# THE EFFECTS AND USE OF FUEL TREATMENTS IN THE SKILAK LOOP AREA DURING THE 2015 CARD STREET FIRE, ALASKA

Photo: USFWS

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## Executive Summary

The Card Street Fire (AK-KKS-503292) was ignited by humans on June 15, 2015. The exact cause and location are still under investigation. The final perimeter shows a total burned area of approximately 8,876 acres. The fire started on private property, and 15-20 mph winds pushed the fire quickly through a residential area. A total of 3 residences and 8 outbuildings were lost. The fire quickly spread to the east onto the Kenai National Wildlife Refuge (NWR) where the majority of the acres burned occurred.

The fire intersected two separate fuels treatment projects. Portions of the northeastern flank of the fire were stopped and ultimately controlled in part due to the change in vegetation types created by these treatments. The first unit is a 672 acre parcel completed in 1984, and the second is a 124 acre unit completed in 2009. Both areas were treated mechanically. The 1984 unit was treated by tree crushing machines. The 2009 unit was completed by a combination of hydraulic axe and feller buncher machines. The feller buncher created several large slash piles throughout the unit, which were later burned. The area was also opened to firewood cutters after completion. The firewood cutters further removed some of the slash left over from the treatment. Effectively, both units were "clear cut", leaving only a small amount of seed trees scattered throughout the units. The purpose of this report is to document the effects and use of these fuel treatments during the Card Street Fire and provide discussion and recommendations that could aid fire managers in future planning efforts.

Both treatment areas were implemented according to the Skilak Wildlife Recreation Area Revised Final Management Plan (May 2007). The justification for treating these areas was identified in the plan as the following:

> ***"This action will also benefit small game as well as moose numbers and the hunters that depend on them for their wildlife-dependent recreation. This work will also provide the public an opportunity to view resulting habitat changes from various manipulation techniques (chain sawing, tree crushing, mastication, and prescribed fire). A trail system will traverse all or most of the treated units and kiosks can provide both before and after photos as well as information on individual treatment options and their benefits."***

Some key points taken from the Card Street Fire incident are:

- Both treatments had some effect on lessening fire behavior and spotting potential at the head of the fire which ultimately aided in the control of the Card Street Fire.

- The 2009 unit provided firefighters with an anchor point and safety zone for their operation on the northeastern flank of the fire due to the lower fire intensities, lower rates of spread, and the lack of fuels and snags.

- The burning conditions exceeded the upper prescription limits set by the Skilak Loop Burn Plan, and therefore the majority of seed trees left on the 2009 treatment were killed.

- The high intensity fire sustained within the 2009 unit is expected to stimulate new growth from the deciduous trees and shrubs found inside the unit, as well as provide an acceptable seed bed for conifer regeneration.

## Introduction

The Card Street Fire started on private property in the Sterling, Alaska area on June 15, 2015 and by July 27th the perimeter encompassed 8,876 acres. The fire was human-caused and occurred in the early summer, when an abundance of tinder dry fuels was available due to the combination of a lack of snow the preceding winter, and a very dry spring. This along with high winds on ignition day led to rapid growth.

Three primary residences and 8 outbuildings were lost in the fire. According to numerous accounts, the fire behavior exhibited at the early stages was extreme, and the resources committed were forced into a defensive structure protection role. As the fire progressed onto the Kenai NWR and more resources arrived, anchor points were established and the fire was attacked in a more aggressive manner. According to Mike Hayes, Heavy Equipment Boss on the Card Street Fire, the fuels treatments did have some effect on the ability to gain control of the fire:

> ***"The fire bumped the road (Skilak Loop) pretty hard and spotted into the clear cut (2009 Treatment). Because of all the slash on the ground, it burned really hot but the flame lengths were down, and it wasn't crowning so the spotting distance was significantly less. The fire burned to a trail created when the treatment occurred and stopped there on its own in some areas. We were able to pick up the slops across it pretty easily because the fuels on the other side were mostly younger deciduous trees that kept the flame lengths manageable. If the fuels on the north side of the road had been the same as they were on the south side, we wouldn't have been able to engage because it likely would have been a crown fire still."***
>
> ***Mike Hayes, Heavy Equipment Boss/Fire Technician Kenai-Kodiak Area DOF***

## Background

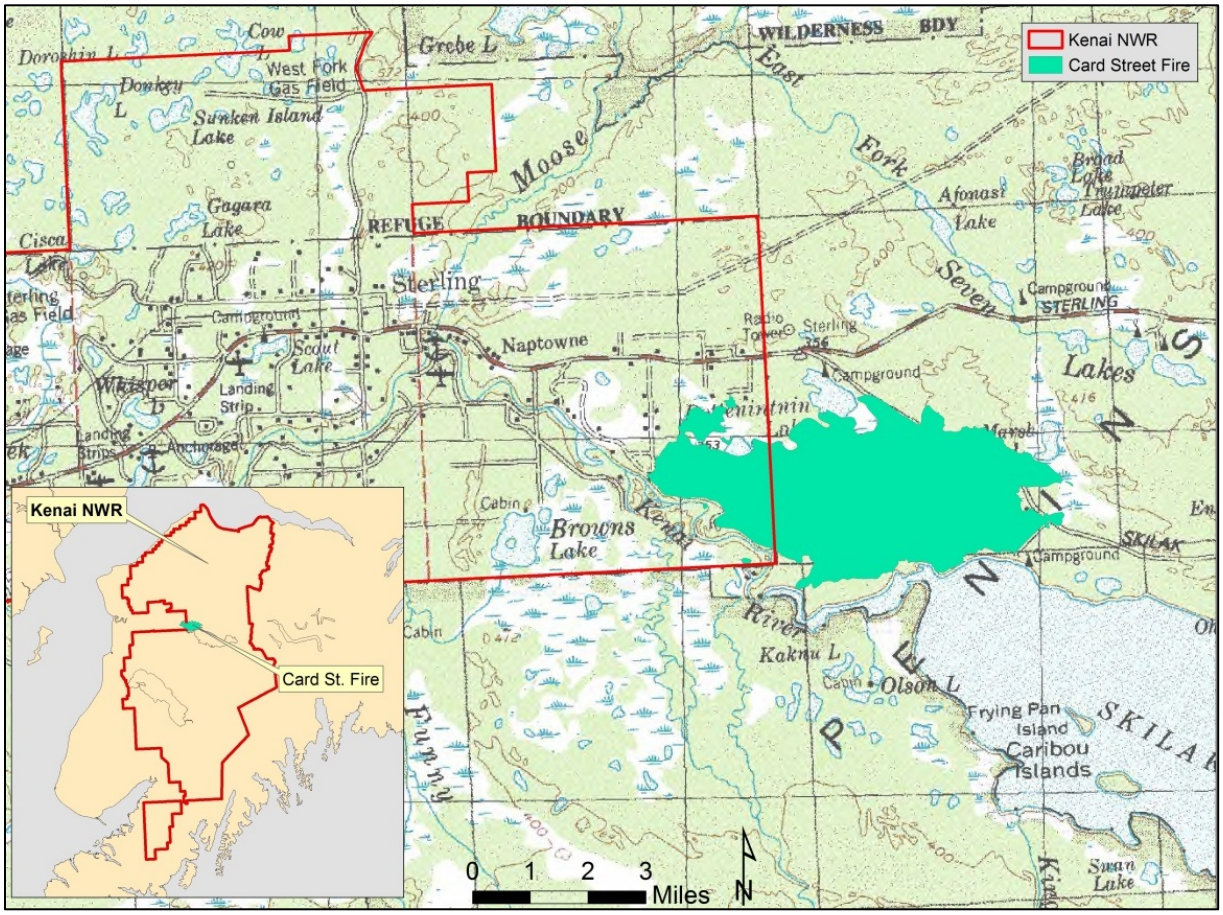
The Kenai Peninsula, located in southcentral Alaska, has a Borough population of approximately 57,157 (U.S. Census Bureau). Most of the residents are located within 10 miles of the Sterling Highway. The Kenai NWR covers approximately 1.92 million acres of the peninsula. It is one of two refuges within the state that are accessible by road. The refuge straddles portions of the Sterling Highway, and lies adjacent to several communities. Because of the close proximity to populated areas, the rate of human caused fires is higher in comparison to most of the rest of the state (see Figures 1 and 2).

The Card Street fire started near Sterling, AK and quickly burned north east onto the Kenai NWR. The fire caused evacuations of several neighborhoods in the Sterling area, as well as

popular campground and day use areas within the refuge. By June 19th most evacuation orders were lifted in the Sterling area. Campgrounds and day use areas remained threatened and were not opened until June 25th.

**Figure 1: Card Street Fire Vicinity Map**

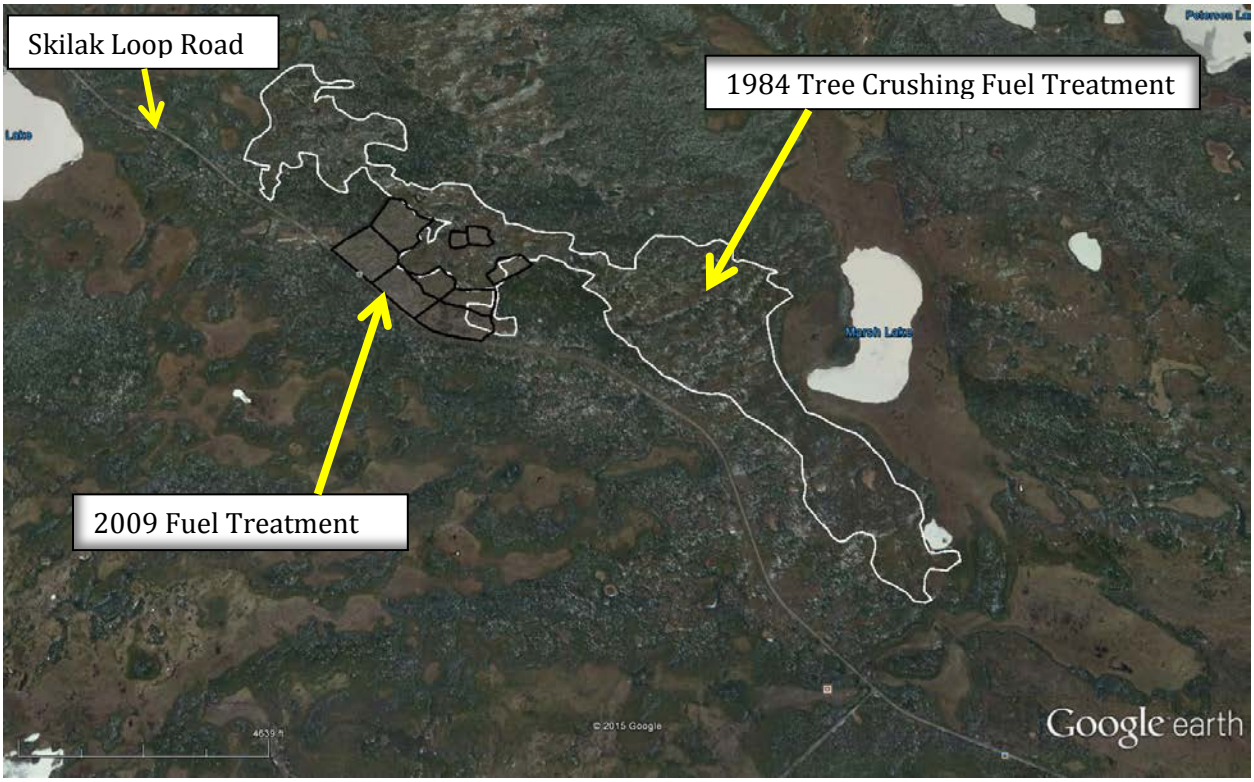
**Figure 2**: **Card Street Vicinity Map (2)***




**Map courtesy of Lisa Saperstein*

The following (Figures 3 and 4) display the location of the 1984 and 2009 fuels treatments relative to the Skilak Loop Road, and also to the Card Street fire perimeter.

**Figure 3: Skilak Loop Fuel Treatments**



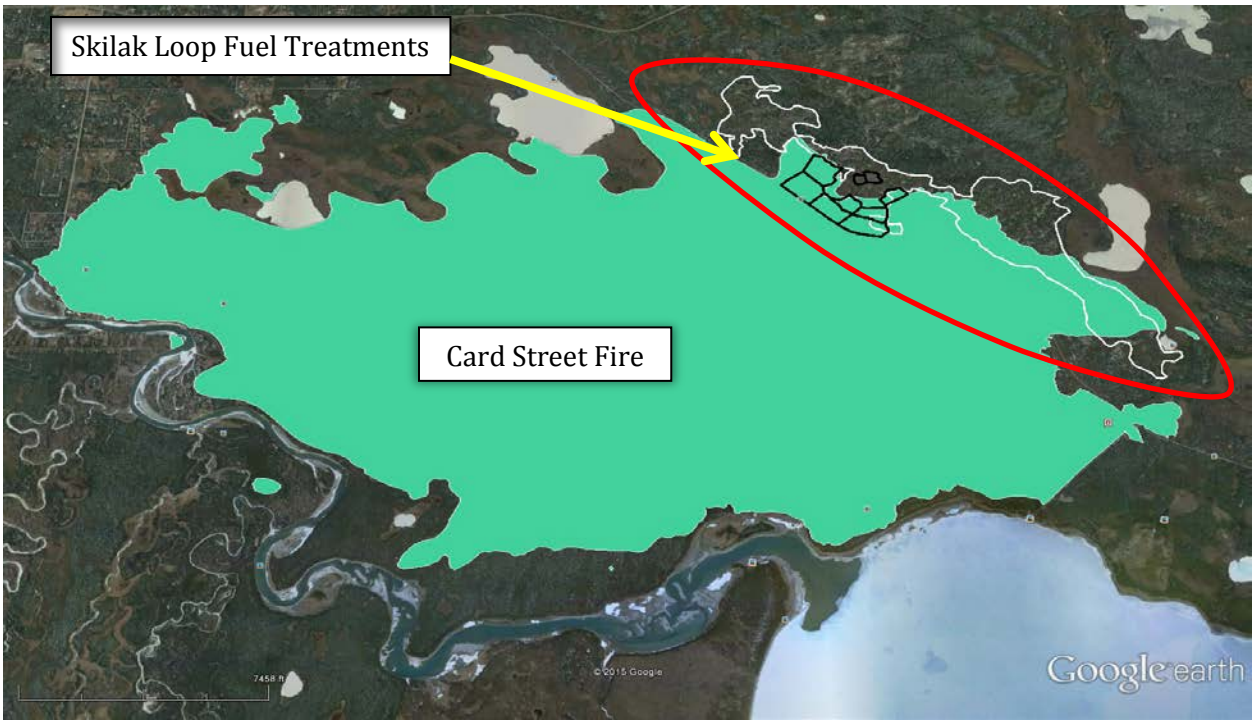




**Figure 4: Skilak Loop Fuel Treatments in relation to the Card Street Fire Perimeter**

## Objective

The objective of this analysis and report is twofold.

1. To evaluate the effect fuels treatments in the Skilak Loop area had on reducing modeled and observed fire behavior of the Card Street Fire.
2. To document observed fire effects within the treated areas approximately 3 months post burn.

## Scope

The analysis is based on the use of the fire modeling program IFTDSS (Interagency Fuel Treatment Decision Support System), firsthand accounts of observed fire behavior, and subsequent action taken by firefighters on the ground. The fuels information used to generate modeled fire behavior is based on data acquired from LANDFIRE. Actual pre fire fuels samplings were not completed to determine fuel loadings in the treatment areas. The 2009 units contained several debris piles, but since the quantity and location cannot be verified they have not been included as part of the analysis.

The outputs of the analysis can be utilized as a general guideline not only for how these treatments affected portions of the Card Street Fire but also the subsequent observed fire effects. The analysis will also serve as a guide as to what future fire effects could be expected in these treatment areas.

## Methods

To determine potential modeled fire behavior outcomes with and without fuel treatments, analyses were run using the Interagency Fuels Treatment Decision Support System (IFTDSS). This workflow utilizes Flammap (v. 3.0) to model fire behavior parameters such as flame length, rate of spread, fireline heat per unit area, and crown fire activity both pre and post treatment.

The analysis was run for conditions encountered on June 17$^{th}$, which is when the fire spotted across the Skilak Loop road and intersected the fuel treatments. Information concerning which parameters were used for the IFTDSS model can be found in the next section.

## IFTDSS Inputs

Inputs for the IFTDSS analysis are shown in Table 1. Weather observations and indices utilized for the inputs were collected from the Skilak Guard Station RAWS (WIMS: 500967), located approximately 2 miles to the southeast of the 2009 treatment area (Figure 5). Live fuel moisture conditions were obtained from Wildland Fire Decision Support System (WFDSS) documents based on an accepted FS Pro run from the incident Fire Behavior Analyst (FBAN). The Scott and Reinhardt crown fire calculation method was used because this method most accurately captured the actual crown fire activity that occurred on the day of the analysis.

The LANDFIRE 2010 landscape was used for all pre-treatment fuel models. The data that LANDFIRE assigned to the 2009 unit was representative of fuel conditions that existed prior to the treatment, but did not accurately depict the post-treatment environment. The LANDFIRE produced mixture of Timber Iitter (TL) and Timber understory (TU) fuel models were changed to Slash/Blowdown 1 (SB1) manually within the post-treatment run in IFTDSS. SB1 was chosen because it was determined that a light slash load as the primary carrier of the fire would most likely represent actual conditions on the ground. Reported fire behavior and photos taken before and after the fire further supported this decision.

It was assumed all other fuel models including those within the 1984 tree crushing treatment were assigned correctly in the LANDFIRE landscape; no changes were made other than the ones noted above.

**Table 1: IFTDSS Weather and Fuel Condition Inputs**

| | |
|---|---|
| **Date and Time** | June 17, 2015 ~ 1500 |
| **Crown Fire Calculation Method** | Scott & Reinhardt |
| **1 Hour Fuel Moisture** | 4% |
| **10 Hour Fuel Moisture** | 5% |
| **100 Hour Fuel Moisture** | 9% |
| **Live Herbaceous Fuel Moisture** | 79% |
| **Woody Fuel Moisture** | 102% |
| **20 foot Wind Speed** | 15 mph |
| **Wind Direction** | 200° |

## Figure 5: Skilak Guard Station RAWS Fire weather indices June 17th, 2015

| Date | Hr | ATF | RHP | WSM | PREC | FFMC | DMC | DC | ISI | BUI | FWI | DSR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 06-17 | 14 | 86 | 29 | 3 | 0.00 | 94.0 | 73.0 | 406.5 | 9.6 | 100.8 | 30.8 | 11.7 |

AICC - Alaska Fire Service
P.O. Box 35005
Ft. Wainwright, AK 99703
907.356.5600
907.356.5678 fax

| Date | Hr | ATF | RHP | WSM | PREC | RNIN | WSMP | WDD | WDDP | FTF | BPHG | BVV | SRW | FMP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 06-17 | 00 | 65 | 54 | 0 | 0.00 | 0.46 | 4 | 53 | 127 | : | : | 13.0 | 1.0 | : |
| 06-17 | 01 | 62 | 52 | 1 | 0.00 | 0.46 | 4 | 338 | 100 | : | : | 12.9 | 0.0 | : |
| 06-17 | 02 | 59 | 61 | 0 | 0.00 | 0.46 | 3 | 351 | 50 | : | : | 12.8 | 0.0 | : |
| 06-17 | 03 | 57 | 66 | 0 | 0.00 | 0.46 | 3 | 6 | 201 | : | : | 12.8 | 0.0 | : |
| 06-17 | 04 | 55 | 69 | 0 | 0.00 | 0.46 | 2 | 33 | 8 | : | : | 12.8 | 2.0 | : |
| 06-17 | 05 | 53 | 77 | 0 | 0.00 | 0.46 | 4 | 156 | 10 | : | : | 12.7 | 13.0 | : |
| 06-17 | 06 | 54 | 79 | 0 | 0.00 | 0.46 | 2 | 337 | 25 | : | : | 12.8 | 26.0 | : |
| 06-17 | 07 | 58 | 79 | 0 | 0.00 | 0.46 | 3 | 178 | 192 | : | : | 12.8 | 39.0 | : |
| 06-17 | 08 | 62 | 63 | 1 | 0.00 | 0.46 | 4 | 164 | 115 | : | : | 12.9 | 52.0 | : |
| 06-17 | 09 | 68 | 50 | 1 | 0.00 | 0.46 | 5 | 268 | 219 | : | : | 13.1 | 124.0 | : |
| 06-17 | 10 | 75 | 37 | 2 | 0.00 | 0.46 | 4 | 141 | 156 | : | : | 14.2 | 598.0 | : |
| 06-17 | 11 | 78 | 35 | 1 | 0.00 | 0.46 | 6 | 159 | 170 | : | : | 13.7 | 680.0 | : |
| 06-17 | 12 | 81 | 34 | 3 | 0.00 | 0.46 | 6 | 182 | 163 | : | : | 14.2 | 672.0 | : |
| 06-17 | 13 | 85 | 29 | 3 | 0.00 | 0.46 | 6 | 141 | 230 | : | : | 13.5 | 814.0 | : |
| 06-17 | 14 | 86 | 29 | 3 | 0.00 | 0.46 | 8 | 156 | 172 | : | : | 13.5 | 725.0 | : |
| 06-17 | 15 | 84 | 28 | 1 | 0.00 | 0.46 | 8 | 200 | 204 | : | : | 13.9 | 531.0 | : |
| 06-17 | 16 | 77 | 35 | 1 | 0.00 | 0.46 | 10 | 270 | 194 | : | : | 13.5 | 145.0 | : |
| 06-17 | 17 | 76 | 38 | 3 | 0.00 | 0.46 | 8 | 193 | 171 | : | : | 13.5 | 86.0 | : |
| 06-17 | 18 | 80 | 32 | 3 | 0.00 | 0.46 | 11 | 231 | 202 | : | : | 13.7 | 299.0 | : |
| 06-17 | 19 | 81 | 29 | 2 | 0.00 | 0.46 | 9 | 225 | 216 | : | : | 13.6 | 370.0 | : |
| 06-17 | 20 | 76 | 33 | 0 | 0.00 | 0.46 | 10 | 265 | 187 | : | : | 13.4 | 205.0 | : |
| 06-17 | 21 | 73 | 38 | 2 | 0.00 | 0.46 | 7 | 175 | 216 | : | : | 13.3 | 73.0 | : |
| 06-17 | 22 | 69 | 43 | 1 | 0.00 | 0.46 | 6 | 214 | 199 | : | : | 13.1 | 27.0 | : |
| 06-17 | 23 | 65 | 45 | 0 | 0.00 | 0.46 | 5 | 158 | 198 | : | : | 13.0 | 4.0 | : |
| | MIN: | 53 | 28 | 1 | 0.00 | 0.46 | 2 | 6 | 8 | : | : | 12.7 | 0.0 | : |
| | MAX: | 86 | 79 | 3 | 0.00 | 0.46 | 11 | 351 | 230 | : | : | 14.2 | 814.0 | : |
| | CHANGE: | 33 | 51 | 2 | 0.00 | 0.00 | 9 | 345 | 222 | : | : | 01.5 | 814.0 | : |

Approximate time the Card Street Fire intersects the treatment areas.

## Results by Treatment Area

### 2009 Treatment area

Results from the IFTDSS analysis indicated that the 2009 treatment had a direct effect on flame lengths, rate of spread, fireline intensity, and crown fire occurrence compared to pre-treatment conditions, based on the model inputs from conditions encountered on June 17th. In the 2009 treatment area flame lengths were reduced post treatment by approximately 76%. Rate of spread was reduced by approximately 60%, and fireline intensity was reduced by about 85% (Table 2). Dramatic landscape depictions of these can be seen in Figures 6 (a-f) by comparing the pre and post treatment areas for each. Figures 6 (g,h) display the measured changes in flame length and rate of spread. Crown fire occurrence within the 2009 unit was reduced to zero as well largely due to the fact the fuel treatment removed all canopy cover [Figure 6 (i)].

**Table 2. Percent Change of Modeled Fire Behavior Post Treatment 2009 Area**

| | Pre-Treatment | Post Treatment | Percent Change |
|---|---|---|---|
| **Flame Length (Ft)** | 15.36 | 3.66 | -76.19% |
| **Rate of Spread (Ch/hr)** | 21.05 | 8.35 | -60.42% |
| **Fireline Intensity (Btu/ft/s)** | 580.12 | 95.67 | -85.84 |

**Figure 6: IFTDSS Outputs Pre and Post Treatment**

**Fig. 6(a) Flame Length Pre-Treatment**

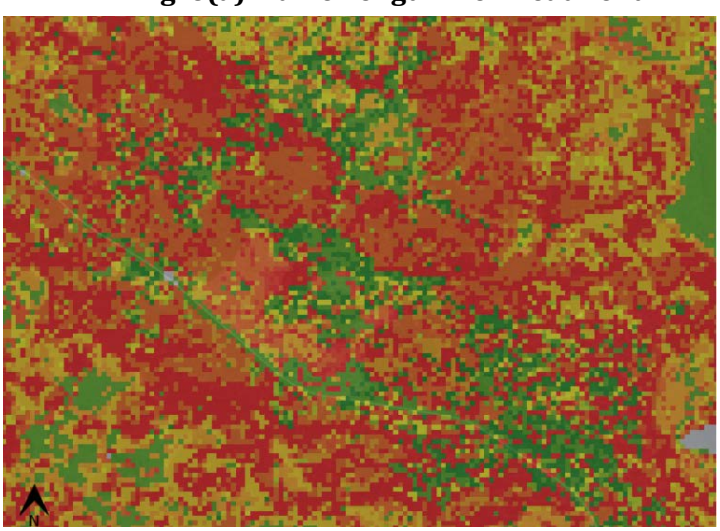


**Fig. 6(b) Flame Length Post-Treatment**

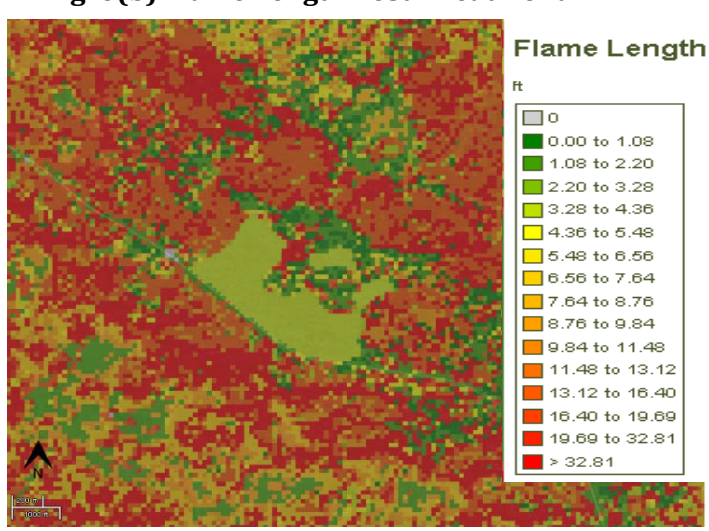


**Fig. 6(c) Crown Fire Activity Pre-Treatment**

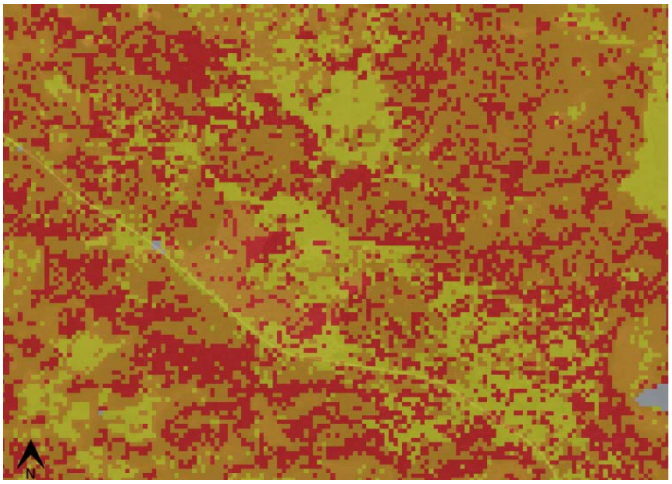


**Fig. 6(d) Crown Fire Activity Post-Treatment**

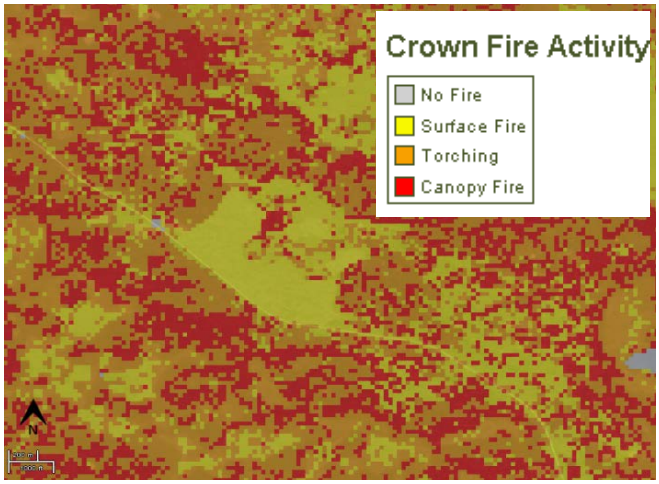



**Fig. 6(e) Rate of Spread Pre-Treatment**

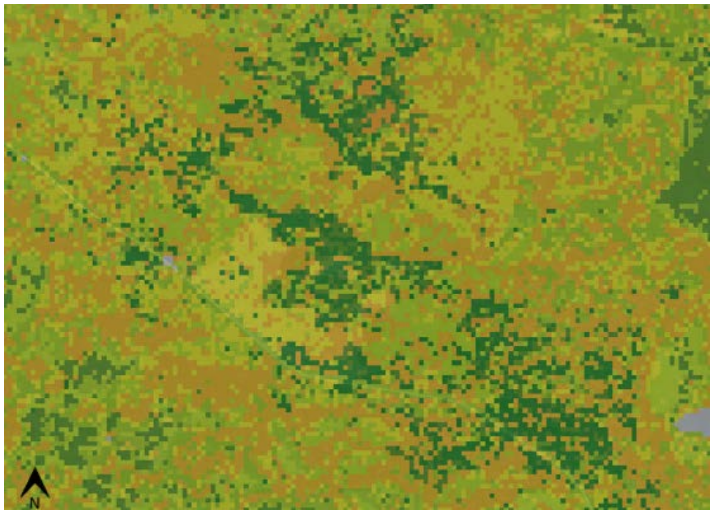


**Fig. 6(f) Rate of Spread Post-Treatment**

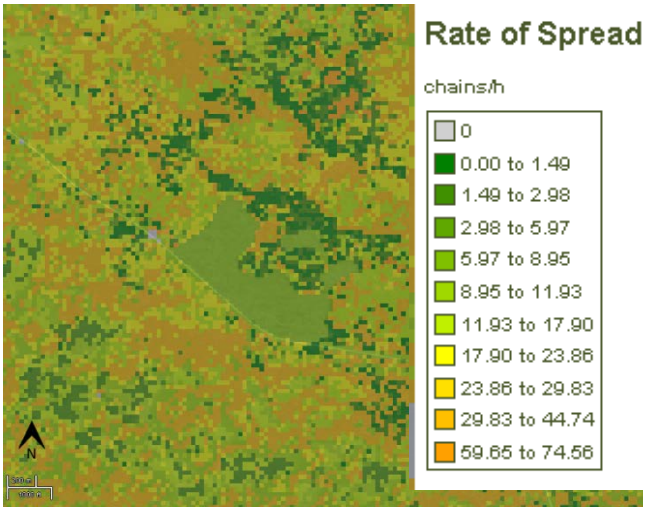


**Fig. 6(g) Flame Length Change Post-Treatment**

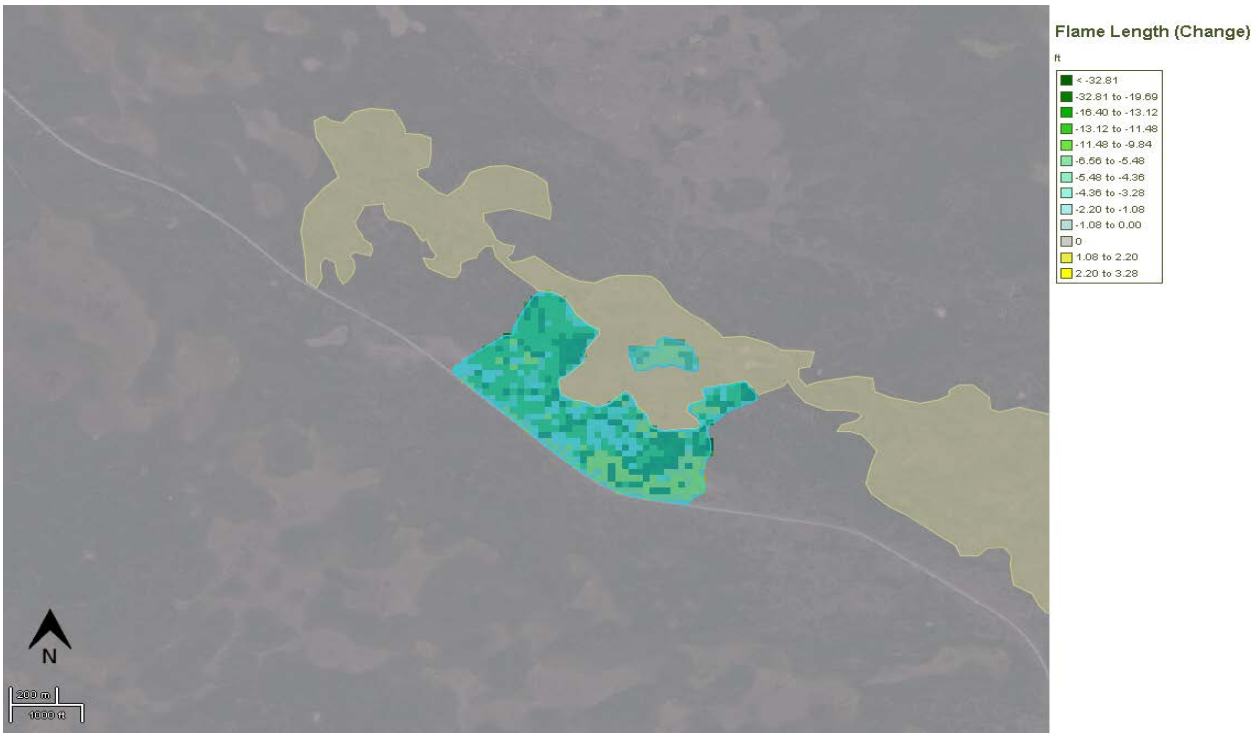



**Fig. 6(h) Rate of Spread Change Post-Treatment**

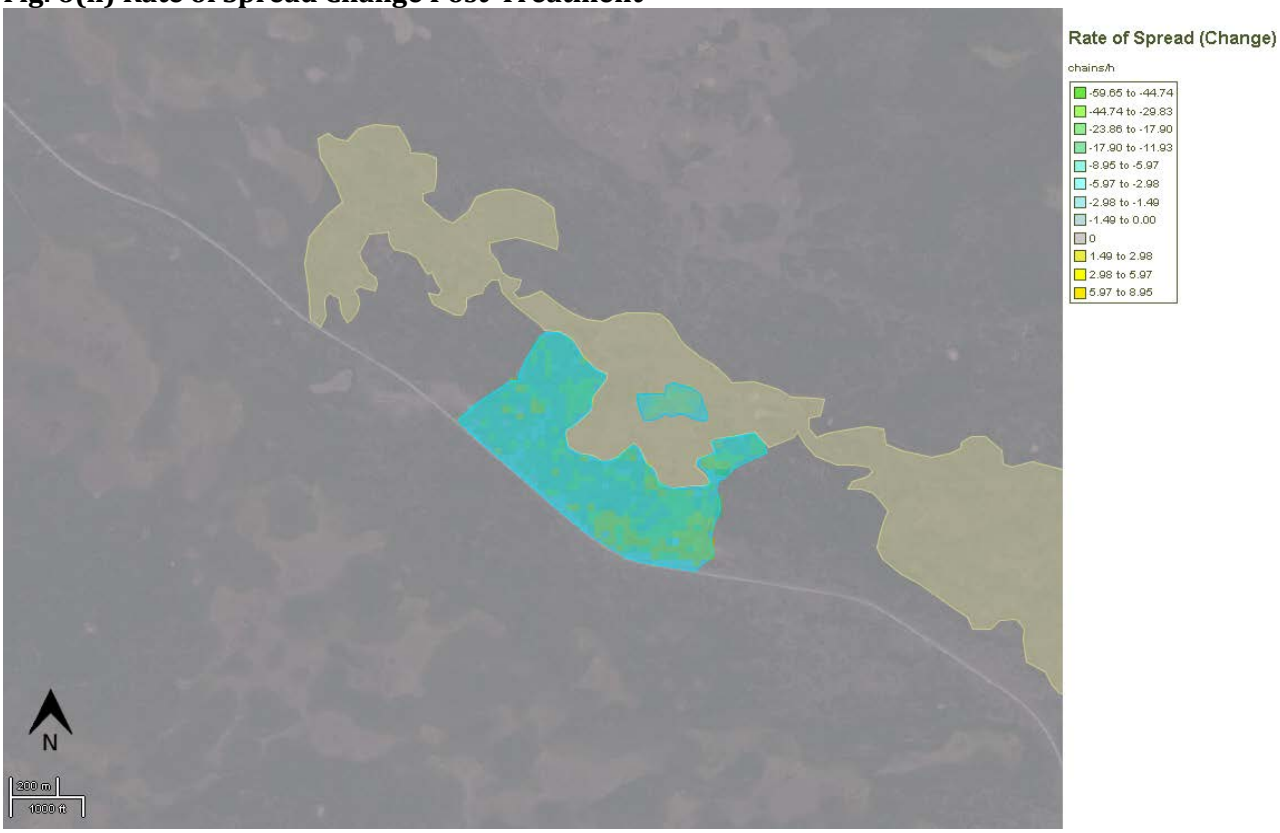
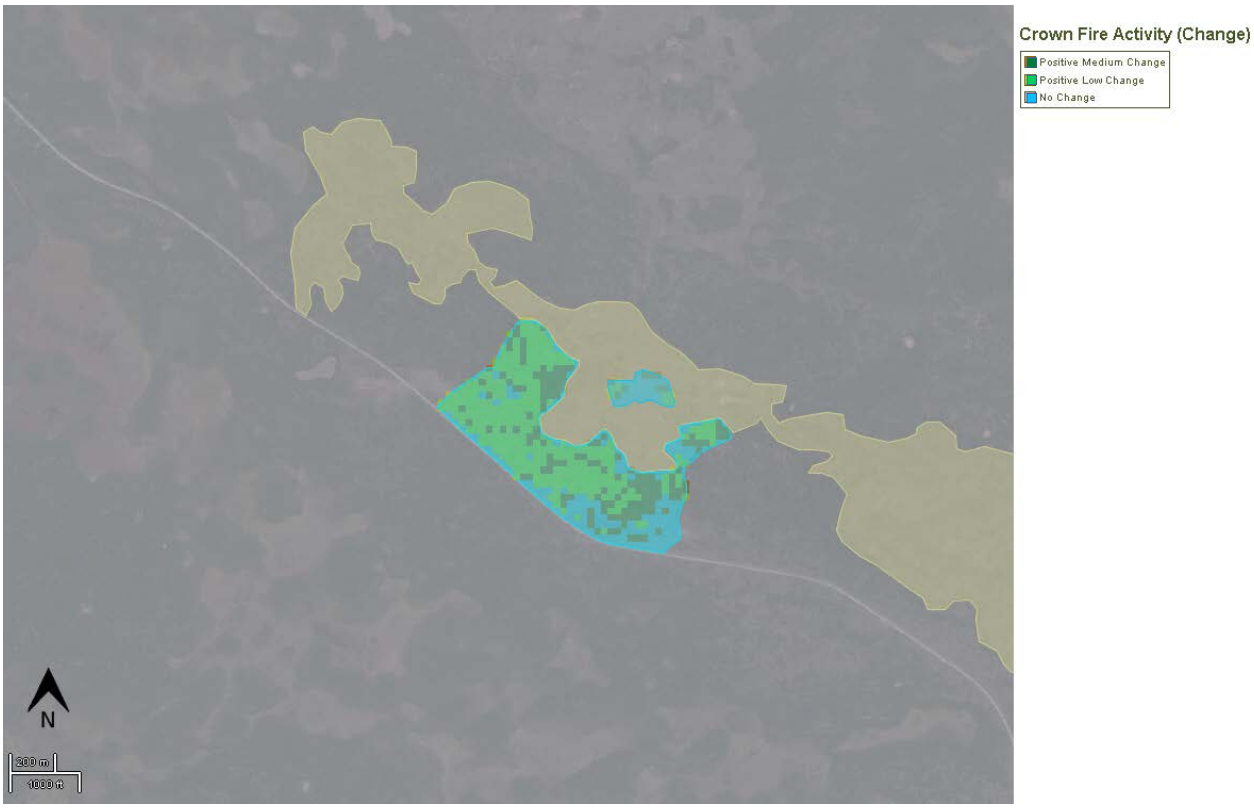


**Fig. 6(i) Crown Fire Activity Change Post-Treatment**




## 1984 Tree Crushing Treatment

The 1984 treatment area likely moderated fire behavior compared to what would have been observed had the fuels treatment not been implemented. Although there is no information concerning the actual fuel conditions that existed prior to the treatment, there is evidence that the untreated vegetation adjacent to the treatment area (LANDFIRE assigned TU 3, 4 and 5) would exhibit more intense fire behavior (Figure 7). LANDFIRE assigned mostly a TU1 and TU2 fuel model inside the treatment polygon. These fuel models show a typical flame length of 1-3 feet, rates of spread of 2-6 chains per hour, and fireline intensities of 13-30 Btu/ft/s. Differences in flame lengths between the separate fuel models are graphically represented in (Table 3). Although we cannot say for certain that the lower TU fuel models found inside the treatment area would not have occurred naturally without treatment; the treatment likely brought a surge of deciduous undergrowth which is associated with a reduction in fire behavior, and was reflected in the LANDFIRE imagery at least 16 years after treatment.

**Figure 7: 1984 Tree Crushing Fuel Models in Relation to Card Street Final Perimeter**

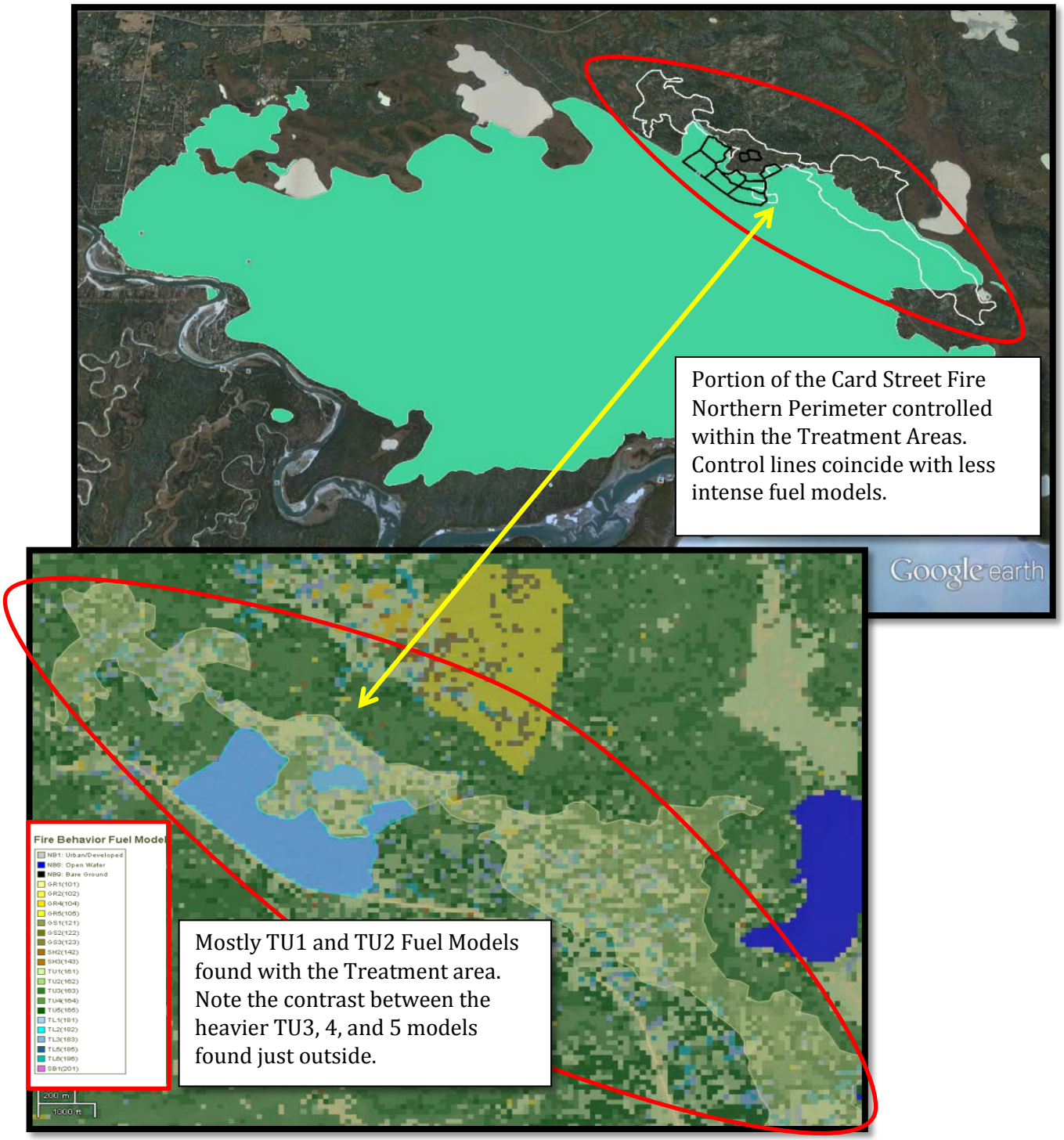
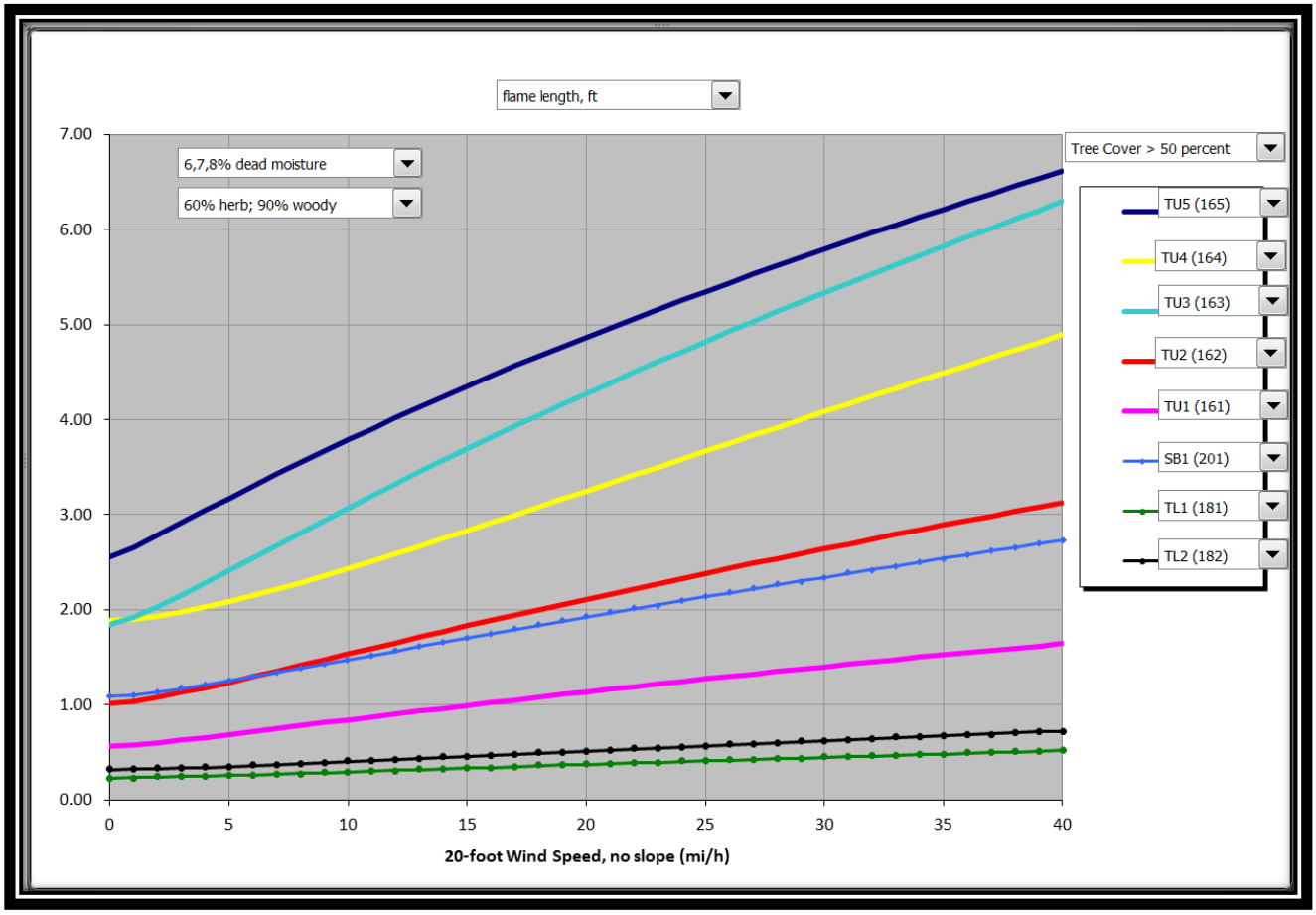


**Table 3: Flame length Comparison of Fuel Models found Within the Treatment Area and Immediately Adjacent**




Flame lengths of fuels typically located adjacent to the treatment area are represented here. Note how the TU 5, 4, and 3 models found adjacent to the treatment areas exhibit longer flame lengths than the typical TU 1, 2 and TL fuel models found within the treatment areas.

The post treatment conditions found within both the 2009 and 1984 treatment areas coincide with where the final northeastern perimeter of the Card Street Fire occurred (Photos in Figure 8).

**Figure 8: 2009 Area Post Fire Photos**

2009 Treatment Area, looking south towards Skilak Loop Road. Trees adjacent to the treatment area are scorched due to crown fire.

**(All Photos by USFWS)**

Inside the 2009 treatment area looking north. Note the lack of an over story that would support crown fire.

Previously established dozer line on the north side that was to be used to control a planned prescribed fire within the 2009 treatment area; was sufficient to stop the Card Street Fire on its own in some areas.

North edge of the 2009 treatment. Just outside the treatment area is the 1984 treatment. The fire spotted across, but due to lower fire intensities crews were able to secure the spots and contain the fire.

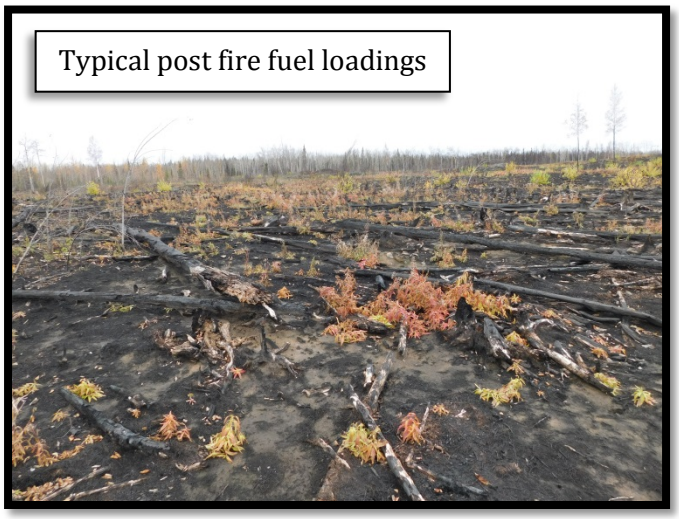
## Fire Effects

There has not been a formal fire effects study conducted at this time. However, visual surveys conducted approximately 3 months post-fire show 100% mortality of the standing seed trees within the 2009 treatment area. The purpose of leaving the trees according to the Skilak Loop Planning Proposal (2009) was to retain mature aspen and birch trees at a density of 0-2 trees per acre for wildlife benefits, to serve as seed trees, and for aesthetic appeal.

It is unclear what effect scorching the seed trees will have on the regrowth of paper birch trees (*Betula papyrifera*). A more thorough look in the spring of 2016 for signs of paper birch re-sprouting will most likely confirm that the species will make a full comeback, even without the benefit of live seed trees to help re-establish new growth. Paper birch is generally killed or top killed by fire due to their thin bark (Day, et al, 1981, pp 29-41). Any paper birch seeds on the ground would be destroyed by fire (Viereck et al, 1972, p 265). Therefore, re-sprouting will most likely need to occur for the re-establishment of the species due to the loss of seed trees. According to Leege, (1979, pp 107-113), Perala, (1974, p 4), and Gilley, (1982, pp 24-25) paper birch trees ranging in age up to approximately 50 years old will re-sprout prolifically from their root systems after a fire. Sprouts appear a few weeks to 2 months after spring or summer fires but not until the following spring after late fall fires. They grow rapidly and are often 20 to 40 inches (50-100 cm) tall after one growing season (Revill, 1978, p 345), (Leege, 1979, pp 107-113). Paper birch is a prolific producer of lightweight seeds that are easily dispersed by wind and readily germinate on fire-prepared seedbeds (Perala, 1974, p 32). The freshly burned off duff layer will make suitable areas for paper birch seeds to germinate, however with the lack of live seed trees within the area the seed source will have to come from the edges of the unit. The small double winged seeds are dispersed mostly by wind action. The seeds typically fall between 100 and 200 feet from the parent tree (Marquis et al, 1979, p 47) but can be dispersed great distances when blown across wind crusted snow (Safford et al, 1983, pp 158-171). Although the seed trees were killed, it is expected that paper birch will make a full and vigorous recovery due to a combination of re-sprouting and seedling establishment.

Additionally within the 2009 treatment area, it appears other deciduous shrub and tree species have been top-killed only and are beginning to re-sprout. The evidence of re-sprouting Scouler willow (*Salix scouleriana*), quaking aspen (*Populus tremuloides*), and balsam poplar (*Populus balsamifera*) within the treatment area suggests that the soil has not been sterilized, nor have the previously established roots been damaged due to the intensity and duration of heat the slash load could have possibly imposed. The duff appears to be burned in a mosaic pattern where mineral soil is exposed in some areas, but appears relatively untouched in others. Photos of these are displayed in Figure 9.

**Figure 9: 2009 Area Fire Effects Photos**



Mosaic of exposed mineral soil and unburned duff. Typical of entire treatment area

**Figure 9: Cont.**

The 1984 unit likely burned under much less intense fire conditions, as evidenced by the observed and modeled flame length, heat per/BTU/Ft/S and rates of spread. Single and some group tree torching occurred, but a stand replacing canopy fire did not occur in this area as it did on the south side of the Skilak Loop Road. Given the lower intensity surface fire experienced in this area, fire effects are generally positive from a fuels reduction and habitat producing standpoint. With the lack of pre-burn fuels information, a post burn study would not be beneficial for either treatment as there would be no way to compare pre and post fire effects.

## Discussion

The Fuel Treatments of the Skilak Loop Road area had a significant effect on the Card Street Fire. The combination of the 1984 tree crushing and the 2009 treatment effectively manipulated the vegetation which resulted in conditions where firefighters could successfully engage the fire in a direct manner. Although the 2009 treatment was mostly intended for educational and habitat enhancement purposes, it was also effective at serving as a fuel break. Neither of the fuels treatments would have stopped the fire on their own, but they undoubtedly were beneficial at slowing fire progress and intensity to a level where firefighters could safely conduct suppression activities. Had the treatments not been there, evidence suggests the fire would have sustained itself as a canopy fire and continued to rapidly spread north and east, potentially impacting private property in the community of Sterling, infrastructure associated with the Skilak Loop Wildlife Recreation Area, and ultimately multiple values associated with the Sterling Highway corridor.

The treatment areas are a way to mimic natural fire cycles. The crushing of trees, use of feller buncher machines, hydraulic axe use and other disturbances create a similar

vegetative response that was mostly achieved by natural fire before human settlement occurred in the area. Naturally occurring fires typically burn in a mosaic pattern, causing some canopy coverage to be lost, and allowing new growth of deciduous pioneer species such as birch, willow, and aspen. By suppressing fires, this natural process has been altered. The treatments are producing similar results without the risk of fire on the landscape.

## Recommendations

- More fuels monitoring pre and post treatment would be beneficial to fully understand the effects of any disturbance. The monitoring would also facilitate cost effectiveness analyses to ensure dollars spent are being utilized in the most efficient way possible.

- Utilize modeling programs such as IFTDSS to conduct risk assessments and implement more fuel treatments in strategic areas. These treatments often provide dual purposes such as enhancing wildlife habitat, while serving as fuel breaks.

- Provide the public with more information on the purpose and effects of fuel treatments. Interpretive signs, school programs, site visits, and visitor center displays are just some of the possibilities for outreach. The refuge will provide relevant and important information to create a better public understanding of the effects and reasoning behind implementing fuel treatments and the importance of future projects.

## References

Day, R. J.; Harvey, E. M. 1981. Forest dynamics in boreal mixedwood. In: Whitney, R. D.; McClain, K. M., compilers. Boreal mixedwood: Proceedings of a symposium; 1980 September 16-18; Thunder Bay, ON. COJFRC Symp. Proceedings O-P-9. Sault Ste. Marie, ON: Environment Canada, Canadian Forestry Service, Great Lakes Forestry Research Centre: pp 29-41

Gilley, Susan. 1982. The non-game update: the Delmarva fox squirrel; making a comeback?. Virginia Wildlife. 43(12): pp 24-25

Leege, Thomas A. 1979. Effects of repeated prescribed burns on northern Idaho elk browse. Northwest Science. 53(2): pp 107-113

Marquis, David A. 1969. Silvical requirements for natural birch regeneration. In: The birch symposium: Proceedings; 1969 August 19-21; Durham, NH. Res. Pap. NE-146. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station: pp 40-49

Perala, Donald A. 1974. Growth and survival of northern hardwood sprouts after burning. Res. Note NC-176. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station: p 4

Perala, Donald A.; Alm, Alvin A. 1990. Reproductive ecology of birch: a review. Forest Ecology and Management: p 32

A. D. Revill Associates. 1978. Ecological effects of fire and its management in Canada's national parks: a synthesis of the literature. Volume two, annotated bibliography. Ottawa, ON: Parks Canada, National Parks Branch, Natural Resources Division: p 345

Safford, L. O.; Bjorkbom, John C.; Zasada, John C. 1990. Betula papyrifera Marsh. paper birch. In: Burns, Russell M.; Honkala, BarbaraH., technical coordinators. Silvics of North America. Vol. 2. Hardwoods.Agric. Handb. 654. Washington, DC: U.S. Department of Agriculture, Forest Service: pp 158-171

Scott, J.H. and R.E. Burgan. 2005. Standard fire behavior fuel models: A comprehensive set for use with Rothermel's surface fire spread model. USDA Gen. Tech. Rept. RMRS-GTR-153. Fort Collins, CO: pp 72

USFWS. Kenai National Wildlife Refuge, Skilak Wildlife Recreation Area Revised Management Plan. Revised September 2007. Soldotna, AK

USFWS. Kenai National Wildlife Refuge. Skilak Loop Planning Proposal. December 2008. Soldotna, AK: pp 2

Viereck, Leslie A.; Little, Elbert L., Jr. 1972. Alaska trees and shrubs. Agric. Handbook. 410. Washington, DC: U.S. Department of Agriculture, Forest Service: pp 265

Washington State Type 2 IMT. 2015. Card Street Fire AK-KKS-503292. Incident Narrative, June 19 – July 2, 2015. Unpublished report: pp 11

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