AN ASSESSMENT OF ABANDONED RAILROAD GRADES IN RIPARIAN AREAS IN THE UNIVERSITY OF IDAHO EXPERIMENTAL FOREST

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AUTHORIZATION TO SUBMIT

THESIS

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Abstract

Timber harvesting has been occurring in the western United States since European settlers first arrived in the 1880s. In that time, it has been a significant source of disturbance to forest ecosystems. One aspect of this disturbance was the construction of railroad grades to transport harvested timber, which were often built in the riparian areas. My study examined abandoned railroad grades constructed on the University of Idaho Experimental Forest to determine whether there might be any residual disturbance to the riparian areas, as well as examining this disturbance in a historical context. Residual effects of railroad construction and use, in a comparison of graded and ungraded sites, were found throughout the riparian zones examined in my study. Light penetration was higher for ungraded, disturbed sites. Mean diameter at breast height (DBH) was highest on ungraded sites. However, there were no discernable differences in species composition or penetration resistance between graded and ungraded sites. Structurally, however, there were many areas where the railroad grades still existed and restricted the flow of the stream.

Overall, the evidence suggests historic railroad construction and use may still have some effect on the function of the riparian areas. These effects appear to be primarily related to the physical restriction of stream channels and possibly erosion of stream banks. More study will be required to determine specifically how this restriction affects the riparian areas.

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Dedication

To God, without whom I would not have even started this work, let alone finished it. For all of the times I desired to put down this task and run away, it was Him above all others that insisted, in His own gentle yet firm way, that I remain committed to its completion.

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Introduction

Riparian areas are ecologically significant components of forest and rangeland ecosystems. A riparian area is any area influenced by the presence of a body of water, either permanent or ephemeral (Briggs 1996). Riparian areas are dynamic systems influenced by many factors, including allochthonous organic matter, slope, adjacent landform, substrate composition, incident radiation, adjacent vegetation, and sediment input (Fisher 1995). These in turn affect the three primary components of a riparian system: soil (substrate), hydrology, and the riparian vegetation (Fisher 1995). A change in one of these components can cause significant change to the function of the riparian area.

A significant change to any component of an ecosystem is defined as a disturbance. The degree to which a riparian area is affected by disturbance depends on the nature (Rosgen 1994) and the severity of disturbance (Briggs 1996). Although riparian areas can recover relatively quickly from disturbance in some cases, the time of recovery may be extended when they are disturbed by multiple factors over long periods. (Allan and Cushing 2001).

There are many natural disturbances to riparian areas, including landslides, flooding and wildfires (Brooks *et al.* 1993, Cline *et al.* 1981). The size of a stream is a factor in determining which types of disturbance are significant because small riparian systems receive a larger percentage of their organic matter, energy and sediment from allochthonous sources while larger streams do not (Allan and Cushing 2001). This makes landslides and flooding more significant in smaller riparian areas.

Within forest ecosystems of the western United States, many riparian areas contain smaller streams. In these ecosystems, streams serve to raise the water table, provide resources for wildlife, cycle nutrients, and move sediment out of the surrounding landscape (Fisher 1995). For humans, riparian systems can provide clean water, recreation, and increase the aesthetic value of the landscape.

Human activities can disturb forested riparian systems through logging, road construction, and urban development. Logging is a prevalent disturbance in my study area (Harold Osborne, personal communication). Logging involves the removal of overstory vegetation. This can increase runoff into streams due to increased water penetration that otherwise would have been intercepted or transpired by the canopy layer (Stednick 2000). Increased runoff can increase the net sediment load on the system. Sediment load is the net amount of fine mineral material washed into the stream.

Construction of roads and railroads can also cause increased sediment load, as vegetation is removed, soil is disturbed, and stream channels are rerouted or constrained. Also, the continuing presence of roads can cause long-term increases of sediment load (Elliott 2000). The long-term effects of this are mitigated both by a road’s distance from the stream and road surfacing (Kerschbaumsteiner 1997).

Grazing can also be a significant influence on riparian ecosystems. Livestock can cause disturbance by destabilizing streambanks, increasing sediment load and accelerating erosion (Kauffman and Krueger 1984). Defecating in the stream can increase nutrient load, though proper management can help mitigate these effects (Clark 1998). This can include the rotation of livestock from area to area over a year, actual resting of areas every other year, or the construction of fences along riparian areas (Platts and Nelson 1985, Fitch and Adams 1998).

Significant disturbance to forest ecosystems has occurred since Europeans settled in the western United States. The clearing of timber, for both farmland and building materials caused a significant amount of disturbance to forest ecosystems in the Pacific Northwest. Railroads were used extensively to transport timber in the first half of the 20^{th} century. The comparatively gentle slope and flat bottom of the riparian areas were often preferred for the construction of railroad tracks and trails. These railroad tracks were usually temporary, and remained for no more than a year. Once a given area was completely harvested, railroad ties and tracks were removed, but the grades themselves remained. Railroad grades are defined as the flat, roadlike structure left behind when tracks were removed. Railroad grade construction caused disturbance similar to that found in road construction, including removal of vegetation and the restriction or rerouting of the stream channel. Like the disturbance caused by roads, this disturbance may have long lasting effects on the riparian areas.

The University of Idaho Experimental Forest (UIEF), located in Latah County, Idaho (approximately 50 km NE of Moscow, Idaho), can be considered a typical regional forest ecosystem harvested early this century. The 2950 ha forest is currently managed for logging, both for profit and experimental purposes, and grazed on a rest-rotation system (Harold Osborne, personal communication, Edelen 1996). Where possible, roads have been built well above the riparian areas to decrease the erosion impact in the streams (Harold Osborne, personal communication).

Several different levels of disturbance have impacted riparian areas in the UIEF (Edelen 1996). Edelen examined four different types of riparian areas: grazed meadow, grazed forest, grazed/harvested forest, and undisturbed. Of these, the grazed meadow areas were the most disturbed, as indicated by mean water temperature, earlier seral vegetation, more fine sediment deposition, and greater incident solar radiation (Edelen 1996). Based on survey guidelines of the United States Forest Service (USFS) and the Bureau of Land Management (BLM), most of these stream reaches were considered to be moderately or non-functional. Prior to being donated to the University of Idaho in 1933 the UIEF was intensively logged from 1900 to 1928. Like in many areas of the Pacific Northwest, this logging included the construction and use of railroads to transport timber. A few are still in use today, although most have been abandoned since the 1920s (Harold Osborne, personal communication). Although the railroads have been abandoned, study of areas that were developed for railroads may lead to greater understanding of their long-term effects on riparian areas.

The purpose of my study was to examine the effects of railroad grades on the condition of riparian areas in the UIEF. The objectives of my study were to determine the: (1) historical context of railroad grade construction and associated archaeological features, (2) current physical conditions of riparian zones associated with railroad grades, and (3) the possible effects of railroad development on the forest community in riparian zones.

Research Questions

Railroad grades may have the potential for long-term effects on the condition and functioning of riparian areas. The degree of their influence may depend on proximity to the stream and techniques used to construct them.

1. What is the historical context behind the construction of railroad grades? The construction of railroads that occurred in the early days of logging would not occur today. Understanding the historical and economic climate of the time will aid in understanding why the grades were built.

2. How has the penetration of solar radiation into riparian areas been affected by disturbance? Since light penetration depends on the density of the overstory canopy, a difference in tree density may cause a difference in overall light penetration. Light penetration may also depend on aspect, slope of the surrounding terrain, and tree species.

3. Is there variation in soil bulk density on the grade and off the grade? Because construction of the grades caused soil compaction, soil bulk density may be higher on the railroad grades. In particular, grades constructed with fill material may experience greater compaction than those constructed by cutting away the topsoil.

4. Does density, size of trees, or species vary between study sites? Tree density is expected to be higher on sites that have been disturbed by the construction of grades. Density will be highest on areas made up of fill material. Size is expected to be greatest on undisturbed sites due to remnant *Thuja plicata.*

5) Is the riparian area still affected by the railroad grade? Preliminary field observations of vegetation and physical stream characteristics indicated that railroad construction and use in the early 1900s may still influence the riparian areas on the University of Idaho Experimental Forest today.

Methods

Study Site

The study was conducted in two of the four management units of the University of Idaho Experimental Forest (Fig. 1, UIEF, 2950 ha, 46° 47' N Lat, 116° 47' W Long). The UIEF is currently managed for timber harvest, grazing, and research. Until recently, about 70% of the UIEF was actively harvested, while the remainder was set aside for research purposes. However, this management policy may change in the future to increase the areas under active timber management (Ross Appelgren, personal communication). Of the four units, all but the Big Meadow Creek Unit are grazed. Road construction is ongoing in the East Hatter Creek unit and is planned for certain parts of the West Hatter Creek unit to provide access for recent timber sales. Due to the recent flooding of many riparian areas in the Big Meadow Creek Unit, it was not included in this study.

The geology of the region consists primarily of basalt flows up to 1 km thick adjacent to and overlying a granite batholith. The UIEF is made up of ridges consisting of granitic rock types. Soils present in the UIEF come from several sources: weathering of the underlying granite, deposition of windblown silt, and volcanic ash from the eruption of Mount Mazama (Edelen 1996). Soils in my study sites are mapped as Vassar or Crumarine silt loams (Barker 1981), which are Andisols and Entisols, respectively. The Vassar series is classified as an Andisol due to the presence of Mazama ash as a component of the soil. The Crumarine series, classified as an Entisol, consists of granite and loess alluvium and is found in valley floors with gentle slopes (Soil Survey Staff 2004).

The climate for the study areas in the UIEF can be classified as a cool temperate subcontinental forest climate (Morin *et al*. 1993), although Latah County stands on the boundary between the forest and dry steppe classifications. Freezing temperatures are common in the wintertime, while summers are hot and dry (Fig. 2). The mean annual precipitation (MAP) in Potlatch, Idaho is 629 mm, most of which occurs in late fall, winter, and spring (National Climactic Data Center Staff 2001). There is comparatively little precipitation in summer and early fall. The MAP for the UIEF varies due to differences in elevation and specific location.

Vegetation throughout the UIEF varies with slope and aspect, soil type, successional stage, and current management/disturbance regime. Riparian areas in this study have communities mostly consisting of overstory canopy species such as *Thuja plicata* (western red cedar) and *Abies grandis* (grand fir). Understory vegetation is generally sparse, and mostly limited to gaps in the forest overstory.

Streams in the UIEF are generally high gradient, headwater streams that experience peak flows in May and early June. In many cases, the streams are reduced to subterranean flows by August and September. My study examined railroad grades built along headwater streams that have small drainages (200 ha) and narrow riparian areas (5-20 m). Riparian areas in the UIEF are most clearly defined by landscape as visible differences between riparian and upland vegetation are relatively rare.

Site Selection

Eight sites, located along headwater streams in the East and West Hatter Units, were selected for the study, six with evidence of railroad grade construction and two without. These sites represented only those graded sites not significantly disturbed since the 1920 logging period. The study sites ranged from 70-150 m long.

Current Riparian Condition

Eight transects, measured to the width of the riparian area, were set up along each transect to measure tree density, ground cover, photosynthetically active radiation (PAR, 400-700 nm), and resistance to penetration. The transects were perpendicular to the stream channel and evenly spaced throughout the study site (Fig. 3).

The PAR was measured using a quantum sensor (Li-Cor model LI-190SA) at 1-m intervals along each transect (see Fig. 3). Photosynthetically active radiation is a weighted measure that measures that part of solar radiation used by plants for photosynthesis. The quantum sensor was held level at a height of 1 m above the ground at each sample point. Total solar shortwave radiation incident on each study site was estimated using the computer program, *Solar Analyst*, which is an extension of the Geographical Information System program (GIS, Arcview version 3.2, ESRI, Inc.). The estimates were compared with measurements of PAR at each study site.

Any tree with its midpoint within a 3.7-m (12 ft) corridor centered on the transect was noted for species, diameter at breast height (DBH), and location.

Understory species were inventoried and their presence or absence in each study site was noted. Species nomenclature follows that of Hitchcock (Hitchcock 1978).

Soil resistance to penetration, as a proxy for compaction, was measured using a proving ring penetrometer (EBSCO/Soil Test) at 1-m intervals along each transect. Due to a lack of proper calibration, absolute measurements were not available but relative measurements were used. Soil samples were taken from one place along each transect to determine approximate soil moisture. Soil samples were weighed on a scale with 0.1-g accuracy, dried for 24 h at 105°C using a soil oven, and weighed again to determine relative soil moisture.

Geographic Information Systems (GIS)

The program, *Solar Analyst,* was used to estimate solar irradiance at ground level. *Analyst* was used to get a broad idea of potential solar irradiance both in my study sites and throughout the UIEF. These estimates were used for comparison to ground-level PAR measurements. *Solar Analyst* uses geographic data including slope, aspect, latitude, and time of day and year to determine the solar radiation incident on the ground. The data were accurate to a 10-m scale, which means each data point is 100 m^2. Three irradiance estimates were created using *Solar Analyst*: one for the whole day at the summer solstice (June 21, 47°N latitude, total day's radiation); one at the winter solstice (December 21, 47°N latitude, total day's radiation); and one representing the vernal and autumnal equinoxes (March or September 21, 47°N latitude, total day's radiation). The summer solstice overlay was used to compare to on the ground PAR readings.

Results

Cultural and development history

Abies grandis and *Thuja plicata* were the climax species in habitats on the north-facing slopes of Moscow Mountain, while *Pinus ponderosa* dominated the drier areas, especially the drier south-facing slopes. (Chichester 1955). *Pinus ponderosa* forests have decreased in distribution since 1900 (Covington and Moore 1994). Before European settlement of Latah County, the extent of *P. ponderosa* dominated forests was estimated at approximately 887 km^2. By 1999, the area covered by forests of *P. ponderosa* was 101 km^2. Over half the historic range of *Pinus ponderosa* is now agricultural land, with only 73 km^2 covered by some other forest type (Johnson 1999). The reasons for the decline in *P. ponderosa* forests are clearing for agriculture, logging, and a change in fire regime. Other forest types are also listed as having declined due to clearing for agriculture. Within the boundaries of the UIEF, it is likely that logging and changes in fire regime were the principal causes of ecosystem change. There is no evidence to suggest that significant agricultural activity ever occurred within the UIEF.

Pinus monticola has also declined in the last century, initially due to logging and later due to the blister rust fungus that was introduced from Europe in the 1950s. These influences have inhibited any recovery of *P. monticola*, which currently exists at a low frequency in the UIEF.

Logging occurred in the UIEF area between about 1900 and 1928. The oldest trees examined on graded sites were about 70 ±5 years old, which suggests that the study sites were logged between 1920-25. Field observations also suggest that fires occurred post-logging, although this was likely for slash removal and fairly localized in nature.

Evidence of the logging and railroad grade construction still exists in the UIEF. The grades themselves still exist in many cases, although they are occasionally obscured by erosion or sediment deposited during flooding events. Log culverts still exist in some places where the stream was diverted under the railroad. Near the end of the railroad grade, tractor trails often lead up the slope on either side where logs were dragged down to the bottom of the draw and loaded on the railroad cars. In rarer cases, drag tracks were observed leading from individual stumps to either tractor trails or the stream bottom where individual logs were dragged into larger groups (Fig. 4).

Along with the landscape features that remain left behind from the construction of the railroad grades, artifactual evidence was also encountered. In the remains of an old logging camp, one can still find tin cans left over from the camp cooks. On or near the study sites stoves, old cables, brackets to go around logs, and even the remains of an old boot were encountered. This evidence was left in the woods and would bear further examination.

The first permanent settlers appeared in the Palouse Region in the 1870s. Most early settlements were located fairly close to timbered areas due to a need for construction material and a lack of efficient transport. Early uses of timber in the Palouse region included construction material and firewood, though mostly at a subsistence level.

Rivers and the surrounding riparian areas have been an integral part of logging since it began, often providing the primary means of transportation. This meant that areas such as the Palouse, which did not have the easy access to waterways of other parts of the west, were limited by a lack of efficient transportation.

Until about 1900, most logs were moved using horses or by water during the spring, when rivers experienced peak flows (Barton 1980). Around 1900, railroads extended into the Palouse region and provided a better mode of transportation. Tracks were often extended as close to the harvest point as possible to provide an easier means of moving logs. Riparian areas provided a good place to build in hillier country. Either horses or tractors were used to move logs from the point of harvest to the loading point (Fig. 4).

Once railroads existed in the Palouse, timber companies were quickly established. The Weyerhauser Company purchased about 360,000 ha (900,000 acres) of land in the region in 1900 (Petersen 1987). In the immediate vicinity, one of the earlier companies to appear was the Potlatch Lumber Company. This was the same company that donated the land to the UIEF in 1933.

Historic Riparian Condition

There is little information regarding the historic condition of riparian areas in Latah County. In lower areas, they were probably wider and meandered much more than today. Closer to the Palouse Range, meandering and size of the riparian areas was often limited by the landscape itself.

The streams served to float timber downstream. Once railroads reached Latah County, many riparian areas were used for their construction due to gentler grades. This construction resulted in rerouting of the stream, removal of stream vegetation, and increased siltation in the stream system caused by construction itself and areas of the banks that might have become destabilized due to removal of vegetation. The precise severity of the disturbance is impossible to ascertain given the length of time since the disturbance as well as the lack of baseline data.

Soils

Relative penetrometer readings ranged from 5 to 75, and were variable over any given transect. For purposes of comparison, the mean value of one of the two undisturbed sites was set to zero and the other seven were adjusted accordingly (Table 1). Adjusted means ranged from –10 ±1 at the East Hatter Tributary site to 7 ±3 for Long Creek and 7 ±4 for Trailer Creek. Three sites show > 0 adjusted means, while four are < 0. Graded sites had significantly ($p < 0.5$) higher values on the grade than off when site means were compared. Three sites, East Hatter Tributary, Middle Creek East Fork Upper, and Trailer Creek, had significantly ($p < 0.05$) higher values on the grade than off for each transect. No association was found between soil data and either PAR or tree data.

Topography

All study sites were on the north side of Moscow Mountain. Five stream sites (Trailer Creek, Long Creek Tributary, and the three sites on Middle Creek) flowed northward, while the two sites on a tributary of West Hatter Creek flowed northeast and the East Hatter Tributary flowed northwest. Slopes for the sampled sites ranged from 8% to 12%. The steepest slopes occurred in the Middle Creek West Fork site, which had no railroad grade. All sites generally had a north aspect with moderate gradient. Four of the six sites that have *Thuja plicata* as the most abundant species were north-flowing streams.

Water

Both the Middle Creek West Fork and Long Creek Tributary sites experienced aboveground flows only in late spring. The West Hatter Creek was dry by mid-summer, while East Hatter Tributary, Trailer Creek, and Middle Creek East Fork experienced limited aboveground flow into late August. All streams are shaded and flow in a substrate of gravel and silt. West Hatter Tributary is the only stream where boulders are present in the stream channel. All streams have large inputs of allocthonous organic material. Long Creek Tributary, which appears to have the least aboveground flow, had leaf litter in the stream channel. Both Trailer Creek and East Hatter Tributary sites experienced clear cuts near the study site in fall and winter 2001.

Streams flowing in all eight study sites are highly restricted by landform. In those with grades, movement of the stream channel still appeared to be restricted by the presence of the grade. This is most notable in the east fork of Middle Creek, Long Creek Tributary, and East Hatter Tributary.

Tree Species

Seven tree species were found in the eight study sites: *Abies grandis, Larix occidentalis, Pseudotsuga menziesii, Pinus contorta, Pinus monticola, Pinus ponderosa, and Thuja plicata* (Table 2). Of the total trees counted, 24% were *Abies* and 70% were *Thuja.* Of the other five species, *Pseudotsuga menziesii* and *Pinus contorta* comprise about 2% each. Of the eight study sites, only two have *Abies* as the dominant species. There was no apparent difference between graded and non-graded sites in tree species (Table 3).

The only remnant trees found in any study sites were *Thuja,* found in the Middle Creek West Fork site. Because the middle of the trunks of *T. plicata* tend to rot at older age, thereby making these trees unsuitable for harvest, trees of *T. plicata* of harvestable size in 1920 were often left standing.

Tree Density and DBH

Tree density ranged from 0.08 to 0.3 trees m^{-2}. Mean density per study site was lowest on average in study sites with no evidence of grade construction. Tree density and mean DBH per study site are closely associated. Trees range in size from 10 mm to over 500 mm DBH on some remnant *Thuja*. Average DBH per study site is between 87 and 248 mm and is greatest on sites without evidence of grading. Mean DBH is highest in the Middle Creek West Fork site, due to the presence of remnant cedars.

Light penetration

In open areas, PAR was about 2000 μmol m^{-2} s^{-1}. The Long Creek Tributary site had the greatest mean PAR at 189 μmol m^{-2} s^{-1} (Table 3 and Fig. 5). The Middle Creek West Fork site, the least disturbed site, had a mean PAR of 62 μmol m^{-2} s^{-1} (Fig. 6). The highest individual transect mean was 344 μmol m^{-2} s^{-1} on the first transect of the Long Creek site. Ten transects (out of 63) in five different study sites had a mean of zero. Mean PAR for graded sites was 51 μmol m^{-2} s^{-1}, compared to 75.2 μmol m^{-2} s^{-1} for non-graded sites. Among graded sites, mean PAR differed significantly ($p < 0.05$) per site. However, when mean PAR values along each transect were evaluated within each site, there was no significant ($p < 0.05$) difference in PAR between railroad grades and the adjacent riparian zones. There was some relationship between PAR and tree species.

GIS

The Solar Analyst models predicted more solar radiation incident during the summer solstice. The winter overlay predicted the lowest radiation levels, with the equinox falling in the middle. All sites are similar in aspect, with all eight study sites at a northerly aspect. All study sites have slopes between 8 and 12%. The models predicted south facing slopes receiving higher irradiance than more north facing slopes, though this difference was most pronounced in the winter model. The East Hatter Tributary site and Middle Creek West Fork sites, with greater slope, displayed the least level of irradiance. The two West Hatter Tributary sites, both graded and non-graded, displayed the highest level of irradiance. These two sites were not on a north aspect (Fig. 7 and Fig. 8). All sites were located in moderate irradiance zones. Summer model irradiance levels range from 30 to 60 kW m^{-2} for total daily irradiance on the summer solstice overlay, with study sites averaging between 40 and 45 kW m^{-2} total daily irradiance. Predicted irradiance levels did not show any direct relationship with PAR data.

Discussion

History

The logging industry today is concerned with sustainability. This was not the case in the past. Not only were forests held to be an inexhaustible resource, but the trees themselves were not seen as having high value (Lucia 1975). Moving logs out of hilly terrain using the railroads was also dangerous (Lucia 1975). Injuries were fairly common and deaths, though rare, were an accepted part of the job. And, though building railroads into hilly terrain such as that around Moscow Mountain was the most economic way to move logs at the time, it was still an expensive proposition, both in monetary and human terms (Adams 1961).

It is tempting to draw certain conclusions about why the railroads were built and why they are no longer there. While it is true that the understanding of how logging practices affect the environment has changed, improved technology and techniques have rendered such practices obsolete regardless of their ecological impact.

Soils

Soil penetration resistance does not appear to be different between graded areas and non-graded ones. The difference in penetration resistance on and off the grade found in three sites may suggest some residual disturbance, but more data, as well as proper calibration to provide absolute values, is needed to determine this for sure.

Studies suggest that soil compaction is a factor in the survivability of tree seedlings in that it limits root penetration (Kormanik *et al.* 1998, Walkinshaw and Tiarks 1998). My observations suggest that there was some association between tree and grade location, but the data collected were insufficient to support this.

Topography

Topography appeared to be an important consideration in regard to where grades were placed. The lack of evidence of railroad grade construction in riparian areas with higher gradients suggests that few, if any, were built there. It was probably less expensive to move trees down slope using tractors or teams of horses than to build the tracks up the steeper slopes.

The reason for a larger amount of *Thuja* on more northerly aspects is most likely due to a greater amount of moisture and cooler temperatures (Arno 1977).

Water

While some streams in the UIEF may always be intermittent, lower than usual flows in larger streams may have been a result of drought. Recorded precipitation for 2001 for Potlatch, Idaho, was 469 mm; significantly lower than the 629 mm mean annual precipitation. (National Climactic Data Center Staff 2001).

During the construction of railroad grades, the stream was often rerouted to a new channel to make placement of the grade easier. In many cases this configuration of stream channel and grade are still relatively intact.

Tree Species, Size and Density

The observed dominance of *Thuja* and *Abies* may result from fire suppression and the particular microclimate within the riparian area (especially moisture and temperature). *Abies* is less fire resistant than *Pinus ponderosa* and *Larix occidentalis* (Flanagan 1996) as well as being easily killed by fire when young (Johnson 1998). This suggests that *Abies* would be favored by fire suppression. In the Long Creek site, which had the highest mean PAR, there was no *Thuja* found.

The disturbance caused by the construction of railroad grades may have promoted recruitment, especially in areas consisting of fill material, but there is no significant difference between densities found on and off the grade (Research Question 1). Over time, competition between trees slowed growth and resulted in denser stands of smaller trees.

Light Penetration

The data collected suggests that there may be a difference in light penetration between areas with railroad grades and those without. Mean PAR was greater in ungraded sites than graded sites; but the variation among study sites was too great to detect a significant difference in PAR between graded and ungraded sites. In a closed canopy environment, most light penetration was through small breaks in the forest canopy, which resulted in large areas with little or no PAR penetration. Some break the type of light penetration in a forest into four categories: forest shade, woodland shade, large gaps, and small gaps (Endler 1993). The understory environment in this study can be characterized by small gaps and forest shade.

Definitions of gaps vary, but small gaps can range in size from sunflecks to openings created by treefall (Brokaw 1982). Understory vegetation only grows in abundance where there are significant gaps in the forest canopy. This suggests that light may be the limiting factor determining growth for understory species. This is not necessarily true for all forest canopy environments (Collins and Pickett 1988, Adams and Schulz 1995).

Light penetration did vary among study sites. Mean PAR per study site differed tenfold between the highest and lowest study site means. All study sites were north-facing sites; and the two northwest-facing sites with did not have mean PAR greater than any of the other sites.

Light Penetration and GIS

The lack of relationship between PAR and predicted incident solar radiation can be explained by the fact that *Solar Analyst* does not account for vegetation in its computations. It is clear that the overstory was a large factor in determining the amount of solar radiation incident on the ground in all study sites. Also, *Solar Analyst* models for all incident solar radiation, whereas a quantum sensor measures only PAR, which weights quanta in solar radiation by their effect on photosynthesis. This coupled with the overstory factor makes it difficult to make any comparisons between the GIS and PAR data.

While *Solar Analyst* was of some use in predicting incident solar radiation in the study sites, it would be of greater use in open terrain. It might be used with greater effect when examining the effects of clear cutting on previously forested areas, allowing the land manager to predict the increase in irradiance levels before the area was cut. This would be especially useful in considering the possible effects of cutting on sensitive riparian areas.

Long-Term Effects

Are there any residual effects of the railroad grades on riparian areas? The fact that the grades still exist in many areas suggests that there must be some effect. In most riparian areas with railroad grades, vegetation present appears to provide sufficient shade, stability, and a source of coarse woody debris. Coarse woody debris (CWD) refers to dead woody debris that has fallen into the stream from the surrounding landscape. Any lack of vegetation present in the riparian area does not appear to have any direct connection to the construction of the railroad grade. Many grades have been used to drag logs harvested in the 1950s and 1960s (Harold Osborne, personal communication). This would have caused severe disturbance to any small trees growing in the grade itself. The study sites do not have any evidence of such disturbance, but any increased use of the grades for travel might have resulted in lower seedling survival.

The effects of grades on the riparian area were physical. In some areas, the stream was still restricted to the same channel it had when the grade was constructed. In other cases, rechannelling of the stream has resulted in erosion. Due to other sources of sediment input (roads and logging) it may not be possible to detect how much erosion is a result of railroad grade construction.

Conclusions

Restoration and Recovery

The idea of environmental restoration is a new and popular trend because many areas have been disturbed by human activities. There are two ways that this can happen: active restoration through human intervention; and passive restoration that proceeds without any human intervention. Both approaches have advantages.

On the UIEF, there are several techniques of restoration in use that fall into both categories. Replanting is an active technique that generally occurs in clear cuts and sometimes when seed trees are left behind. In seed tree cuts or other more selective techniques, passive restoration is more common. Controlled fire is also used, both for slash removal and in an attempt to encourage regrowth of *P. ponderosa*.

In the case of the graded areas, any recovery that occurred appears to be natural. There is no evidence to suggest that any replanting occurred on any of the study sites. While the actual rails and ties were removed from the grades when logging was finished in a given area, no attempt was made to remove the grade or rechannelize the stream to a more natural course.

It is clear that the landscape has recovered to a large degree. In some cases, grades were used in the 1950s and 1960s to drag logs out with trucks. This caused further disturbance, but not to the extent that occurred in the 1920s. Even in areas where this did not occur, the area is still affected by other, non-direct forms of disturbance. Overall, though, the riparian areas have been left alone since the tracks were pulled out. The relatively dense forest canopy on all study sites indicated that a fairly complete restoration of the vegetative component of these disturbed sites has occurred. Physically, recovery is more sporadic and will probably take much longer.

Would active restoration aid in restoring the streams to a more natural course? Had it happened immediately after the abandoning of the railroad grades, a fully restored riparian ecosystem would probably have been possible. A program of active restoration seventy years after the construction of grades would be less likely to result in a pre-construction ecosystem. Removal of grades and rechanneling of streams would require removal of trees growing where the new stream channel would be installed. The need to restore the course of the stream should be weighed against the negative effect of removing the overstory. Further investigation needs to occur to determine the necessity of this. Given that the UIEF is a working forest, removal of overstory might not be difficult to achieve.

Further Research

This study has established a baseline, but further research is needed to determine more specifically what effects the grades still have. Based on results obtained, two main areas of interest can be suggested. The first would be the stream itself. While the riparian area was examined, little information was obtained from the stream. Closer surveys of sediment, flow rates, and macroflora and fauna found in the stream might help delineate whether there is any difference in stream condition between sites. The second area would be history. There is a large amount of archaeological data that could lead to a fuller understanding of logging practices in this area.

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Table 1. Mean relative soil compaction data for the eight study sites. Relative penetrometer readings provide a comparison between study sites. A penetrometer measures the force necessary to push a tipped pole into the soil a set distance. Penetrometer readings serve as a proxy for soil density. Mean force used was set to zero for the most undisturbed study site and compared to results for the other seven study sites. Sites marked with a superscript "1" have evidence of grade construction; sites with a "2" do not. The location of each study site is noted in UTM (Universal Transverse Mercator) coordinates.

	Relative penetrometer reading	**UTM Coordinates**	
Study site		X	Y
Long Creek Tributary[1]	7 ±3	512798	5187532
Trailer Creek[1]	7 ±4	514851	5186387
East Hatter Tributary[1]	-10 ±1	516008	5186614
Middle Creek West[2]	0 ±1	515243	5186234
West Hatter - Ungraded[2]	-3 ±1	512556	5186742
West Hatter – Graded[1]	-3 ±3	512317	5186687
Middle Creek East Upper[1]	-8 ±1	515267	5186344
Middle Creek East Lower[1]	-7 ±1	515310	5186240

Table 2. A sample of overstory and understory species present in the eight study sites. Overstory species were inventoried along a 3.7-m corridor centered along each transect while understory species were inventoried in the entire study site. Overstory species are recorded by number found per study site while presence of understory species is noted with an x. Sites marked with a "1" have evidence of grade construction; sites with a "2" do not.

Species	**Study Sites**							
	East Hatter 1	Middle Creek East Lower 1	Middle Creek East Upper 1	Middle Creek West 2	Trailer Creek 1	Long Creek 1	West Hatter Un-Graded 2	West Hatter Graded 1
Overstory*								
Abies grandis	4	26	2	13	17	26	16	8
Larix occidentalis					2	1		1
Pinus monticola					1			
Pinus contorta					1	3	2	2
Pinus ponderosa					1	4		
Pseudotsuga menziesii	2	1			3			1
Thuja plicata	73	80	65	28	58		3	19
Understory**								
Amelanchier alnifolia						x	x	
Arnica cordifolia	x	x	x	x	x	x	x	x
Athyrium felix femina	x	x	x		x		x	x
Acer glabrum	x				x		x	
Actaea rubra							x	
Cornus canadensis	x	x	x	x	x	x	x	x
Carex spp.					x			
Fragaria vesca				x				
Gymnocarpium dryopteris		x	x	x	x		x	
Lathyrus spp.				x				
Physocarpus malvaceus						x	x	
Polystichum munitum							x	
Prunus spp.							x	
Rosa nutkana	x	x	x	x	x	x	x	
Symphorocarpus albus		x	x		x	x	x	
Smilocina racemosa	x	x	x	x	x	x	x	
Trillium ovatum	x	x	x	x	x	x	x	
Veratrum caudatum	x	x		x				

Table 3. Summary light and tree statistics for the eight study sites. A quantum sensor was used to measure the μmol $m^{-2} s^{-1}$ quanta of PAR penetrating the forest canopy. Higher percentages of *Thuja* seem to coincide with lower quantum sensor readings. The PAR is highly variable, as light penetration is largely dependent on gaps in the canopy. The diameter at breast height (DBH) measurements are highest in the study site with residual old growth *Thuja.* The light and DBH readings represent the mean per study site ±1SE of the mean. Sites marked with a superscript "1" have evidence of grade construction; sites with a "2" do not. The location of each study site is noted in UTM (Universal Transverse Mercator) coordinates.

	PAR (μmol $m^{-2} s^{-1}$)	**DBH (mm)**	**Species (% Per Site)**		**UTM Coordinates**	
	Mean ±1 SE	Mean ±1 SE	*Abies grandis*	*Thuja plicata*	*X*	*Y*
Long Creek Tributary[1]	189 ±41	176 ±18	76	0	512798	5187532
Trailer Creek[1]	42 ±12	141 ±21	20	69	514851	5186387
East Hatter Tributary[1]	20 ±12	99 ±14	5	92	516008	5186614
Middle Creek West[2]	62 ±23	250 ±63	31	68	515243	5186234
West Hatter Ungraded[2]	75 ±27	155 ±41	76	14	512556	5186742
West Hatter Graded[1]	38 ±15	248 ±31	25	61	512317	5186687
Middle Creek East Lower[1]	28 ±12	87 ±10	24	74	515267	5186344
Middle Creek East Upper[1]	40 ±27	113 ±15	3	97	515310	5186240

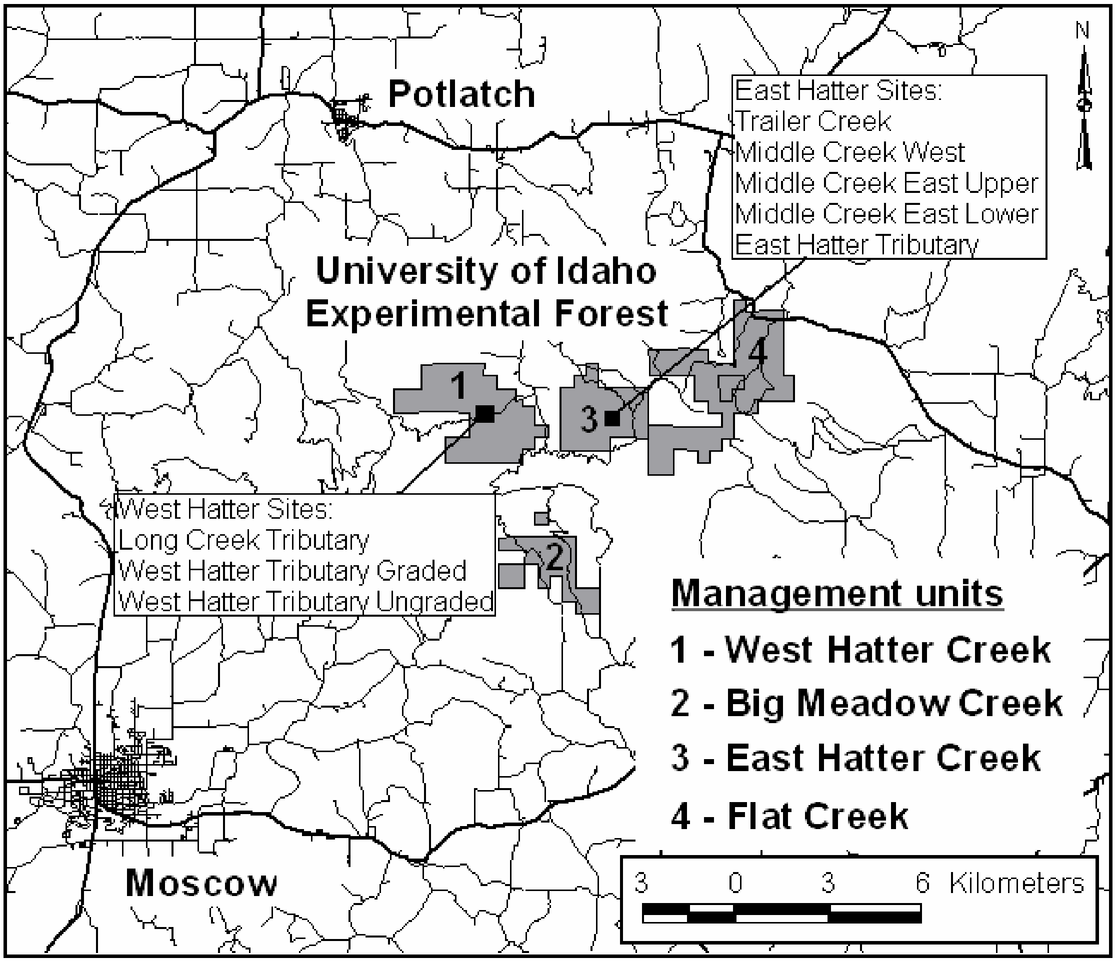


Figure 1. The University of Idaho Experimental Forest (UIEF), located 50 km northeast of Moscow, Idaho, with four management units. The UIEF is comprised of 2950 ha and is managed for multiple use, including timber harvesting, grazing, research, education, and conservation.

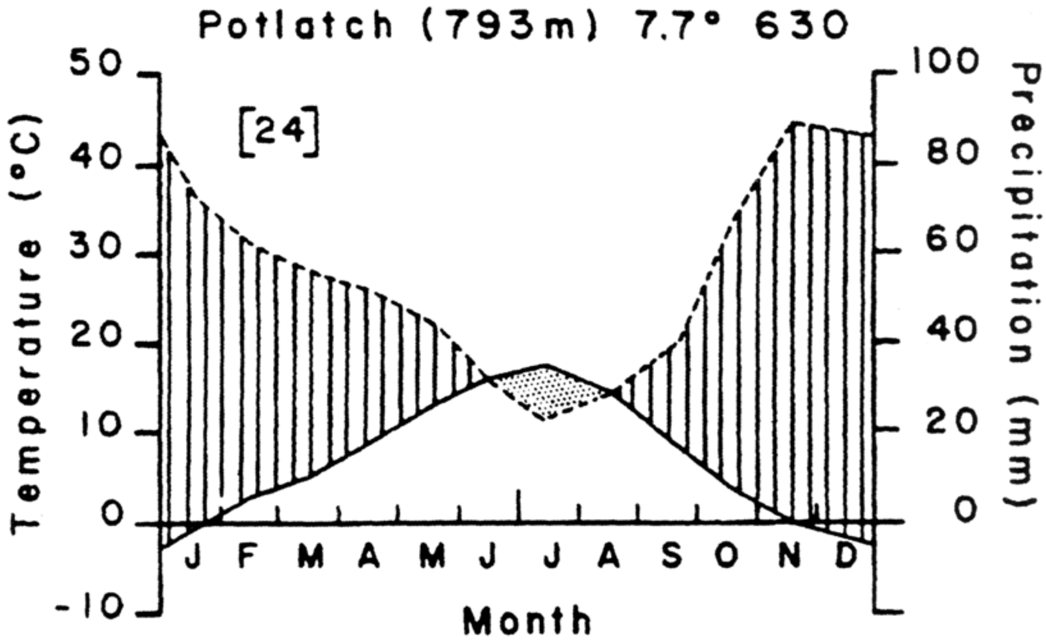


Figure 2. A climate diagram, in the format of Walter and Lieth (Walter and Lieth 1967), of Potlatch, Idaho, located approximately 8 km north of the University of Idaho Experimental Forest (Kolb 1995). Temperature (°C) is represented by the solid line, precipitation (mm) by the dashed line. Where the precipitation is above the temperature, it is considered a humid period for plant growth (vertical lines), the opposite represents water deficit (stippled region). The streams in my study sites are generally reduced to subterranean flows by the end of the deficit period.

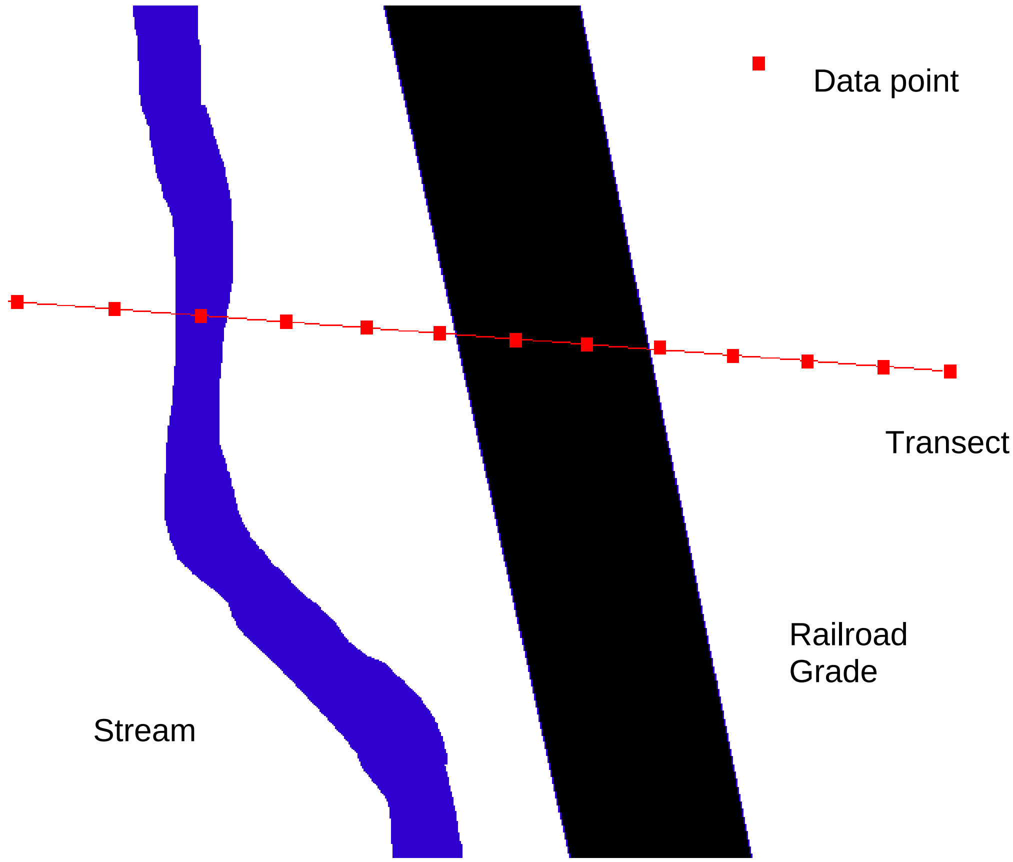


Figure 3. Diagram of transect set up for all eight study sites. The transect extended the width of the riparian area, between 5 to 20 m. Points are set up at 1-m intervals along transects perpendicular to the stream channel. Data collection points were the same for both penetrometer and quantum sensor readings. There were eight transects per study site set set equadistant from each other.

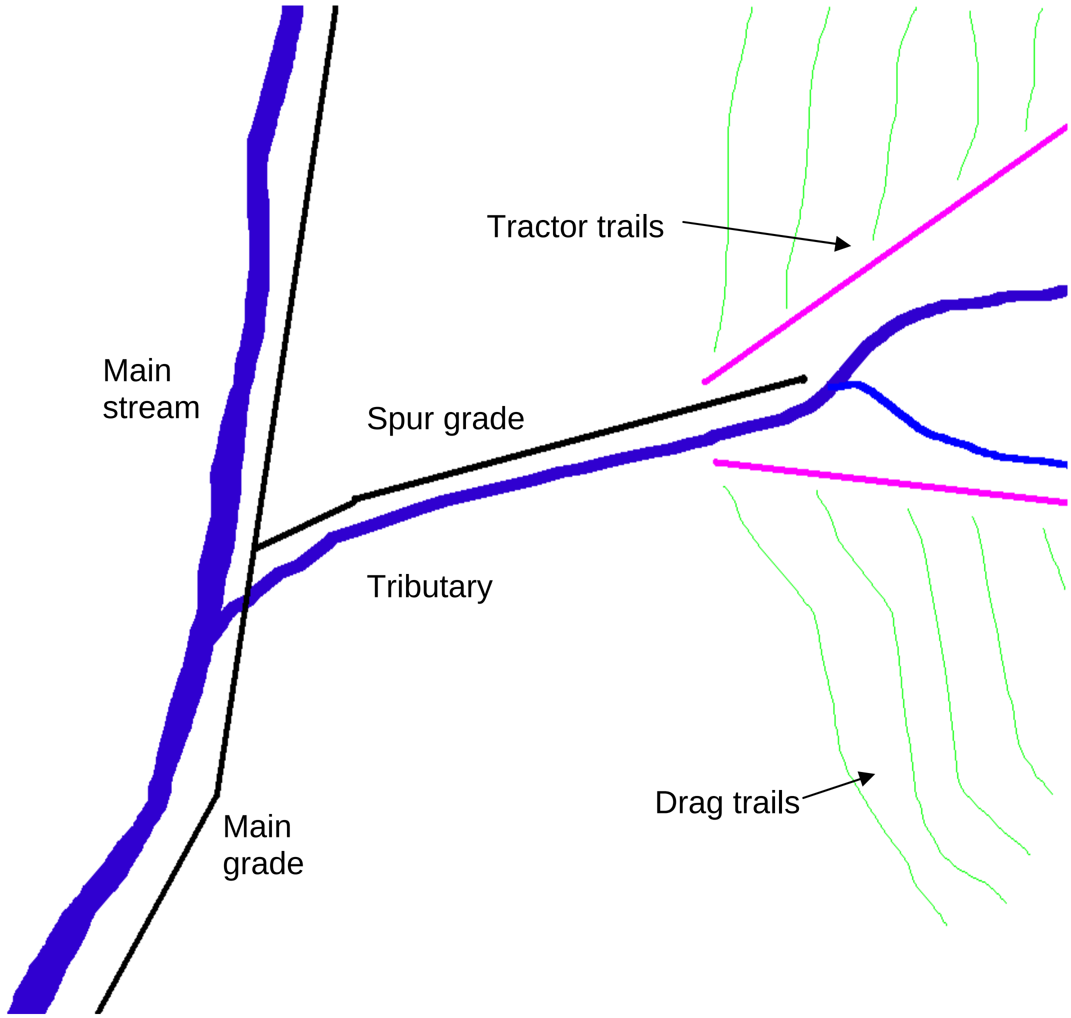


Figure 4: Diagram of surface earthwork features found on the UIEF relating to railroad grades. The spur railroad grade is a temporary grade built to move logs out of a given drainage to the main railroad grade. Tractor trails were used by tractors or possibly horse teams to move logs down slope to rail cars. Drag trails were created by dragging logs to the tractor or horse team from the harvest point.

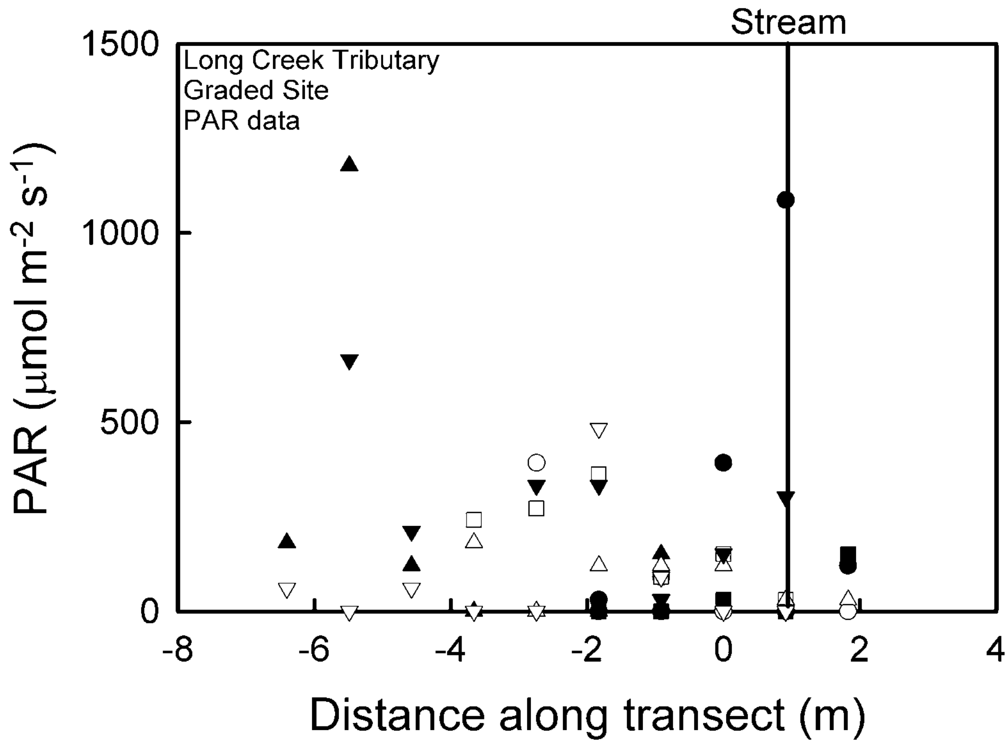


Figure 5. Photosynthetically active radiation data collected for the Long Creek Tributary Site. The different shaped symbols represent data collected along different transects. The Long Creek site had the highest mean PAR in the project. While PAR values are relatively low, there are a significant number of points above zero reflecting a canopy which was much more open. The dominant tree species encountered at the Long Creek site was *Abies grandis.*

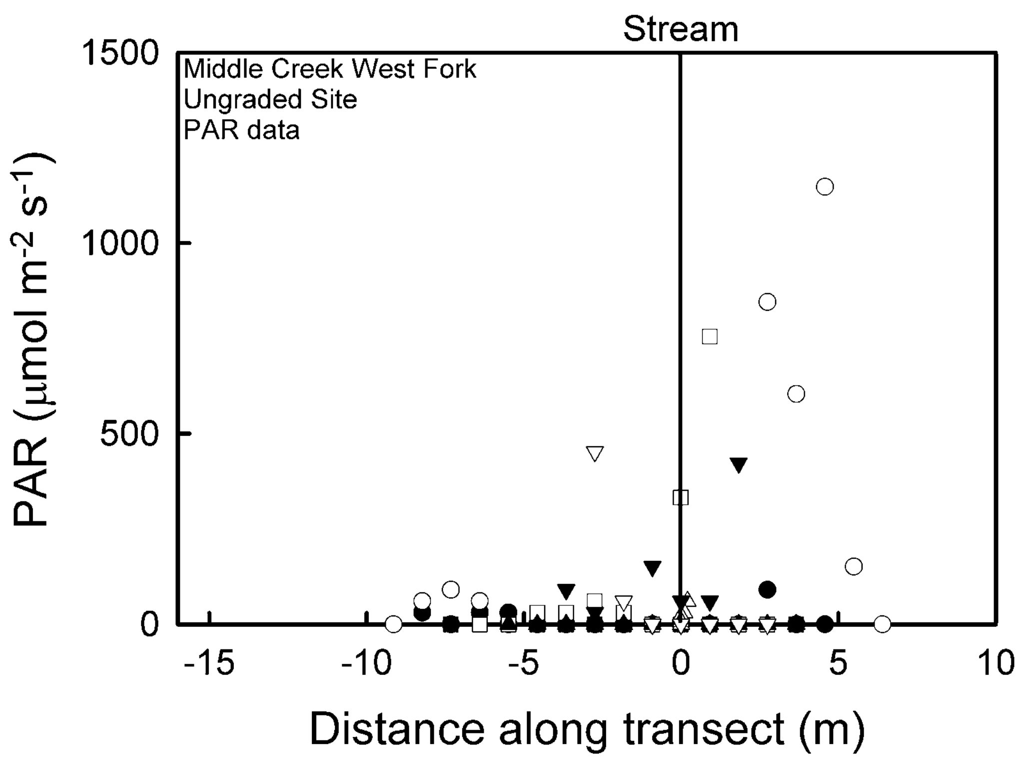


Figure 6. Photosynthetically active radiation data collected for Middle Creek West Fork Site. The different shaped symbols represent data collected along different transects. The Middle Creek West Fork site was ungraded and contained the largest diameter trees measured in the project. Most of the data points are either at or near zero, with very little PAR reaching the understory. The dominant tree species found at the Middle Creek West site was *Thuja plicata*.

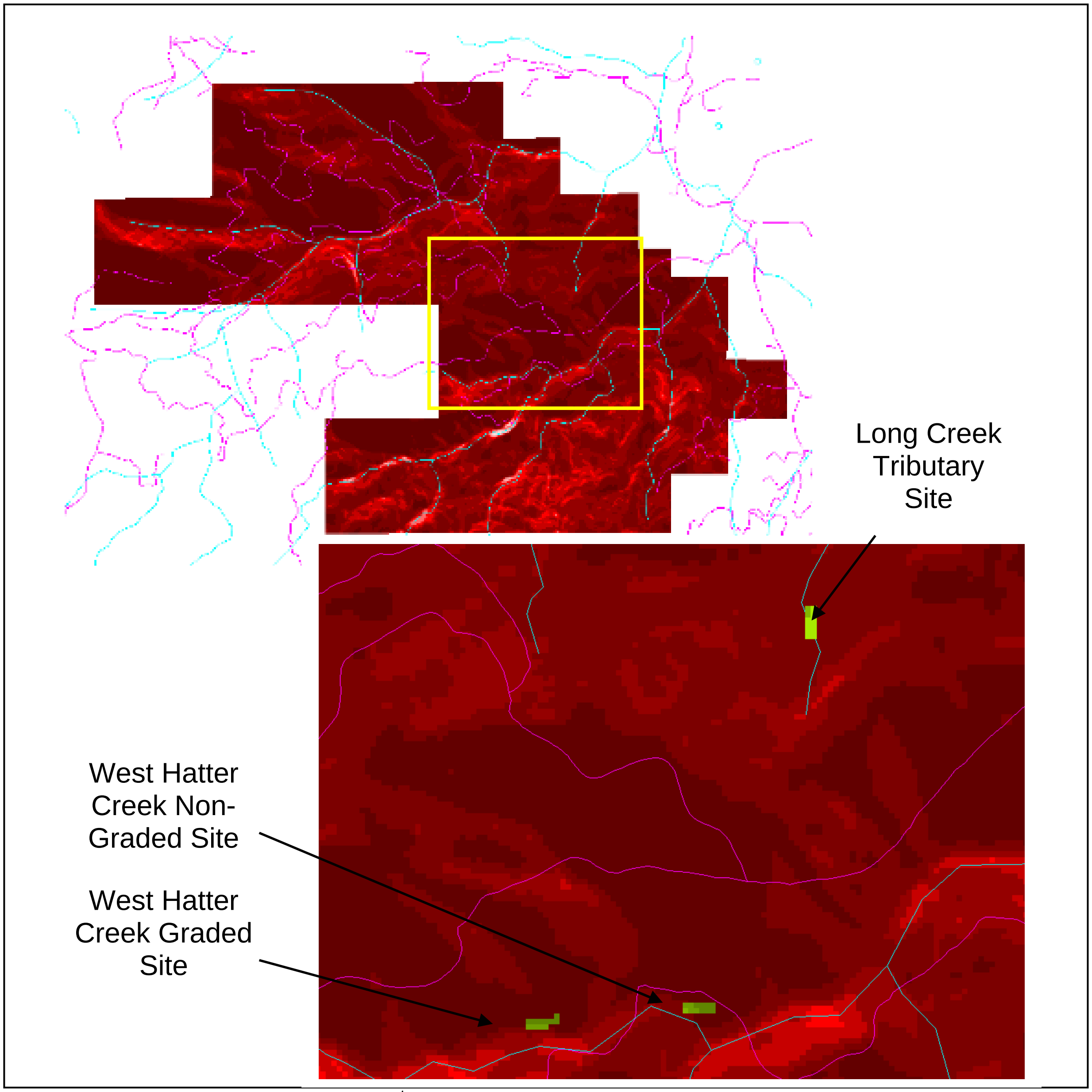
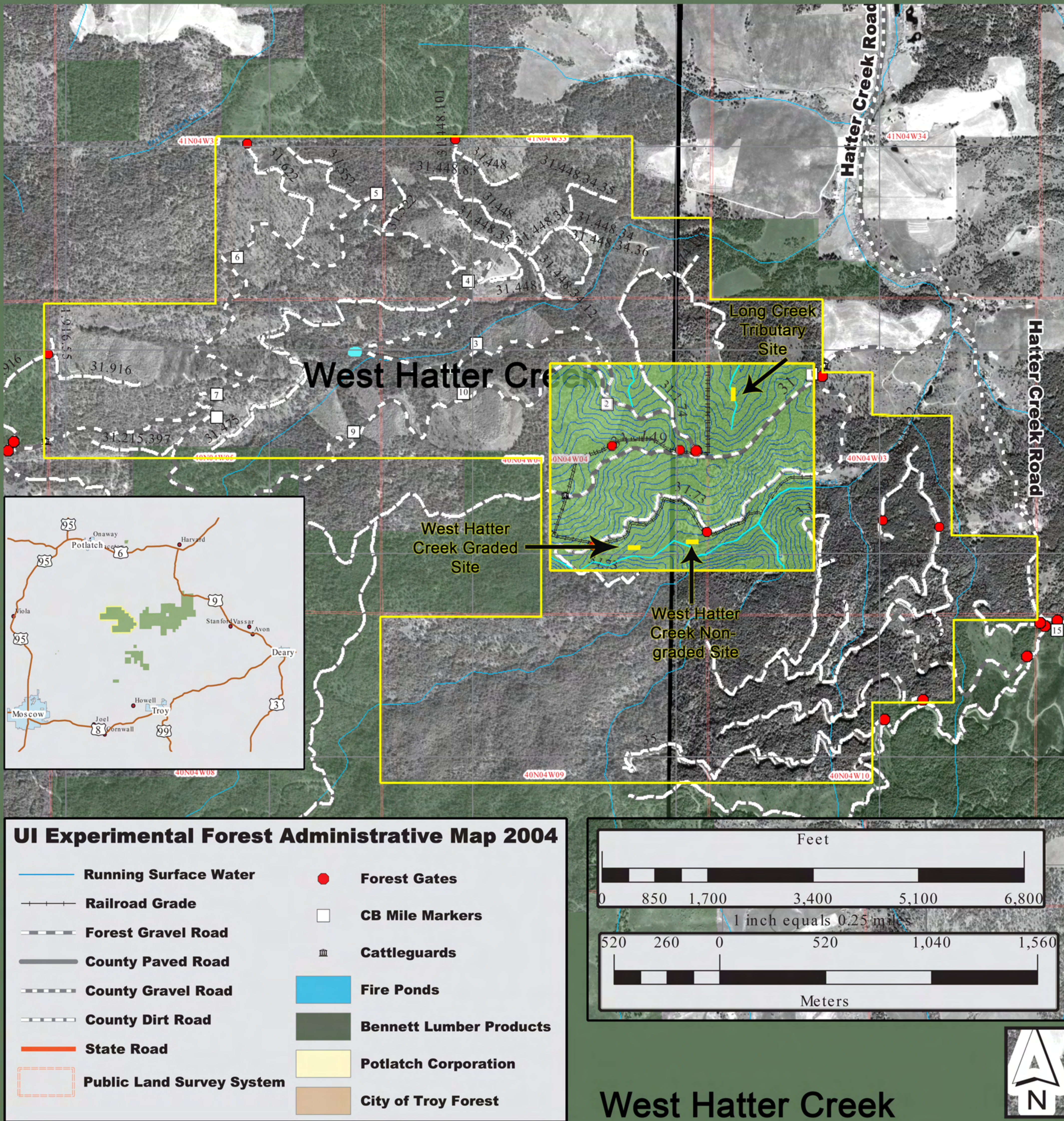


Figure 7. Diagram of June 21st *Solar Analyst* model illustrating potential incident solar radiation on study sites in the West Hatter Creek area. The yellow rectangle is the enlarged area. Darker color represents more sunlight. Pink lines represent roads, blue represent streams, and the green sections are locations of the study areas. East-west facing riparian areas lie on a distinct border between light and dark areas. The two west-hatter sites are the only ones facing primarily east-west.


West Hatter Creek
Hatter Creek Road
Long Creek Tributary Site
West Hatter Creek Graded Site
West Hatter Creek Non-graded Site
Onaway
Potlatch
Harvard
Viola
Stanford
Vassar
Avon
Deary
Moscow
Howell
Troy
Joel
Cornwall
UI Experimental Forest Administrative Map 2004
Running Surface Water
Railroad Grade
Forest Gravel Road
County Paved Road
County Gravel Road
County Dirt Road
State Road
Public Land Survey System
Forest Gates
CB Mile Markers
Cattleguards
Fire Ponds
Bennett Lumber Products
Potlatch Corporation
City of Troy Forest
Feet
0 850 1,700 3,400 5,100 6,800
1 inch equals 0.25 miles
520 260 0 520 1,040 1,560
Meters
N
West Hatter Creek

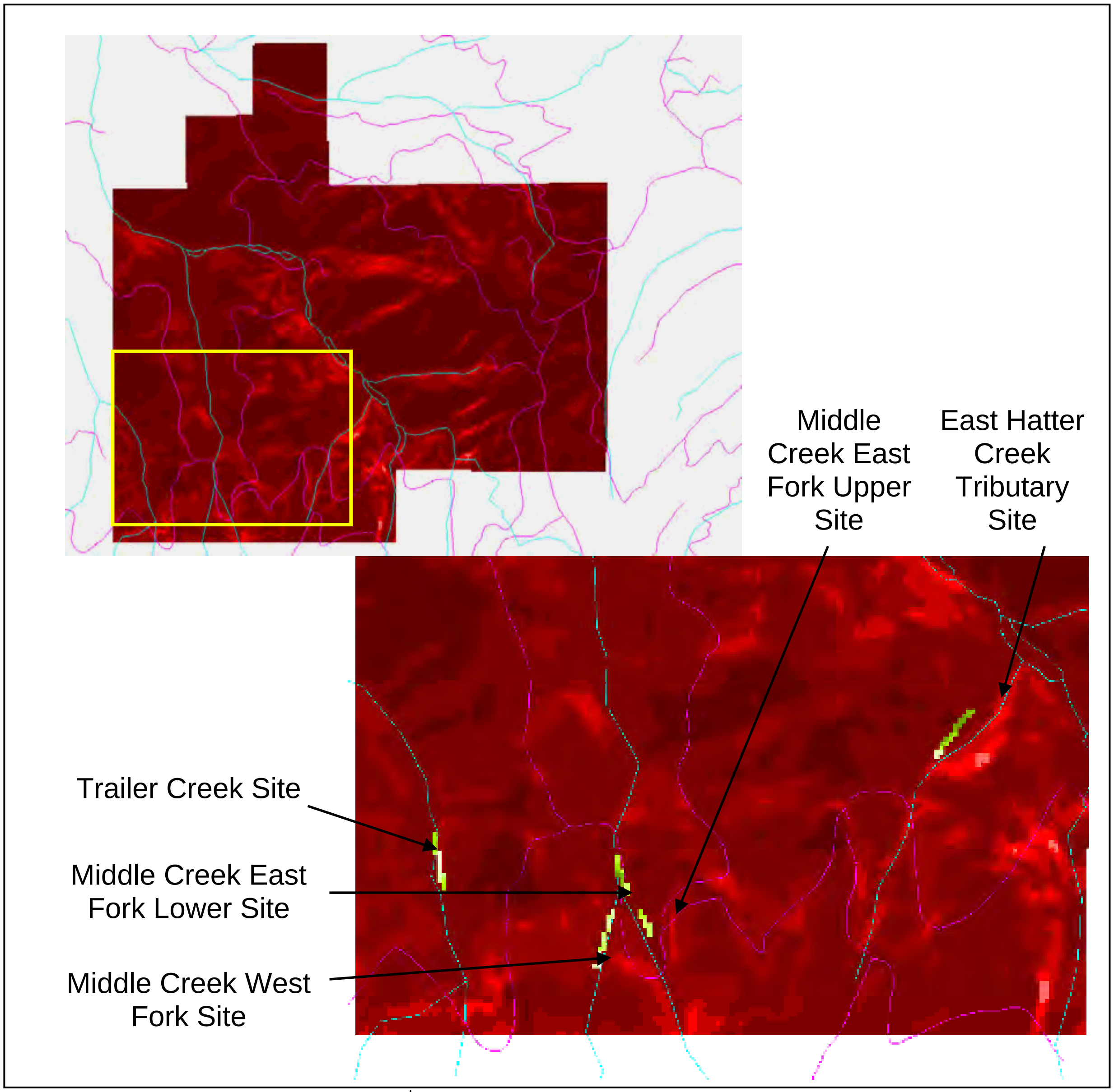
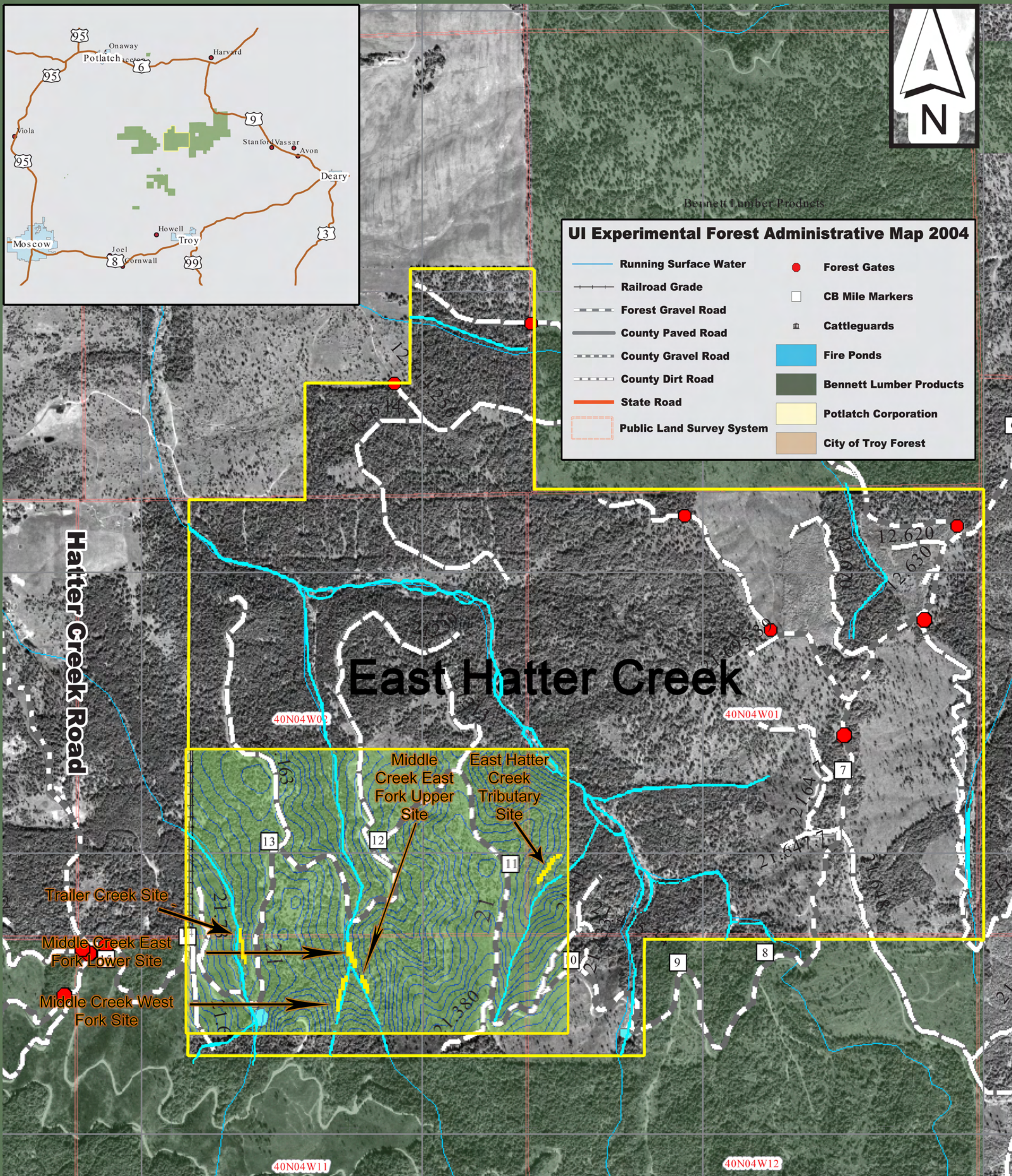
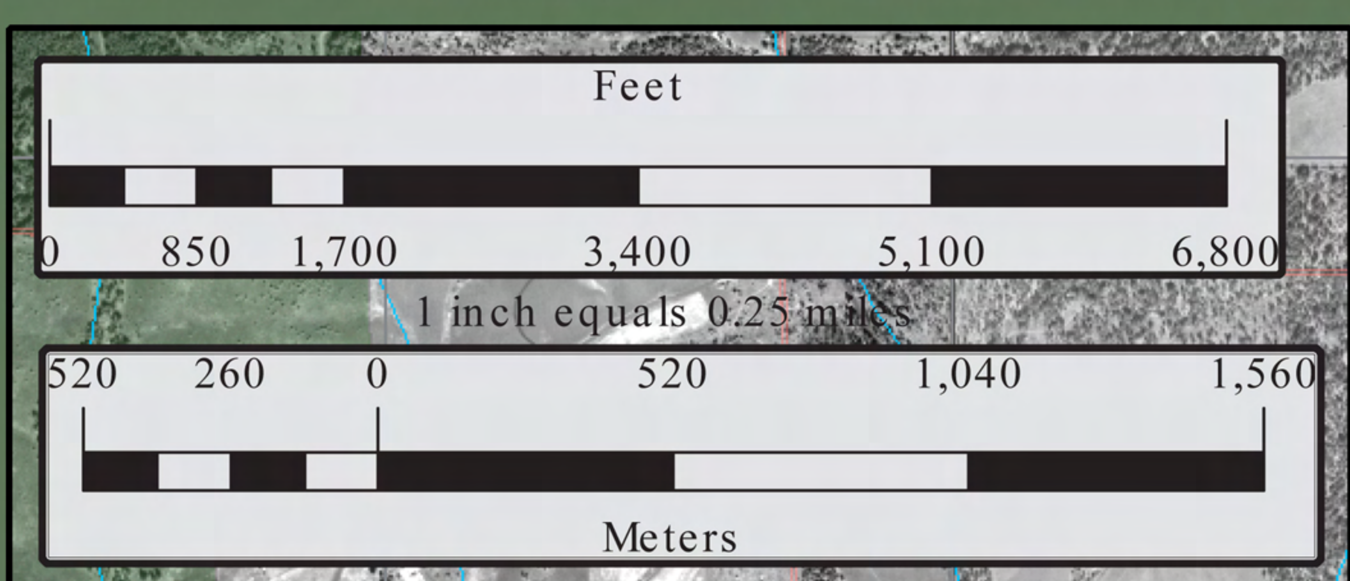


Figure 8. Diagram of June 21st *Solar Analyst* model illustrating potential incident solar radiation on study sites in the East Hatter Creek area. The yellow rectangle is the enlarged area. Darker color represents more sunlight. Pink lines represent roads, blue represent streams, and the green sections are locations of the study areas. All study sites in the East Hatter Creek area are located in areas of moderate incident solar radiation.





East Hatter Creek

PICTURES FOLDER 1






Pictures Folder 2

P1






Pictures Folder 2

P2






Pictures Folder 2

P3






Pictures Folder 2

P4






Pictures Folder 2

P5





Pictures Folder 2

P6

Pictures -Set 1

P1






PICTURES -SET 1

P2






PICTURES -SET 1

P3

PICTURES -SET 1

P4





Pictures -Set 1






PICTURES -SET 2

CAMP ONE

PI

PICTURES -SET 2

CAMP ONE






PICTURES -SET 2

CAMP ONE

PICTURES -SET 2

CAMP ONE






PICTURES -SET 2

CAMP ONE

PICTURES -SET 2

CAMP ONE

MIDDLE CREEK EAST FORK UPPER SITE

P1






Pictures -McEfuss

P2






Pictures -McEfuss

P3






PICTURES -MCEFUSS






Pictures -McEfuss






PICTURES -MCEFUSS





Pictures -McEfuss

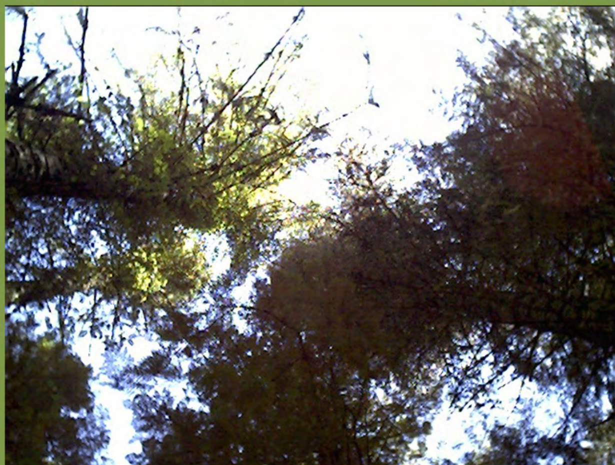


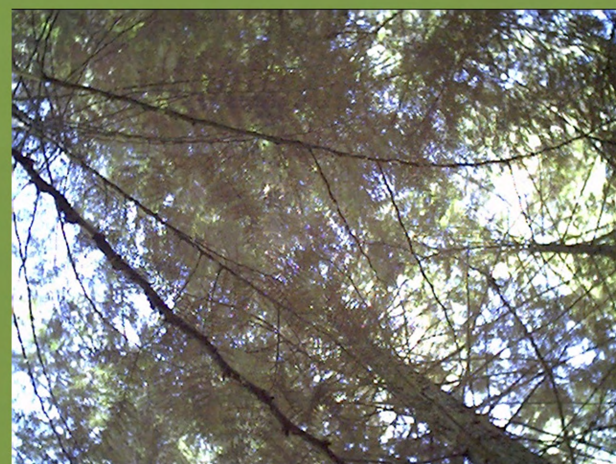


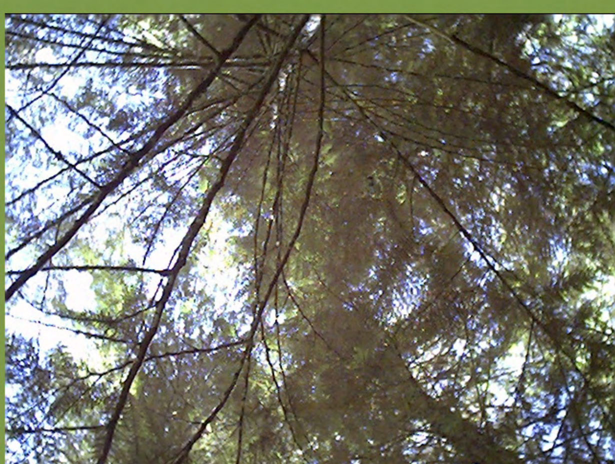

EAST HATTER CREEK STUDY AREA

MIDDLE CREEK WEST FORK-TRANSECTS

P1







PICTURES -MCWF-TRANSECTS

P2

PICTURES -MCWF-TRANSECTS

P3






PICTURES -MCWF-TRANSECTS

P4






PICTURES -MCWF-TRANSECTS

P5

PICTURES -MCWF-TRANSECTS

P6

WEST HATTER CREEK GRADED SITE

P1






PICTURES -WHT-RRG-TRANSECTS

P2






PICTURES -WHT-RRG-TRANSECTS






PICTURES -WHT-RRG-TRANSECTS

P4






PICTURES -WHT-RRG-TRANSECTS

P5

PICTURES -WHT-RRG-TRANSECTS


PICTURES -WHT-RRG-TRANSECTS

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