Carbon River Access Management Finding of No Significant Impact

Floodplains Statement of Findings

Carbon River Area Access Management
Environmental Assessment
Mount Rainier National Park, Washington
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1. Introduction

This Statement of Findings (SOF) was proposed as part of the Carbon River Area Access Management Environmental Assessment (EA). The Carbon River Road corridor (FIGURE 1) was originally constructed in the early 1920s and has historically been an important cultural resource to the region, providing access to a uniquely wet habitat on Mount Rainier National Park's northwest side. The road corridor has also been classified in the National Register of Historic Places as part of the Mount Rainier National Historic Landmark District (NHLD). Additionally, vast tracts of designated wilderness are accessible from the northwest side of the park along the roadway. The goal of the Carbon River Road Area Access Management plan is to preserve year-round sustainable public access to the northwest corner of the Carbon River Valley. Executive Order 11988 (Floodplain Management) requires the National Park Service (NPS) to evaluate likely impacts of actions in floodplains. NPS Directors Order #77-2 (Floodplain Management) provide policy and procedural guidance for complying with these orders. This SOF documents compliance with these orders.

The Carbon River's headwaters are at the Carbon Glacier, the lowest elevation alpine glacier in the continental United States at approximately 3,500 feet (1,067 meters) above sea level (ASL). The Carbon River then flows north and west to the park boundary at 1,750 feet (533 meters) ASL. The Carbon Glacier begins its downward movement from near the summit of Mount Rainier at Liberty Cap, approximately 14,112 feet (4,301 meters). Along the way, the glacier scrapes and scours the volcanically-formed andesite rock below and adjacent to the glacier. The glacier acts as a giant conveyor belt and carries this rock and debris downstream to the headwaters of the Carbon River, for the river to carry out of the park. The river flows as a braided stream through a wide glacially-formed valley, constantly changing its braids and bars as sediment and water discharge fluctuate. Over time and owing to the river's exceedingly large sediment source, the riverbed is rising, or aggrading, as more sediment is provided to the river than can be conveyed out of the system. The Carbon River has historically aggraded up to 0.559 feet/year (0.170 meters/year) in a period between 1915 and 1971; or raising a total of 31.329 feet (9.549 meters) in 56 years (Beason, 2006). The Carbon River's 52.023 square mile (134.739 square kilometer) drainage basin at the park entrance receives 99.4 inches of rain and is covered with approximately 57.9% forest (TABLE 1).

In November 2006, almost 18 inches of rain fell park-wide and lead to the single longest closure in the park's history (6 months between November 6, 2006-May 5, 2007; The Carbon River Road currently remains closed to public vehicle traffic at the Carbon River Entrance). The Carbon River valley was one of many areas in the park that received significant infrastructure damage. Between November 5, 2006 at 2:00 P.M. and November 7, 2006 at 2:15 P.M., 8.76 inches (22.25 cm) of precipitation was recorded at the USGS stream gauge on the Carbon River near Fairfax, WA (USGS Gauge #12094000). Flood stage of 13.5 feet (4.1 meters) was recorded at the gauge around noon on November 6th and the stream gage reached its highest recorded gauge height of 16.93 feet (5.16 meters) about six hours later. The flood significantly damaged the Carbon River Road, especially near Falls Creek (2,600 linear feet; 792 meters) and just before Ipsut Creek Campground (1,350 linear feet; 411 meters). In these locations, the road was washed away and replaced with a gully approximately 6-10 feet (2-3 meters) deep. Also, one lane of the Carbon River Road was washed away in two locations and both lanes were removed in one location between the Green Lake Trailhead and just before the Ipsut Creek Campground. Low recurrence interval (approximately 15-year) floods since 2006 have caused more damage to both the roadway and park infrastructure, mainly the loss of a structure by bank erosion at the Carbon River maintenance area.

ENTRIX (2008) have shown that there may be an increase in the frequency and intensity of flood events as recorded by United States Geological Survey (USGS) stream gauges near the park. For instance, on the Carbon River at Fairfax, WA, the 100-year flood during the period of record from 1930-1977 now has a recurrence interval closer to 70 years when compared with the entire period of record (1930-2006) (FIGURE 2). Therefore, ENTRIX (2008) states that design conditions are changing and larger, more intense floods should be anticipated. On the Nisqually River, on the park's southwest side, there were no 10-year recurrence interval floods that occurred before 1970. Since then, there have been 6, including two events with recurrence intervals greater than 50 years. The general trend for the Nisqually River and Carbon River is an increase in the size of annual peak flows since the period of record began in 1940 and 1930, respectively. According to research by the University of Washington Climate Impacts Group (UW CIG), it is anticipated that by 2080, average yearly temperatures in the Washington Cascades region will be approximately 5.9°F warmer with an overall increase in precipitation of about 1-5%. Most of the anticipated increases in temperature will be between October and January (Mote, personal communication, 2008). The trend is for dryer summers and wetter winters, which is significant in that the largest and most destructive floods occur in the late fall during the period of record at both the Nisqually and Carbon Rivers.

The Carbon River valley has had a long history of flooding since the establishment of the Carbon River Road. Large floods in 1990, 1996 and 2006 caused major damage to the roadway (the second, third and largest floods on record since 1930, respectively) (FIGURE 3). Following the 1996 flood, Mount Rainier National Park spent approximately $787,000 on a repair to the road. Two medium-size floods five weeks later destroyed the recently-repaired sections of roadway, washing out a 1,200 foot (366 meter) section of roadway to a depth of about 2-3 feet (0.6-1.0 meters). Even low recurrence interval floods have historically caused damage to the roadway and associated park infrastructure near the river (FIGURE 4)[1]. The Mount Rainier General Management Plan (GMP) signed in 2002 stated that the park would no longer maintain the Carbon River Road after the next major washout. The GMP did not define what a "major washout" of the road would be but under the guidance of the GMP, Mount Rainier National Park is not considering repairing and reopening the entire road corridor in its previous condition as part of the current EA.

2. Proposed Actions

The Carbon River Area Access Management EA has five alternatives:

1) **Continue Current Management** (*no action alternative*) – Maintain a primitive trail within the historic road corridor. The Ipsut Campground would be retained with 24 individual and 2 group sites. Public vehicle access would end at the park entrance.
2) **Hike and Bike Trail** (*preferred alternative*) – Construct a formal hike/bike trial to Ipsut Creek trailhead. Retain the Ipsut Creek Campground with a minimum of 15 individual and 3 group sites.

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[1] Chapter 1 section D of the Carbon River Area Access Management EA has a flood damage timeline that shows years and extents of flood damage.

Public vehicle access would end at the Old Mine trailhead, approximately milepost 1.2 on the Carbon River Road.

3) **Public Vehicle Access** – Reconstruct a one-lane road open to public vehicle access to milepost 3.6 (near Chenuis Picnic Area). Construct a formal hike/bike trail from there to the Ipsut Creek Trailhead. Retain Ipsut Creek Campground with 15 individual and 3 group sites.
4) **Shuttle Access** – Reconstruct a one-lane road to milepost 4.4 for shuttles only. Construct a formal hike/bike trail from there to Ipsut Creek Trailhead. Retain the Ipsut Creek Campground with 20 individual and 3 group sites. Public vehicle access would end at the Old Mine trailhead, approximately milepost 1.2.
5) **Wilderness Reroute Trail** – Construct a hiking-only trail in the wilderness area from the Entrance along the south valley wall to the Ipsut Creek Trailhead. Close Ipsut Creek Campground and create a new backcountry camp elsewhere. Public vehicle access would end at the park entrance.

Alternative 2, the preferred alternative, involves the following measures:

- Visitor parking would be available at the Carbon River entrance and former Carbon River maintenance area for approximately 68 cars.
- The historic Carbon River Road would be retained between the entrance to the former Old Mine trailhead, approximately 1.2 miles (1.9 kilometers). Public vehicles would be allowed to travel on this portion of the road.
- The Old Mine trailhead would become a vehicle turnaround area.
- Constructing or maintaining a 10-foot wide trail in the former road prism that can accommodate disabled visitor access, hiking, biking and occasional all-terrain vehicle (ATV) access in emergencies or for maintenance. When flood damage occurs to the roadway, a reroute trail would be constructed around the washout.
- **Carbon River Entrance:** Existing buildings except vault toilets at the Carbon River entrance would be removed and the footprints from these areas would be reconfigured and replaced with formal parking and picnicking. A one-room visitor contact station would be constructed on the south side of the road at the entrance. The Carbon River entrance arch would be reconstructed.
- **Carbon River Maintenance Area:** All buildings and structures (except the weather station and radio tower/shed) at the Carbon River maintenance area would be removed and replaced with formal parking and picnicking.
- **Ipsut Creek Campground:** Both vault toilets at the Ipsut Creek Campground would be removed and replaced with backcountry (composting) toilets. All asphalt bumper-stops, buildings, some picnic tables and campsites and most signs would be removed. The former Chlorinator building and amphitheater storage shed would be removed. The campground would retain a minimum of 15 individual and 3 group sites. Bear proof storage lockers would be added. The former Ipsut Creek patrol cabin would be reconstructed at the Ipsut Campground in one of the two former parking areas at the campground (exact location to be determined).
- **Erosion protection measures:**
    - Four engineered log jams would be constructed between the Carbon River Entrance and Maintenance Area. These structures would consist of:

        - Stabilization/augmentation of a large natural log jam with two log reinforcing structures (LRS) upstream and downstream of a natural log jam near the Entrance;
        - One new LRS in the Maintenance Area;
        - One LRS downstream of a natural log jam located upstream of the Maintenance Area;
        - One new ELJ upstream of the natural log jam (Maintenance Area); and
        - Immediately construct two temporary barbs in the Maintenance Area - to later be converted into log jam and LRS ballast when constructed.
    - As many as 24 rock-cored, log-cored, or gravel covered log road humps would be constructed to divert sheet flow on the roadway off and back to the river.
    - Toe-roughened gabion or toe-roughened log crib walls will be constructed at milepost 3.463, 3.939 and 4.484, in areas that the river as significantly eroded the bank and road prism down to one or both lanes. These structures will be approximately 200-400 feet (61-122 meters) in length.
    - Additional log crib walls would be constructed at milepost 4.658 and milepost 4.802. These structures are much smaller (approximately 50 feet in length; 15 meters) and designed to protect rapidly bank-eroding areas that are not already exposed.
    - A “launchable” groin would be constructed at milepost 4.621, at the end of the remaining road just before Ipsut Creek Campground. This structure looks similar to a complex crib wall but is buried into the extant bank with the anticipation that floods will cause bank erosion up to the structure, exposing it rather than constructing it in the already-exposed riverbed.
    - In the Falls Creek area, spanning trees whose root wads are on the left (south) bank of the river will be cut, notched and pulled into the new Carbon River side channel/former road prism. The root wad would remain on the left bank. Large woody debris would be chocked on the left side of the channel behind the structure to encourage aggradation and bank protection of the left bank.
- **Grade control weirs:** Where large culverts are going to be removed (e.g., at Ranger Creek and an unnamed tributary at the Chenuis Falls trailhead), a series of 3 log grade control structures will be constructed to prevent the release of stored sediment behind the culvert.
- Several culverts will be removed and replaced with trail bridges.

Under the preferred alternative, the management actions that could negatively affect the Carbon River floodplain are as follows:

1. Erosion protection measures: Under alternative 2, new erosion protection measures would be installed in a total of 11 sites along the river channel. This number jumps up to 35 sites including road humps which would be built on and along the roadway to divert sheet flow across the roadway back into the river channel. The sites have been previously described but include a variety of technologies: ELJs, gabion baskets, crib walls, road humps and spanning trees. Impacts to the floodplain are major and include prevention of bank erosion within the river’s channel migration zone. Many of the erosion protection measures are long term in design: ELJs are designed to be self-mitigating and self-sustaining, which means the structure is designed to stay as part of the landscape for the long-term. These would be the first major structures built in the Carbon River reach within the park boundary in the attempt to prevent short- and long-term infrastructure damage.

Bank erosion is a natural process in this and other major braided rivers at the park and is only a noted issue in this area due to the presence of the road and infrastructure near actively bank-eroding rivers. In non-developed areas, a balance is generally developed between large trees that fall into the river channel and temporarily prevent the further bank erosion. However, given that the entire valley bottom has little relief, over centuries, the channel migration zone *is* the valley bottom between the steep valley walls on either side of the active channel.

2. Farming of rock and cobble in the river for erosion protection structures: Many structures require not only large numbers of logs for their construction, but also ballast material in the form of gravels and cobbles from the riverbed. In order to avoid trucking in thousands of cubic yards of material, much of this material will be removed from the riverbed by heavy equipment. This is a significant impact that will not only disrupt the natural process of sediment deposition and transport, but could also negatively affect threatened and endangered species that live in the river and adjacent riparian areas. Some of the structures are so robust that they will require significant amounts of farmed material from the riverbed. It may not be feasible to collect the adequate amount of material for all of these structures while remaining outside of the bankful high water mark.

3. Prevention of channel avulsion: This is primarily a major concern in the Falls Creek area. The river in this reach is up to 16 feet higher than the road and within 50-100 feet of the road itself. During the 2006 flood (as well as prior floods), a significant percentage of the Carbon River main stem flowed south and ran over the roadway. The upshot is that approximately 2,600 feet of roadway was eroded away. Looking at the area geomorphically, the former road prism is essentially a high-flow flood channel and has a significant chance to catch a major main stem Carbon River avulsion here.

This issue is shown in sharp focus when using a method of map analysis called “Height Above Water Surface” (HAWS). HAWS is an analysis that uses survey data from 2008 (Light Detection and Ranging, LiDAR) and sets the cross section datum at the river elevation. The rest of the cross section is subtracted from the river elevation. This displays a map that shows the relative elevation along the cross section above and below the water surface. FIGURE 5 shows the HAWS map for the Falls Creek reach of the Carbon River. On the upstream end of the Falls Creek area, the Carbon River main stem is within 1-2 feet of overtopping the overbank area between the active channel boundary and the post-2006 channel. The floodplain mapping that is described later shows a significant portion of the Carbon River flowing into this channel at as low as a 2-year recurrence interval flood (FIGURE 6). The active channel here is relatively perched above the surrounding overbank area to the south; the Carbon River Road happens to be in this overbank area. When the Carbon River flows into this side channel/former road prism, there is a chance the river could establish this as the new main stem; and thus, an avulsion could and likely will occur. Any protection measures that prevent this from happening encourage the river to build up higher than the land surrounding it.

4. Levee effects: The Carbon River is a naturally sediment-rich system, evidenced by its braided form and channel development. Many of the erosion protection measures attempt to prevent the river from flowing into overbank floodplain areas adjacent to the active channel. This may keep the river in the active channel in the short term but presents a problem when sediment is deposited into the active channel and not the overbank areas. Over time, unvegetated active channel may build up higher than the land around it at a faster rate than has been seen historically as the river is confined in its active channel. This increases the risk of a catastrophic channel avulsion into the floodplain.

Several actions in the plan would enhance floodplain values and mitigate some of the impacts of retaining the road in the floodplain. These include focusing NPS facilities and contact areas at the entrance and at boundary expansion lands rather than along and within the floodplain (geomorphically active) and removal of infrastructure in the floodplain which would contribute to an overall more natural floodplain. Specific actions include:

1. Removal of the NPS maintenance facilities and most facilities at the park entrance: Alternative 2 calls for the removal of most facilities at both the former maintenance area and park entrance, with limited replacement of some facilities at the park entrance. As evidenced during a flood in 2008, the highly erodible bank and a small to moderate size flood led to bank erosion and collapse of a building in the maintenance area. The park entrance and maintenance area are both above the regulatory 100 and 500 year floodplain but not out of the potential channel migration zone of the Carbon River in its valley. Highly erodible banks and possible extreme floods can lead to rapid bank erosion that places structures built near the river to be undercut and fail. Any removal of infrastructure from within the valley bottom within the potential channel migration zone of the Carbon River is a positive impact to the overall floodplain.

2. Removal of vault toilets and formal car camping facilities at Ipsut Creek Campground: Despite the fact that the Ipsut Creek Campground is not within the regulatory 100 and 500 year floodplain, the campground itself is only situated less than 10 feet (3 meters) above the 100-year high water mark. This places the facility within the potential channel migration zone of the Carbon River within the valley floor. Additionally, due to a severe avulsion risk upstream of the campground, there is a possibility that at least some percentage of the main stem Carbon River could flow into a newly-formed channel along the west valley wall, which joins with Ipsut Creek. This, in essence, creates a possible “island” scenario for the Ipsut Creek Campground, where, at high flow, the campground could potentially be surrounded on all sides by significant flood flows (see FIGURE 6).

The preferred alternative calls for the removal of facilities that would support public car camping at Ipsut Campground. This would enhance floodplain values as it removes a potential source of pollutants from automobiles as well as making the continual formal maintenance of the Carbon River Road not necessary within the park boundary. This allows the river to reclaim portions of its floodplains that have been cut off over time and as human infrastructure has impinged on the floodplain. Removal of permanent structures, especially vault toilets that contain hazardous human waste, allows the floodplain to return to a more rustic and natural setting and would allow the river to reclaim these areas as channel migration and avulsion occurs. The vault toilets would be replaced composting toilets, similar to toilets in other remote areas of the park. These changes are overall a positive change for the floodplain environment.

3. Removal of 3.8 miles (6.1 kilometers) of roadway within the floodplain: Alternative two of the EA calls for the decommissioning of the roadway from milepost 1.2 until the end of the roadway at the Ipsut Creek Campground, approximately at milepost 4.992; therefore decommissioning approximately 3.792 miles (6.103 kilometers) of former roadway within the river bottom. In its place would remain a 6- to 10-foot (2- to 3-meter) hike and bike path. Where the river has bank eroded the roadway and left a new riverbed, a reroute trail would be constructed around the washout. The removal of the roadway would be a positive impact overall to floodplain values as it decreases the risk of air and water pollution in the vicinity of the roadway from both park visitor and administrative traffic. It also allows the river to naturally move about its floodplain and channel migration zone without confining it in a set channel over time. Rerouting the hike and bike trail around future washouts is a slightly negative overall effect on the floodplain as it potentially would mean removal of large trees in the riparian areas. However, the net effect of allowing hiking or biking on the remnant and newly-constructed portions of the trail would be a much better change for the floodplain environment over the potential of allowing vehicle access to the Carbon River Road.

4. Removal of undersized culverts and stabilizing stored mobile sediment upstream of culverts: The preferred alternative calls for the removal of two large, undersized culverts at both Ranger Creek and an unnamed tributary in the vicinity of the Chenuis Falls trailhead. The unnamed tributary additionally has a hanging culvert of approximately 6 feet (2 meters) above the Carbon River main stem, which effectively cuts off fish passage for the tributary. The plan is to remove these two culverts and install a series of up to three grade control structures to stabilize sediment that has accumulated in the backwater area upstream of the culvert since its installation. The grade control structures would allow small drops over logs and other structures, which would support the highly-mobile stored sediment load and prevent headcutting in the tributaries. The overall effect of this is that it would prevent a sudden surge of mobile sediment into the Carbon River, which is a positive effect overall.

Additionally, there are plans to remove many undersized and/or clogged culverts along the entire reach and replace them with larger, bottomless culverts or trail bridges. Any culvert that is removed and replaced with a bottomless culvert or bridge is a positive change for the floodplain as it allows sediment load passing through the culvert in a more efficient manner than has previously been allowed with the culvert. It also allows for much better fish passage, especially in areas with noted threatened and endangered species.

3. Site Description

The project area along the Carbon River Road includes approximately 5 miles of active river channel and associated riparian habitat, from the river corridor adjacent to and just upstream of Ipsut Creek Campground downstream to the park boundary (FIGURE 1). The Carbon River valley has designated wilderness beginning 100 feet south of the road centerline until near the Green Lake trailhead, then 100 feet on both sides of the road until the Ipsut Creek Campground. The overall Carbon River watershed at the park boundary is 52.023 square miles (134.738 square kilometers), of which, 74.7% or 38.871 square miles (100.676 square kilometers) is within the park boundary. The remaining 13.152 square miles (34.062 square kilometers is within the Mount Baker-Snoqualmie National Forest, just north of Mount Rainier.

3.1. Change in flood frequency and magnitude on the Carbon River

The Carbon River in Mount Rainier National Park is flood-prone because of the shape of its watershed, steep slopes within the watershed, its glacial source which can be prone to glacial outburst floods, and the location of the drainage basin with relation to the Pacific Ocean. Mount Rainier is a large obstruction to the eastward movement of moisture. As the moisture is forced to rise up against the mountain, it cools, condenses and forms clouds. As it continues to rise, the moisture is squeezed out of the clouds in the form of rain or snow.

The Carbon River is also flood-prone because it can flood at least two times each year. Heavy, warm November and December rainfall trigger rapid snowmelt and flooding within the reach and within the park as a whole. The entire watershed receives most of its precipitation in the winter as snow, and warm spring temperatures and rain can trigger rapid snowmelt and flooding. Unlike fall flood peaks, which typically pass within a few days, spring floods are smaller, but last for several weeks between May and June.

In 2008, ENTRIX Environmental Consultants produced a hydraulic study on the Carbon River that showed there may be an increase in the frequency and intensity of flood events as recorded by United States Geological Survey (USGS) stream gauges near the park. On the Carbon River at Fairfax, WA, the 100-year flood during the period of record from 1930-1977 now has a recurrence interval closer to 70 years when compared with the entire period of record (1930-2006) (FIGURE 2). Therefore, ENTRIX (2008) states that design conditions are changing and larger, more intense floods should be anticipated. On the Nisqually River, on the park's southwest side, there were no 10-year recurrence interval floods that occurred before 1970. Since then, there have been 6, including two events with recurrence intervals greater than 50 years; this trend is also noted on the Carbon River and, to a lesser extent, the Puyallup and White Rivers. There is also a regional trend that is similar in nature to what has been observed in Mount Rainier's rivers. The general trend for the Nisqually River and Carbon River is an increase in the size of annual peak flows since the period of record began in 1940 and 1930, respectively. According to research by the University of Washington Climate Impacts Group (UW CIG), it is anticipated that by 2080, average yearly temperatures in the Washington Cascades region will be approximately 5.9°F warmer with an overall increase in precipitation of about 1-5%. Most of the anticipated increases in temperature will be between October and January (Mote, personal communication, 2008). The trend is for dryer summers and wetter winters, which is significant in that the largest and most destructive floods occur in the late fall during the period of record at both the Nisqually and Carbon Rivers.

In the past 20 years, the Carbon River has had the three largest floods on record (TABLE 2). The November 2006 flood event (14,500 cfs at Fairfax, WA) was believed to have a 100-year recurrence interval, a trend that matches streams park-wide from that flood. The 1996 and 1990 floods had recurrence intervals near 35 and 50 years, respectively. Not only do the largest floods cause damage. As shown in FIGURE 4, many smaller events with recurrence intervals near 1.5 to 2 years have historically caused damage to the road corridor. As larger events potentially become more common, the anticipated damage to park infrastructure in the river bed is greater risk.

Small, steep, straight tributaries to the Carbon River, especially those north of the park boundary from logged and clear-cut areas, can carry debris flows during large precipitation events. Debris flows can occur many times during the year along the entire stretch of the river, especially during periods of hot weather where stored water can surge out the glacier (glacial outburst floods). Additionally, as climate change leads to increased glacial recession, steep-walled lateral moraines are prone to failure as the ice buttressing effect of the glacier is diminished. These walls of loose, unconsolidated glacial till can fail at anytime and provide significant sources of sediment to the river.

3.2. Carbon River Valley floodplain and landforms

The Carbon River floodplain is located along the floor of the Carbon Valley in a deep glacially-formed canyon, with peaks rising more than 3,000 feet (914 meters) above the river. The valley floor contains a wide variety of sediment sizes from sand and silt to large cobbles and erratics, debris flow deposits from small, steep tributaries, alluvial fans from larger tributaries and the Carbon River and its floodplain. The terraces are composed of gravel, cobbles and boulders and are crossed by numerous old flood channels. Debris flow deposits and alluvial fans have slopes steeper than 10-15% and are covered with boulders, levees and deeply incised channels at junctions with the Carbon River floodplain.

Chenuis and Cayada Creeks have deposited large alluvial fans on the Carbon Valley floor. This is especially true for Cayada Creek, which has provided a significant amount of sediment to the valley floor. The Carbon River main stem has moved south from the valley floor at the confluence of Cayada Creek, likely due to these debris deposits. Other major tributaries like Ipsut Creek, Ranger Creek and Falls Creek likely deposit large amounts of sediment as they reach the valley wall, but the active channel of the Carbon River is away from the alluvial fans that developed from the change in slope as the tributaries reached the valley bottom.

Areas of sediment storage in the lower valley are marked by channel instability and wide floodplains. Sediment transport is a major feature of the Carbon River as it flows from its glacial source downstream to the park boundary. Significant channel alteration can occur as sediment waves move through the system, locally aggrading and/or incising large areas of the valley bottom. Large falling trees can also see large-scale aggradation immediately upstream of the falling tree. Not only do large trees contribute to aggradation, but they also are a significant “sediment source” in of themselves. Wood is a natural part of the floodplain and there are large accumulations of woody debris throughout the whole reach.

4. Justification for Use on the Floodplain

Most of the proposed actions under this alternative would seek to remove, modify or build infrastructure within the Carbon River floodplain and channel migration zone. Most of the road would be either converted to a hike or bike trail or would be decommissioned. Erosion protection measures and road humps would be built on and in the vicinity of the main stem in order to prevent further erosion of trail segments and areas of human infrastructure.

The Carbon River Road was constructed in the 1920s as a way for park visitors to have access to the relatively remote areas in the northwest corner of Mount Rainier National Park. As such, the road was constructed in the valley bottom rather than along the steep valley wall due to difficulties in building on the steep wall compared with the relatively flat areas near the rivers. Over time, the roadway itself became part of the historical character of the park, eventually being integrated into the Mount Rainier National Historic Landmark District. Repeated repairs to the roadway have attempted to retain this historical character of the roadway, despite the relatively unsustainable nature of portions of the roadway where the river threatens it.

As rivers aggrade and move around in the Carbon River valley, the potential for more roadway damage over time increases, especially if the river is confined in one place for a long time. Moving the roadway out of the floodplain and/or from river conflicts would require a major act of congress to redesignate wilderness areas in the park, blasting and/or heavy excavation work across cliffs and unstable slopes, require the removal of hundreds of large old growth trees, provide extreme disturbance to threatened and endangered species, and/or cause major impacts to undisturbed wetlands.

There are recreation sites near the floodplain. Ipsut Creek Campground was one of two year-round campgrounds in Mount Rainier National Park and is located in the channel migration zone, approximately 10 feet higher than the 100-year floodplain inundation level (both of the year-round campgrounds were destroyed in the same 2006 flood). The site is low relative to the river and has the possibility of becoming an “island” during large floods, surrounded on all sides by surging flood flows. NPS plans to remove vault toilets and replace them with composting or pit toilets in the campground, but the camp sites remains in a potential channel migration zone. Flooding at the site occurs over a period of days or hours; flood conditions are summarized in TABLE 3.

5. Description of Site-Specific Flood Risk

5.1. Recurrence Interval of Flooding

Information on flood recurrence interval comes from USGS stream gauging data collected since the 1930s on the Carbon River near Fairfax, WA (USGS stream gauge #12094000) and a HEC-RAS model built for this study that incorporates interpolated peak flows using regional regression equations. The flows used for the study reach are based on USGS StreamStats software (USGS StreamStats, 2010). StreamStats uses regional regression equations, drainage basin size, precipitation and other statistical data to estimate 2, 10, 25, 50, 100 and 500 year flood flows. An analysis of the USGS StreamStats peak flows with observed flood recurrence intervals at USGS gauging stations near the park found that the StreamStats regional regression equations under estimated peak flows for smaller drainage basins in the park. Because of this finding, the modeled flows were increased by between 18-30% from the StreamStats flows, as defined by a statistical relationship to the flows. Given work by ENTRIX (2008) and others which is showing changing design conditions for the entire region, using slightly higher flows will adequately address future design conditions as climate warms and precipitation patterns change region-wide. The modeled flood flows are shown in TABLE 3 and the model results are shown in TABLE 4.

The “100 year flood,” or, 1% chance of exceedance in a given year, in the reach varies between 6,560 to 13,444 cubic feet per second (cfs), depending on location in the reach (i.e., As the river flows downstream, it accumulates water from hill slope runoff and major tributaries; thus, flows upstream will be lower than flows downstream). The 500-year flood, or 0.2% chance of exceedance in a year, varies between 8,683 to 17,776 cfs.

5.2. Hydraulics of Flooding at the site (depths, velocities)

Information on flood flows and floodplain risk comes from studies done by ENTRIX (2008) and a 1-D HEC-RAS floodplain model constructed by the NPS. The regulatory 100- and 500-year floodplains (1% and 0.2% exceedance probability) were delineated using ArcGIS 9.3.1, HEC-GeoRAS 4.2.93 and HEC-RAS 4.1.0 as well as 1-meter LiDAR (Light Detection and Ranging) elevation survey of the Carbon River Valley as determined by aerial surveys in September, 2008. HEC-RAS is a one-dimensional steady-state open-channel-flow hydraulic modeling program which is used to route water through a drainage basin to determine a variety of flow characteristics. These include, but are not limited to: discharge, water surface elevations, flow area, channel velocities, shear stresses, and others.

Using the 2008 LiDAR for the Carbon River valley, a series of river cross sections were digitized across the valley bottom. For this study, 228 cross sections were digitized from just south (upstream) of Ipsut Creek Campground to just west (downstream) of the Carbon River Entrance at the park. The stream center line was delineated by the LiDAR flow accumulation layer and river banks were delineated by analysis of the LiDAR hillshade and LiDAR Canopy Height layer. The stretch of drainage basin varies considerably between the most upstream and downstream locations. For instance, the upstream drainage basin size is 20.742 square miles (53.722 square kilometers), whereas the drainage basin size at the park boundary is 52.023 square miles (134.738 square kilometers). The difference between the two drainage basins is result of large tributaries which empty into the mainstream Carbon River. These tributaries include Ipsut Creek, Chenuis Creek, Ranger Creek, Cayada Creek and Falls Creek. The stream network used in HEC-RAS for this project takes into account the accumulation of progressively larger flows downstream as result of these tributaries adding flow to the main stem Carbon River.

With the exception of the Falls Creek area, the majority of the NPS road and visitor facilities lay outside of the regulatory 100 and 500 year floodplains (FIGURE 6). However, a portion of the roadway between the park entrance and maintenance area as well as a large portion of the roadway from the Chenuis Falls trailhead to Ipsut Creek Campground has the main stem river flowing within 10-50 feet of the roadway. This is a risk as large rates of bank erosion can occur with moderate to large floods.

The Falls Creek area is a 2,600 foot (792 meter) stretch of roadway near milepost 9.75 that has had a significant history of flood damage. As mentioned previously, in 1996, this stretch was damaged by flood flows before and 5 weeks after repairs were completed. In 2006, a major portion of the roadway was effectively eroded and became a new side channel of the Carbon River. As the 2008 LiDAR topography shows now, the roadway is up to 16 feet below the adjacent main stem Carbon River (FIGURE 5). HEC-RAS flood-inundation modeling completed for this study show that even a 2-year recurrence interval flood would cause a significant portion of the main stem Carbon River to pour into this new channel. The side channel/former roadway here is much narrower, only approximately 20-30 feet wide compared to the 100-200 foot-wide main-stem. Therefore, any flows that would fall into the side channel would likely experience higher velocities and associated shear stresses.

TABLE 6 shows the general depths and associated velocities for the regulatory 100 and 500 year floods on the Carbon River from upstream of Ipsut Creek Campground downstream to the Carbon River Entrance. In general, the higher velocities are at the upper extent of the reach, as expected with steeper slopes. The deepest flows are in the new Carbon River/Ipsut Creek side channel to the west of the Ipsut Creek Campground.

5.3. Time Required for Flooding to Occur (Amount of Warning Time Possible)

The amount of time required for warning of possible flooding in the Carbon River floodplain ranges from a few hours to a few days, depending on the nature of the flood hazard. The largest floods have historically occurred within days of large, heavy rain events and the Carbon River can rise quickly. The flood crest generally passes quickly and most peaks occur between 6 pm and midnight. The National Weather Service has developed an “Advanced Hydrologic Prediction Service” (AHPS) system that predicts anticipated river peaks based on forecasts, snow packs, temperatures and other weather data. While the AHPS system does not have a station within the Carbon River valley in Mount Rainier, the downstream station at Fairfax, WA[2] can be interpolated for the upstream reach. This data can be accessed by anyone with a web browser on the internet.

Other natural phenomena also provide serious risks to visitors, staff and infrastructure in the Carbon River valley. These include glacial outburst floods, debris flows, lahars, volcanic eruptions, and volcanic edifice failure. A park-wide hazard analysis was undertaken as part of the GMP planning effort in 1996. Field analysis by Jon Riedel (NPS, 1997) determined the debris flow hazard in the Carbon River area to be a "Case III," with small debris flows affecting the area on the order of one every 100 years or less. Riedel also determined the rate of aggradation on the Carbon River to be approximately six inches per year. Riedel recommended the closure of the walk-in sites at the Ipsut Creek Campground and the removal of housing at the Carbon River Entrance. These sites have since been closed or made into a day-use facility. Riedel also determined that the majority of the Ipsut Creek Campground was outside of the regulatory 100- and 500-year floodplains but their proximity to the floodplain and relatively low elevation in relation to the main stem Carbon River was a high hazard.

Mount Rainier has had a history of producing lahars, or volcanic mudflows, whose spatial extent is extensive. Lahars are the most far reaching hazard from the volcano, and have travelled as far as the Enumclaw plain, with some events reaching the Puget Sound (Scott and Vallance, 1995). According to research by Sisson, Vallance and Pringle (2001), the northwest corner of the volcano, with its numerous dikes and vents, provides an abundance of hydrothermal alteration of volcanic andesite, which leads to the development of a clay-like material, prone to failure. Edifice failure, both due to and independent of volcanic eruption is a risk to low-lying areas near and far from the volcano.

6. Opportunity for Evacuation of the Site in the Event of Flooding

Evacuations for the Carbon River floodplain would involve the public, NPS personnel, and possibly outside agencies. Since vehicular access with the preferred alternative is limited to only the first 1.2 miles of the former road, in the event of a flooding event, the public traveling in motor vehicles would be evacuated west on the Carbon River Road until the intersection of State Route 165. The public would then travel northwest to the areas downstream of Carbonado, WA. For foot and bike traffic between the entrance to the Ipsut Creek Campground, a more complicated evacuation route would be necessary and would be dependent on the location of visitors in relation to trailheads and evacuation routes. In most cases, floods can be adequately predicted ahead of time and the public can be summarily notified of the anticipated flood risks. Floodplain and volcano evacuation routes are being developed in accordance with the EA to prevent injury or death to park visitors. Dependant on the location of the visitor, the following routes are being proposed:

- *Travel near the park entrance and former maintenance facilities:* The proposed evacuation route involves traveling south on the Rainforest Loop Trail until the intersection of the Boundary Trail. The evacuation route would continue on the Boundary Trail until a posted assembly area, approximately 200 feet above the elevation of the valley bottom.

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[2] National Weather Service Advanced Hydrologic Prediction Service forecast for the Carbon River at Fairfax, WA can be found at: http://water.weather.gov/ahps2/hydrograph.php?wfo=sew&gage=ffxw1&view=1,1,1,1,1,1,1,1

- *Travel near the Old Mine trailhead:* The posted evacuation route involves traveling south on the non-maintained Old Mine trail until the end of the trail and a posted assembly area, approximately 200 feet above the elevation of the valley bottom.
- *Travel near the Green Lake trailhead:* The posted evacuation route involves traveling southwest on the Green Lake trail until a posted assembly area, approximately 200 feet above the elevation of the valley bottom.
- *Travel near the Chenuis Falls trailhead:* The evacuation route here is dependent on the location of the visitor in relation to the active channel. For visitors on the west side of the active channel, a proposed sign would notify visitors to not cross the log bridge spanning the Carbon River and instead travel to the Green Lake trailhead. The sign would then notify visitors to follow the posted instructions at the Green Lake trailhead to safely evacuate. For visitors on the east side of the active channel, a sign would notify visitors to proceed east on the Chenuis Falls trail until a posted assembly area, approximately 200 feet above the valley bottom.
- *Travel near the Ipsut Creek Campground:* The Ipsut Creek Campground is one of the more unsafe locations for park visitors during flood events due to the “island” effect of the combined Carbon-Ipsut Creek on the west side of the campground and the main stem Carbon River on the east side of the campground. In essence, during a large flood, the entire campground is an island surrounded on all sides by water. However, a potential posted evacuation route would involve traveling south on the Wonderland trail spur from the Ipsut Creek trailhead to the junction of the Wonderland Trail. The evacuation route would continue west on the Wonderland Trail until a posted assembly area adjacent to Ipsut Creek, approximately 200 feet above the elevation of the valley bottom.

Additionally, it should be noted that most of the large floods that occur in the Carbon River valley occur between September to May, during a time when park visitation is significantly lowered. This does not imply that the area is vacant of visitors but only that the higher crowds appear during the warmer, dryer summer months where flooding is relatively uncommon. With lower numbers of park visitors during the potential months for flooding, notification of flood hazards to the visiting public may be easier to accomplish with the limited fall and winter staff.

7. Geomorphic Considerations (Erosion, Sediment Deposition, Channel Adjustments)

The Carbon River is remarkable for the dramatic changes it undergoes in the wide alluvial valley. Throughout the entire reach from Ipsut Creek Campground to the Park Entrance, the river transports a significant amount of sediment, including silt/sand, gravels, cobbles, boulders and occasional erratics. The river also moves large woody debris, frequently creating large jams of debris. Floods dramatically change the shape and braiding pattern of the river as well as the location of the main stem of the river within the active unvegetated channel.

Gradient in the active channel of the reach varies between approximately 1.3 to 3.5% in the reach, from downstream to upstream, respectively. Tributary channels are much steeper, exceeding 10 to 15% in some places. Many tributaries are relatively straight, steep reaches and are transport zones for sediment and large wood. Some tributaries, especially those on the downstream side of the reach, are from areas of clear-cut logging on U.S. Forest Service property, part of the Mount Baker-Snoqualmie National Forest.

While it is a study need, it is anticipated that these areas are significant sediment sources, especially after they have been cleared.

The Carbon River also has a significant history of bank erosion, especially witnessed along the Carbon River Road. It is not uncommon for bank erosion rates in some areas along the road to exceed tens of feet per year. Almost all of the bank erosion occurs during floods, with some erosion occurring as lower flows travel along the newly formed and highly mobile banks. Locally, bank erosion can lead to channel incision and channel widening, but the overall trend, even with bank erosion, is net channel aggradation.

Exact rates of bed and suspended sediment transport are unknown for the reach, owning to the extreme difficulty in calculating bed load transport in cobble-bedded rivers as well as difficulties in adjusting sediment transport equations to the braided river environment at Mount Rainier. Because of the volcano and the erosion of the volcano by various forces of ice, wind and water, the rivers at Mount Rainier are constantly provided with an excess of sediment. Over time, the bed is highly mobile and frequent major channel changes occur. Year-to-year aerial photos prove that the Carbon River (among others in the park) is constantly in flux and adapting to the changing sediment loads.

8. Description and Explanation of Flood Mitigation Plans

This plan includes only a few limited measures to reduce hazards to human life and property. All action alternatives propose placing at least some infrastructure within regulatory floodplains in many areas, including the construction of bank protection or erosion protection structures, road humps, trail reconstruction and others in areas where floods inundate at 100- and 500-year events. Removal of the road from the Old Mine trailhead to Ipsut Creek Campground, however, will be a net benefit to the floodplain as it provides for visitor and NPS safety in the event of a flood, as well as decreasing a possible non-point-source pollutant. NPS proposes to mitigate these hazards by placing interpretive and warning signs at selected pullouts. These signs will inform people about the nature of the hazards and what precautions to take during periods of heavy rainfall. These precautions would include signed evacuation routes for visitor and park staff.

These proposed signs will be located along the road and trails and will have a negligible impact to the natural resources of the floodplain (and associated wilderness). Parts of the road, camps, and trails will remain within the floodplain, however. Roads, trails, and campgrounds that remain in the floodplain will be subject to periodic flooding.

9. Summary

This statement of findings accompanies an Environmental Assessment (EA) for the Carbon River floodplain for actions designed in the Carbon River Area Access Management plan.

Recent major floods and the resulting landscape changes on the upper Carbon River have intensified flood and erosion threats to National Park Service facilities and natural resources within Mount Rainier National Park. The three largest floods on the Carbon River have occurred in the last 20 years; the last of which in 2006 has significantly altered the historic use of the Carbon River Road corridor. The NPS has spent hundreds of thousands of dollars to protect access to the 5 miles of the Carbon River Road and one of two year-round public car-camping locations in the park (the other of which was also destroyed in the 2006 flood). The roadway was constructed in the valley bottom in the 1920s, providing a relatively easy construction compared to constructing a roadway along a steep valley wall. While this construction was easier, it did not address the problems of flooding, channel migration and channel avulsion. Now, recognizing the changing design conditions of flood frequency and magnitude, combined with the issues of excess sediment accumulation in the river (aggradation), the NPS will use a more conservative approach of the channel migration zone to direct planning actions in the Carbon River valley.

The proposed action in the preferred alternative, Alternative 2, will reduce flood risk by removing NPS facilities and most of the Carbon River Road from the floodplain. The primary negative impacts to the floodplain in this alternative are impacts from installing new bank erosion measures thereby limiting the channel migration and floodplain utilization of the Carbon River. Other negative impacts include reconstructing trails in the floodplain, prevention of channel avulsion, and the prevention of floodplain sedimentation that could lead to a "levee" situation that could lead to catastrophic flooding and channel movement. New recreational opportunities proposed would also be within the channel migration zone.

Impacts to floodplain values are offset by several proposed management actions. These include: (1) removal of the NPS maintenance facilities and most facilities at the park entrance; (2) removal of vault toilets and formal car camping facilities at Ipsut Creek Campground; (3) decommissioning of 3.8 miles (6.1 kilometers) of the roadway within the floodplain; and (4) removal of undersized culverts and stabilization of stored mobile sediment upstream of the culverts.

10. Conclusion

Floodplain values are moderately to severely impacted by several actions of the preferred alternative in the proposed in the Carbon River Area Access Management Environmental Assessment, including placement of new erosion control structures, farming of rock and cobble in the active channel of the Carbon River for use in erosion protection structures, prevention of channel avulsion, and the prevention of channel overbank sedimentation that would lead to an increased threat of catastrophic flooding. For facilities that remain in floodplain, and with the exception of bank erosion, flood hazards are relatively minor (depth less than about 3.4 feet, velocity less than 4.3 ft/sec) and advance warning of hours to days is likely.

These impacts are mitigated, to some extent, by several actions that enhance floodplain values. These include removal of NPS maintenance facilities and most facilities at the park entrance, removal of vault toilets and formal car camping facilities at Ipsut Creek Campground, decommissioning of 3.8 miles (6.1 kilometers) of roadway within the floodplain and removal of undersized culverts and stabilization of stored mobile sediment upstream of the culverts.

11. References

Beason, S.R., 2006. The environmental implications of aggradation in major braided rivers at Mount Rainier National Park, Washington. M.S. thesis, University of Northern Iowa, Cedar Falls, IA. 165 p.

ENTRIX, 2008. Topographic survey, hydraulic modeling and design assessment of the proposed Carbon River Road flood damage reduction measures: Final technical memorandum. ENTRIX Environmental Consultants, Seattle, WA.

National Park Service, 1998. Director's Order #77-2. Floodplain procedural manual. Washington D.C.

Riedel, J.L., 1997. Geologic hazards and floodplain management, Mount Rainier General Management Plan: Unpublished internal document, National Park Service, 61 p.

Scott, K.M. and J.W. Vallance, 1995, History of landslides and debris flows at Mount Rainier: United States Geological Survey Open File Report 93-111, 2 p.

Sisson, T.W., J.W. Vallance, and P.T. Pringle, 2001, Progress made in understanding Mount Rainier's hazards: EOS, Transactions of the American Geophysical Union, p. 113-120.

United States Geological Survey (USGS) Stream Stats, 2010. Washington StreamStats basin characteristics report [Online]. Fetched June 22, 2010 from http://streamstats.usgs.gov. Last modified 03/14/2007.

FIGURE 1: Overview map of the Carbon River watershed at the park entrance and the analysis area covered by this SOF.

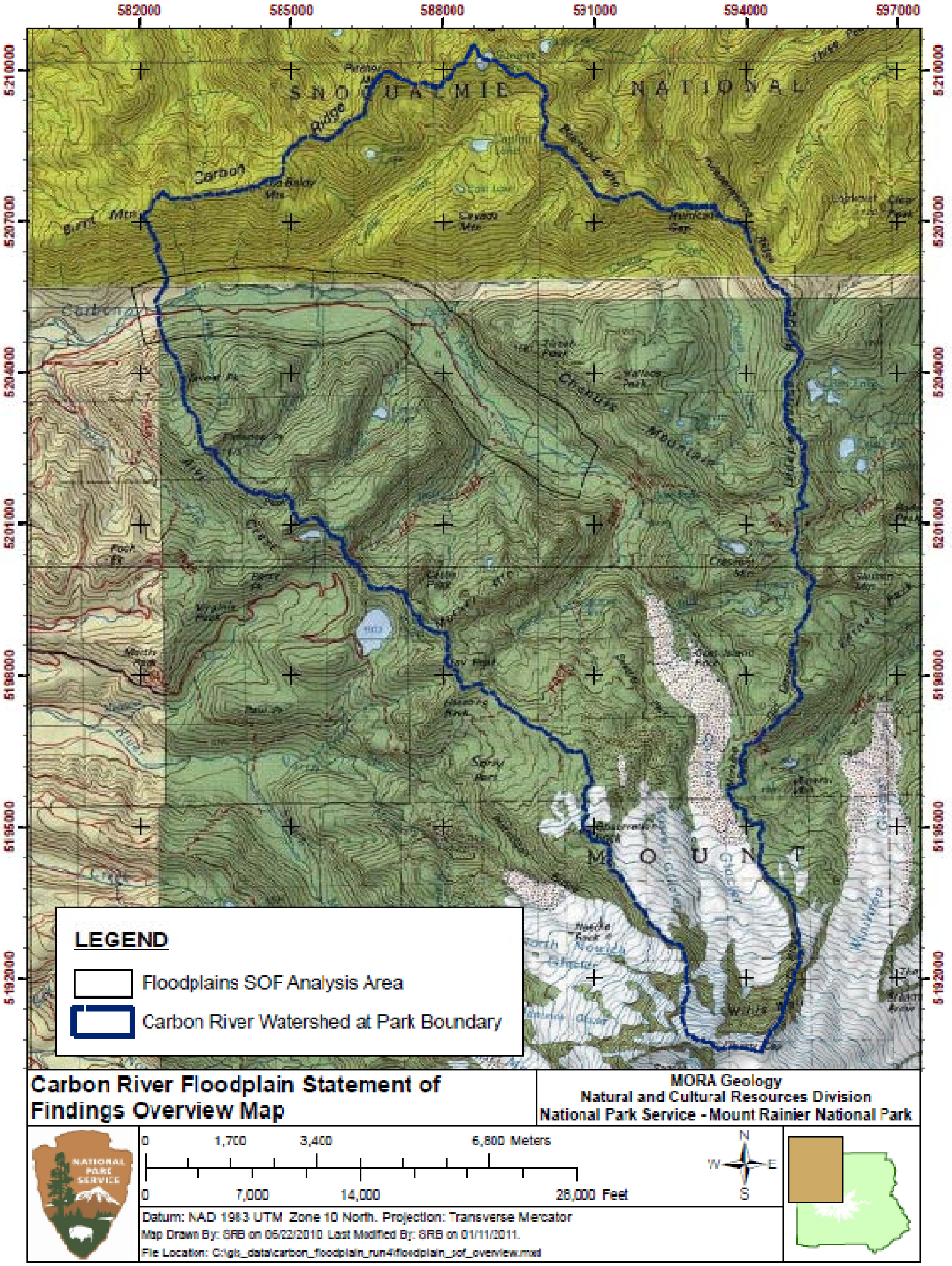

FIGURE 2: Comparison of flood recurrence intervals in the periods of 1930-1977 and 1930-2008 based on annual peak flows from the USGS stream gauging station #12094000 – Carbon River at Fairfax, WA (Modified from ENTRIX, 2008).

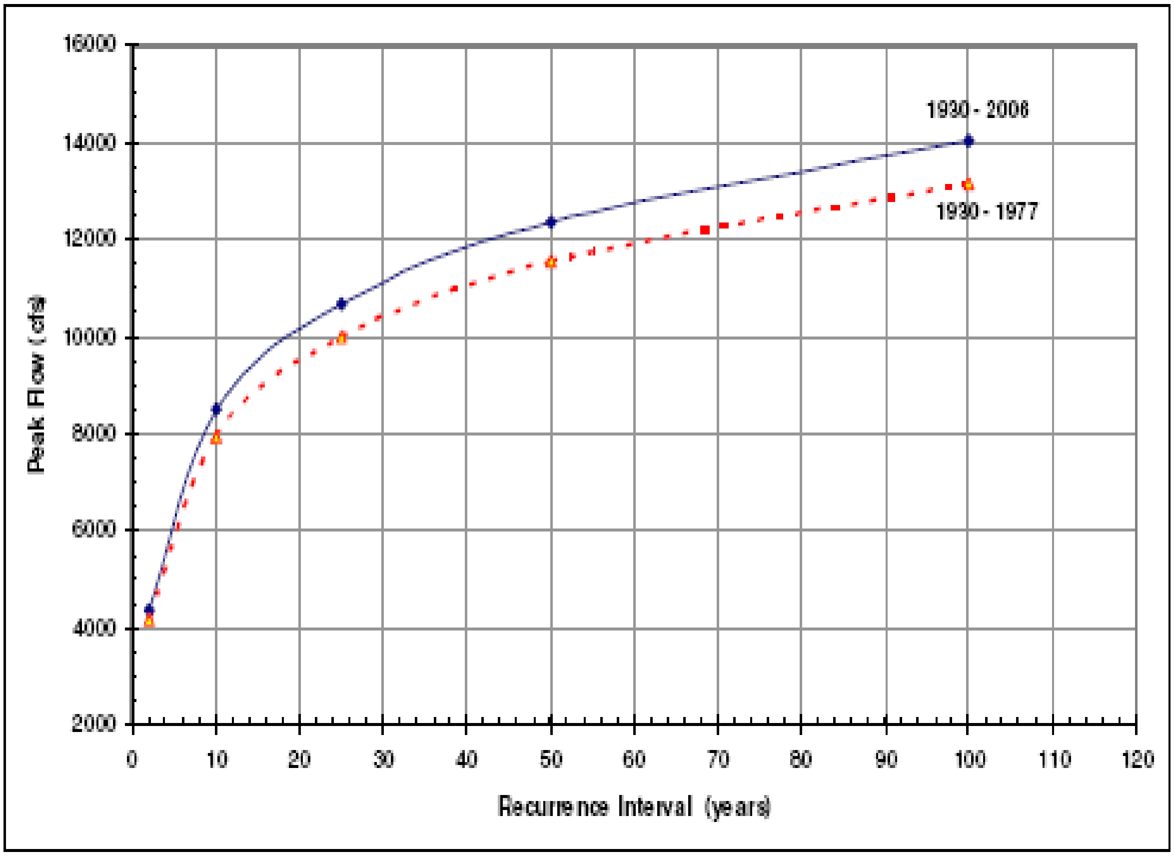

FIGURE 3: Annual peak flows at USGS stream gauging station #12094000 – Carbon River at Fairfax, WA from water years 1930-2008.

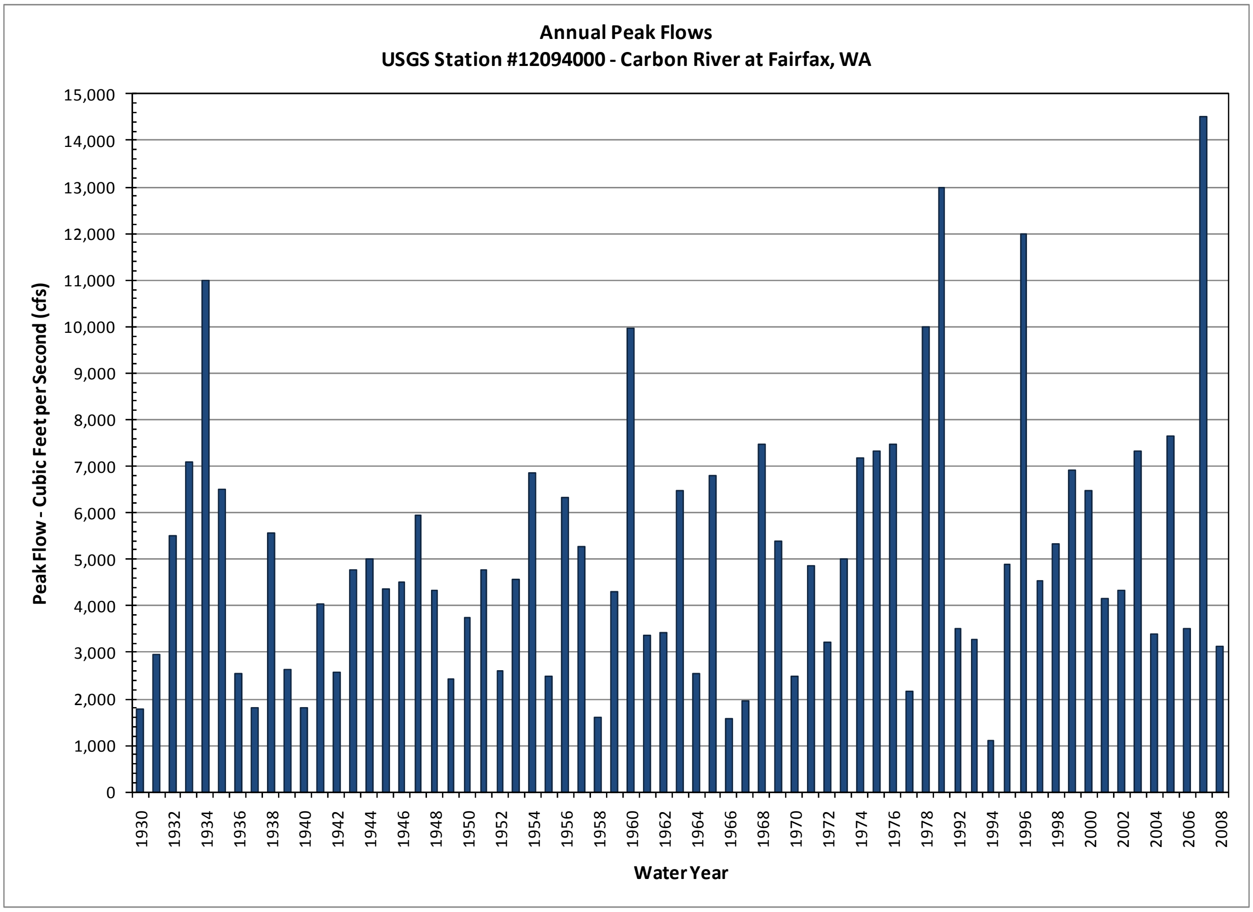

FIGURE 4: Comparison of mean daily flow of large floods that did and did not cause damage on the Carbon River Road. Based on data from the USGS stream gauge #12094000 – Carbon River at Fairfax, WA

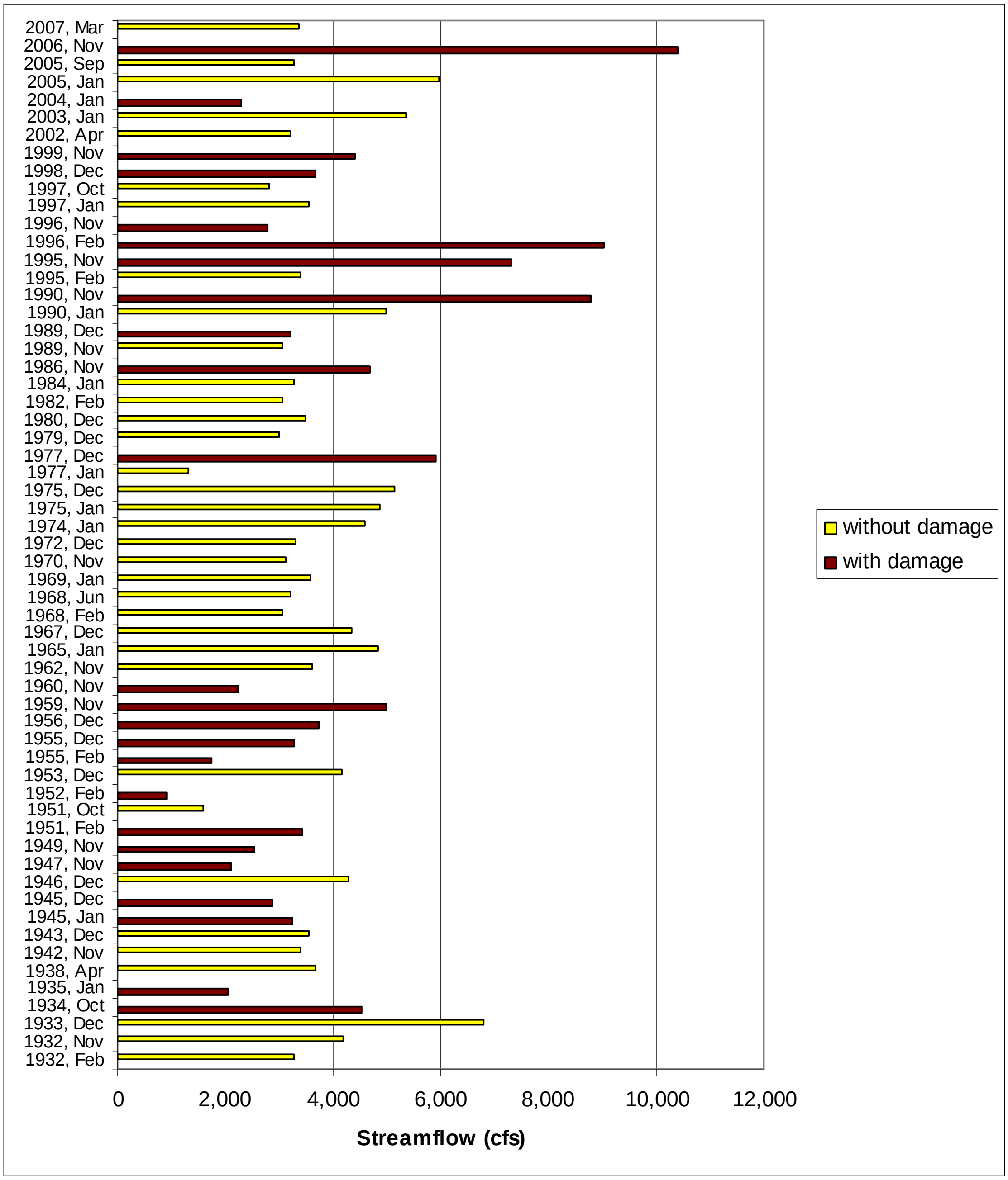

FIGURE 5: Height Above Water Surface (HAWS) map for the Falls Creek reach of the Carbon River.

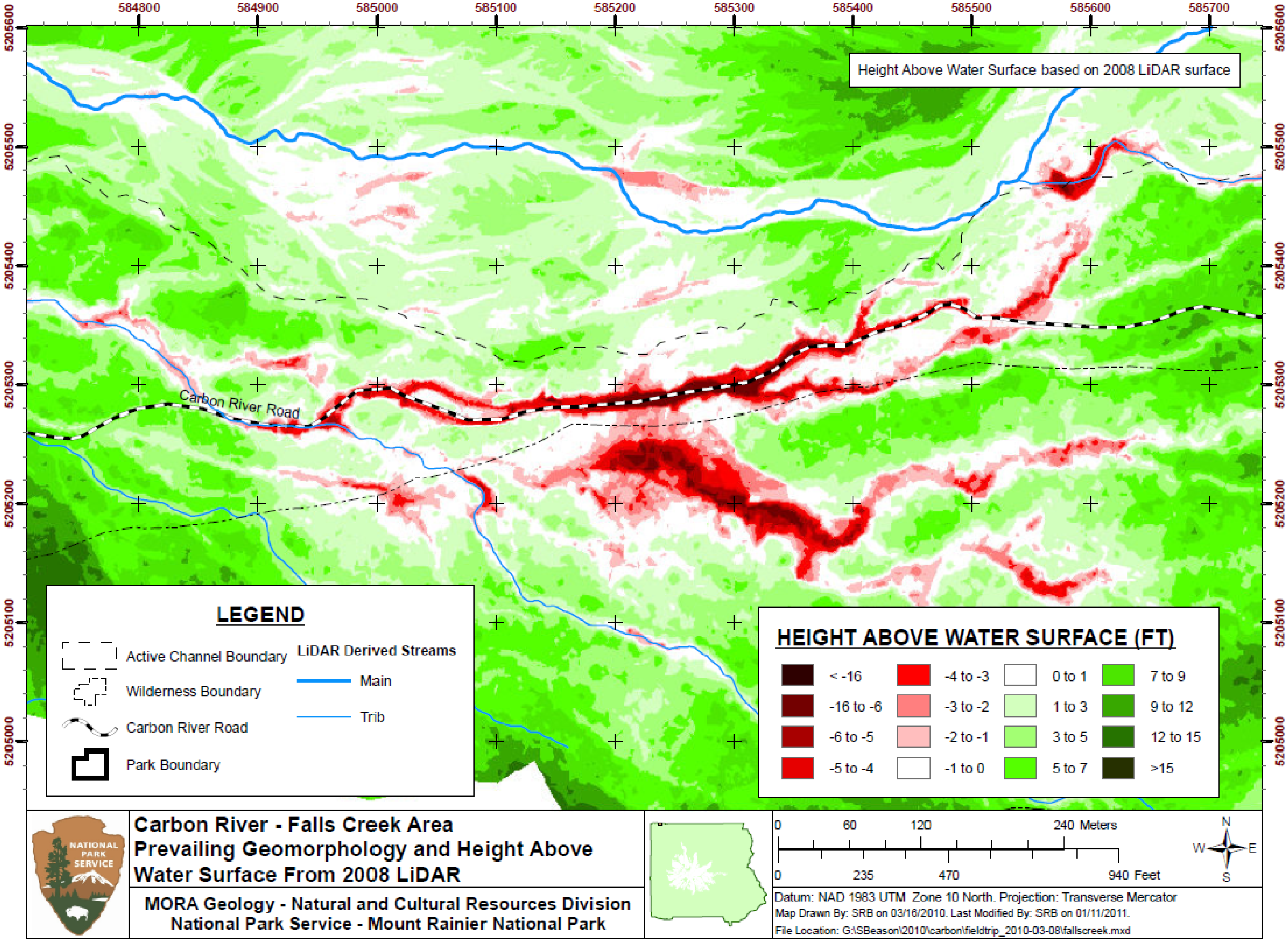

FIGURE 6: Carbon River 100- and 500-year floodplain inundation map based on 1-D HEC-RAS open channel flow models.

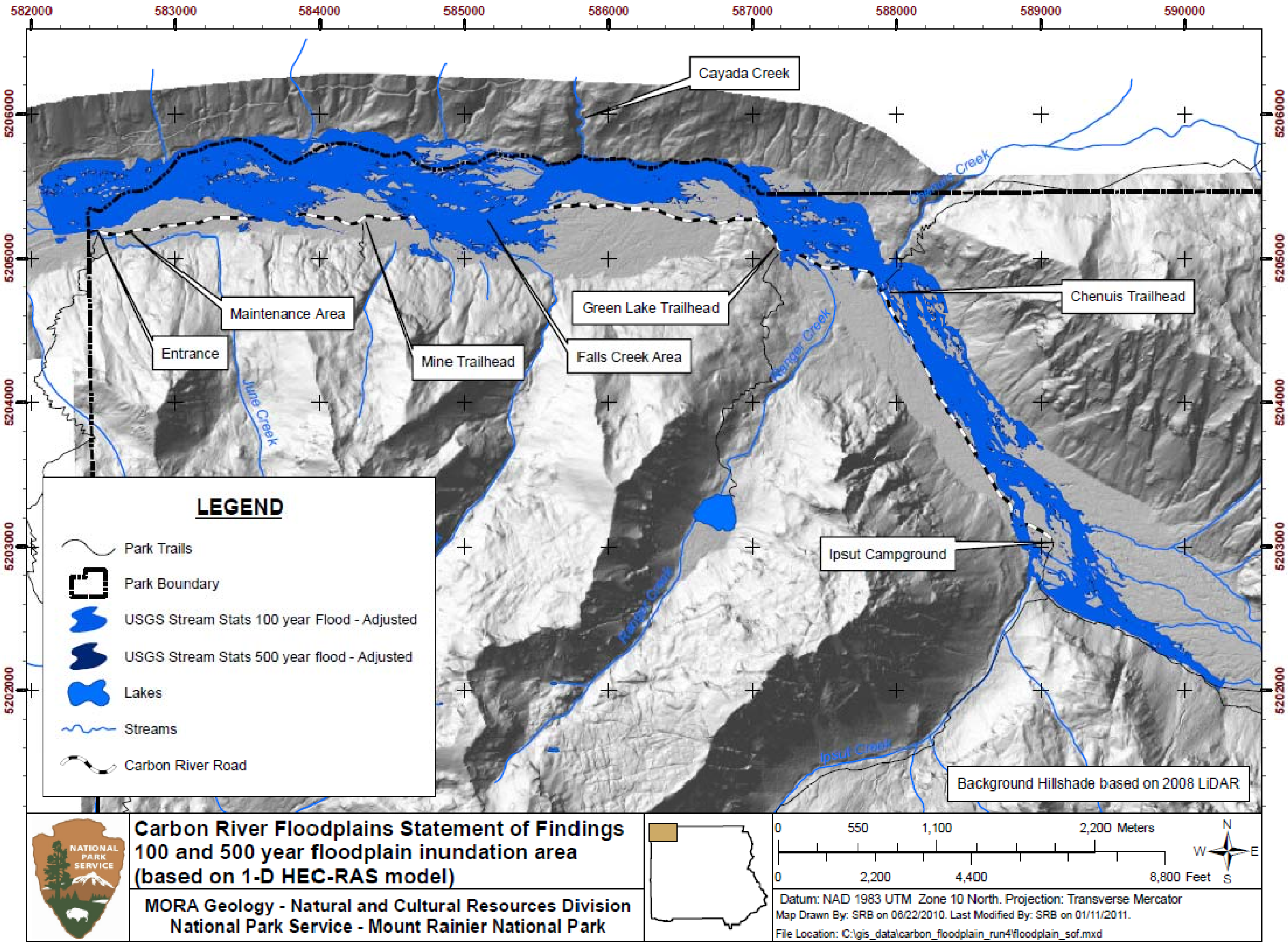

TABLE 1: USGS StreamStats Basin Characteristics Report – Carbon River at the Park Entrance (USGS StreamStats, 2010).

Parameter	Value
Pour point latitude (NAD83)	46.9955° (46° 59’ 43”)
Pour point longitude (NAD83)	-121.9163 (-121° 54’ 58”)
Drainage basin area	52.023 square miles (134.739 square kilometers)
Maximum relief	12,300 feet (3,749 meters)
Mean basin elevation	4,800 feet (1,463 meters)
Maximum basin elevation	14,100 feet (4,298 meters)
Minimum basin elevation	1,750 feet (533 meters)
Mean basin slope	53.4%
Percent of area with slope greater than 30%	81.1%
Percent of area with slope greater than 30% facing north	30.2%
Percent of area covered by forest	57.9%
Mean annual precipitation	99.4 inches (252.5 centimeters)

TABLE 2: 15 largest flows on record for the Carbon River as recorded at Fairfax, WA.

Rank	Date	Discharge (cfs)	Damage?
1	11/06/2006	14,500	Yes
2	11/24/1990	13,000	Yes
3	02/08/1996	12,000	Yes
4	12/09/1933	11,000	No
5	12/01/1977	10,000	Yes
6	11/23/1959	9,970	Yes
7	11/18/2005	7,650	No
8	12/25/1967	7,480	No
9	12/01/1975	7,460	No
10	01/18/1975	7,320	No
11	01/31/2003	7,310	No
12	01/15/1974	7,180	No
13	11/13/1932	7,100	No
14	12/29/1998	6,900	Yes
15	12/09/1953	6,860	No

TABLE 3: Modeled flood magnitude and frequency for the Carbon River.

Location and Flood Frequency	2 yr	10 yr	25 yr	50 yr	100 yr	500 yr
Probability of exceedence in a given year	**50%**	**10%**	**4%**	**2%**	**1%**	**0.2%**
Carbon River upstream of Ipsut Campground	1,858	3,794	4,863	5,713	6,560	8,683
Carbon River downstream of Ipsut Creek	2,260	5,918	5,925	6,961	8,002	10,593
Carbon River downstream of Chenuis Creek	3,030	6,177	7,934	9,302	10,696	14,147
Carbon River downstream of Ranger Creek	3,256	6,641	8,533	10,006	11,506	15,221
Carbon River downstream of Cayada Creek	3,643	7,425	9,541	11,184	12,866	17,011
Carbon River downstream of Falls Creek	3,806	7,756	9,968	11,686	13,444	17,776

TABLE 4: Site specific 100- and 500-year recurrence interval flood conditions for locations of the Carbon River floodplain covered within the Carbon River Access Management EA. Values derived from 1-D HEC-RAS open-channel flow model results. Numbers in parenthesis are averages.

Site	Flood	Discharge	MAIN STEM		OVERBANK AREAS		Top Width
			Depth	Velocity	Depth	Velocity	
	RI	Cubic Feet/Second	Feet	Feet/Second	Feet	Feet/Second	Feet
Ipsut Campground (Main stem)	100	4,592	1.61-3.19 (2.34)	3.96-7.08 (5.17)	0.02-2.68 (1.25)	0.27-5.19 (2.74)	290-569 (416)
	500	6,078	1.79-3.41 (2.64)	4.45-7.56 (5.59)	0.04-3.07 (1.38)	0.26-5.78 (2.96)	307-585 (455)
Ipsut Campground (Side channel)	100	3,410	1.06-4.62 (3.43)	3.68-10.09 (6.41)	0.13-3.50 (1.81)	1.11-8.42 (3.58)	87-317 (218)
	500	4,515	1.54-5.19 (3.95)	4.08-10.45 (6.95)	0.50-4.03 (2.06)	2.01-8.76 (3.99)	102-372 (243)
Chenuis Falls Trailhead	100	10,696	2.10-4.76 (3.05)	3.09-7.08 (4.80)	0.08-3.96 (2.30)	0.36-4.88 (3.13)	355-1,198 (758)
	500	14,147	2.44-5.55 (3.54)	3.32-7.91 (5.27)	0.47-4.68 (2.69)	0.92-5.30 (3.46)	358-1,246 (792)
Green Lake Trailhead	100	11,506	1.85-3.39 (2.57)	3.79-5.79 (4.40)	0.87-7.09 (3.37)	2.27-6.27 (4.39)	527-1,264 (855)
	500	15,221	2.00-3.92 (3.08)	4.25-6.52 (4.96)	0.35-7.32 (3.39)	0.92-6.19 (4.36)	600-1,428 (989)
Falls Creek	100	12,866	1.13-3.34 (2.14)	2.19-4.67 (3.53)	0.56-4.92 (2.50)	0.98-4.71 (3.28)	773-1,784 (1,363)
	500	17,011	1.29-3.76 (2.41)	2.64-4.93 (3.84)	0.95-5.08 (2.72)	1.67-4.91 (3.50)	920-2,020 (1,575)
Maintenance Area	100	13,444	3.12-3.39 (3.27)	4.06-5.43 (4.72)	1.98-4.32 (3.04)	3.17-4.81 (3.63)	1,06-1,206 (1,141)
	500	17,776	3.56-3.89 (3.76)	4.56-5.99 (5.20)	2.18-4.76 (3.38)	3.20-5.16 (3.86)	1,180-1,363 (1,274)
Entrance Area	100	13,444	2.81-3.49 (3.16)	4.15-4.64 (4.41)	1.31-2.60 (2.18)	2.55-3.66 (3.02)	1,287-1,544 (1,386)
	500	17,776	3.13-4.06 (3.61)	4.50-5.14 (4.83)	1.58-3.07 (2.51)	2.72-3.80 (3.25)	1,405-1,617 (1,497)