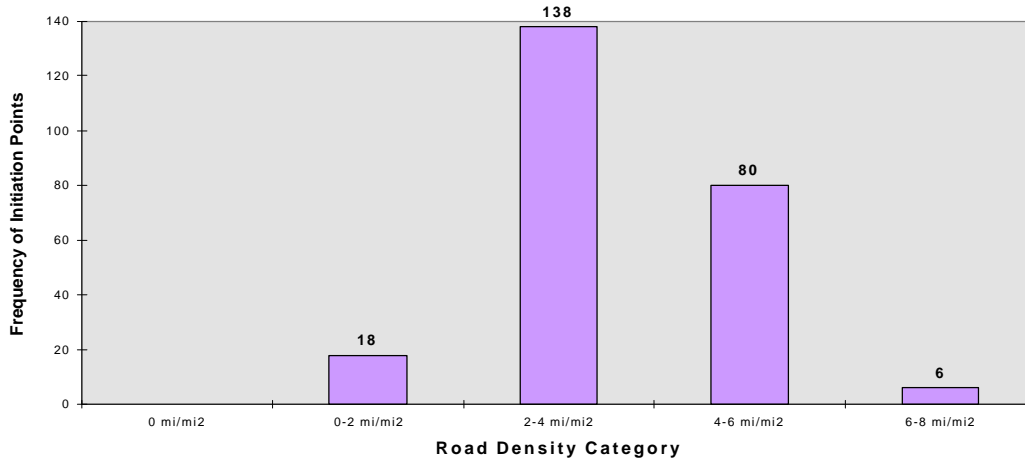


Chart B5b: Study Area and Initiation Point Distribution by Road Density Category

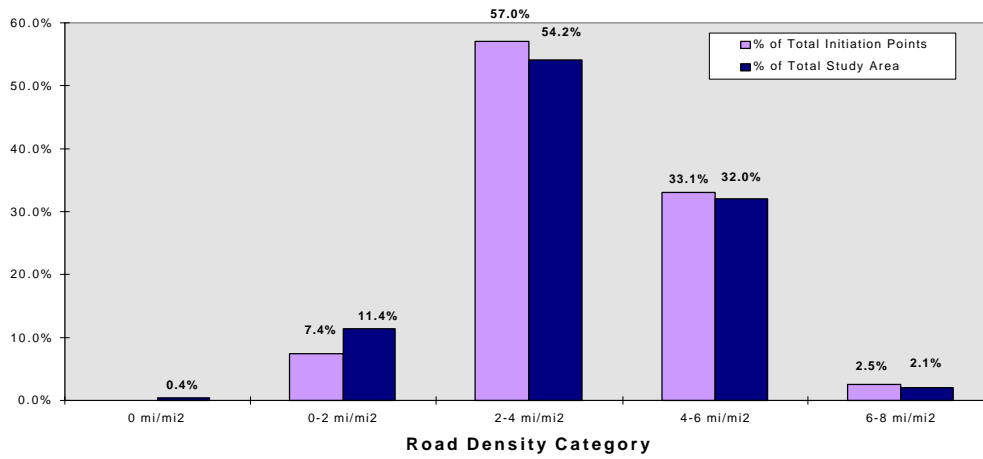
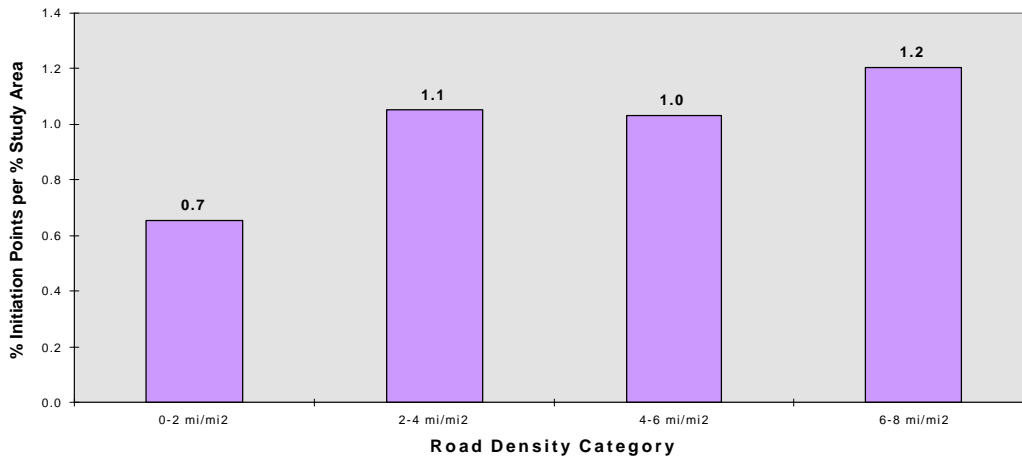


Chart B5c: Ratio of Initiation Points to Total Study Area by Road Density Category



Natural Soil Stability Rating

The soil stability rating is based on the relative stability of the mapped soil units as they occur in the natural state. This includes any soil movement or loss other than surface erosion. Kinds of movement include slumps, slides and all kinds of deep-seated failures. Anthropogenic factors like road construction or timber harvest are not considered in this rating.

Soil stability characteristics were taken from the Soil Resources Inventory (SRI) GIS layer found in the directory, [/fsfiles/ref/library/gis/wil](#). The item, STABILITY, was used for this analysis. The soils in the Willamette Province were originally mapped 1971-72 and updated 1990-92.

Soil stability categories with highest percentage of initiation points (normalization method 1, see charts A6b and B6b):

GIS Category	Blue River Study Area		Rigdon Study Area	
Stability	Stable	60.8%	Stable	78.1%

Soil stability categories with highest ratio of initiation points to area (normalization method 2, see charts A6c and B6c):

GIS Category	Blue River Study Area		Rigdon Study Area	
Stability	Stable-Unstable	2.9	Stable	1.4

Stability definitions for the categories found in the above normalizations:

Stable Occasional failures are observed.

Unstable Many failures are observed.

Soils rated as 'unstable' are susceptible to erosion much more readily than stable soils; major natural events, such as the floods of 1996, are not necessary to remove soils with this rating. The frequency of debris flow initiation points in the stable category can be mostly attributed to the absence of unstable soils in both study areas. Historical events and normal erosion have removed unstable soil so material is not available to create debris flows.

BLUE RIVER STUDY AREA

Chart A6a: Flood Damage Initiation Points by Soil Stability Category

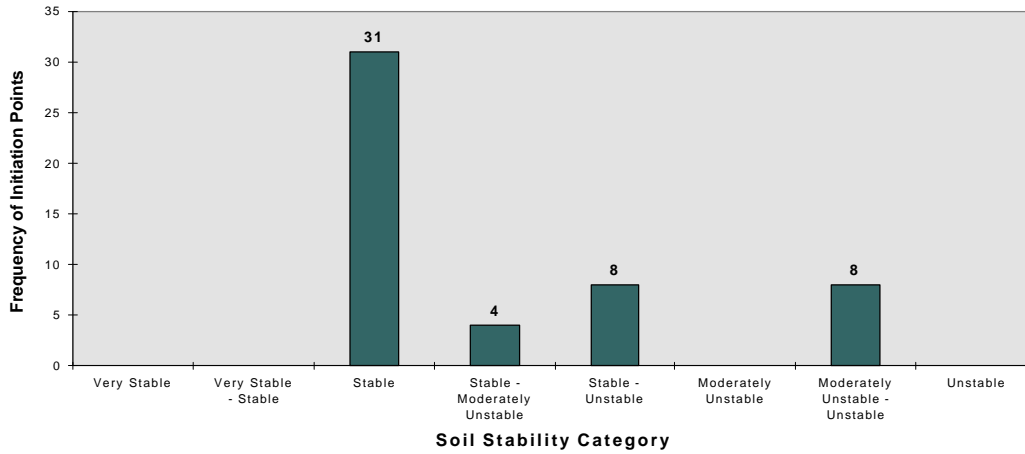


Chart A6b: Study Area and Initiation Point Distribution by Soil Stability Category

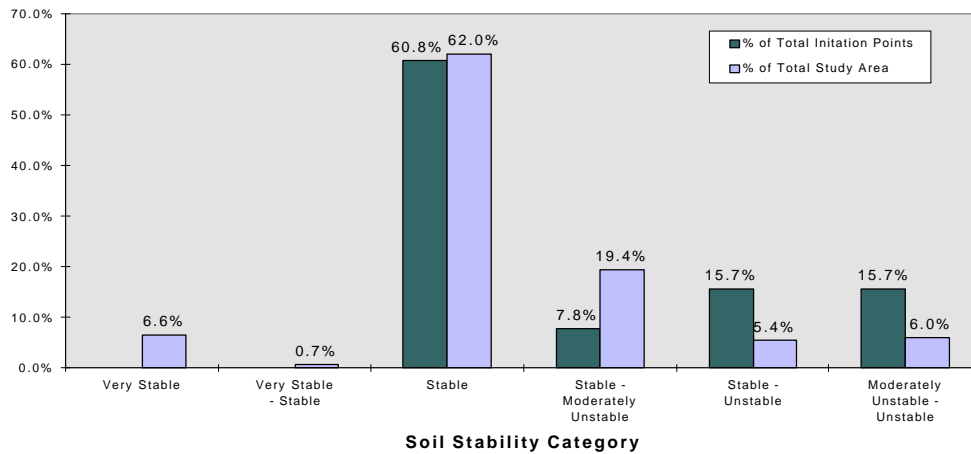
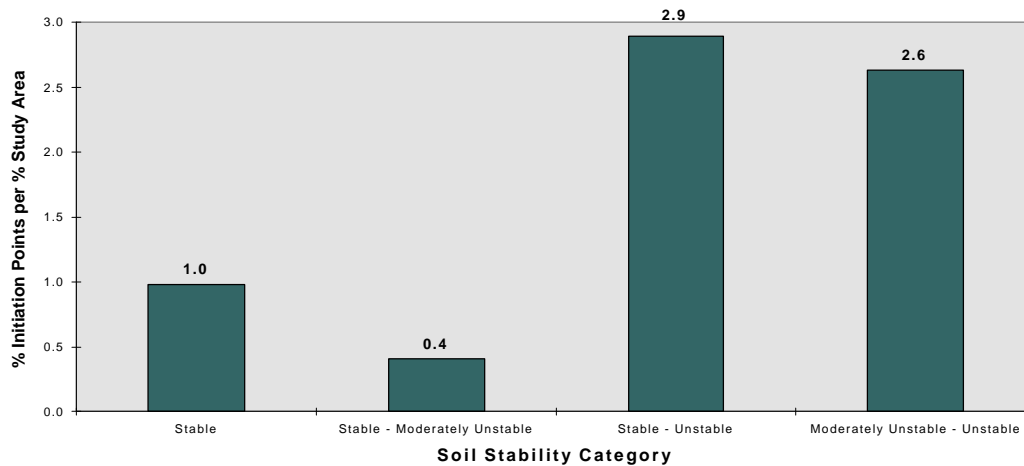


Chart A6c: Ratio of Initiation Points to Total Study Area by Soil Stability Category



RIGDON STUDY AREA

Chart B6a: Flood Damage Initiation Points by Soil Stability Category

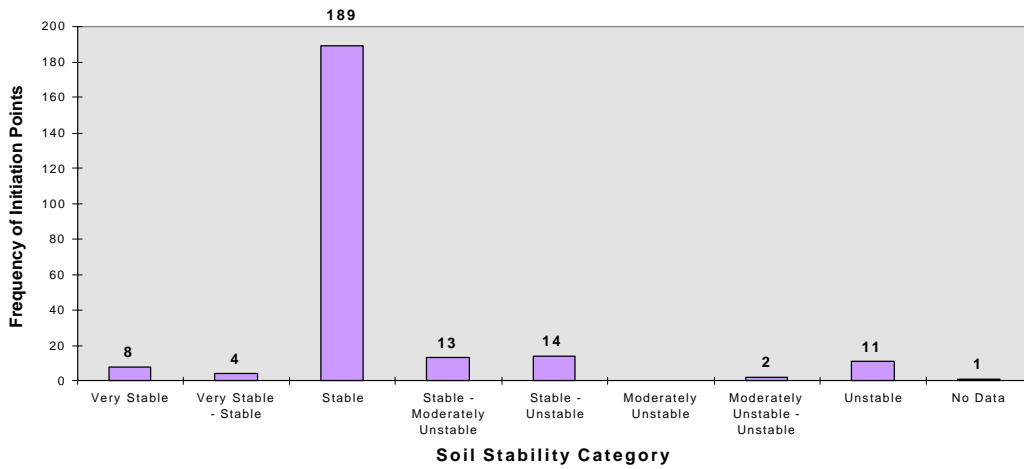


Chart B6b: Study Area and Initiation Point Distribution by Soil Stability Category

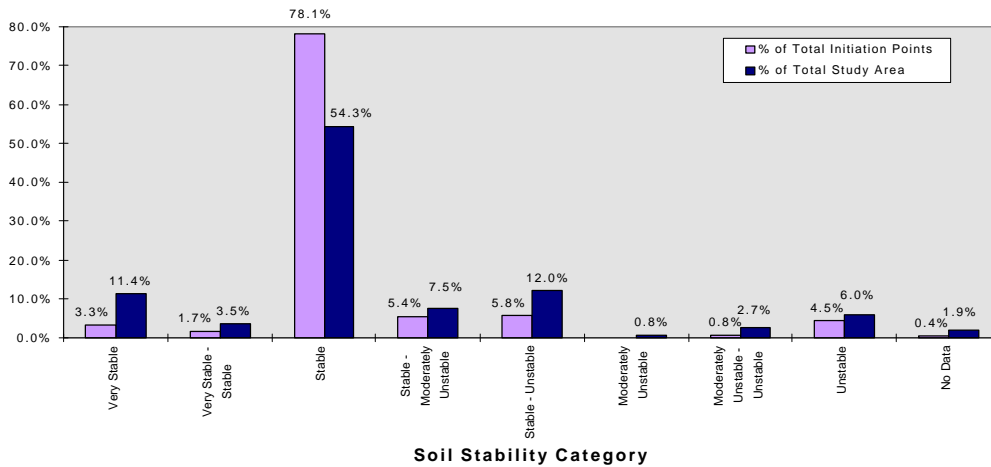
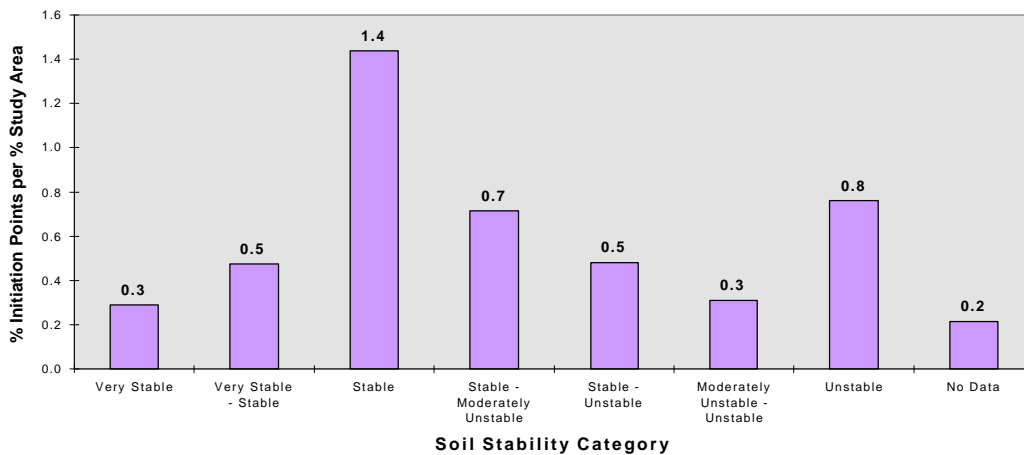


Chart B6c: Ratio of Initiation Points to Total Study Area by Soil Stability Category



By definition, the stability rating is based on evaluating the soil **as it occurs in nature**, not after roads are built on it or vegetation is removed from it. A second STABILITY item added to the SRI layer might be useful to reflect the soil stability rating after it is naturally or anthropogenically disturbed and to what degree. It makes sense that road construction and timber harvest should take place on soil with a naturally stable rating, but decisions to do so should take into consideration any other natural and/or anthropogenic disturbances that have occurred to affect the natural rating.

It should also be observed that the majority of the land within each study area has been assigned to the 'stable' rating—62.0% in the Blue River study area and 54.3% in the Rigdon area.

Summary of Results within GIS Categories

GIS categories with highest percentage of initiation points (normalization method 1):

GIS Category	Blue River Study Area		Rigdon Study Area	
Elevation	2000-2500'	51.0%	4500-5000'	28.1%
Geology	Tu	78.4%	Tbaa	54.5%
Slope Percent	20-30%	39.2%	30-40%	21.1%
Stand Stage	Old Growth	41.2%	Stand Initiation	56.8%
Road Density	4-6 mi/mi ²	58.8%	2-4 mi/mi ²	57.0%
Stability	Stable	60.8%	Stable	78.1%

GIS categories with highest ratio of initiation points to area (normalization method 2):

GIS Category	Blue River Study Area		Rigdon Study Area	
Elevation	2000-2500'	3.3	4500-5000'	2.1
Geology	Tbaa	3.4	Tub	2.5
Slope Percent	40-50%	1.6	90-100%	2.9
Stand Stage	Stand Initiation	1.6	Stand Initiation	1.6
Road Density	4-6,6-8 mi/mi ²	1.6	2-4,4-6,6-8 mi/mi ²	1.1
Stability	Stable-Unstable	2.9	Stable	1.4

Overall summary of ratio of initiation points to total area in each study area:

Blue River Study Area			Rigdon Study Area		
Total Initiation Points	Total Study Area	Ratio	Total Initiation Points	Total Study Area	Ratio
51	60.4 mi ²	0.84	242	~290.0 mi ²	0.83

Even though the study areas are remarkably different in size, the proportions of debris flow initiation sites to total area are nearly identical.

FUNCTIONAL RELATIONSHIPS BETWEEN GIS LAYERS

Characteristics of Other GIS Layers in Categories with Highest Percentage of Initiation Points

All GIS layers represented in this section were intersected using the ARC IDENTITY command to describe the functional relationships between the layers. The attached charts in Appendix III are graphical representations of these relationships. The charts also show how much of the entire study area falls into each category.

Following are two tables, which represent the intersections of the other GIS layers as above in each study area. Cells with values highlighted in red represent categories with the highest percentage of initiation points from each layer. Values in the corresponding row represent the majority characteristic in each layer according to the highlighted category. For example, in the first row of values:

The greatest percentage of initiation points occurred in the 2000-2500' range in the Blue River study area. When compared to the other GIS layers in that range, Tu is the dominant geologic type, 10-30% is the most common slope percent range, old growth predominates in stand stage, road density is greatest at 4-6 mi/mi², and 'stable' is the soil rating that best characterizes the range.

Blue River study area

GIS layer	Elevation	Geology	Slope %	Stand Stage	Road Density	Stability
Elevation	2000-2500'	Tu	10-30%	Old Growth	4-6 mi/mi ²	Stable
Geology	2000-3000'	Tu	10-30%	Old Growth	4-6 mi/mi ²	Stable
Slope %	2500-3500'	Tu	20-30%	Old Growth	2-4 mi/mi ²	Stable
Seral	2500-3500'	Tu	20-30%	Old Growth	2-4 mi/mi ²	Stable
Road Density	2500-3000'	Tu	10-20%	Old Growth	4-6 mi/mi ²	Stable
Stability	2500-4000'	Tu	20-30%	Old Growth	2-4 mi/mi ²	Stable

Rigdon study area

GIS Layer	Elevation	Geology	Slope %	Stand Stage	Road Density	Stability
Elevation	4500-5000'	Tbaa	N/A	Old growth	2-4 mi/mi ²	Stable
Geology	5000-5500'	Tbaa	N/A	Old growth	2-4 mi/mi ²	Stable
Slope %	N/A	N/A	30-40%	N/A	2-4 mi/mi ²	N/A
Seral	3000-4000'	Tbaa/Tu	N/A	Stand Initiation	2-4 mi/mi ²	Stable
Road Density	4500-5500'	Tbaa	20-50%	Old growth	2-4 mi/mi ²	Stable
Stability	4000-5500'	Tbaa	N/A	Old growth	2-4 mi/mi ²	Stable

The similarities of items within the columns in both tables seems to indicate that these categories are essential to debris flow occurrence. However, the majority of these items occupy the greatest percent of total area within each study area. The following section shows additional information involving the initiation point data and the functional relationships between the GIS layers to narrow which categories were present most often where the 1996 debris flows occurred in each study area.

Initiation Points as They Occur in Combinations of GIS Layers*

Again, the GIS categories summarized as those containing the highest percentage of initiation points:

Summary Table (from Summary of Results within GIS Categories)

GIS Category	Blue River Study Area		Rigdon Study Area	
Elevation	2000-2500'	51.0%	4500-5000'	28.1%
Geology	Tu	78.4%	Tbaa	54.5%
Slope Percent	20-30%	39.2%	30-40%	21.1%
Stand Stage	Old Growth	41.2%	Stand Initiation	56.8%
Road Density	4-6 mi/mi ²	58.8%	2-4 mi/mi ²	57.0%
Stability	Stable	60.8%	Stable	78.1%

(Refer to the above **Summary Table** throughout the remainder of the **Functional Relationships Between GIS Layers** section.)

The frequencies of initiation points in recurring combinations of the GIS categories above are as follows (where the categories represented in the combinations are not necessarily in any order or specified combination):

Blue River Study Area	
Total number of combined GIS categories	Percent of initiation points
1	7.8%
2	17.6%
3	35.3%
4	21.6%
5	13.7%
6	3.9%

Rigdon Study Area	
Total number of combined GIS categories	Percent of initiation points
0	3.3%
1	12.0%
2	25.6%
3	31.0%
4	23.1%
5	5.0%

The highest percentage of initiation points occurred where three GIS categories overlapped in both study areas. Lower percentages occurred on either end of each distribution. This shows that 75-80% of the 1996 debris flows were initiated where 2-4

* The IDENTITY command in ARC was used to intersect the initiation point coverages for each study area with the desired categories reflected in the Summary Table to create new point coverages. Combinations of categories were determined by flagging each category with a unique value inside the created point coverages and then running frequency reports for the flagged items.

of the factors described in the **Summary Table** overlapped under the given climatic conditions. One factor generally was not enough to initiate debris flows and 5-6 factors don't overlap often enough to have been a significant source of initiation sites.

Initiation Points as They Occur in Individual GIS Categories within Combinations

Following is a table that specifies which GIS categories show up most often within combinations. Values are normalized as percentages of the total initiation points in each study area. Refer to the **Summary Table** above for categories represented in each study area.

GIS category within a combination	Blue River Study Area	Rigdon Study Area
Elevation	51.0%	27.3%
Geology	78.4%	54.5%
Slope Percent	37.3%	Not Available
Stand Stage	41.2%	56.6%
Road Density	56.9%	57.0%
Soil Stability	60.8%	78.1%

Geology (Tu) and Soil Stability Rating (Stable) appear as components in most of the combinations for the Blue River study area. Soil Stability Rating (Stable), Road Density (2-4 mi/mi²) and Stand Stage (Stand Initiation) are the most prevalent combination components for the Rigdon study area.

Most Frequent GIS Category Combinations

In the Blue River study area, the two-category combination of Geology (Tu) and Soil Stability Rating (stable) occurs five times. The combination of Elevation (2000-2500'), Geology (Tu) and Road Density (4-6 mi/mi²) occurs four times. These occurrences represent 12.2% and 9.8% of the total initiation points respectively. No debris flows were initiated outside of the GIS categories listed in the **Summary Table**.

In the Rigdon study area, Stand Stage (Stand Initiation), Road Density (2-4 mi/mi²) and Soil Stability Rating (Stable) occurs 24 times. Ten percent of the initiation points in the Rigdon study area occur where those three categories overlap. Geology (Tbaa), Stand Stage (Stand Initiation), Road Density (2-4 mi/mi²) and Soil Stability Rating (Stable) occur in combination where 23 debris flows were initiated (9.5% of total). Twenty-one

initiation points occurred where Stand Stage (Stand Initiation) and Soil Stability Rating (Stable) overlap (8.7%). Only eight debris flows were initiated where none of the specified GIS categories are found.

CONCLUDING REMARKS

The 1996 floods were unique mainly due to the high intensity of rainfall and the persistence of both storms over a period of days on the Willamette National Forest. Given those conditions, this study has found that most of the 1996 debris flows occurred in areas where 2-4 of the discussed GIS categories overlapped. The predominant combinations were found to be those listed in the previous two paragraphs. These findings can potentially help natural resource managers on the Forest to consider focussing restoration projects in the areas described by the combinations or in areas where 2-4 of those GIS categories overlap. In addition, the resulting combinations may help managers to plan future recreational and economic activities on the Forest in anticipation of additional events of similar magnitude and timeliness of the 1996 floods.

Even though the Rigdon study area is almost five times larger than the Blue River study area, resource managers may take note of the similar ratio of occurrence of debris flows to area in each study area. The outcome of this study shows that about 0.84 debris flows occurred per square mile. Predictions as to the reaction of particular landscapes in response to similar preexisting and storm conditions may be based on this value. Managers may expect to see similar results under similar conditions.

Some suggestions to make future additions to these layers and this study easier to manage:

- Field data collectors should use a standardized protocol (e.g. the attached data dictionary) to record appropriate data when observing debris flows in the field. This would smooth the data input process and speed communication between field and GIS personnel.
- Field personnel should mark debris flow locations onto a field map at the time of discovery and take care to place endpoints accurately (initiation and run-out locations).
- Field data collectors should try to obtain original slope percent values at debris flow initiation sites. Besides providing actual measured data, this would be useful to compare to generated slope values. An attribute to accommodate measured slope should be added to the standard protocol for documenting debris flows.

Questions regarding this study and requests for additional information and/or maps can be directed to:

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ACKNOWLEDGMENTS

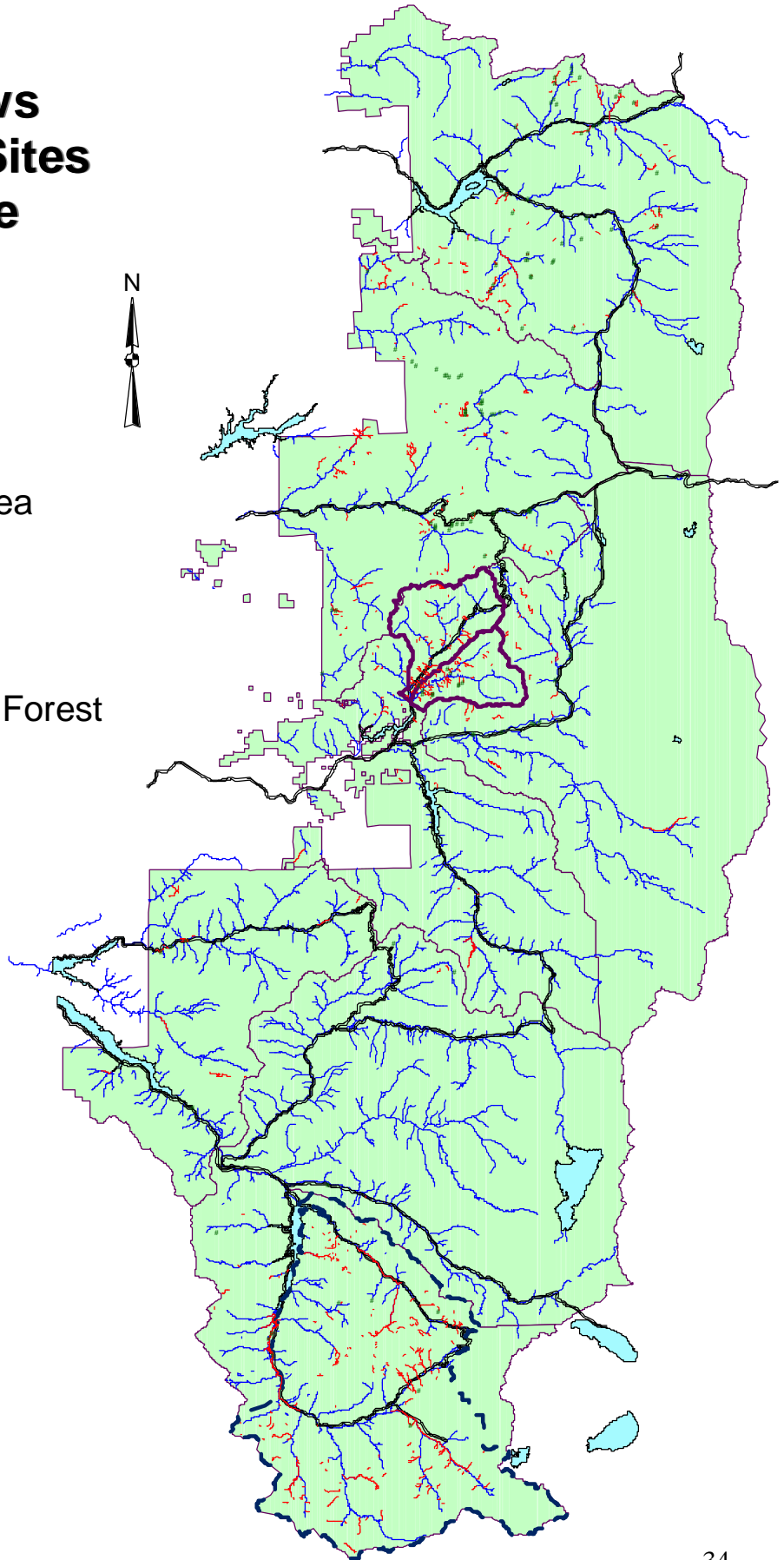
Special thanks to Bruce McCammon, Region 6 Hydrologist, for proposing this project and providing financial support for its completion. On the Willamette, thanks to Deigh Bates, Forest Hydrologist, for guidance, technical advice and document review; Henry Jennings provided crucial GIS and computer equipment support as well as inspiration and Tina Hougan supplied encouragement and praise when necessary. Much appreciation to Doug Shank of the Detroit Ranger District and Dennis Maupin of the Middle Fork Ranger District, and to all of the non-ERFO project managers Forest-wide who provided data and input. Appreciation is also expressed to Kai Snyder for providing Blue River data, and to Fred Swanson, Julia Jones and Beverley Wemple of the Forestry Sciences Lab for their time in reviewing this project in its early stages.

1996 Debris Flows and Non-ERFO Sites on the Willamette National Forest

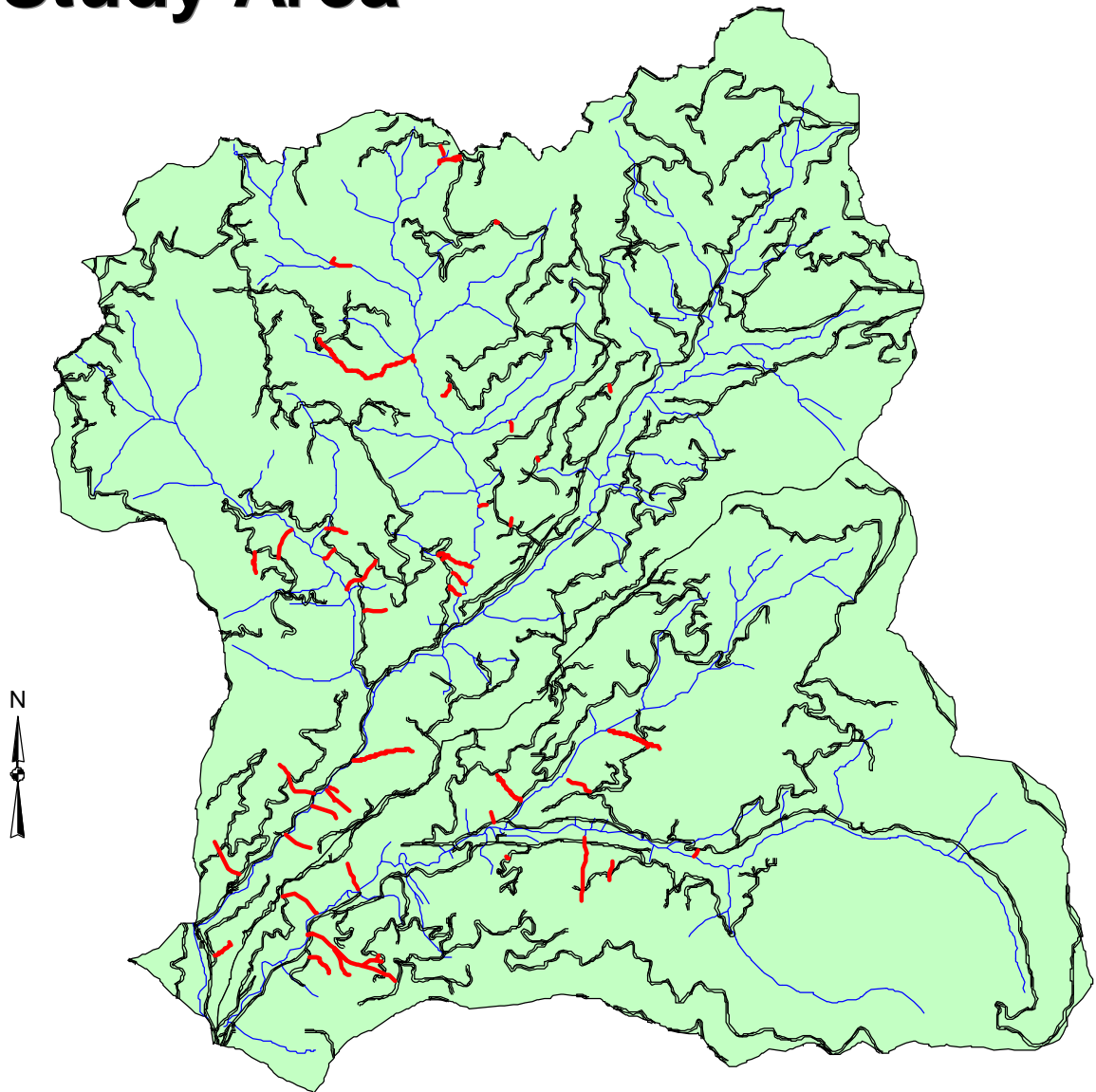
- Non-ERFO Sites
- 1996 Debris Flows
- Blue River Study Area
- Rigdon Study Area
- Major Roads
- Lakes
- Streams (Class 1,2)
- Willamette National Forest




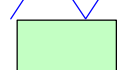


4 0 4 8 Miles



Blue River Study Area

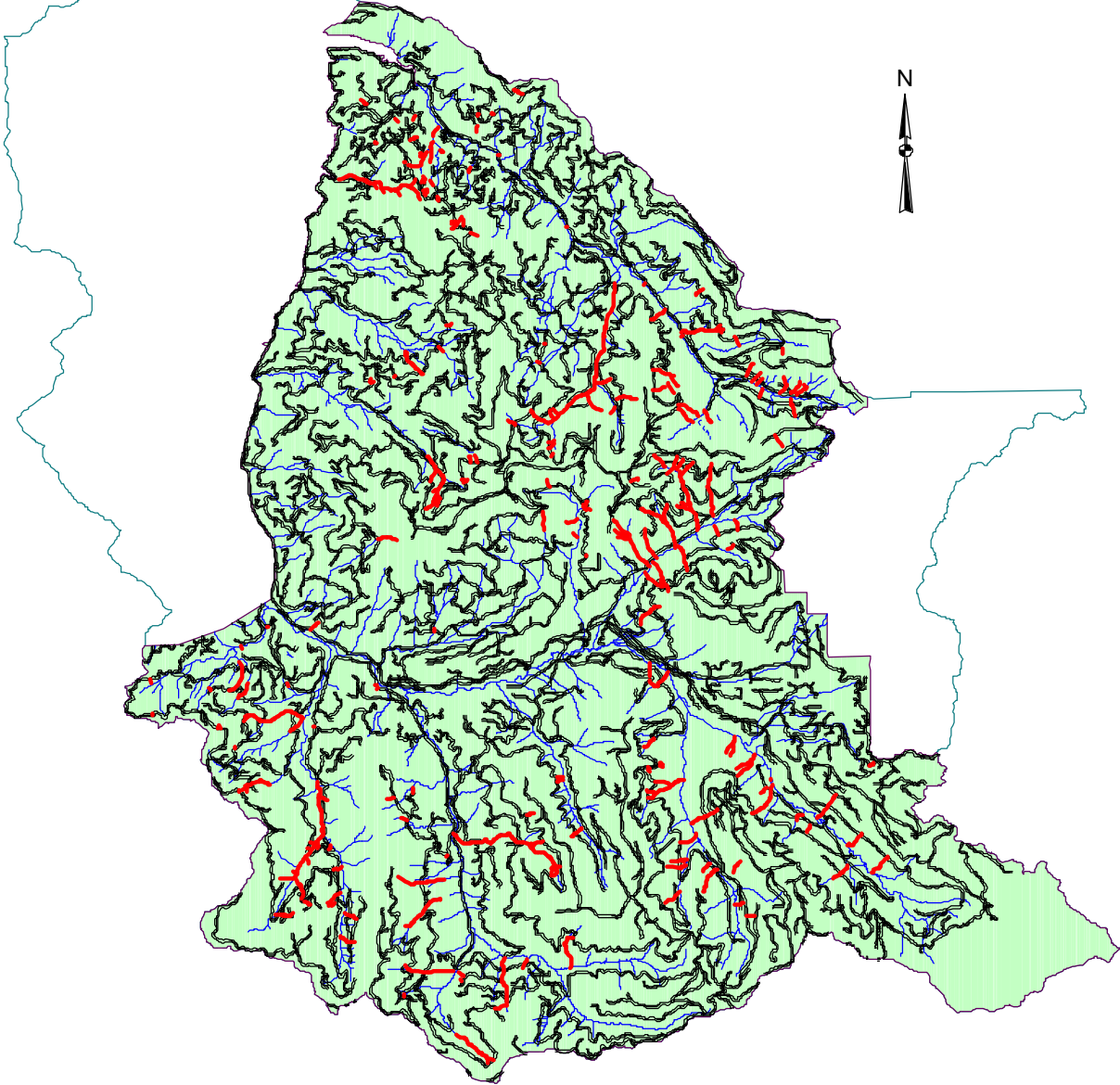





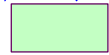

-  Debris Flows
-  Roads
-  Streams (Class 1,2,3)
-  Blue River Study Area

1 0 1 2 Miles



Rigdon Study Area



-  Debris Flows
-  Roads
-  Streams (Class 1,2,3)
-  Rigdon Study Area
-  Former Rigdon RD Boundary



