Lightning Creek Restoration Project

Geology and Engineering Report

Prepared by:
Jim Nieman
Geotechnical Engineer

for:
Sandpoint Ranger District
Idaho Panhandle National Forests

July 2008

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or part of an individual's income is derived from any public assistance program. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at (202) 720-2600 (voice and TDD). To file a complaint of discrimination, write to USDA, Director, Office of Civil Rights, 1400 Independence Avenue, S.W., Washington, D.C. 20250-9410, or call (800) 795-3272 (voice) or (202) 720-6382 (TDD). USDA is an equal opportunity provider and employer.

Table of Contents

Geology of the Lightning Creek Drainage 1
Bedrock 1
Structure 1
Surficial Deposits 1
Geologic History 2
Existing Conditions 3
Historical Summary of Flood Events 6
Forest Service Road Maintenance and Repair Funding 14
Historic Costs for Road Repair in the Watershed 14
Rattle Creek Road 473: Pre-2006 Flood Reconstruction Alternatives 15
Reconstruction of Lightning Creek Road 419 19
Bridge to Porcupine Road 642 21
Project Design Criteria 23
References 26

Geology of the Lightning Creek Drainage

Bedrock

Two basic rock types are found in the Lightning Creek drainage. These are the metasediments of the Belt Supergroup and igneous rocks that intruded into the metasediments. The metasediments constitute the majority of the rock types found in the drainage. They consist primarily of quartzites, siltites, and argillites of the Pritchard Formation, the lowest member in the Belt-Purcell Supergroup sequence. The metasediments generally strike to the north northeast and dip to the east. Nearly 15,000 feet of metasediments are found in the drainage area. The intrusive igneous rocks consist of mafic sills that vary from quartz diorite to gabbro in composition, and granodiorites of the Lightning Creek Stock. The mafic sills are found in the lower portions of the Pritchard Formation throughout the drainage while the granodiorites are found primarily in the lower west flank of the drainage.

Structure

The structural setting in the drainage is one of simple folds with moderately complex faulting. Structures consist of folds, faults, and fault blocks with the metasediments dipping to the east. The Hope fault is the defining structure in the area with a geomorphic expression that is quite notable. The fault trends to the northwest with that area of the drainage to the north of the fault being significantly higher in elevation. The fault has a complex movement history with large scale offsets as evidenced by the abrupt and significant elevation change that occurs along the fault scarp. Fault blocks reflect a mosaic pattern of faults north of the Hope fault with displacements in the range of a few hundred feet. Other faults trending along some of the area drainages, including Lightning Creek are inferred.

Surficial Deposits

There are several types of glacial and glacially related flood deposits found in the drainage. These deposits are ubiquitous throughout the drainage and reflect the complex depositional and erosional sequencing of glacial activity that has occurred. In many areas these deposits grade into one another and are difficult to differentiate. A summary of the various deposits is as follows:

Glaciolacustrine deposits from Glacial Lake Missoula are found along areas of Lightning Creek and in tributary valleys including Rattle Creek and East Fork Lightning Creek that were protected from glacial and flood erosion. These deposits can be found up to 4200 feet in elevation in the drainage. The glaciolacustrine deposits consist primarily of silt to sandy and clayey silts with some fine sands in sequences that are up to 150 feet thick in some areas.

Glacial outwash materials are found along the flanks of Lightning Creek and in tributary valleys to Lightning Creek. These deposits consist of unsorted to semi-sorted sands, gravels, cobbles, and boulders that are interbedded in areas with glaciolacustrine and ice contact sediments. These deposits can be up to 100 feet in thickness.

Deposits of till from alpine glaciation are found in areas of the drainage from 3800 to 5600 feet in elevation. The tills generally consist of unsorted, short transport distance, subrounded to subangular sandy gravels, gravels, cobbles, and boulders of varying thicknesses up to 50 feet.

Glacial till deposits from continental glaciation are found in the lower most areas of the drainage. These consist of relatively dense, compact unsorted mixtures of clay through boulder sized material that may exceed 150 feet in depth in areas.

Basal till deposits from valley glaciation are also found throughout the drainage. These deposits consist of a dense compact unsorted mixture of clay through boulder sized materials that are up to 10 feet in depth.

Alluvial deposits are found in the present day flood plain of Lightning Creek and the other major tributaries in the drainage. These deposits consist of sand, gravel, and cobbles to very large boulder sized material, generally transported during spring snowmelt runoff and or high intensity runoff flood events. These deposits vary from 12 to 35 feet in thickness. The alluvial material originates from reworked and eroded glacial, glacial outwash, and flood deposits.

Alluvial fan material consisting of sand to boulder sized material deposited at the mouth of local tributary drainages. Alluvial fans are common throughout the drainage with very large fans occurring along Lightning Creek. Material is transported during spring snowmelt runoff and or during high intensity flood events. Landslide deposits from debris flow/torrents and hyperconcentrated flows are commonly intermixed with the alluvial fan deposits.

Mass wasting or landslide deposits consisting of unsorted to poorly sorted clay through boulder sized material are found throughout the drainage. The deposits vary in size with a maximum thickness up to 100 feet. Mass wasting consists of debris flow/torrents, debris avalanches, and earth flows associated with saturation of the unconsolidated glacial deposits, snowmelt runoff, and rain on snow and or flood events. The mass failures that occur in the glacial till, outwash, glaciolacustrine, and flood deposits come primarily from over steepened previously failed slopes, steep incised drainages and draws, and or directly off of bedrock. The mass failures are found throughout the drainage, but are concentrated in steeper terrain along the flanks of Lightning Creek, Rattle Creek, and in other tributary drainages to Lightning Creek.

Geologic History

A brief summary of the geologic history of the Lightning Creek drainage begins with the deposition of approximately 15,000 to 20,000 feet of sand, silt, and clay in a subsiding, intracratonic basin during the Middle Proterozoic, 1.4 to 1.47 billion years ago. Deposition occurred primarily in a relatively shallow marine environment. The sands, silts, and clays, subjected to lithification and a later low grade regional metamorphism became the quartzites, siltites, and argillites of the present day Pritchard Formation. The mafic sills found in the drainage were contemporaneous with the formation of the sediments and intruded the lower Pritchard around 1.47 to 1.45 billion years ago. Initial movement of the Hope fault may also have occurred at this time. Subsequent movement of the Hope fault, folding, and thrust faulting took place approximately 700 to 800 million years ago.

The next significant geologic event took place during the Cretaceous Period, approximately 70 to 75 million years ago, with the intrusion of the granodiorite of the Lightning Creek Stock and associated faulting of the metasedimentary rocks overlying the intrusion. Consequently, the terrain took on a very steep and jumbled appearance. Movement along the Hope fault likely occurred periodically from that time until approximately 50 million years ago. More recent movement along the fault is speculative. The prominent scarp seen today is a result of these periodic movements.

The next major event occurred during the Pleistocene approximately 2.5 million years ago with the onset of continental glaciation. There were several periods of glacial advance and retreats during this period. The period of glaciation having the most affect on the drainage began approximately 80,000 years ago and continued until approximately 9,000 years ago. Mountain sides were scoured, and drainages widened and scoured by the nearly half mile deep ice advancing from the north. Deposition of glacial till and associated outwash deposits also occurred at this time with the successive advance and retreats of the continental ice sheet. These same lobes of ice also blocked

the ancestral drainage of the Clark Fork River between 11,000 and 17,000 years ago creating Glacial Lake Missoula. The deposits of glaciolacustrine sediments found in the drainage are remnants of this proglacial lake. Multiple damming and catastrophic flooding of Glacial Lake Missoula occurred during this time frame.

The last glacial advance to occur in the drainage took place after deposition of the Glacial Lake Missoula sediments. Alpine glaciation took place in the drainage after the maximum extent of continental glaciation. Glacial tills were deposited and the prominent cirques and valleys were deepened and extended at this time. The present rocky mountain peaks, sharp ridges (arêtes), cirque basin and lakes, and U-shaped valleys received their final sculpting from the alpine glaciation. The most recent geologic history involves down cutting through the glacial deposits to their prefill levels with associated erosion and mass wasting, and the formation of the Clark Fork River Delta.

Existing Conditions

The present day Lightning Creek drainage can be characterized as being a very active, geologically immature drainage that is prone to flood events, erosion, and mass wasting due to a combination of factors. These factors include the existing geology and geomorphology, geologic history, and climatic conditions. The combination of these elements has created the conditions making Lightning Creek and Rattle Creek in particular, unique drainages in terms of channel instability, flooding, erosion, and mass wasting. These factors are summarized below and include the following:

A. Significant depths of the various surficial glacial deposits cover extensive portions of the drainage. These surficial deposits, including finer grained glaciolacustrine material, glacial outwash deposits, reworked flood deposits, and glacial till were emplaced throughout the drainage primarily during the last major stage of glaciation. These deposits are unconsolidated, are often found on steeper terrain lying directly on bedrock including areas of outfaced dip slopes, often have a distinct density differential that creates a natural slide plane, and in areas are located in over steepened existing draws and tributaries, and are thus extremely prone to erosion and mass failure when saturated and or during runoff/flood events.

B. The average sideslopes in the drainage are generally quite steep. Movement along the Hope fault, thrust/block faulting, downcutting in the major tributaries and channels to match gradient, and glacial scour have all contributed to the highly dissected and generally steep nature of the drainage. The resulting existing numerous drainages, tributary drainages, draws, and existing debris slide channels quickly concentrate any excess runoff resulting in very rapid, high volume flows with corresponding erosion and or mass wasting of the unconsolidated glacial deposits.

C. Due to faulting and glacial scour there are significant areas of very steep, exposed bedrock terrain with little or no vegetation that allows for extremely rapid runoff. These are primarily in the higher elevation areas, and contribute to concentrating runoff at a very rapid pace into the existing draws, debris slide channels, and drainages.

D. Lightning Creek, Rattle Creek, and the East Fork of Lightning Creek are all aggrading, braided channels to varying degrees that carry a tremendous amount of excess bedload. These stream channels are generally very unstable and unpredictable with a penchant for dramatic movement of the active channel throughout the historical floodplain. The excess bedload is due to erosion of the susceptible glacial deposits in the drainage during the post-glacial period.

E. The Lightning Creek drainage has the highest average annual precipitation of any area in the State of Idaho. Measurements from the NRCS SNOTEL site located on Bear Mountain at the head of Rattle Creek show a yearly average of 94 inches of precipitation. During the November 2006 event, a State of Idaho record of 9.4 inches was set for the most rainfall to ever occur during a 24-hour period. Rain-on-snow flood events are common and occur in the drainage when warm moist southwesterly weather systems track into the area, adding melt water from the snow pack to the rainfall from the system. Much of the Lightning Creek drainage is in the primary rain-on-snow zone between 3,000 to 4,500 feet in elevation, although rain-on-snow events can occur up to 7,000 feet in elevation during particularly warm events. Due to the annual precipitation in the area, the existing soils are generally in a near saturated condition and have little capacity to absorb additional moisture or runoff. This contributes to the very rapid runoff prevalent in the drainage and to the rapid saturation of the glacial surficial deposits, setting the stage for erosion and mass wasting of these deposits. Peak flows in the drainage are thus also extreme and tremendous amounts of bedload are moved through the system.

A possible explanation for the high average precipitation and rain-on-snow events that occur in the drainage entails a combination of factors. Warm moist weather systems from the south and southwest are funneled up the Purcell Trench (a broad valley extending 50 miles to the south of the drainage area) and through the Lake Pend Oreille basin. These systems are then funneled up the Lightning Creek drainage where they abruptly rise in elevation over the Hope Fault scarp and mountain peaks in the drainage. This abrupt rise in elevation results in cooling and condensation triggering increased rainfall. In addition, weather systems seem to also stall over the area, particularly along the eastern portion of the drainage including the upper end of Rattle Creek. This is likely due to the topography of the surrounding area. The high levels of precipitation, extreme rainfall, and snow on rain events that occur in the drainage area are obviously paramount in terms of the causal factors that make the drainage so unique in terms of its susceptibility to flooding, erosion, and mass wasting.

Lightning creek; note Hope Fault trace

Glaciolacustrine/glacial outwash material

Glacial material; note dipping bedrock in draw

Debris torrent - alluvial material

Mass failure in glaciolacustrine outwash deposits

Historical Summary of Flood Events

A critical element in evaluating the proposed infrastructure, or the road system in the Lightning Creek drainage, is the history of the drainage. Specifically, the relationship of the drainage's active history of flooding, erosion, and mass wasting to the infrastructure located in the drainage needs to be reviewed to give an accurate picture of what to expect in the future. In this regard, a summary discussion of the history in the drainage, as it relates to the infrastructure is given below.

As stated in the Geology of the Lightning Creek Drainage section, Lightning Creek can be characterized as a geologically immature drainage that has not yet reached an erosion/depositional equilibrium. The drainage is thus very active and prone to flood events, erosion, and mass wasting with inherently unstable channel courses that are filled with vast amounts of bedload. This condition was likely periodically the norm during the last 80,000 years and has been prevalent since the end of the last glacial period nearly 9,000 years ago. As evidenced by some of the very large alluvial fans, mass failure deposits, tremendous quantities of bedload, and other large-scale erosional features, the history of flood events in the drainage goes back into geologic time and predates any human activity.

An early notation from a railroad engineering survey in 1869 called the drainage Lightning River. According to *Idaho Place and Names: A Geographical Dictionary* (Boone 1988), the name Lightning Creek is derived from the nature of the creek. It is evident that the earliest observers of the drainage were aware of its inherently unstable characteristics.

The earliest recorded events that occurred in Lightning Creek were documented in terms of the interaction of flooding with the town of Clark Fork, the roadway bridge over Lightning Creek near the town, and or the railroad bridge. The railroad crossed the lower portion of the creek flood plain approximately 2000 feet from the mouth of Lightning Creek where it enters the Clark Fork River. The town of Clark Fork is also located within the lower portion of the creek flood plain with the roadway bridge located approximately 4,000 feet from the mouth of Lightning Creek. These events took place in 1894 and 1913. Another, evidently more intense event took place in January 1918. The following is a telling quote from the Pend D Oreille Review concerning this event:

> Lightning creek has gone “hell west and crooked” and members of the county board who were in Clarksfork yesterday reported that another foot or two of water may force the creek’s channel through the village. The county’s bridge across the creek, just west of Clarksfork village, has been left high and dry with the change of the stream’s course 50 feet to the eastward. The east approach to the bridge has been washed out and the piers have been warped all out of shape in the flood. The stream is about five feet higher than it has ever been before in a winter or spring freshet.

Additional events relating to the railroad and roadway bridges, and or the town of Clark Fork were recorded in 1921, 1922, and in 1932.

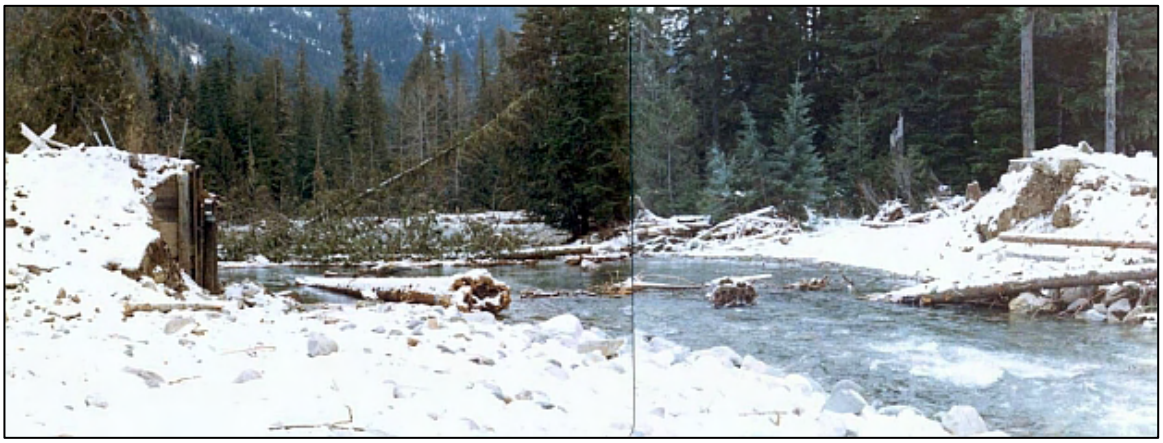
The initial period of road construction into the drainage occurred in the early to mid 1930s. By 1938 the road extended up Lightning Creek to the mouth of Rattle Creek. During the 1950s, construction extended the road system past Rattle Creek and into some of the tributary drainages. Maps indicate that by 1966 the basic road system as it exists today was in place. Events again took place in the drainage in 1948 and 1964. The nature, extent of, and specific damage done to the infrastructure from these events is generally unknown. The next documented flood event took place in 1969. Again, the general nature and extent of damage that took place is unknown except for the fact that the north abutment of the East Fork Bridge was washed away.

In 1974, there was a widespread flood event that impacted much of the drainage. A geological reconnaissance report of the northern portions of the drainage including Rattle Creek, done by the Idaho Geological Survey (IGS) in 1975, stated the following regarding access into the area:

> At the time of the present investigation, a large number of the roads were partly to completely inaccessible to four wheeled vehicles and locally even to trail bikes. Numerous portions of the roads were destroyed by an excessively large runoff of water in January 1974 due to an unusual mid-winter thaw of the snow pack accompanied by heavy rains. Thus, areas which basically have excellent access for reconnaissance type mapping could not be mapped in the time available as adequately as they could have been just one year earlier.

Specific documented damage that occurred during the 1974 event included the Lightning Creek road being washed away in the area of the five mile marker along with the recently repaired north abutment of the East Fork Bridge being destroyed. Based on the previous IGS statement regarding access into the area there was obviously other damage with that damage likely being road segments washed away, severe surface erosion on portions of roads, alluvial material from side drainages depositing material on roads, mass failures depositing material on roads and or destroying portions of roads and plugged or washed out culverts.

The next flood event occurred in December 1980. There was major damage throughout the Lightning Creek drainage. The scale of damage to the infrastructure during this event was at the time, the greatest to have yet occurred in the drainage. Specific damage related to the event included many areas of the Lightning Creek road being washed away or eroded to varying degrees by the action of Lightning Creek, side drainages, and major tributary drainages. The East Fork Bridge over East Fork Creek and the Porcupine Bridge over Lightning Creek were both washed away and completely destroyed while the Rattle Creek Bridge along with other bridges in the drainage suffered damage to varying degrees. Portions of both the Rattle Creek road and East Fork road were severely eroded or washed away while other roads in the drainage suffered erosion to varying degrees. In addition, massive quantities of alluvial and or debris torrent/slide material were deposited on the main Lightning Creek road as well as on the East Fork and Rattle Creek roads from both major tributaries and smaller side drainages. In regards to the Lightning Creek road, several of the fans contained upwards of 5,000 cubic yards of material. Culverts throughout the drainage were destroyed, buried, or washed out. Mass failures also deposited material on and or destroyed roads throughout the drainage, primarily along portions of the Lightning Creek road, Rattle Creek road, and East Fork road.



Porcupine bridge wash out, 1980

Alluvial fan material over lightning creek road, 1980

The next significant event in the drainage took place in 1986. Damage in some areas was severe although the overall impact throughout the drainage was much less than the 1980 event. The damage consisted of varying degrees of erosion to the Lightning Creek road as well as other roads in the main tributary drainages along with some deposition of alluvial material, plugged and or washed out culverts in areas, and some mass failures that impacted the roads in areas. The concrete East Fork crossing structure was damaged, and gabions along the flanks of the structure were partially destroyed by impact of the bedload movement in the creek. The west approach to the Porcupine Bridge was partially washed out.

Another significant flood event occurred in 1990-1991. There was major damage in the Lightning Creek drainage during this event. The damage again consisted of erosion to varying degrees along portions of the Lightning Creek road and other roads in the tributary drainages as well as the deposition of alluvial and landslide material onto these roads. Culverts were also plugged and or washed out. Specifically, nearly 1500 feet of the Lightning Creek road was destroyed in the area of the five mile. This length of road became the main channel of the creek after the event. The two approaches to the Porcupine Bridge were eroded, and overflow from Morris Creek destroyed a portion of the Lightning Creek road. There was a large-scale mass failure in the area of the East Fork crossing and several large road fills were washed out in the Porcupine Creek drainage.

The next significant events occurred in the late fall of 1996 and again in the late winter early spring of 1997. There was isolated damage in the drainage with some alluvial material being deposited on the Lightning Creek road and in some of the tributary drainages, isolated erosion of some road surfaces in areas, and some plugged culverts. In the Rattle Creek drainage, the Benning Creek culvert was plugged with debris and bedload, causing Benning Creek to flow down the Rattle Creek road, destroying nearly 1800 feet of the road.

Damage to road 419 in area of box culvert, 1990-1991

Benning creek culvert inlet, Rattle Creek Road, 1996-1997

The November 2006 Flood

The latest flood event to occur in the drainage took place in November, 2006. There was significant damage done to the Lightning Creek road itself in areas with severe damage to the roads in the Rattle Creek and East Fork Lightning Creek drainages. This event was somewhat unique for the Lightning Creek drainage in that it was not a classic rain-on-snow event but primarily a rain event. Heavy rains had saturated the area for several days, preceding a state of Idaho record rainfall for a 24-hour period of 9.4 inches that precipitated the event. According to initial estimates from the U.S. Geological Survey, peak flows from the Lightning Creek stream gage were greater than 18,700 cubic feet or 139,876 gallons per second, a record volume since installation of the gage in 1988. It

should be noted that peak flows in the days previous to the event were only12 cubic feet or 90 gallons per second.

Damage from this event along Lightning Creek included the main channel of Lightning Creek shifting, eroding into, and destroying nearly 1,700 feet of the Lightning Creek road with the majority of that occurring in one area near the 4.8 mile. The main channel of the creek now occupies this area. The deposition of substantial quantities of alluvial fan and or debris torrent/slide material onto the Lightning Creek road with subsequent covering, plugging, and or washing out of existing concrete box culverts and other culverts with associated erosion of the road in these areas also occurred. The majority of the material deposited came from those tributary drainages between Mink Creek and Trapper Creek. Overall, nearly 2,000 feet of the road surface on the Lightning Creek road was eroded to varying degrees. Culverts in other areas were also washed out, covered, and or plugged. The Rattle Creek Bridge was inundated with bedload and debris and suffered substantial damage to its superstructure and to one abutment. The main channel of Lightning Creek shifted, washing away approximately 165 feet of the approach to the Porcupine Bridge. The main channel of Lightning Creek now flows through this area. Erosion below the abutments at the bridge exposed the upper areas of the steel H pile foundation.

Lightning Creek road - creek shifted and main channel now occupies area where road was located, 2006

Fall Creek on Lightning Creek road 419, 2006

The damage to the infrastructure in the Rattle Creek drainage during this latest event was severe, especially in the lower reaches of the drainage. Rattle Creek shifted to the north side of the drainage eroding into several areas of the roadway destroying a total of approximately 1,130 feet of the Rattle Creek road along with two large-scale concrete box culverts and smaller pipes. The creek channel now occupies these areas. An additional 430 feet of road was destroyed by Rattle Creek but the creek does not now occupy these areas. The large bottomless arch located at Benning Creek and the Button Creek pipe were both overwhelmed with bedload and debris, causing diversion of water down the Rattle Creek road severely eroding the roadway. A total of approximately 7,435 feet of the Rattle Creek road was eroded to varying degrees. Various culverts were plugged, covered, or washed out, and alluvial or debris torrent/slide material was deposited on the road and or in drainage ways.

Lower end of Rattle Creek road. Creek shifted destroying road. Creek now occupies where road originally was this is in the narrow portion of the flood plain. Note concrete box in creek. Note steep eroded banks (2006)

Rattle creek road bridge. Note culvert washed down from rattle creek (2006)

The East Fork road suffered similar damage. The creek was diverted by debris jams and bedload into the road at several locations eroding away significant portions of the road. In other areas debris flows impacted the road and in one area diverted the creek into the road, destroying the road prism for a distance of 310 feet. Approximately 935 feet of road was totally destroyed with another 2300 feet of road severely eroded. Culverts were also covered, plugged or washed out.

East Fork Creek ford crossing area, 2006

Forest Service Road Maintenance and Repair Funding

The Northern Region receives approximately 10 percent of the funds required to maintain the National Forest System road system. Road maintenance funding on the Idaho Panhandle National Forests for fiscal year 2008 is expected to be approximately $1.5 million as compared to $2.1 million in fiscal year 2004. The funding trend for the Idaho Panhandle National Forests illustrates a 26 percent decline in appropriated funding over the last four years (USDA Forest Service white paper, 2008).

Out of the total budget received, the portion allocated for road operations and maintenance varies from year to year. Anywhere between 40 to 50 percent of funding dollars is available for operations and maintenance of roads. Road maintenance accomplishments reports for the IPNF for the past four years (2004-2008) show that approximately 20 percent of the road system on the IPNF was maintained annually. Projecting this percentage maintained to the inventory on the Sandpoint Ranger District, approximately 142 miles of system road is maintained annually (USDA Forest Service white paper, 2008). Currently there is a $730 million dollar backlog of deferred maintenance needs in the Northern Region (USDA Forest Service unpublished report). It is clear that appropriated funding can only maintain a small fraction of the current road system. The results of not maintaining the existing system roads are greater risk to public safety, loss of investment in infrastructure, resource impacts to fisheries, degradation of water quality, and limited public access.

The road damage from the November 2006 flood event was evaluated and approved for funds from the Federal Highway Administration's (FHWA) "Emergency Relief for Federally Owned Roads" (ERFO) funding. This type of funding has been used to repair roads in the Lightning Creek watershed several times in the past. Under the ERFO disaster assistance program, funding is provided from the Highway Trust Fund through the Federal-Aid Highway Emergency Relief Program (supported solely by gas tax), and provides assistance for roads and bridges that have been defined as Federal roads. With a diminishing source of gas tax funding and more competition among federal agencies for ERFO funding associated with recent weather related disasters, FHWA has changed policies associated with providing ERFO funds for of our lower level secondary roads. Because ERFO funding is limited and the administration cannot invest in continually failing roads, FHWA is clear that this time funding approved for some repair work will be contingent on the Forest Service's decommissioning of several lower level secondary roads that have had chronic failures in the past.

Historic Costs for Road Repair in the Watershed

The following information provides historic cost estimates based on reviewing district files about the type of repair and reconstruction work done. All cost estimates are estimates based on professional experience.

1974 – Major flood. #419 road washout at milepost 5; East Fork bridge abutment washed out; surface erosion; alluvium over road; blown culverts. *Significant cost (no data to provide estimate)*.

1980 – Major flood. East Fork bridge lost; Porcupine bridge lost; major road failure on Lightning Creek road; surface erosion; alluvium over road; plugged/blown culverts; mass failures. *Cost ,approximately $1,800,000*.

1986 - Flood. East Fork gabion crossing destroyed; west approach to Porcupine bridge partly washed out; surface erosion; alluvium over road; plugged/blown culverts. *Cost approximately $100,000.*

1990-1991 – Major flood. #419 road destroyed at milepost 5; approaches to the Porcupine bridge washed away; major failures on Porcupine road; mass failure at East Fork crossing; surface erosion; alluvium over road; plugged/blown culverts. *Cost approximately $350,000.*

1996 – Flood. 1,800 feet of the Rattle Creek road severely eroded; surface erosion; alluvium over the road; plugged/washed out culverts. *Cost approximately $70,000*.

2003-2004 – Flood. East Fork crossing destroyed months after repair.

2006 – Major flood. The largest recorded flood stage in period of record. Numerous road washouts; Porcupine, Rattle, and Char Creek bridges damage; alluvium over road; severe road erosion; extensive riparian damage. *Cost approximately $2,500,000.*

Rattle Creek Road 473: Pre-2006 Flood Reconstruction Alternatives

The in-place reconstruction of Forest Road 473 in the Rattle Creek drainage was considered but not included in the alternatives in the post-2006 flood event Environmental Assessment for the Lightning Creek Restoration Project. Reconstruction of road 473 or motorized trails in alternative locations in the drainage were also considered but not included in the alternatives. The unique nature of the drainage in terms of the geology, geomorphology, and prevailing climatic conditions; the nature of previous damage and in particular the damage suffered in the 2006 event, projected potential for future catastrophic damage and cost, and projected future maintenance and associated costs were the basis for the exclusion of the reconstruction alternative. A summary narrative detailing the aforementioned reasons is given below.

Geology of the Rattle Creek Drainage

The bedrock in the Rattle Creek drainage is comprised of competent metasedimentary rocks consisting primarily of quartzites and siltites, with some argillites. Intrusive sills consisting of quartz diorite to gabbro are also found. Glacial deposits consisting of outwash, till, and finer grained glaciolacustrine material are found in the drainage. Faulting, glacial scour, and erosive processes have created a generally steep topography with exposed bedrock along ridges and in the higher elevation areas (see Geology of the Lightning Creek Drainage). Runoff during precipitation events rapidly flows down the steep, exposed bedrock slopes, quickly concentrating in draws and tributary drainages to the creek, contributing to quickly developing, intense flows in the drainage. It also facilitates rapid saturation of the unconsolidated glacial deposits. The glacial deposits have been plastered onto side slopes throughout the drainage which makes them especially susceptible to mass failure when saturated and or in the presence of rapid runoffs. The intermixed glaciolacustrine and outwash deposits found throughout the narrow, lower reach of the drainage are subject to earth flow type mass failure as well.

In terms of the geomorphology of the Rattle Creek drainage area, the lower mile and a half has a great impact on the sustained feasibility of maintaining a road system in the drainage. This area is quite steep with a confined and narrow active flood plain. Glacial deposits consisting of outwash and glaciolacustrine materials are found throughout the area. When saturated and or rapid runoff conditions exist and or in the presence of flood events this area becomes very unstable in terms of the potential for mass failure. It also has a very high potential for flood damage from Rattle Creek due to the limited area the active creek channel can occupy. The other primary geomorphic factors that heavily influence the feasibility of maintaining a road system in Rattle Creek are the presence of the Purcell Trench, the location of the Hope Fault scarp, and the high elevation terrain in the Rattle Creek area (see Geology of the Lightning Creek Drainage). Moisture laden weather systems

tracking from the southwest are funneled up the Purcell Trench and over the Lake Pend Oreille Basin into the Lightning Creek/Rattle Creek drainage. The rise of these prevailing weather systems due to the fault and the surrounding terrain greatly contribute to the orographic rainfall effect, making the Rattle Creek drainage subject to intense and or prolonged precipitation events. The Bear Mountain SNOTEL site, located in the headwaters of Rattle Creek, is the wettest recorded site in the state of Idaho.

Factors Affecting the Rattle Creek Road System

The transportation system, consisting of both primary collector class and logging access roads, constructed in the Rattle Creek drainage has been severely impacted by rain, rain on snow, and associated flood events numerous times. General impacts from events in the drainage were noted from the January 1974 flood event and included roadways being washed out and or becoming impassable due to washouts and material deposition over the roads. Another event occurred in 1980 in which portions of the Rattle Creek road were severely eroded or washed away in areas, sections of road were covered with alluvial deposits while mass failures also deposited material on and or destroyed portions of roads. In addition, culverts were plugged or washed out and the Rattle Creek Bridge was also damaged. Some damage also occurred in 1986 and 1990-1991. Another event in the fall of 1996 overwhelmed and plugged the Benning Creek culvert causing the destruction of nearly 1,800 feet of road. In addition, numerous mass failures and alluvial material from various side drainages impacted the road system.

The latest flood event (as of the date of this report) to occur in the Rattle Creek drainage took place in November 2006. Damage to the road system during this event was extreme, especially in the lower reaches. Approximately 1130 feet of the road was washed out and destroyed along with two large-scale concrete box culverts when the active channel of Rattle Creek shifted to the north side of the drainage where the road was located. Riprap and gabion retaining structures placed along the fill side toe areas of the road after previous events in these areas were also destroyed to varying degrees. The active channel of Rattle Creek now occupies the former location of the road in these areas. An additional 430 feet of road was completely destroyed by the encroachment of the creek where the creek does not now occupy the former location of the roadway. The large bottomless arch located at Benning Creek and the Button Creek pipe were both overwhelmed and plugged with bedload and debris, causing diversion of water down the Rattle creek road severely eroding the roadway in these areas. A total of approximately 7,435 feet of roadway was eroded to varying degrees in addition to those sections that were destroyed. Various culverts were plugged, covered or washed out, with alluvial and debris torrent/slide material deposited on the road and or in drainage structures causing varying degrees of damage to the road.

It is then a combination of steep slopes, exposed bedrock in the upper elevation areas that facilitate rapid runoff, rapid concentration of runoff into existing drainages/ draws and or slide channels, unconsolidated glacial deposits that are susceptible to erosive processes and mass failure during flood and or saturation events located throughout the drainage, being located directly at the wettest site in the state of Idaho, a creek prone to sudden and dramatic increases in flow in an unstable channel system, geomorphology that sets up conditions for intense record setting precipitation events in the drainage, and a portion of the drainage that has a very narrow active flood plain that is bounded by steep slopes prone to mass failure that creates the situation where any road or motorized trail system will be subject to periodic damage with much of that being catastrophic in nature.

Without the option of moving the road location, reconstruction of the road in place would entail placing the road directly into the channel now occupied by the creek. This places the road prism in direct contact with the creek itself, increasing chances of road failure due to high intensity floods

overwhelming the rip-rap protection and or eroding and destroying adjoining sections of the road. This also creates a condition that further constricts the channel, causing sequential impacts upstream such as bedload aggradation and associated debris jam potential that further threatens the road in those areas during flood events. In addition, the very steep, freshly eroded slopes in the glacial material above the road prism are now increasingly prone to erosion and mass failure that will further impact the road.

The costs associated with maintaining the Rattle Creek road if it were reconstructed were also considered and were especially critical in light of ever declining road maintenance funds available to the Forest Service. It was determined that future limited maintenance dollars should be prioritized for other primary road systems in the IPNF due to the nature of the drainage which directly leads to high maintenance and or road repair costs. In the Rattle Creek drainage, maintenance of a routine nature would include removing bedload build up at culvert inlets, removal of debris flow/alluvium on the road from side channels and draws, cleaning out of debris flow/alluvium from open top grated concrete box culverts, grading of eroded and washed out road surfaces, as well as periodic brushing and blading. All of these routine items would need to be done frequently, making the cost of routine maintenance on the road very high. Non-routine maintenance costs for emergency repairs are also likely to be quite high and could be prohibitive depending on the degree of damage. Repair of road damage due to mass failure, the removal of excessive amounts of alluvial/debris flow material from culvert inlets, the roadway, and from open top box culverts, replacing disturbed or eroded away rip rap, reconstructing segments of road that are severely eroded, and reconstructing road segments that have been eroded into or destroyed by the action of Rattle Creek itself all have a high probability of occurrence in the drainage in both relative and absolute terms to other roads in the northern portion of the IPNF.

There were five separate sections of road repair in Rattle Creek from the 2006 event that individually would exceed the entire projected future road maintenance budget for the northern half of the IPNF. There is also a high probability that major damage could occur in the drainage during an event that does not qualify for ERFO funding based on the ERFO definition of a qualifying event. To qualify for ERFO funding, events have a dollar threshold with damage needing to occur over a generally widespread area. The nature of the Rattle Creek drainage substantially increases the likelihood of a significant localized event that would not qualify for ERFO, in which case repairs to the drainage would be cost prohibitive for the Forest Service. It should also be noted that there is no guarantee that ERFO funding would be received in the future even during a widespread event due to funding levels, priority commitments, and recurrence of damage issues.

Alternatives to Reconstructing Rattle Creek Road Prior to the 2006 Flood

Alternative routes for the 473 Rattle Creek road were actually considered just prior to the 2006 flood event. An assessment study of the Lightning Creek Drainage, titled “Lightning Creek Watershed Assessment” was completed by Philip Williams and Associates, Clearwater BioStudies, and JUB Engineers in 2004. One of the assessments recommendations was to move the lower portion of the Rattle Creek road due to its proximity to Rattle Creek and the associated problems with erosion and flood damage. Three alternative routes were reviewed using air photo and contour map interpretations along with field reviews of proposed location corridors. It was determined that due to stability issues related to the road prisms themselves, old growth timber stands, mass failure potential, visual issues, high maintenance and or road repair costs, and road construction costs that the alternative routes were not feasible. The chosen course of action was ultimately to do some mitigation work on the existing road to make it less prone to erosion, flood damage and mass failure. A summary of the road alternatives is listed below.

Alternative 1 - This alternative entailed construction of a mid-slope road along the north side of the drainage, taking advantage of sections of existing logging access roads. This route crossed areas of steep, dissected terrain in glacial deposits with a high probability of mass failure. Alluvial deposition and or debris slide/torrent material from side draws would still impact the road in this location. Several of the existing draws were large and deeply incised making crossing these very difficult and costly. Portions of the logging access roads that crossed these areas were no longer in place, having been destroyed during previous events in the drainage. The cost for this alternative was estimated at $173,024.

Alternative 2 - This alternative entailed construction of a mid-slope road along the southern side of the drainage that would ultimately tie into the existing 473A road. The route crossed steep terrain in glacial deposits with some areas being quite dissected with small wet draws. These areas have a high probability of mass failure. The route also crosses through old growth timber stands where new road construction is prohibited. Reconstruction of the existing 473A road would include drainage mitigation with additional and or upgraded culverts, brushing and blading, possible reinforcement of unstable/wet cut slopes, outfall armoring, as well as erosion mitigation along portions of the existing road surface. The 473A road also has two areas where the road has been taken out by bedload and debris from alluvial and or debris torrents overwhelming the existing drainage structures that were located in large fills. These sites would require major repairs to reopen the road. Mass failure in areas and or the plugging or washing out of drainage structures due to alluvial or slide deposition in areas along the 473A road are also likely to occur during future events. Cost estimations for this route were approximately $211,486

Alternative 3 - This alternative included reconstruction of the Mud Creek 340 road, constructing a switchback off the 340 road with new construction along the slope above the 340 road and eventually tying into the end of the 473A. The 340 road and 473A road would both need reconstruction work. Reconstruction of the Mud Creek 340 road would entail upgrading of culverts and some drainage mitigation, removal of rock fall hazards in a few areas, blading and brushing along with erosion mitigation along portions of the road surface. The switchback site is extremely difficult as the side slopes are nearly twice as steep as the standard maximum for switchback construction. Although there is bedrock in a portion of the site the remainder consists of finer grained glacial material. The ensuing cut would be extremely large and subject to mass failure, sheet and rill erosion. The cut would also be highly visible. Excessive amounts of excavated material would be generated and with most of that material needed to be end hauled for disposal.

Due to the extremely high cut slopes, retaining structures would be needed along the fill and cut slope to improve stability and to reduce the overall exposed cut height. The retaining structures at the site would be extensive and costly and would still not eliminate the potential for erosion as the cut slopes would still be very high. The new road construction after the switchback crossed steep terrain in glacial material with four larger incised draws to cross. These draws would entail significant fills with large and long culverts and possible retaining structures along the cut slopes to ensure stability and prevent erosion. One of the draws crossed is also a snow avalanche chute that would have the potential to impact the road with debris as well as snow. Bedrock is located near surface in the steeper areas as well as in the area of some of the major draw crossings along the proposed route. The 473A road would then need to be reconstructed. This would include drainage mitigation with additional and or upgraded culverts, brushing and blading, possible reinforcement of unstable/wet areas, outfall armoring, as well as erosion mitigation along portions of the existing road surface. The road also has two areas where the road has been destroyed by bedload and debris from alluvial and or debris torrents overwhelming the drainage structure and subsequently destroying the road through these areas. These sites would require major repairs. Additionally, mass failure and or the plugging of drainage structures due to alluvial and or slide material deposition in

areas along the 473A road are likely to occur during future events. Cost estimations for this route were approximately $384,682.

Reconstruction of Lightning Creek Road 419

Several factors were considered concerning the decision to not include reconstruction alternatives for Rattle Creek road 473 while including the reconstruction alternative for Lightning Creek road 419 in the Lightning Creek Restoration Environmental Assessment. The reasons for not including the Rattle Creek road are specified in the section above, Rattle Creek Road 473 Reconstruction Alternatives. The factors relating to the decision to include the Lightning Creek road are summarized as follows:

Although the Lightning Creek road shares many of the conditions that exist for the Rattle Creek road, there are also some differences in terms of geomorphology, road reconstruction options, costs, road use priorities, and access.

Other than the five-mile site on the Lightning Creek 419 road, the damage that occurred during the November 2006 event was generally on a smaller scale than what occurred to the Rattle Creek road. The average spacing of the damage sites was also significantly greater on the Lightning Creek road meaning that there were greater distances of roadway that were not damaged between sites as compared to the Rattle Creek road.

The flood plain of Lightning Creek is generally much broader than that of Rattle Creek, and especially so relative to that area of the Rattle Creek flood plain from the confluence with the flood plain of Lightning Creek up the drainage for a distance of 1.6 miles. The flood plain of Rattle Creek in that area is quite narrow and is bounded by unstable steep slopes (see Rattle Creek Road 473 Reconstruction Alternatives). With the wider flood plain in main Lightning Creek there are more options with relocating the road away from the active channel, greatly decreasing the likely hood of future and or additional damage to the road as opposed to reconstructing the road directly into the active channel of the creek with its inherent risks. A case in point is the major damage that was incurred at the five mile on the Lightning Creek road where the main channel of the creek washed out the road and now occupies the former location of the road. Similar damage occurred along the Rattle Creek road in several areas along the lower portion of the drainage in that area with the narrow flood plain. The broader flood plain will enable the road location at the five mile in Lightning Creek to be relocated away from the active channel of the creek. The road segments that suffered similar damage (see Rattle Creek Road 473 Reconstruction Alternatives) in Rattle Creek cannot be relocated and would have had to been reconstructed directly in the active creek channel.

Due to the wider flood plain in the Lightning Creek drainage, alluvial material and or debris flow/torrent slide material generally impacts the road by covering it to varying degrees as the material is generally being deposited after hitting the flatter ground of the flood plain where the road is located so that the amount of damage to the road prism itself is thus generally not great. The maintenance and road repair in this case would entail removal of the material overlying the road and or movement of the road up and over the deposit. There is also generally room to move the road location in these areas if that would be advantageous. The Rattle Creek road on the other hand, especially along the lower 1.6 miles, is located at the edge of a steep slope such that alluvial and or slide debris impacts the road to a greater degree as the energy of the material is not dissipated as it has not yet hit the flatter ground of the flood plain. The full impact of the material is received by the road prism leading to a much higher chance of damage to the road itself in addition to being covered by the material. Road repairs would entail removing and end hauling the material along a relatively narrow road prism as well as actual repair to those portions of the roadway

impacted by the alluvial and or slide material. There is generally no option of moving the road location to mitigate the impacts during future events.

Repairs done to portions of the Lightning Creek road from past events in the drainage have generally been successful and have withstood subsequent events. The bin walls and rip rapped relocation areas along the five mile, the gabions at the Big Bend area, the raised road grades along significant portions of the road, and the open topped box culverts are a few examples. Some of the repairs along portions of the Rattle Creek road from past events have not been as successful. The Benning Creek pipe/arch has been overwhelmed several times and failed again in 2006. Portions of the Rattle Creek road in the area of the narrow flood plain have had subsequent damage to gabions, rip-rap, road fills and box culverts resulting in the road being completely washed away.

The cost for Rattle Creek road repair per mile of the road system affected by the latest November 2006 event is nearly double that of the Lightning Creek road. Based on damage site assessment reports, costs for the 6.5 miles of the Rattle Creek road averaged nearly $168,700 per mile while costs per mile for 10.0 miles of the Lightning Creek road were around $90,000 per mile. Costs for the lower 1.6 miles of the Rattle Creek road were nearly $500,000 per mile, a testament to the potential for damage this section of road has (see Rattle Creek Road 473: Pre-2006 Flood Reconstruction Alternatives). Funding for future damage due to an ERFO qualifying event is more likely for a major access road in a major drainage as opposed to a secondary road accessing a side or tributary drainage. Acquiring U.S. Forest Service funding for road damage during a non-ERFO event or for road repair maintenance is also more likely for the Lightning Creek road for the same reasons.

Lightning Creek Road - Open top grated concrete box culvert, structural integrity maintained. Note room to adjust road location. (1986 event)

The Lightning Creek road is the major access for the entire drainage. It provides the ability for motorized vehicles to enter a very large area for a myriad of general recreation purposes as well as management activities. It provides motorized access to the mouth of all the major side drainages in

the area such as Rattle Creek, Porcupine Creek, Mud Creek, East Fork of Lightning Creek, and Wellington Creek. The Lightning Creek road is a major collector class road. The Lightning Creek road also is part of a major drivable loop that also includes the Trestle Creek 275 road. In addition, the Lightning Creek road also allows motorized access and entry to nearly 30 camping sites along Lightning Creek. The Lightning Creek road also has a much higher use than the Rattle Creek road.

Lightning Creek Road - Creek shifted and main channel now occupies road location. Note broad floodplain with flat ground providing room to relocate road

Bridge to Porcupine Road 642

The November 2006 flood washed out the east approach of the bridge that spans Lightning Creek at the beginning of road 642 to Porcupine Lake. This bridge was constructed in 1982 following the 1980 flood event that destroyed the original bridge at the site. The location of the bridge site is problematic due to the fact that the creek enters a wider valley section and Lightning Creek is able to move laterally across a very broad floodplain. Review of aerial photos taken before the original bridge construction shows a well-vegetated stream meander with a dynamic yet well established meander pattern beginning just upstream from the

The concrete span that leads to road 642 (constructed in 1982) after the peak flows of the November 2006 flood event

Porcupine-Lightning confluence. In the early 1950s, the original bridge was constructed on the west side of the valley over what appears to be a newly formed channel. This channel could have been created by natural processes such as a flood, but it is likely that the channel was constructed to create a straight path for the creek to flow under the narrow span of the original bridge. The original meander channel on the east side was then also completely filled to create the approach to the bridge. The site was extensively disturbed during construction as is shown in 1958 aerial photos. Aerial photos from 1963, 1965, 1968, and 1975 show a steady recolonization of plants (i.e., willow, dogwood, and cottonwood) in the disturbed areas of the floodplain immediately surrounding the bridge site. Any improvements through natural regeneration of riparian plants were reversed after the 1980 flood event that washed the original bridge away. The 1983 aerial photos show extensive damage to the bridge site after the 1980 flood. Most of the fill in the east side channel is gone. The channel upstream of the bridge shows large-scale aggradation that caused the channel to shift and widen considerably. Downstream the channel widened and there was significant bank scour and braiding.

Lightning Creek at bridge to Porcupine Lake (looking south). Note expansive flood plain to the east (left) where the main channel of Lightning Creek could migrate or move further east during a future event

The present bridge was constructed in 1982 at the same site. Although the bridge structure has survived intact, the approach has been damaged several times leading up to the November 2006 flood event. Following the 2006 flood, Lightning Creek shifted and reestablished a new channel to the east of the bridge site, destroying the approach fill and damaging the east end of the bridge in the process. The channel incised several feet into the aggraded substrate upstream and adjacent to the bridge site. The channel has become well established in its new location to the east of the bridge while no water currently flows under the bridge (see photo, left). The elevation difference from the top of the deposited material under the bridge to the bottom of the current channel is approximately 6 feet.

The existing channel configuration at the bridge site, combined with the broad floodplain and the propensity of the creek to move eastward creates a situation where manipulation to restore the channel under the bridge would require extensive work to establish a functioning channel. Channel manipulation would entail excavating the aggraded bedload underneath the bridge and excavating the channel for a distance of approximately 800 to 1,000 feet upstream to realign the channel approach to the bridge. Engineered structures such as rip-rap, log vanes, rock weirs, and grade control structures would be required to maintain the realigned channel in the new configuration. The channel work would be very expensive. A high degree of risk would still exist for the creek channel to shift again during a major flood event, destroying the approach and/or damaging the bridge. The channel could shift back to where it is now (post-2006 flood event) or it could move 100 feet or more to the east. In addition, the risk to fisheries resource is high. Depending on the season of a flood event (spring vs. fall) the added bedload and sediment delivered downstream could entomb or smother bull trout redds. The

only way to ensure that this would not have a damaging effect on the site and the aquatics resource would be to span the entire channel/floodplain with a bridge.

A new extended bridge would be very expensive and would still have an element of risk associated with the structural integrity of the mid-span supports due to the changing nature of the channel in this location. The cost of this structure would not be justified when considering the risk and limited recreation and management opportunities that the access provides.

Project Design Criteria

The following design criteria elements are common to the repair mitigations for the Lightning Creek Road 419 as well as other areas that are proposed for repairs.

Rip Rap: Rip-rap is rock that is placed against an earthen surface for protection against the action of water. Designed rip-rap will be used extensively to protect the road prism from the erosive action of excessive flows during runoff and or flood events. Properly designed rip-rap consists of the appropriate size, shape, and gradation of the rock to be used in addition to proper installation. In some instances the rip-rap will be grouted together to add additional resistance. Specific rock types found in the drainage that are significantly heavier than the common rock found in the drainage will also be utilized to add additional resistance to flow.

Rip-rap is a standard mitigation that has a long history of use in preventing damage from the action of water. Rip rap has been used previously in repairs in the Lightning Creek drainage. It has been particularly successful during subsequent flood events where a proper size and gradation was used.

Concrete Grated Open Top Drainage Structure: These are square concrete drainage structures with a grated top located at road grade. They are designed to allow normal flows to pass through with the grate providing a driving surface. When excess flows deposit bedload and or debris over the structure the structure is stout enough to resist damage and the grate can be removed to allow easier cleaning out of bedload and debris. These will be utilized in areas where bedload and debris periodically are deposited from drainage ways onto the roadway.

These structures have been used with general success in Lightning Creek since the 1980 event. Similar structures have also been used in other areas of the Idaho Panhandle National Forest in lieu of standard culverts.

Overflow Areas: Overflow areas are sites where excess water flow from blocked drainages or from water flowing down a road surface can exit the road prism prior to causing major damage. These generally take the form of dips, design vertical dips, or broad swales in the road grade. They are sometimes armored where conditions warrant to with stand erosion from excess flows. They are often placed strategically to relieve drainage structures.

Overflow areas have been used extensively and successfully on roads throughout the Idaho Panhandle National Forest. They are a standard element often used in U.S. Forest Service road design. Overflow areas have been used in the Lightning Creek Drainage since 1980 and have generally preformed well.

Raising Road Grade: Raising road grade consists of increasing the elevation of the road surface in areas prone to flooding and or high water. Rock, consisting of gravel to boulder size material, or rip rap is used to raise the grade, providing resistance to damage from flood waters and keeping the road surface from being inundated.

Raising road grade is a standard engineering practice in constructing roads in areas prone to flooding and or high water and has a long history of use. Raising road grade with rock has been done to significant areas of the Lightning Creek road 419 in response to past flood events. Those areas have suffered significantly less damage in subsequent events.

Oversized Corrugated Metal Pipes: Corrugated Metal Pipes or culverts as they are commonly referred to are a standard engineering element used in road design to facilitate the passage of water under roadways. Using oversized culverts allows the passage of excess flows even if the culvert has been partially blocked by bedload and or debris. This decreases the probability of the culvert being damaged and road being washed out. Overflow structures are often placed just down gradient of the culverts as a relief in case the culvert is plugged and or its capacity is exceeded.

Oversized Corrugated Metal Pipes have a long history of being used to facilitate the passage of waters subject to sudden increased flows that may or may not also include bedload and debris. Oversized culverts have been used on the Idaho Panhandle National Forests for many years. Use of oversized culverts, along the Lightning Creek road 419, often combined with other aforementioned design criteria have generally decreased the frequency of damage to roads in areas prone to high flows and flooding.

East Fork Bridge Design Criteria

Bridge design criteria will generally be very conservative due to the nature of the East Fork of Lightning Creek crossing site in terms of the creek channel and flood plain geomorphology, flashy high volume flows, and bedload and debris transport. The specific design criteria listed below will act in concert to enhance the stability of the bridge structure.

Clear Height: Clear height is the vertical distance between stream bottom and the bridge superstructure or more specifically to the bottom of the bridge girders. Clear height is designed to give adequate distance between the bottom of the girders and elevation of water flow under the bridge during high water events (free board). Having adequate clear height is critical in ensuring that water and debris during flood events do not impact the bridge superstructure. Impacts to the bridge superstructure can obviously cause direct damage to the bridge as well as damage to the abutments and bridge approaches due to damming at the bridge site causing additional flow around the bridge structure. Clear heights at the East Fork crossing will be very high to account for potential bedload aggradation at the site, extremely high flows during flood events, and large volumes of woody debris in the form of large trees with correspondingly large root wads.

Determining adequate clear height is a standard engineering practice when designing bridge structures. Using a conservative approach to clear height determination has been successful in protecting bridge structures from damage during extreme high water events.

Span: Span is the horizontal distance between support abutments on a bridge. Span is critical to overall bridge design in terms of allowing room for the active channel to flow in an unimpeded manner under the bridge. The potential for channel change, channel and flood plain geomorphology, flow volumes, and potential debris loading during flood events are all factors in determining an adequate span for a bridge. An adequate span is necessary to prevent damage to the bridge structure, as well as preventing upstream changes in channel or flood plain geomorphology that increases the potential for additional and or future damage. The span for the East Fork Bridge will be on the order of 110 to 120 feet, a very long span, to ensure there is unimpeded flow under the bridge with adequate room for channel migration.

The determination of an adequate span for bridge structures is a standard engineering practice that has been used successfully for many years.

Steel H pile foundation: A steel H pile is a long slender steel structural element that is driven into the ground for the purpose of supporting a load. The East Fork Bridge would be a bridge having a pile foundation with the load from the bridge being carried by the steel H piles. The piles would be driven a significant distance below streambed. Use of the steel H piles generally eliminates any chance of the bridge failing due to the undercutting of the foundation as opposed to a standard spread footing or grade beam footing placed in the fill approach. Adequately sized piles would be used so that if any of the piling would be exposed by down cutting they would resist warping or bending damage by flows, debris, and or bedload saltation.

The use of piling for bridge foundations has a long history and is a standard engineering practice. Piles have been successfully used for bridge foundations at sites with dynamic channel and flow characteristics. The Porcupine Bridge over Lightning Creek constructed after the existing bridge structure was washed away in the 1980 event was built using steel H piles for its foundation as opposed to the initial structure. The bridge has survived multiple flood events since that time including one event that would have undercut a buried spread footing.

Overflow Channels: Engineered overflow relief channels are areas where excess flows due to debris jams, channel migration, or other flood event dynamics will be diverted to take pressure off the bridge structure itself and the bridge approaches. Relief channels will be constructed to provide overflow channels at the East Fork Bridge site.

Relief over flow channels have been used at various sites on the Idaho Panhandle National Forest. They have generally been successful in diverting some of the flow during flood events and taking **pressure off of the primary structure at the site.**

Rip-Rap composed of mafic rock types: Rip-rap is rock that is placed against an earthen surface for protection against the action of water. Rip-rap composed of mafic rock types weighs close to 19 pounds more per cubic foot that the commonly found metasedimentary rock types present in the drainage. An equivalent two foot square sized piece of mafic rip rap would weigh 152 pound greater than the commonly found rock while an equivalent three foot squared sized piece of rip rap would weigh over 500 pounds more. Use of the mafic rock types at the bridge site gives the rip-rap a higher degree of integrity due to the increased weight of the rock and thus provides a much higher degree of protection for the bridge structure and or approaches. Mafic rock types are present in the Lightning Creek drainage and will be utilized at the East Fork Bridge site.

Rip-rap has been used successfully for many years to protect bridge and bridge approach structures and is a standard engineering practice. Use of mafic rock types for rip-rap has been successfully used on several projects on the Idaho Panhandle National Forests

Grouted Rip-Rap: Grouted rip-rap is standard rip rap material that is grouted using a pressure hose delivery system. The grout mixture fills in the open areas between the individual fragments of rip-rap essentially cementing the rip rap structure together. This eliminates the chance of individual rip-rap fragments coming loose, resulting in portions of the rip rap structure losing its integrity. The rip-rap acts as a single massive structure due to the cementing and has a much greater resistance to impact from flows and or debris.

Grouted rip-rap has been used successfully on several bridge sites in the Idaho Panhandle National Forests.

References

Idaho Geological Survey. 2004. Geologic Map of the Clark Fork Quadrangle, Bonner County, Idaho.

Idaho Geological Survey. 2004. Geologic Map of the Scotchman Peak Quadrangle, Bonner County. Idaho.

Idaho Bureau of Mines and Geology. 1975. Reconnaissance Geology and Geochemistry of the Mt. Pend Oreille Quadrangle and Surrounding Areas.

University of Idaho. 1987. Analysis of the Stability of the East Fork of Lightning Creek, ed. F.J Watts. Available from project file.

Boone, Lalia. 1988. Idaho Places and Names: A Geographical Dictionary. Moscow, ID:, University of Idaho Press. First Edition. (ISBN: 0893011193)

USDA Forest Service. 1981 Lightning Creek Flood Engineering Geology Report, Unpublished report, District Files

Idaho Department of Environmental Quality. 2007. Lower Clark Fork River Subbasin Assessment and TMDL

Idaho Geological Survey. 2006. Earth Science Teachers Field Workshop, Geology and Geologic Hazards at Clark Fork-Pend Oreille Lake Area