Pre-construction Evaluation of Collision Potential for Fall Migrating Raptors with a Transmission Line across Burch Mountain, Chelan County, Washington

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February, 2006

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ABSTRACT

We monitored numbers and patterns (corridors and altitude) of fall migrating raptors using visual observation stations and a marine radar unit to assess collision potential for fall migrants for a proposed 230 kV transmission line. A 3.5 mile section of the designed transmission line near the top of Burch Mountain in central Washington was monitored from late August through mid-October, 2005. Visual observers recorded 1,665 raptors from 3 observation stations, of which, 1,472 were considered migrating raptors. Accipiters were the most common group observed (77.1%), followed by Buteos (8.1%), Eagles (6.4%), Falcons (4.0%), unidentified raptors (2.8%), Osprey (1.2%), and Vultures (0.4%). A total of 14 species were recorded. The mean passage rate of migrating raptors from visual observation stations was 5.6 ± 0.3 migrants/hr (n = 226). Radar passage rates were higher with 8.1 ± 0.5 events/hr (n = 203) in the horizontal mode and 12.1 ± 0.6 event/hr (n = 203) in the vertical mode. Passage rates were highest in the afternoon hours. Throughout the day, the mean altitude of vertical radar events increased from 187.4 m (0900 hour) to 347.3 m (1500 hour). Only 4.7% (n = 58) of migrants were observed passing below the estimated pole-top height from visual observation stations. Vertical radar reported 8.1% (n = 78) of events below estimated pole-top height. The distribution of raptors across each span was significantly different ($\chi^2 = 580$, $P < 0.001$) than expected based on span length. Although more migrants were observed along the west portion of the line, the east side had a higher proportion of migrants that passed below pole-top height. Span 6, the shortest span of the designed line (215.4 m) had the highest proportion (58%) of migrants that passed below estimated pole-top height. The recommendation to install the Optical Ground (OPG) wire on the north side of the transmission line to reduce collision potential was provided too late to be employed in the construction of the line. Therefore, Chelan County PUD and the Washington Department of Fish and Wildlife (WDF&W) agreed that all seven spans where raptors passed more frequently than expected would be marked with Bird Flight Diverters

INTRODUCTION

In 1998, the Public Utility District of Chelan County (PUD) completed a comprehensive analysis of its transmission system that identified transmission deficiencies by the year 2004. To meet demand and industry standards (Western Electricity Coordinating Council and North American Electric Reliability Council), the PUD proposed five alternatives in 2001 to address anticipated transmission deficiencies. As part of a public review process, it was determined that a transmission line from Rocky Reach Dam to the Monitor substation could meet demand and bring the transmission system into compliance. A route passing across the upper slopes of Burch Mountain was chosen as the most feasible alternative after considering potential environmental impacts, operational and maintenance factors, right of way and permitting requirements, and cost (Chelan PUD, 2004). The transmission line will be built in 2006.

Raptors are less likely to collide with power lines than other bird groups and relatively few raptors are victims of power line collisions (Olendorff and Lehman 1986, APLIC 1994, Alonso and Alonso 1999, Janss 2000). The low incidence of raptor collisions with power lines is because raptors fly slow, soaring, or hovering; they are agile in flight; they do not fly in large flocks; they have great visual acuity to avoid collisions; and they migrate at high altitudes (James and Haak 1979, Olendorff and Lehman 1986, Kerlinger, 1989, Brown 1993). Most avian collisions with power lines are related to large birds with relatively low maneuverability that fly in flocks at low altitudes, often during poor visibility conditions, such as cranes and waterfowl (James and Haak 1979, Brown 1993).

During project consultation and negotiations, the Washington Department of Fish and Wildlife (WDFW) expressed concerns that migrating raptors may be vulnerable to collision with the proposed transmission line, especially juveniles with limited flight skills. This WDFW concern was emphasized for a 4.6 mile section of land managed by WDFW. In the fall of 2004, the WDFW conducted a pilot survey to document numbers of migrating raptors along Burch Mountain. While the survey was limited in effort (6 days), raptor migration estimates were similar to those reported by HawkWatch International (HWI) at the Chelan Ridge observation site in 2003 (Smith 2004) and 2004 (Smith 2005). As a result, the PUD agreed to monitor fall-migrating raptors along a 3.5–mile (5.6 km) segment of the designed transmission line crossing WDFW lands. A coordinated group of biologists agreed that this segment of the designed line posed the greatest risk to migrating raptors because of its elevation and it bisects the fall migration route used by raptors in 2004 (Tom McCall pers comm.). Other portions of the line were considered less likely to create a collision problem for migrating raptors by the coordinating group since they are lower in elevation and run more or less parallel with the topography.

To identify collision potential for fall-migrating raptors within the area of concern, observers monitored numbers of migrating raptors (by species) and their migration patterns (corridors and altitude) using visual and radar observations from late August through mid-October, 2005. Monitoring was designed to identify specific spans along a portion of the of the designed transmission line route that may pose a high collision risk for fall-migrating raptors near Burch Mountain. Spans identified as high risk will be modified during construction by installing devices designed to minimize collision potential for migration raptors.

After this transmission line is built, a post-construction fall raptor migration monitoring study will be conducted in 2007. The post-construction study will evaluate raptor flight behavior relative to the transmission line and the effectiveness of any devices installed to reduce collision potential.

The objectives of this survey are to determine: 1) passage rates, 2) flight patterns, 3) height above ground level, and 4) species composition of migrating raptors that intersect the vertical plane of the transmission line within the area of concern during the fall of 2005. To meet these objectives, a combination of visual observers and radar technology was used. An independent review of the study plan and data collected was sought to provide an assessment of collision potential and potential mitigation options.

Project Area

The route for this 230kV transmission line (Figure 1) begins on the east side of Rocky Reach Dam located on the Columbia River 4 miles north of Wenatchee, Washington. The route proceeds north 300 yards and then turns west over the Columbia River upstream from Rocky Reach Dam. The route continues uphill and west along the foothills of Burch Mountain for approximately 4.4 miles, and then turns south for 3.6 miles to the Andrew York/Monitor switchyard located 4 miles west of Wenatchee. The transmission line right-of-way is 200 feet wide and 8.8 miles long.

Land ownership along the route includes state, federal, and private lands. State and federal land includes 4.6 miles managed by the WDFW, 0.7 miles managed by the U.S. Bureau of Land Management, and 0.5 miles managed by the Washington Department of Natural Resources. The PUD owns 1.1 miles along the route, the remaining 1.6 miles of the transmission line will be constructed on private lands, for which the PUD has secured easements. The designed transmission line crosses over sagebrush and grassland upland habitat types. At the highest elevations of the transmission line (1,158 m), the route passes adjacent to forested habitats extending westward to the top of Burch Mountain (1440 m).

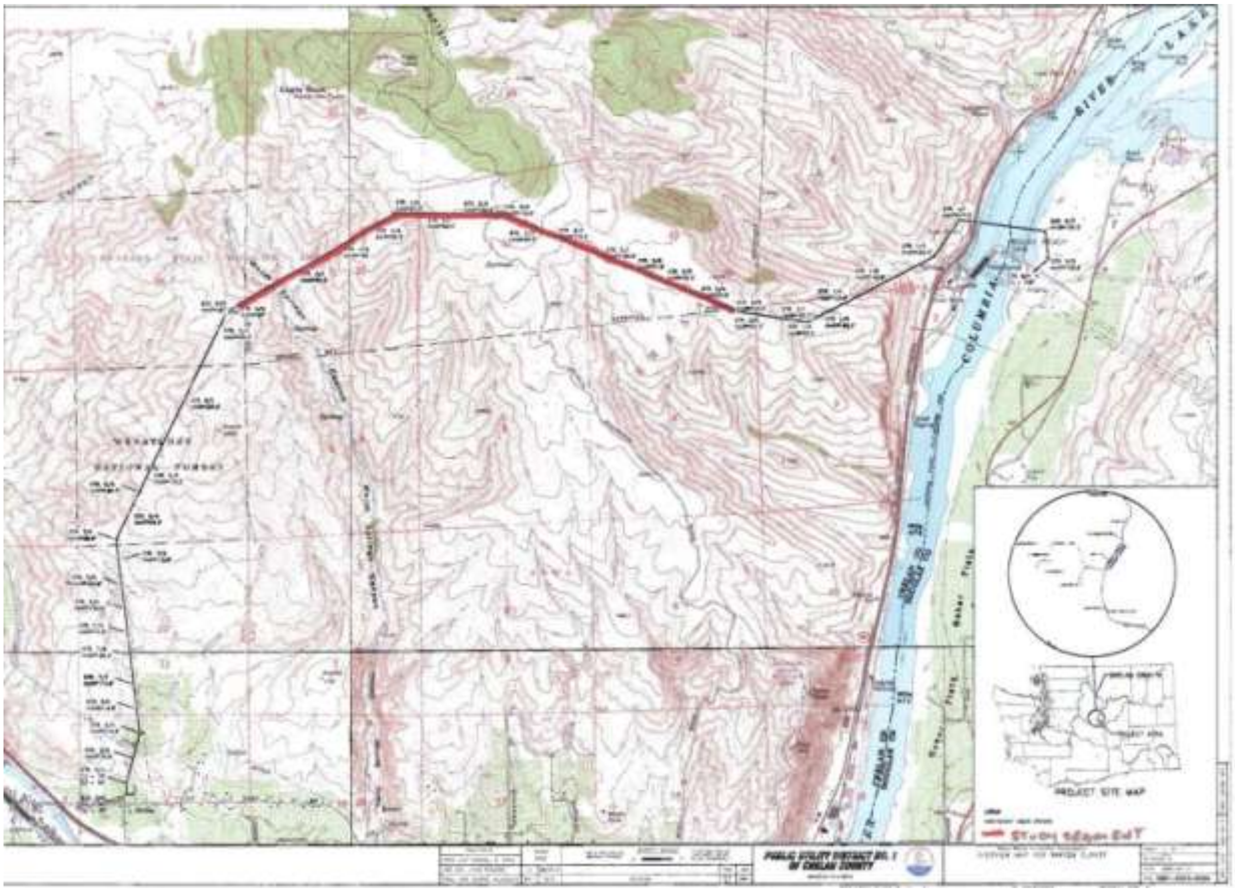

Figure 1. Study Area showing 230 kV transmission line route and study segment within the line.

Line Design

The 230 kV transmission line is of horizontal construction with three electrical conductors suspended at the same altitude between support structures (i.e., they exist in one plane). Tangent structures are H-frame design with two vertical steel support poles, a cross brace, and a single cross arm (approximately 44 feet wide mounted 15 feet below the pole top) with suspension insulators that hold the conductors. Angle structures consist of 3 single pole structures and associated guy wires. Conductor spacing is approximately 22 feet. Shield (ground) wires will be strung between pole tops above the conductor to protect the system from lightning strikes. Two types of shield wire will be used. A standard diameter 0.37 inch (0.95 cm) static wire along with a 0.63 inch (1.6 cm) optical ground wire containing fiber optic cables will be placed within the same plane. Since the fiber optic cable is almost two times larger in diameter than the standard static wire, it is expected to be more visible to migrating raptors. The electrical conductor is 1.35 inches (3.42 cm) in diameter. Relative wire sizes are shown in Figure 2. The maximum height above ground of any structure along the entire line is approximately 148 feet (45 m). The average structure height above ground is 106 feet (32 m).

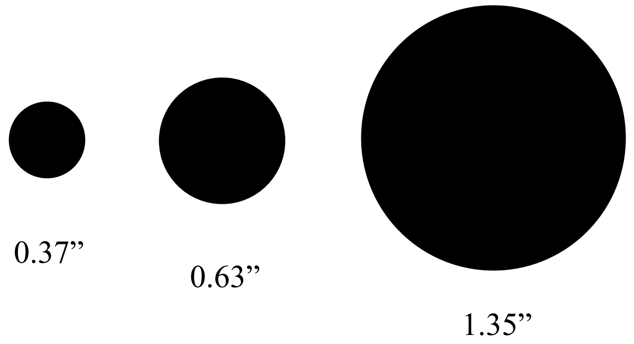

Figure 2. Relative size differences between standard shield wire (0.37”), optical ground wire (0.63”), and electrical conductor to be used on the Burch Mountain 230 kV transmission line.

METHODS

The survey was conducted on a 3.5 mile (5.6 km) section of the designed transmission line comprised of individual 14 spans, hereafter referred to as the study segment (Figure 2). Three visual observation stations were established adjacent to the transmission line, including two primary observation stations (east and west) and a secondary station above Warm Springs Canyon (Figure 2). Since the average height above ground for all 15 structures in the study segment is 30 m (99 ft), observation stations were located upslope approximately 30 m in altitude from the base of adjacent poles, placing observers near the estimated pole-top elevation for structures in the area. Placing the observation station near pole-top elevation provided a reference altitude for the designed transmission line. Structure locations were surveyed and marked to help observers identify individual spans.

The two primary observation stations (on either side of Burch Mountain Road) had two observers each, a primary observer responsible for identification and classification of migrating raptors and one to assist with data recording and detecting migrating raptors. The secondary station, above Warm Springs Canyon, was sub-sampled each week using only one observer. Sampling was necessary in Warm Springs Canyon since it has the longest span along the designed transmission line. Raptor observations for each station were independent. Observers communicated via two-way radios to determine which station would record raptors observed from more than one station.

Since the height and distance of passing raptors is difficult to accurately quantify visually, we relied on radar monitoring to quantify the height above ground and flight paths of raptors as that passed within the radar sweep. The radar was mounted on the camper of a pick-up truck that was driven to the sample site daily. The radar was positioned on Burch Mountain Road along the proposed transmission line in span 8 (Figure 3).

The radar sampled in both the horizontal and vertical plane to meet research objectives. In the horizontal mode, the radar tracked flight speeds and passage rates of birds (events) across different spans of the transmission line. In the vertical mode, the altitude above the radar unit was measured for each event. Radar sampling modes were alternated every 40 minutes.

Since the radar cannot determine species, the radar technician was in constant contact with visual observers to assign species to radar events via two-way radios. The radar technician radioed event locations (height and distance) to the visual observers in an attempt to get species confirmation. The topography included small draws and valleys that the radar could not sample, visual observations were the only method used to document migration in these areas.

Data were collected on weekdays (holidays excluded) from August 30 to October 13, 2005. This period covers the 80% bulk passage rate for the fall migration of raptors documented in the 2003 and 2004 raptor migration surveys at Chelan Ridge (Smith 2004, 2005). Hours of visual observation were primarily from 0900 hrs to 1600 hrs, which includes the time of day when thermal updrafts are most prevalent and the bulk of raptor migration occurs (Newton 1979, Kerlinger 1989).

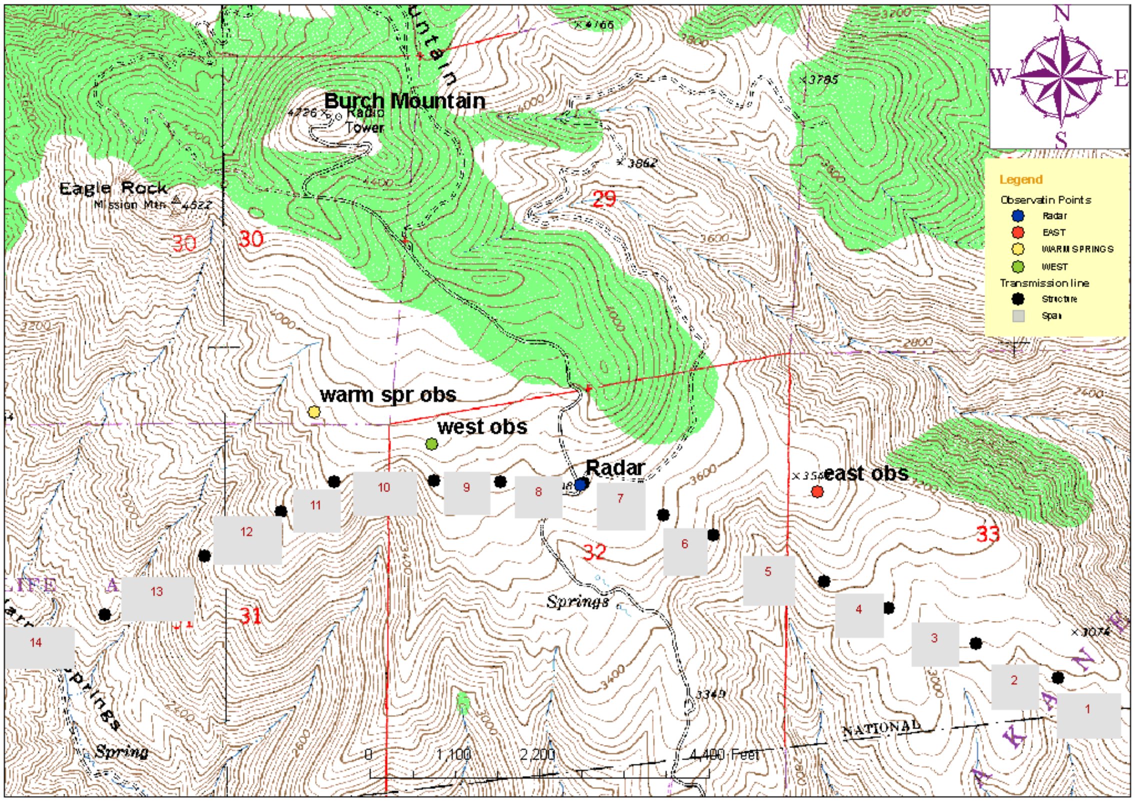

Figure 3. Study Segment for the transmission line, Burch Mountain 2005.

Visual Observers

Methods used to count migrating raptors at visual observation stations were similar to those used by HWI at Chelan Ridge (HWI 2005), located approximately 33 miles north northeast of the study area. However, unlike the HWI observations at Chelan Ridge, more than one observation station was used and the stations were not located on ridge tops. Observers used 10x42 binoculars (Swarovski) to scan the horizon regularly. When raptors were observed, they were followed to determine migration status and proximity to the designed transmission line. Raptors were defined as migrants if they passed from the north and continued south out of the observers view. Raptors that perched in the area or foraged in the area (never passing out of view to the south) were considered local raptors.

Migrating raptors that passed the vertical plane of the study segment were assigned to the span crossed and to one of two elevation categories, 1) above or 2) below pole top height. Observers used a combination of surrounding trees, a hand level, and topographic features to assess whether observed raptors were above or below the eye level of the observer (stationed at pole tope height). Migrating raptors that passed beyond the extent of the study segment (i.e., too far east or west) were recorded as migrants outside the study segment. Observers recorded migrating raptors to species when possible.

Numbers of migrating raptors observed from visual observation stations were summarized by day and station and by species and family. Weekly numbers of raptors are reported as the total number of migrants observed daily divided by the number of days surveyed per week. Hourly passage rates are calculated as the number of migrants observed in each hour divided by the proportion of each hour sampled at a station (i.e., the number of observers does not affect station effort). This rate allows for general comparisons among all visual stations and data collected by radar. For an overall passage rate for comparison with radar data, the total number of migrants observed at the east and west observation stations were pooled and divided by the average effort in each hour at each station.

For the visual observation data, only raptor species are reported. Raptor species observed beyond the extent of the power line were included in overall migration numbers but withheld from span passage calculations. Span lengths were determined using GIS with GPS coordinates for each structure. Span passage rates were calculated by dividing the total number of raptors observed in each hour divided by the effort surveyed for each hour. Since the Warm Springs site was only sampled for 11 of the 32 days surveyed and it had limited radar support, radar data were only compared to the combined east and west station data.

A Chi Square analysis was used to determine if raptors where crossing through each span more or less than expected based on span length. This analysis was done using the visual data only for all crossings (above and below) and was repeated using only below pole-top height crossings.

Radar Survey

The horizontal radar scanning array was operated at 0.9 mile (1.5 km) radius at a short pulse length. In order to improve the efficiency of data collection, an acetate overlay was used to divide the display screen into east-west transect lines of equidistant "bins". The radar detected raptors out to 4,511 feet (1,375 m) on each side of the radar for a total diameter of 9,022 feet (2,750 m). At this range, spans 3 to 12 along the proposed transmission line were surveyed by radar. On the horizontal scale, ground clutter (trees and hillside) was considerable north of the radar station due to the topography rising up to the peak of Burch Mountain.

The radar transect line was placed 1,519 feet (463 m) south of the radar unit so that it was in clear air space beyond the corona effect of the radar. Distance to each radar target (raptor) from the radar was recorded when raptors crossed the transect line on a southerly trajectory. We also collected overall flight path direction, distance from the radar, bearing of the flight path, and flight speed of each raptor.

The vertical radar scanning array was operated at the 0.47 mile (0.75 km) radius at a short pulse length. This range facilitates detection and recording of low altitude targets. Using the 0.75 km range, the radar was primarily sampling from span 5 to 10. The vertical radar was oriented to collect data along an east-west transect that is perpendicular to the main axis of raptor migration. The acetate overlay consists of a grid of "bins", corresponding to assigned altitudes and distances. For the 0.47 mile (0.75 km) range, the lowest height category was from 0-121 feet (0-37 m) high. This is the maximum height of the transmission towers within the study segment. The next bins were in height increments of 623 feet (190 m) to a maximum height of 3,871 feet (1,180 m). To limit contamination of the data set by insect detections and the "corona effect" of the radar, the four bins nearest the radar units (E1, E2, F1 and F2) were excluded from data collection. The width of the vertical bins was 492 feet (150 m). The radar technician recorded the exact heights and distances to each.

For the radar data, non raptor species (mostly corvids) confirmed by visual observers were removed from analysis. Unconfirmed radar targets potentially include local raptors as well and non raptor species. Span passage rates were calculated as the number of targets passing through each span in each hour divided by the survey effort in that hour. Using data from confirmed sightings allowed us to calculate mean migration heights by species.

RESULTS

VISUAL OBSERVATIONS

During fall 2005, we monitored diurnal raptor migration over Burch Mountain for 32 days during a 45 day period (30 August – 13 October). This period included the 80% bulk passage rate for all migrating raptors observed at the nearby Chelan Ridge HawkWatch International site from 2003 and 2004 (HawkWatch International 2004, 2005). Visual observation data included all migrating raptors and non–migrating raptors (local birds) that crossed the vertical plane of the proposed transmission line. Daily observations began at approximately 0900 hours and ended by 1600 hours.

Migrating Raptors

Observers recorded 1,665 raptors for all days and all observation stations, of which, 1,472 were considered migrating raptors. Accipiters were the most common group observed with 1,135 (77.1%), followed by 119 buteos (8.1%), 94 eagles (6.4%), 59 falcons (4.0%), 41 unidentified raptors (2.8%), 18 Osprey (1.2%), and 6 Turkey vultures (0.4%). A total of 14 species were recorded (Table 1, Appendix 1). Sharp-shinned Hawks (*Accipiter striatus*) were the most common migrant observed (39.5%), followed by Cooper's Hawks (*Accipiter cooperii*) (23.2%), unidentified accipiters (13.5%), Golden Eagles (*Aquila chrysaetos*) (6.0%), and Red-tailed Hawks (*Buteo jamaicensis*) (5.8%). Remaining species and groups occurred in relatively small numbers accounting for the remaining 12% (Table 1, Appendix 1).

Table 1. Number of migrating raptors by species observed at each observation station (and number of observation days per station), Burch Mountain, 2005.

		Station			
Species	Species Code	East (32 days)	West (32 days)	Warm Springs (11days)	Total (75 days)
Sharp-shinned Hawk	SSHA	231	247	104	582
Cooper’s Hawk	COHO	145	137	60	342
Unidentified Accipiter	UACC	53	119	27	199
Golden Eagle	GOEA	27	44	17	88
Red-tailed Hawk	RTHA	37	37	11	85
Unidentified Raptor	URAPT	3	24	14	41
American Kestrel	AMKE	16	5	3	24
Merlin	MERL	13	5	3	21
Osprey	OSPR	2	14	2	18
Northern Harrier	NOHA	4	10	1	15
Unidentified Buteo	UBUTEO	5	10	0	15
Northern Goshawk	NOGO	3	3	6	12
Unidentified Falcon	UFALC	3	5	1	9
Turkey Vulture	TUVU	3	3	0	6
Rough-legged Hawk	RLHA	1	2	1	4
Unidentified Eagle	UEAGLE	1	1	2	4
Prairie	PRFA	1	2	0	3
Bald Eagle	BAEA	1	1	0	2
Peregrine Falcon	PEFA	1	1	0	2
Total		**550**	**670**	**252**	**1472**

Total daily numbers of migrating raptors varied from a minimum of 4, recorded on 9 September, to a maximum of 118 recorded on 13 October (Table 2, Appendix 1). Likewise, total numbers of migrating raptors observed weekly were highly variable (Figure 4). Mean (± SD) weekly migration rates (total migrants/day/week) ranged from a low of 16.0 ± 5.2 (n = 4) in week 1 to a high of 66.8 ± 39.0 (n = 4) in week 7. The numbers of migrating raptors observed late in the survey period may indicate high overall migration numbers for 2005 with later mean passage dates in this area.

Table 2. Number of migrating raptors observed by station and date and number of days surveyed, Burch Mountain, 2005.

	Station			
Date	East (32 days)	West (32 days)	Warm Springs (11 days)	Total (75 days)
30-Aug	4	6	.	10
31-Aug	9	5	.	14
1-Sep	5	13	.	18
2-Sep	3	19	.	22
6-Sep	6	19	.	25
7-Sep	52	31	.	83
8-Sep	33	20	16	69
9-Sep	1	3	.	4
12-Sep	5	16	.	21
13-Sep	6	34	17	57
14-Sep	8	53	.	61
15-Sep	11	20	29	60
16-Sep	4	10	.	14
19-Sep	39	18	.	57
20-Sep	15	15	12	42
21-Sep	18	36	.	54
22-Sep	40	44	25	109
23-Sep	22	15	.	37
26-Sep	15	34	.	49
27-Sep	19	17	27	63
28-Sep	6	19	.	25
29-Sep	8	11	20	39
30-Sep	8	16	.	24
3-Oct	4	11	.	15
4-Oct	37	28	27	92
5-Oct	22	11	.	33
6-Oct	25	11	16	52
7-Oct	35	21	.	56
10-Oct	14	37	.	51
11-Oct	31	25	16	72
12-Oct	8	18	.	26
13-Oct	37	34	47	118
TOTAL	**550**	**670**	**250**	**1472**

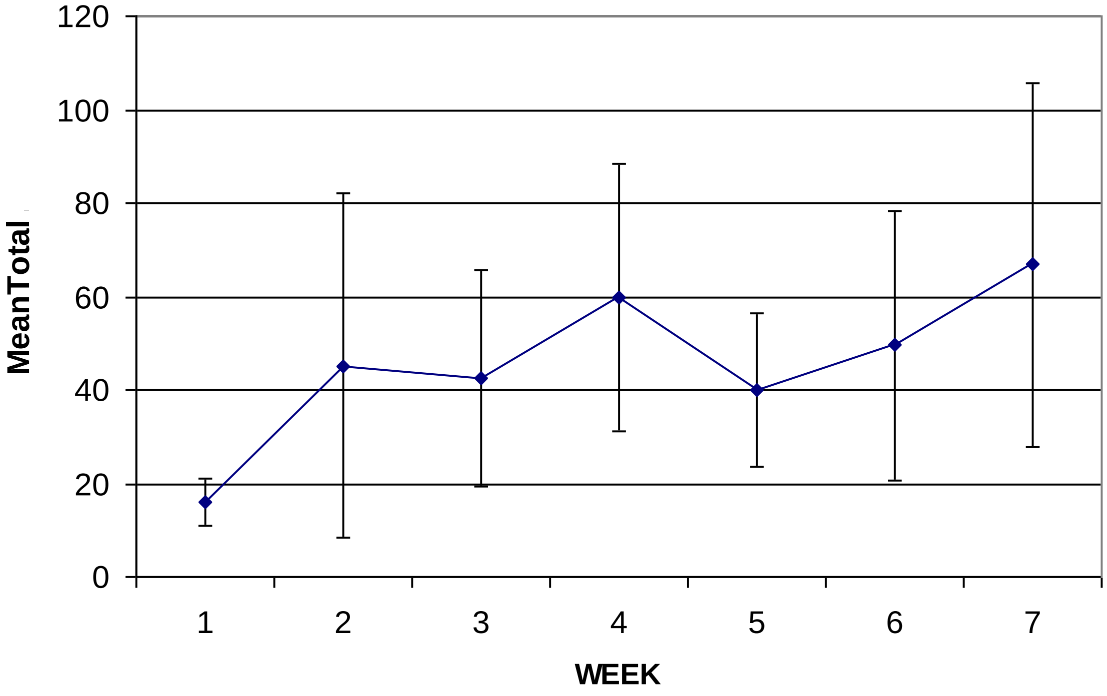

Figure 4. Mean (± SD) total weekly raptor migration rates (total birds/day/week) from visual observation stations, Burch Mountain, 2005 (n = 32).

The east and west observation stations had similar numbers of migrating raptors during the 32 days each was surveyed. The west observation station recorded greater numbers of migrating raptors (670) compared to the east station (550) and reported the majority of migrants on 59% of the days surveyed. However, the maximum number of migrants recorded were similar with 53 at the west (4 September) and 52 at the east (7 September) (Table 2). In either case, migrants were typically closely associated with either the west or east slope of Burch Mountain.

From the west station, it was common to see birds approach from the north just over the trees on Burch Mountain. The raptors would then soar, over Eagle Rock and the head of Warm Springs Canyon, gaining altitude before they continued south. At times, raptors soared beyond our sight even with the aid of 10x42 power binoculars. A similar pattern occurred at the east station. Raptors approached from the north and began to soar over Swakane Canyon gaining altitude until they departed south. Occasionally, migrants passed just east of Burch Mountain passing over the prominent ridge where the east observation station was located. Migrants often soared directly over this ridge (and the radar station) gaining altitude before continuing south. Weather patterns may affect which side of Burch Mountain migrants pass. On 16 days, either the east or west station recorded double the number of migrants recorded at the opposite station. This was most common at the west station (13 days).

Since the proposed power line descends into the Warm Springs Canyon which is not visible from the west observation station, the Warm Springs station was established to monitor spans 12 - 14 in this canyon. The Warm Springs site had only one observer and was monitored for 11 of the 32 survey days (34%). During these 11 days, the Warm Springs site observed the greatest number of migrants observed at all stations on 4 of those 11 days surveyed (36%).

Passage Rates

Passage rates are reported for individual stations and pooled for the east and west stations which had similar effort. Hourly passage rates were calculated for each observation station as the total number of migrating raptors recorded each hour divided by the effort in that hour for each day. Pooled passage rates are the total number of migrants observed at the east and west stations divided by the average effort between the east and west stations in each hour for each day.

The mean passage rate (migrants/hr ± SE) for each station ranged from 2.5 ± 0.2 (n = 226) at the east observation station to 3.3 ± 0.3 (n = 79) at the Warm Springs station. However, Warm Springs was not sampled in the first 6 days, when passage rates were the lowest. The west station had a passage rate of 3.1 ± 0.2 (n= 226). The pooled passage rate for the east and west stations was 5.6 ± 0.3 migrants/hr (n= 226). This pooled passage rate most closely resembles the area surveyed by radar.

Mean daily and weekly passage rates (migrants/hr) were highly variable. The highest mean daily passage rates were observed on 7 September with 6.28 migrants/hour, 13 October with 5.85 migrants/hr, and 14 September with 4.72 migrants/hr (Figure 5). The lowest daily passage rates were observed on 9 September with 0.3 migrants/hr, 30 August with 0.9 migrants/hr, and 14 September with 1.0 migrants/hr (Figure 6). Weekly mean passage rates were highest in week 7, with 3.9 ± 0.4 migrants/ hr (n = 70) and was influenced by the highest daily total recorded during the survey. Week 4 had the next highest weekly average with 3.4 ± 0.3 migrants/hr (n = 92).

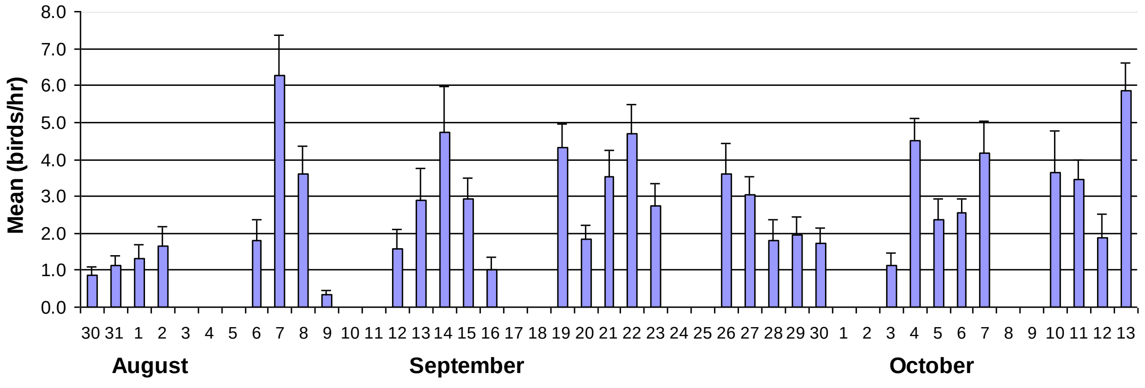

Figure 5. Mean daily raptor passage rate (migrants/hr) for visual observation stations, Burch Mountain, 2005. Dates with no values were not surveyed.

The maximum migration rate for all hours observed was 16.8 migrants/hr, observed on 13 September; from 1500-1600 hrs at the west station followed by 15.0 migrants/hr observed at the east station on 13 October; 1100–1200 hrs. The lowest rate was 0.0 migrants/hr and was common, particularly during the morning hours. In fact, 24.5% of all hours had passage rates of 0.0 (Figure 6). The majority of passage rates were between 1.0 and 2.0 migrants/hr (31.3%), followed by 2.0 to 4.0 migrants/hr (19.6%), and 6.0 to 10.0 (13.2%) migrants/hr. Higher hourly passage rates were rare, only 2.3% of all hours exceeded 10.0 migrants/hr (Figure 6).

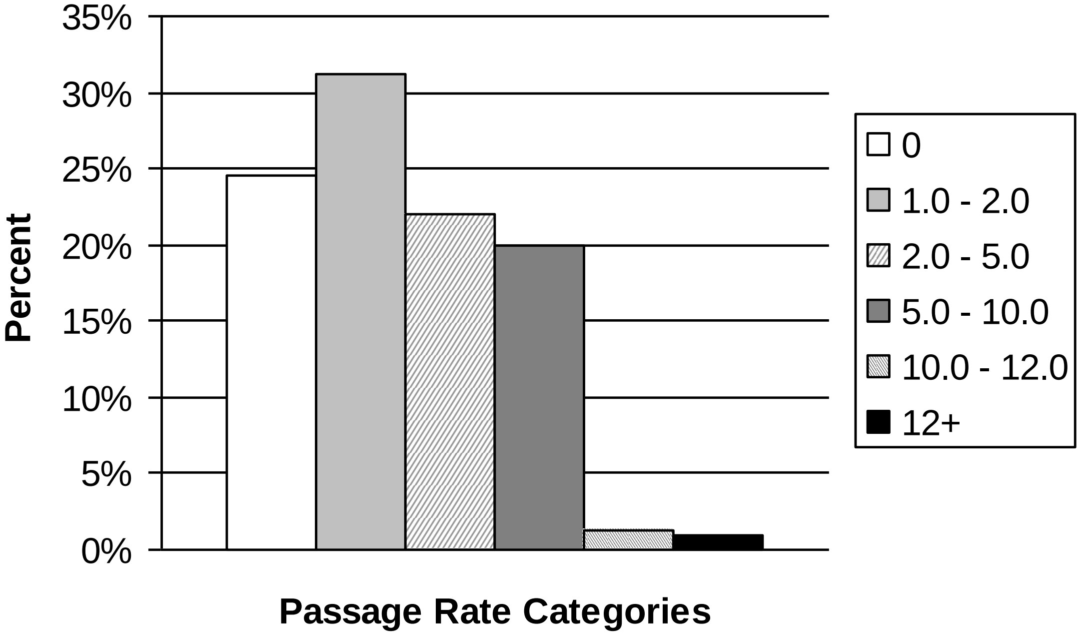

Figure 6. Histogram of raptor passage rates (migrants/hr) from all visual observation stations, Burch Mountain, 2005.

Overall, the raptor migration was low during the morning hours, increased through midday, then declined into the afternoon (Figure 7). The bulk of raptors migrated between 1000 and 1400 hrs (83.8%) with only 5.5% moving before 1000 hrs and 11.1% after 1400 hrs. On September 20-22 we began the survey one hour early (0800) to document early raptor migration. No migrants were observed prior to 0900 on these days although the daily passage rates for days 12 and 14 had higher than average (2.9 migrants/hr) daily passage rates (3.5 and 4.7 migrants/hr, respectively).

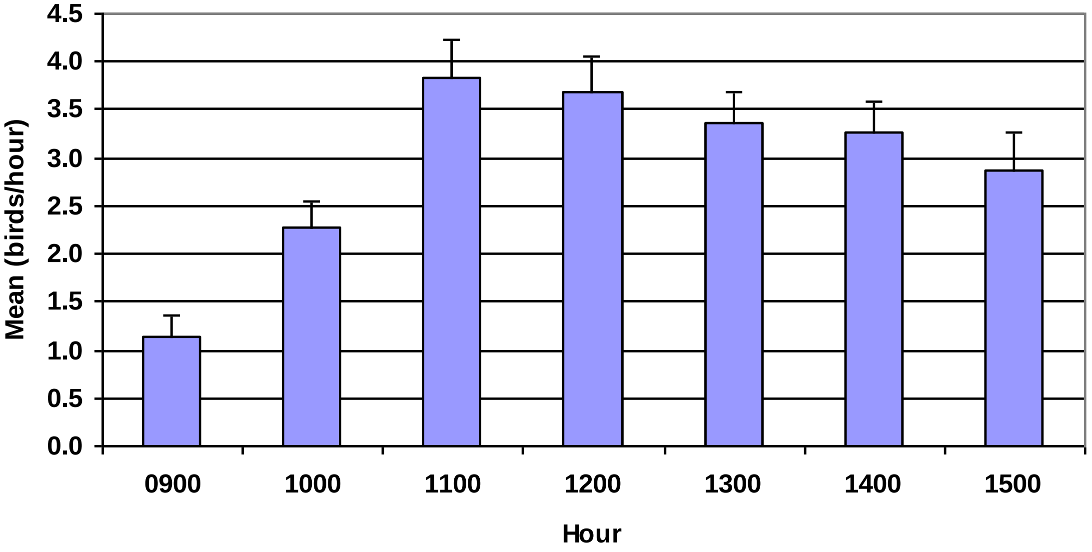

Figure 7. Mean hourly raptor passage rate (migrants/hr + SE) from all visual observation stations, Burch Mountain 2005.

Local Birds

Raptors observed perching and or hunting in the vicinity of the line were not classified as migrants to reduce the potential of inflating the number of migrating raptors observed (HawkWatch 2005). While many of these raptors were likely migrants, they were not migrating at the time observed and were often observed crossing the line multiple times in a short duration. Observers recorded a total of 193 crossings by local raptors during the survey. Red-tailed Hawks were the most common local raptor observed crossing the vertical plane of the transmission line (28.0%), followed by the Golden Eagle (26.4%), Sharp-shinned Hawk (20.7%), Cooper's Hawk (8.3%), American Kestrel (*Falco sparverius*) (5.7%), Northern Harrier (*Circus cyaneus*) (5.2%), unknown accipiter (2.6%), unknown raptor (1.6%), and Osprey (*Pandion haliaetus*), Merlin (*Falco columbarius*), and unknown buteo (0.5% each).

Line Crossings

Of the 1,472 migrants observed, 237 were observed beyond the extent (too far east or west) of the proposed transmission line; therefore, 1,235 migrants passed the vertical plane of the proposed transmission line. Numbers of migrants passing the vertical plane were greatest near the center of the proposed line with 75.4% passing from span 5 to 11. The west portion (spans 8-14) accounted for 751 migrants (60.8%) while the east portion of the line (spans 1-7) accounted for 484 (39.2%) migrants. Span 10 had the highest number of migrants passing with 191 (15.5%).

The number of birds passing each span (above or below) was significantly different (χ^2 = 580,13 df, $P < 0.001$) than the expected based on the span lengths (Table 3). Only span 4 had an observed number of birds that was not significantly different than expected.

Examination of the standardized residuals indicates that both ends of the study segment (spans 1-3 and 12-14) had fewer passages than expected while spans 5-11 experienced higher numbers than expected (Table 3).

Table 3. Number of migrant raptors observed passing (above and below pole-top) and their expected values based on the span lengths used to calculate Chi-Square values to determine if migrating raptors passed through spans in proportion to availability, Burch Mountain, 2005.

Span	Length (m)	Proportion of Study Segment	Proportion of Raptors Observed	Raptors Observed	Raptors Expected	Chi-Square	Standardized Residuals	Utilization
1	351.6	6.9%	1.4%	17	85	54.633	-7.390	Avoid
2	351.3	6.9%	1.1%	13	85	61.154	-7.823	Avoid
3	375.8	7.4%	1.8%	22	91	52.422	-7.259	Avoid
4	276	5.4%	4.9%	60	67	0.714	-0.819	Neutral
5	474.5	9.3%	11.1%	138	115	4.583	2.160	Preferred
6	215.4	4.2%	9.2%	114	52	73.083	8.627	Preferred
7	342.9	6.7%	9.7%	120	83	16.349	4.096	Preferred
8	331.7	6.5%	9.9%	122	81	21.501	4.657	Preferred
9	265.5	5.2%	9.9%	122	64	51.600	7.210	Preferred
10	396.9	7.8%	15.5%	191	96	93.346	9.646	Preferred
11	243.1	4.8%	10.0%	124	59	71.823	8.406	Preferred
12	351.5	6.9%	4.6%	57	85	9.344	-3.056	Avoid
13	460.3	9%	3.9%	48	112	36.242	-5.990	Avoid
14	657.5	12.9%	7.0%	87	160	32.888	-5.729	Avoid
Total	**5094**	**99.9%**	**100%**	**1235**	**1235**	**579.682**		

The majority (95.3%) of migrating raptors crossed above the estimated pole-top height along the vertical plane of the proposed transmission line. From visual observation stations, only 4.7% of migrants were observed passing below pole-top height. Although more migrants were observed along the west portion of the line, the east side had a higher proportion of migrants that passed below pole-top height (58.6%). The mean below pole-top passage rate for all observations was 0.02 ± 0.003 migrant/hr). Spans 6 and 7 accounted for 51.7% of migrants passing below pole-top height. The mean below pole-top passage rate (migrants/hr ± SE) for spans 6 and 7 were low with 0.07 ± 0.02 and 0.06 ± 0.02 migrants/hr respectively.

The distribution of migrating raptors passing below the estimated pole-top height for all spans was significantly different than uniform ($\chi^2 = 145$, 13 df, $P < 0.001$) in proportion to span lengths (Table 4). Span 6 had the greatest number of migrants passing below estimated pole-top height despite being the shortest span in the study segment. Overall spans 6 through 9 had higher numbers of migrants passing below pole-top height while either end of the study segment recorded fewer than expected (Table 4).

Table 4. Number of migrating raptors observed passing below pole-top heights and their expected values based on the span lengths used to calculate Chi-Square values to determine if migrating raptors passed below spans in proportion to availability, Burch Mountain, 2005.

Span	Length (m)	Proportion of Study Segment	Proportion of Raptors Observed	Raptors Observed	Raptors Expected	Chi-Square	Standardized Residuals	Span utilization
1	351.6	6.9%	0%	0	4	4.003	-2.001	Avoided
2	351.3	6.9%	1.7%	1	4	2.250	-1.500	Neutral
3	375.8	7.4%	1.7%	1	4	2.513	-1.585	Neutral
4	276	5.4%	0%	0	3	3.143	-1.773	Avoided
5	474.5	9.3%	3.4%	2	5	2.143	-1.464	Neutral
6	215.4	4.2%	27.6%	16	2	74.834	8.651	Preferred
7	342.9	6.7%	24.1%	14	4	26.106	5.109	Preferred
8	331.7	6.5%	12.1%	7	4	2.751	1.659	Preferred
9	265.5	5.2%	13.8%	8	3	8.194	2.863	Preferred
10	396.9	7.8%	6.9%	4	5	0.060	-0.244	Neutral
11	243.1	4.8%	8.6%	5	3	1.800	1.342	Neutral
12	351.5	6.9%	0%	0	4	4.002	-2.001	Avoided
13	460.3	9%	0%	0	5	5.241	-2.289	Avoided
14	657.5	12.9%	0%	0	8	7.486	-2.736	Avoided
Total	**5094**	**99.9%**	**99.9%**	**58**	**58**	**144.526**		

Accipiters accounted for 86.2% of all migrants passing below the estimated pole-top height. Other species were rare, including Merlin (6.9%), Red-tailed Hawk (3.4%), and 1.7% for each the Golden Eagle and Northern Harrier (Table 5). Sharp-shinned Hawks were the most common raptor species (60.3%) crossing below pole-top height and account for the majority of migrating raptors passing below each span.

Table 5. Number of migrant raptor species passing below estimated pole-top height by span, Burch Mountain 2005.

	Species[1]							
Span	COHA	GOEA	MERL	NOHA	RTHA	SSHA	UACC	Total
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	1	1
3	0	0	0	0	1	0	0	1
4	0	0	0	0	0	0	0	0
5	1	0	1	0	0	0	0	2
6	2	0	2	1	1	9	1	16
7	3	1	1	0	0	6	3	14
8	0	0	0	0	0	4	3	7
9	0	0	0	0	0	8	0	8
10	1	0	0	0	0	3	0	4
11	0	0	0	0	0	5	0	5
12	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0
Total	**7**	**1**	**4**	**1**	**2**	**35**	**8**	**58**

[1] See Table 1 for species code names.

The majority of local raptors crossing the vertical plane of the proposed transmission line (69.9%) were above pole-top height. Similar to the migration data, crossings by local raptors were more frequent on the western portion of the line with 118 (61.1%) crossings with only 30 (25.4%) below pole-top height. Conversely the eastern portion of the line only had 75 (38.9%) crossings by local raptors but 28 (37.3%) were below the estimated pole-top height. Like the migrating raptor data, span 6 (the shortest span in the study segment) accounted for the greatest number of crossings (14) by local raptors. When combined, spans 6-10 accounted for 77.6% of local birds passing below pole-top height (Table 6). The ridge separating the east and west portions of the proposed line has a number of pine trees that local birds used frequently.

Table 6. Number of local raptors passing above and below pole-top height by span along the proposed Burch Mountain 230 kV transmission line, 2005.

Span	Above	Below	Total
1	1	0	1
2	1	1	2
3	3	1	4
4	6	3	9
5	10	3	13
6	13	14	27
7	13	6	19
8	20	10	30
9	29	3	32
10	29	12	41
11	7	5	12
12	3	0	3
13	0	0	0
14	0	0	0
Total	**135**	**58**	**193**

WEATHER

Observers at each station recorded general weather information hourly at a minimum. As weather conditions changed, more frequent entries were made. Weather observations recorded from observation stations included visibility, precipitation, cloud cover, and thermal lift conditions. Data are reported as the proportion that each variable was observed for all days.

Visibility

Each day, visibility was recorded hourly, at a minimum, for each station and is reported as the percentage of days observed for each category. Unlimited visibility (> 30 km) prevailed for 92.8% of all days for all stations. Good visibility (5-29 km) was observed 6.6% of the days, while fair visibility (1-5 km) and poor visibility (<1 km) were observed 0.2% and 0.4% of the all days surveyed, respectively. The west observation station reported 93% unlimited visibility and good visibility for the remaining 7%. The east observation station reported 90.0% unlimited visibly, 8.5% good visibility, 1% fair visibility, and 0.5% poor visibility. Poor visibility was only observed one morning at the east observation station (3 October), when low clouds and fog were observed only on the eastern portion of Burch Mountain. The Warm Springs Station recorded unlimited visibility for all 11 days surveyed. Passage rates were highest during unlimited visibility (0.433 migrants/hr) followed by 0.132 migrants/hr in good visibility. No migrants were observed during hours with fair or poor visibility, however, these conditions were rare (0.6% combined) during the survey.

Precipitation

Precipitation during the survey was limited and only occurred during 5 of the 32 survey days. On days when precipitation occurred, it was light (drizzle – light rain) and only occurred for a portion of each day. The majority (70.4%) of hours with precipitation occurred during the afternoon hours. At the east observation station, precipitation was recorded on 4 separate days for a total of 5.6 hrs. The west observation station recorded precipitation on 5 separate days for a total of 7.3 hrs. Precipitation was only recorded on 2 separate days at the Warm Springs station for a total of 3.8 hrs. A total of 20 migrating raptors were recorded during hours with rain for the entire survey.

Cloud Cover

Mean passage rates were significantly higher ($F = 12.806$, $P < 0.001$, $df = 3$, $n = 531$), when partly cloudy skies were observed compared to other sky conditions. The mean passage rate (migrants/hr ± SE) under partly cloudy skies was 4.3 ± 0.3 followed by 2.7 ± 0.3 under mostly cloudy skies. As cloud cover increased, the passage rate decreased (Figure 8). Some form of cloud cover was observed during 54.6% of the survey while clear skies (no cloud cover) were observed during 45.4% of the survey. No migrants were observed during foggy conditions. While this result is likely the result of a visibility bias (i.e., birds may be more visible with a cloudy background), it's interesting to note the decrease in migration rate with increasing cloud cover.

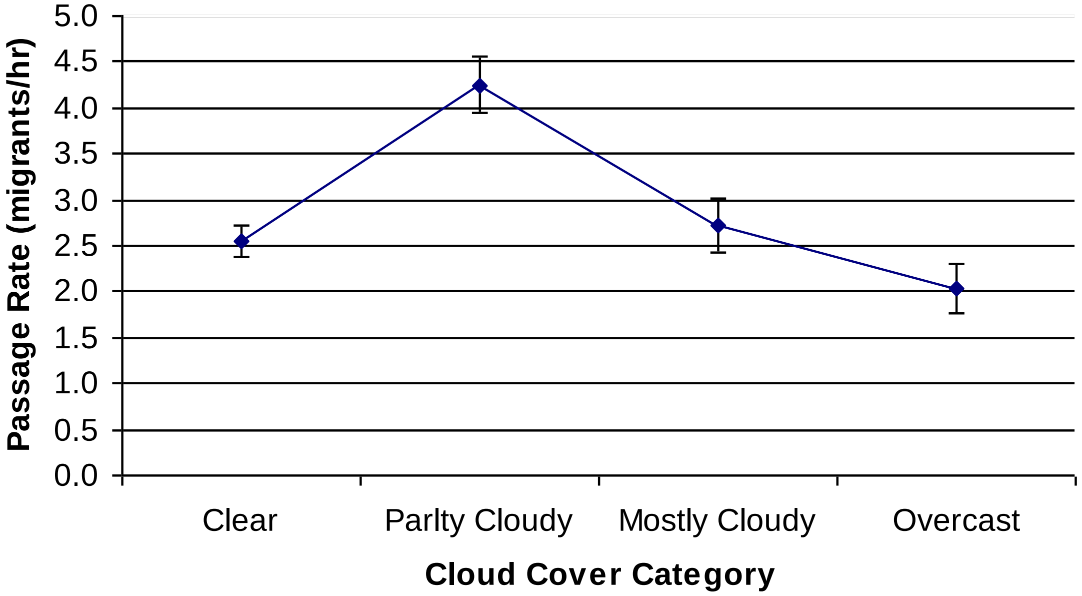

Figure 8. Mean passage rates (migrants/hr ± SE) by cloud cover category for all hours of observation (n = 531) at Burch Mountain, 2005.

Wind

The lowest daily number of migrants recorded (4 on 9 September) occurred on the windiest day of the survey with an average wind speed of 15.5 mph. However, no significant difference was found between hourly wind speed and hourly passage rates ($R^2 = 0.00$, $P = 0.91$, $n = 197$). Mean hourly passage rates were highest when the wind direction was from the west (10.26 migrants/hr, n = 15) and north-northwest (10.25 migrants/hr, n = 4) and lowest when the wind was from the south-southwest (2.2 migrants/hr, n = 11) and south (2.3 migrants/hr, n = 10). In general, hourly migration rates were higher when the wind had a westerly or easterly component.

RADAR SUPPORT

Visual observers recorded 2,011 birds in 1,812 events, including migrating raptors, local raptors and other large local birds (Common Ravens (*Corvus corax*)). A portion of these events (35.6%) were not available for radar sampling since 21% (421) of the events were beyond the extent of the radar and another 14.6% (265) occurred during periods when the radar was off or absent. Of the remaining 1,126 visual observations, 55.2% (621) were confirmed by the radar unit. The remaining 44.8% of the events were not confirmed. Unconfirmed events were attributed to radar corona or clutter (21.0%), birds below the radar sweep (13.4%) or for undetermined reasons (10.3%). Raptors detected below the radar sweep were not necessarily below pole-top height because the topography drops from the radar station to the east. As a result, some migrants were observed passing below the radar but still above the estimated pole-top height.

RADAR OBSERVATIONS

Results for radar sampling include 28.25 of the 32 days of the study. Data from the first day are not included in the results as they were used for radar training and calibration. Technical problems prevented radar sampling for another 2.75 days (19-21 September). Results for the radar sampling include both confirmed events (observed by visual observers and radar) and unconfirmed (radar only) events. Unconfirmed radar events are assumed to be migrating raptors based on information (echo size, speed, and direction) gleaned from confirmed events. Numbers are reported as events rather than bird numbers, since some events may have included multiple individuals.

Radar sampling coincided with visual sampling beginning at approximately 0900 hrs and ended by 1600 hrs. Horizontal and vertical sampling modes were sampled alternately every 40 minutes yielding 9 sessions a day. Each day the radar unit began sampling in the opposite mode from the previous day. All radar detections of sufficient size were radioed to visual observers for confirmation attempts. In total, the radar unit recorded 1,633 events excluding confirmed non–raptor species (i.e. Common Ravens) in 159.1 hours of sampling for an overall rate of 10.3 events/hr. Only 569 (34.8%) of these events were confirmed by visual observers.

While the effort was similar between vertical and horizontal sampling modes (78.3 and 80.8 hrs respectively), the vertical mode recorded more events (961) than the horizontal mode (672), despite the fact that the vertical mode sampling radius was half (0.75 km) of the horizontal sampling mode (1.5 km). Visual confirmations were similar for horizontal and vertical radar sampling (35.2% and 34.5%, respectively).

Horizontal Radar Sampling

Daily mean passage rates (± SE) for the horizontal mode ranged from a low of 2.9 ± 0.9 events/hr (9 September) to a high of 17.4 ± 3.5 events/hr (7 September) (Figure 9). The average daily passage rate was 8.1 ± 0.5 events/hr. Similar to visual sampling results, a large proportion of hours (25.6%) had passage rates of 0.0 events/hr. Passage rates between 5.0 - 10.0 events/hr were most common while higher rates were much less common (Figure 10).

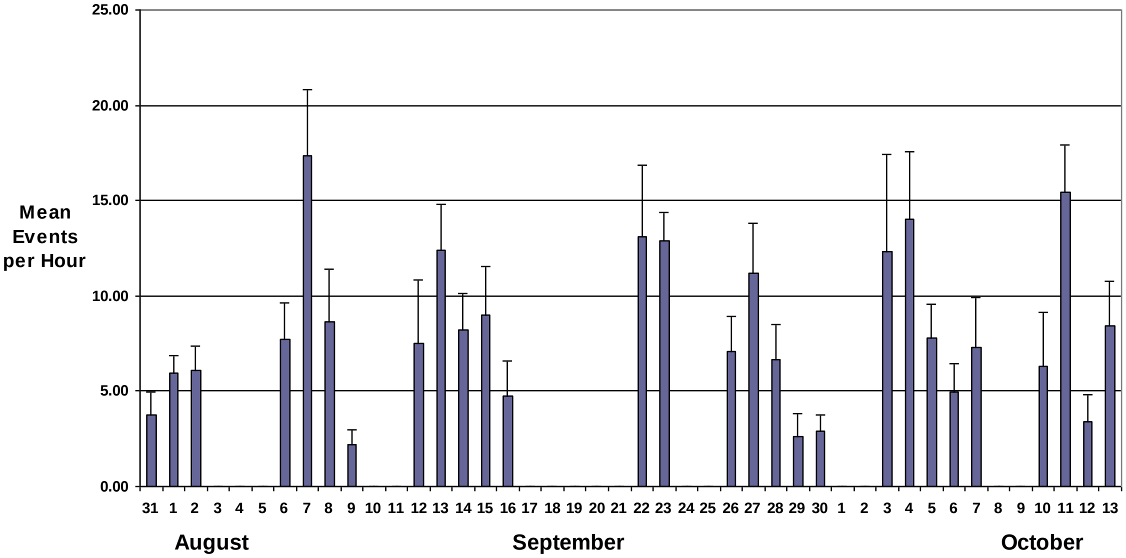

Figure 9. Mean daily passage rates (events/hr ± SE) for the horizontal radar mode, Burch Mountain 2005.

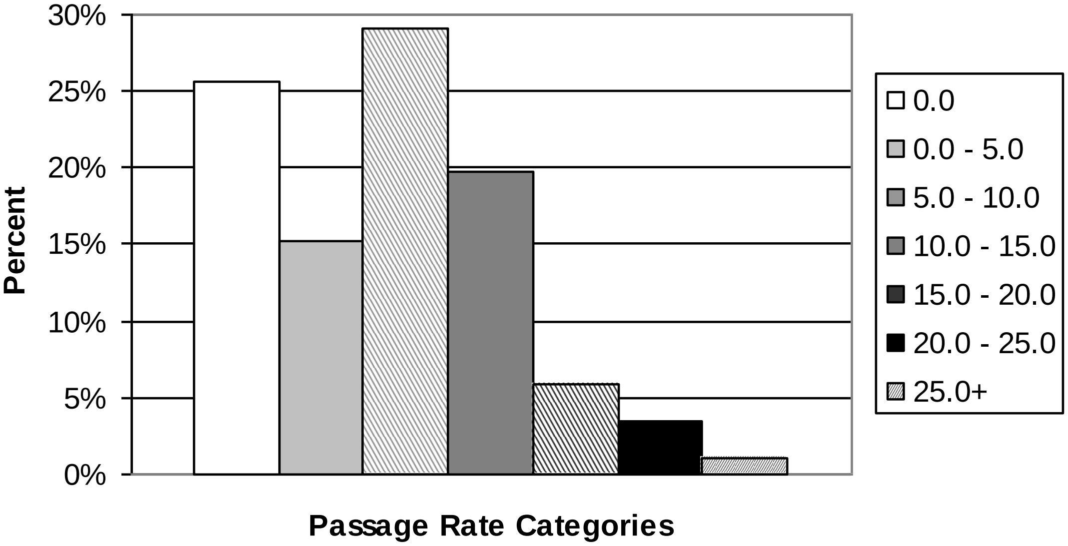

Figure 10. Histogram of hourly passage rates for horizontal radar, Burch Mountain 2005.

The median passage rate for the horizontal radar was 6.6 events/hr (n = 203). Similar to visual observation data, the horizontal radar showed an increase in the migration rate through the morning hours and even into the early afternoon, then a decline later in the afternoon (Figure 11).

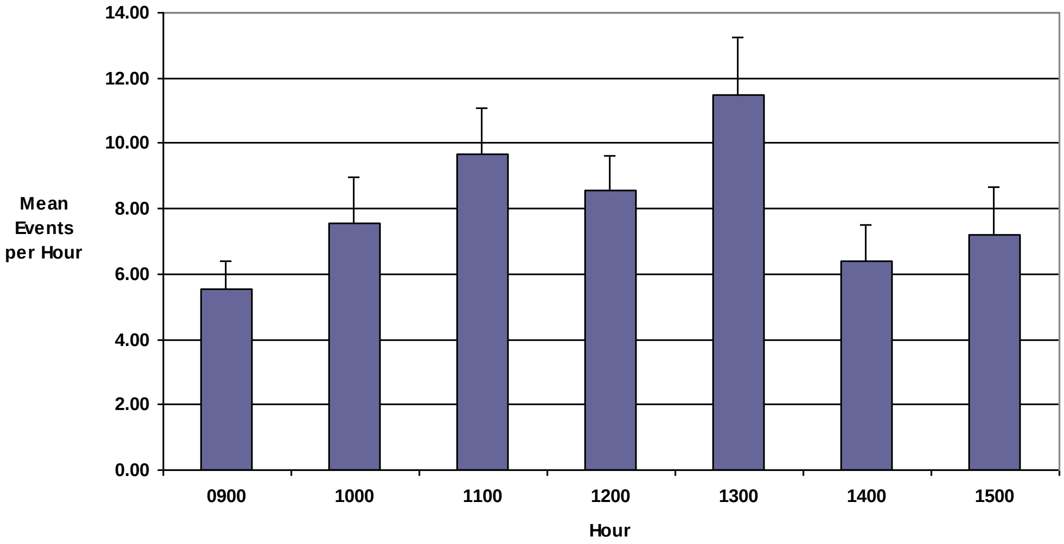

Figure 11. Passage rates by hour observed by the horizontal radar, Burch Mountain 2005.

Vertical Radar Sampling

Daily mean passage rates (± SE) for the vertical radar ranged from 4.7 ± 2.5 events/hr on 29 September to 26.0 ± 3.8 events/hr on 22 September (Figure 12). The average daily passage rate was 12.1 ± 0.6 events/hr. Passage rates between 5-10 events/hr (23%) and 10-15 events/hr (28%) were most common and account for 51% of the hourly rates observed. Vertical radar passage rates above 15.0 events/hr were less common and 8.9% of hours had 0.0 events/hr (Figure 13).

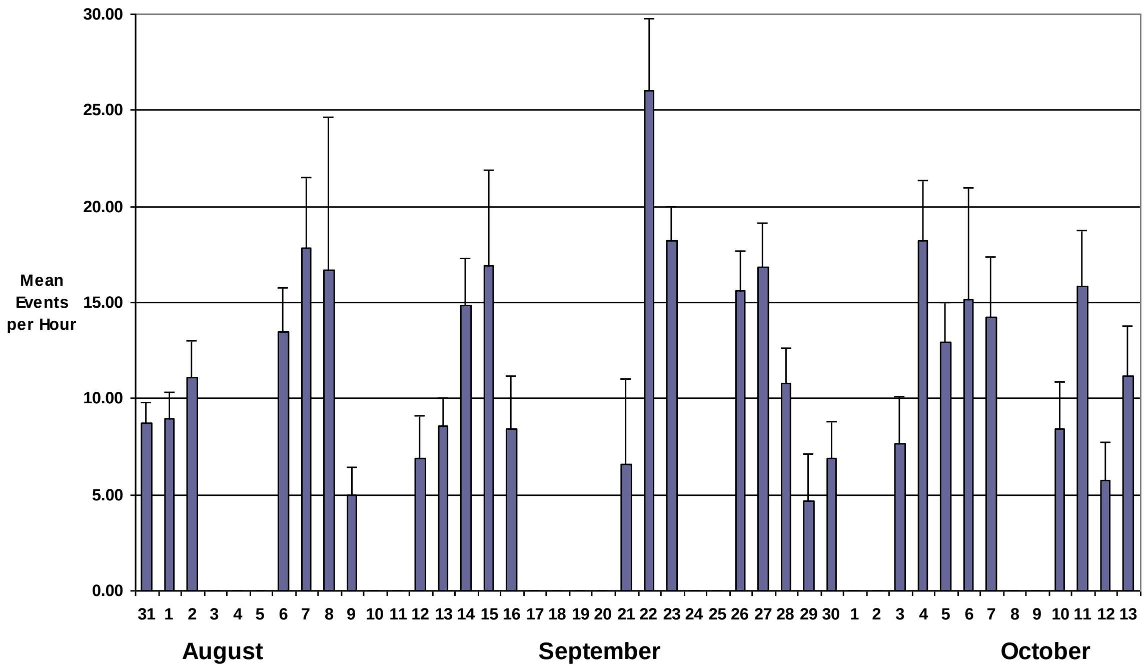

Figure 12. Mean daily passage rates (events/hr ± SE) for the vertical radar mode, Burch Mountain 2005.

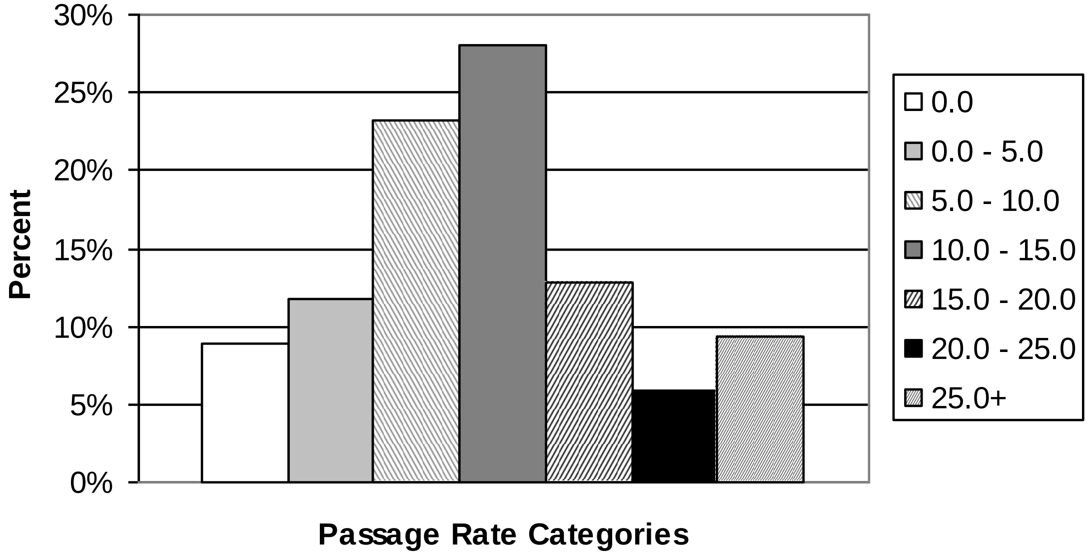

Figure 13. Histogram of vertical radar passage rates, Burch Mountain 2005.

The median hourly passage rate was 10.4 events/hr (n = 203). No events were recorded during 18 vertical sampling sessions. Vertical radar passage rates also showed an increasing trend in passage rates throughout the morning hours into the early afternoon and then a decreasing trend into mid-afternoon (Figure 14).

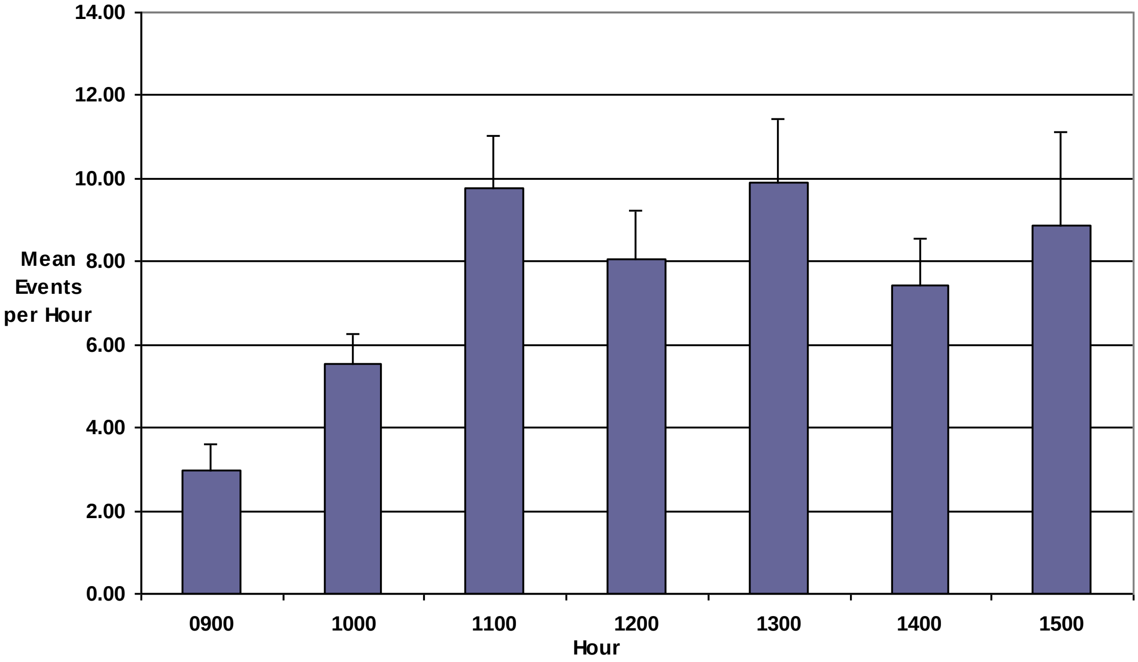

Figure 14. Hourly passage rates (events/hr) for the vertical radar, Burch Mountain, 2005.

Line Crossings and Altitudes

Radar data indicate a similar pattern to the visual data with the bulk of raptor movement occurring through spans 9 and 10 on the west side of the line and spans 5 and 6 on the east side of the line. Passage rates (both above and below pole-top height) for the horizontal and vertical radar are shown in Figure 15. The decline in birds observed in spans 7 and 8 are more likely the result of corona and ground clutter interference on the radar screen (especially for the horizontal radar) obscuring the relatively high number of raptors seen by the visual observers in this region. Since 65.2% of radar observations were unconfirmed, line crossings and altitude data include both migrating and local raptors.

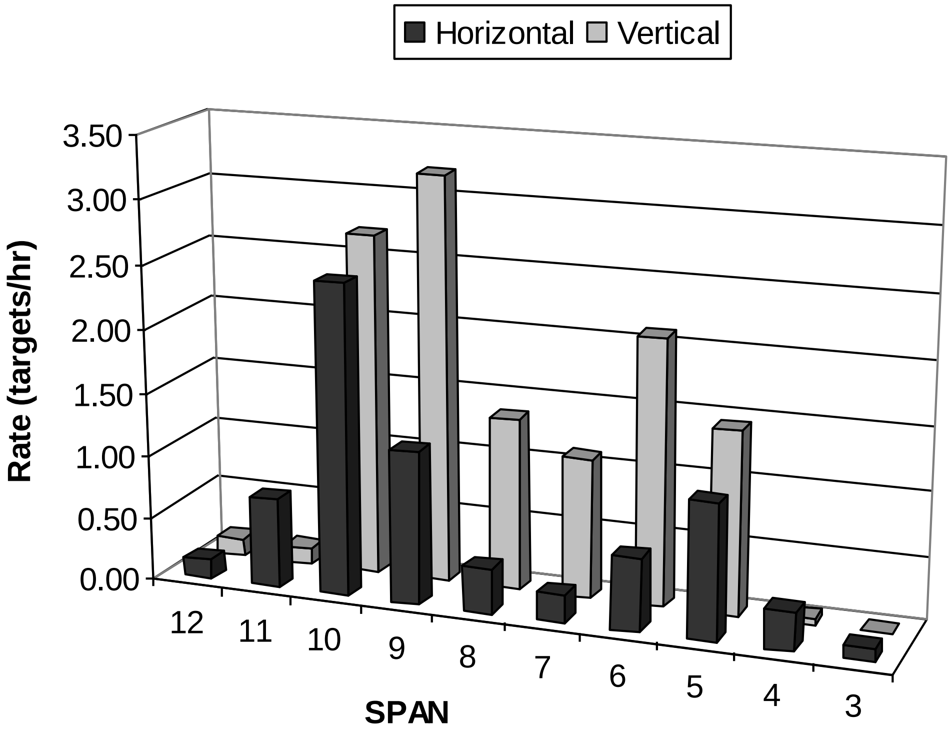

Figure 15. Horizontal and vertical radar passage rates (events/hr) by span (above and below pole-top height). Burch Mountain, 2005.

Altitude data from 961 vertical radar events showed that 8.1% (n = 78) of all events (including local birds) passed below pole-top height (≤ 37 m) along the vertical plane of the proposed transmission line (Table 7). Based on passage rates for the vertical radar, most below pole-top crossings occurred through spans 6, 8, 9, and 10, which is consistent with visual observation data. Confirmed raptor species (n = 28) crossing below the pole-top height included the American Kestrel (50%), Merlin (33%), Osprey (17%), Red-tailed Hawk (13%), Cooper's Hawk (10%), Sharp-shinned Hawk (8%), and Golden Eagle (4%) (Table 8). However, many of these confirmed observations were of local raptors including crossings by Red-tail Hawks (4), American Kestrels (2) and Golden Eagle (1). Consequently, the number of confirmed migrating raptors passing below pole-top height is reduced by 25%, to 21.

Table 7. Radar-measured flight altitudes of targets observed in the Burch Mountain Study Area, Washington, by detection method and number of targets ≤ 37m, during fall 2005.

Detection Method	Sample size	Mean	Minimum	Maximum	SD	SE	Targets ≤ 37m
Radar Only	629	315	0	1122	248	10	50
Confirmed Only	332	251	0	933	211	12	28
All Detections	961	293	0	1122	238	8	78

Throughout the day, the mean altitude of events detected by the vertical radar increased from 187.4 m in the 0900 hr to 347.3 m in the 1500 hr (Figure 16). The mean height for visual observations confirmed by radar was 251 m while the mean altitude for radar only detections was 315 m (Table 8). This may explain differences between numbers of migrants observed in the afternoon by radar compared to visual observations. As the mean migration altitude continued to increase, the ability of visual observers to detect migrants decreased.

Table 8. Radar-measured flight altitude statistics for confirmed raptor species and below ≤37m pole-top height, Burch Mountain, 2005.

		Altitude (m)[1]						
Species/ species-group	n	Mean	Minimum	Maximum	SD	SE	Detections ≤ 37m	Proportion ≤ 37m
Turkey Vulture	3	547	215	814	305	176	0	0%
Golden Eagle	48	410	25	933	224	32	2	4%
Northern Harrier	6	179	105	309	86	35	0	0%
Sharp-shinned Hawk	97	177	12	632	139	14	8	8%
Cooper's Hawk	81	223	11	758	182	20	8	10%
Accipiter spp.	27	389	67	812	208	40	0	0%
Red-tailed Hawk	47	149	16	444	117	17	6	13%
Buteo spp.	2	579	474	683	148	105	0	0%
Osprey	6	444	15	922	378	154	1	17%
American Kestrel	4	154	0	521	246	123	2	50%
Merlin	3	124	0	249	125	72	1	33%
Prairie Falcon	1	433	433	433	-	-	0	0%
Falco spp.	2	78	39	116	54	39	0	0%
Raptor spp.	5	589	63	933	383	171	0	0%

[1] Altitude above the radar station

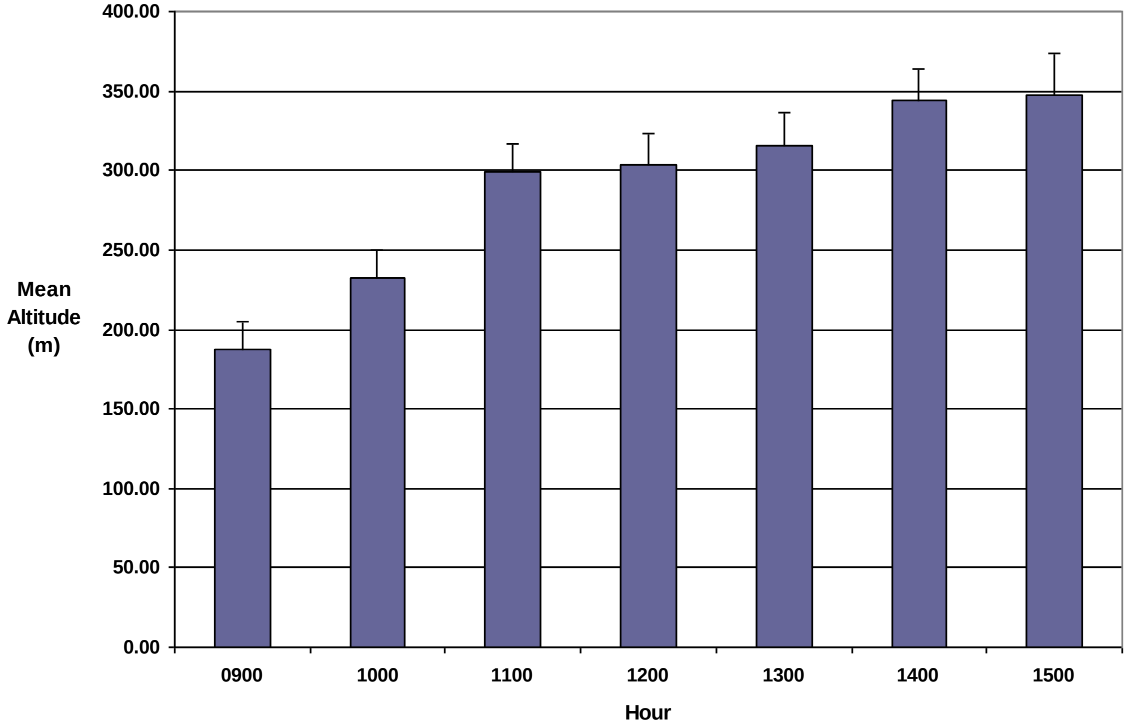

Figure 16. Mean altitude above radar (m) of raptors by hour of the day measured by vertical radar (n = 961), Burch Mountain, 2005.

DISCUSSION

Migration

We observed a minimum of 1,472 migrating raptors during 32 sample days from visual observation stations. This is similar to the total number of migrants observed at Chelan Ridge in 2004 (Smith 2005) over a 59 day period. While the numbers of migrating raptors across Burch Mountain were similar to that observed at Chelan Ridge, the species composition was not. We observed a greater proportion of accipiters (77%) compared to Chelan Ridge in 2003 (56%) and 2004 (54%) (Smith 2003, 2005). This difference was exacerbated with higher numbers of accipiters and relatively fewer hawks and eagles recorded at Burch Mountain. Higher accipiter numbers might be expected with two observations stations located further south compared to Chelan Ridge. However, we would expect similar increases in the more visible eagles and buteos as well. Differences in migration timing, patterns, or altitude by eagles and buteos may be why fewer were observed. An additional 1,064 unconfirmed events were recorded using radar, many of which were at higher altitudes.

The height at which migrating raptors passed over Burch Mountain hindered our ability to classify many migrants to species. Compared to Chelan Ridge data (Smith 2004, 2005), we recorded a high number of unclassified accipiters. The mean height of unclassified accipiters confirmed by radar was 389 m. At this altitude, accipiters gliding to the south were difficult to accurately identify. The average migration altitude reported for Sharp-shinned (117 m) and Cooper's Hawks (223 m) near Burch Mountain is a conservative estimate, since only visually confirmed accipiter species were used in the sample.

Radar data showed that the altitude at which raptors migrated increased from the morning hours into the afternoon. This trend has been reported by Kerlinger (1989) as being associated with the formation of thermals used by raptors as a source of lift during migration (Kerlinger 1989). Further evidence of this trend is the steady increase in migration passage rates throughout the morning hours into the afternoon with 83.8% of migrants passing between 1000 and 1400 hours. While visual observation data showed a slight decline in the afternoon passage rates, radar data did not. The decline reported by visual observers was likely the result of a bias in visual observations. As the migration altitude increases, the ability of visual observes to document this migration diminishes.

While raptor power line collisions are documented in the literature (Olendorff and Lehman 1986, APLIC 1994, Janss 2000) they are relatively uncommon compared to other species groups. Most avian collisions with power lines occur within daily use areas (APLIC 1994) and involve large birds with low wing loading and birds that form flocks (Beavanger 1994). Furthermore, raptor collisions are more likely to occur when the birds are distracted during courtship, prey capture, or predator avoidance (Olendorff and Lehman 1986).

Weather has often been implicated as a contributing factor in avian collisions with power lines (APLIC 1994 and Bevanger 1994). Kerlinger (1989) indicated that while migrating raptors have been observed flying in cloudy conditions, it occurs seldom and is not supported by a variety of radar studies. While we observed greatly reduced passage rates during periods of rain and low visibility (for visual and radar observations), the proportion of days with rain or low clouds was too limited to examine this question. Cloud cover may reduce the formation of thermals by limiting ground heating (Kerlinger 1989). As a result, when clouds continue to develop through the afternoon hours thermal conditions may deteriorate leading to a decline in migration. This may explain why passage rates level off in the afternoon hours.

Crossings

Because the transmission line was not present during our survey, we used the estimated pole-top elevation as the critical reference altitude for visual observation sites. Observation stations placed at pole-top height provided a conservative estimate with regard to the phase conductors because the phase conductors are attached 15 ft to 22 ft below the pole-top. From this point the conductor sags to its lowest point at or near mid-span before rising back up to the next pole.

Differences between radar and visual observations of migrating raptors are to be expected (Newton 1979) and were observed. Visual observations are biased toward migrants at lower altitudes while radar can not differentiate between species (Kerlinger 1989). However, trends in span passage were similar between the two methods. Both showed the highest passage rates across spans 5 and 6 and 9 and 10. While the radar indicated a decline in the spans 7 and 8 this is more likely a biased result due to ground clutter and radar corona that limited radar detections in these spans. Visual observations showed relatively high passage rates from spans 5 to 10 which are the highest elevation spans along the entire transmission line. While these spans were frequently crossed by migrating raptors, they passed predominately (95.3%) above pole-top height.

For the small portion of migrants that passed below the pole-top height (4.7%), most (57%) passed under spans 6 and 7. Span 6 had the highest number of migrants that passed below the estimated pole-top height, yet it is the shortest span along the study segment. Some migrating raptors passed over the prominent ridge to the southeast at a relatively low altitude. Typically, migrants began to soar over this ridge gaining altitude before passing south. However, occasionally migrants maintained a relatively low altitude, using power flight as they passed over this ridge. Migrants on the west side of Burch Mountain typically approached at a higher altitude and soared over ridges and canyons to the north, gaining altitude before departing south.

Forested habitat to the north of spans 8-10 acted as a natural obstacle to low flight for migrating raptors as did Burch Mountain itself. At its highest point, the designed line will pass approximately 250 m below the top of Burch Mountain. Migrating raptors typically passed over the mountain and maintained their altitude, in which case they were well above the line. Migrants that flew beside Burch Mountain and crossed at spans 5-7 or 10 were still above tree height and passed above the estimate pole-top elevation.

Of the migrating species that crossed at or below pole-top height, the most common species were accipiters (86.2%) which are the least likely group of raptors to collide with power lines. Accipiters are agile forest-dwelling hawks (Dunne et. al. 1988) with keen eyesight (Ehrlich et al. 1988) that are largely absent from the collision literature.

Recommendations

The collision potential for migrating raptors with the proposed 230 kV transmission line is low for most spans. Spans 6 and 7 appear to have an increased risk compared to other spans sampled. While only spans 6 and 7 may warrant the installation of wire markers to increase the visibility of the shield wires, all seven spans where raptors passed more frequently than expected will be marked with Bird Flight Diverters. This is due to an agreement between Chelan County PUD and WDFW after it was found that the line was engineered with the larger diameter optical ground wire being placed on the downslope side of the structures. The OPG wire was recommended on the north (upslope) portion of the line to increase the visibility of this wire to southbound fall migrants. However, this recommendation was not timely enough to influence the final design of the line.

Only the shield wires will be marked since the voltage of the 230 kV line is too great for any device to be installed directly on the conductor. The type and spacing of the wire markers as recommended by EDM International (Appendix 2) will be at 10 m on each wire at a staggered interval giving the appearance of 5 m spacing for approaching birds. In

2007, a post-construction survey will be conducted to document raptor migration and behavior relative to the transmission line with wire markers in place.

Acknowledgements

We would like to thank secondary observers Eric Degman, Paula Lamanna, Todd Jackson, and Josh Boyd for their assistance at the visual observation stations and Nathalie Denis and Eric Bendseil for radar data collection and summary. We would also like to thank the following cooperators for their collaboration with this project; Beau Patterson, Tom McCall, and Jim Watson, Washington Department of Fish and Wildlife, Jeff Smith, HawkWatch International, Jon Soest and Dan Stephens, Northwest Chapter Audubon Society, Bud Anderson, Falcon Research Group, Kent Woodruff, U. S. Forest Service and John Musser, Bureau of Land Management.

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Appendix 1. Daily raptor migration observations and observer effort at visual observation stations, Burch Mountain 2005.

DATE	Total Effort (hr)	SSHA	COHA	NOGO	UACC	RTHA	RLHA	UBUTEO	BAEA	GOEA	UEAGLE	AMKE	MERL	PRFA	PEFA	UFALC	TUVU	NOHA	OSPR	URAPT	TOTAL
30-Aug	22.0	3	3	0	2	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	10
31-Aug	25.7	9	3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	14
1-Sep	26.5	4	4	0	6	2	0	0	0	0	0	1	0	0	0	0	0	0	1	0	18
2-Sep	25.2	8	6	0	6	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	22
6-Sep	23.5	11	6	0	3	0	0	1	0	0	0	0	1	0	0	0	1	1	1	0	25
7-Sep	24.1	43	18	0	10	3	0	1	0	1	0	2	2	1	0	0	1	1	0	0	83
8-Sep	32.5	39	12	0	12	0	0	0	0	2	0	1	1	0	0	0	0	0	1	1	69
9-Sep	24.2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4
12-Sep	26.0	11	7	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	21
13-Sep	33.2	23	11	0	13	0	0	1	0	1	0	3	0	0	0	0	1	3	0	1	57
14-Sep	26.4	32	10	0	5	3	0	0	0	2	0	1	0	1	0	1	0	0	0	6	61
15-Sep	33.3	23	15	0	8	1	0	1	0	3	0	2	0	0	0	0	0	1	2	4	60
16-Sep	25.2	5	1	0	4	0	0	2	0	0	0	0	0	0	0	0	0	2	0	0	14
19-Sep	24.6	29	15	1	7	1	0	0	0	1	0	0	0	0	0	1	0	0	0	2	57
20-Sep	34.5	17	9	0	7	1	0	0	0	0	0	1	3	0	0	0	0	1	1	2	42
21-Sep	25.9	19	15	0	10	2	0	4	0	3	0	0	0	0	0	0	0	0	1	0	54
22-Sep	34.9	50	24	0	17	3	0	0	0	3	0	1	1	1	0	1	0	0	3	5	109
23-Sep	25.5	11	12	0	5	2	0	0	0	3	0	0	0	0	1	1	0	1	0	1	37
26-Sep	26.3	18	13	0	3	2	0	0	2	3	0	0	2	0	0	0	0	1	0	5	49
27-Sep	35.7	20	20	0	7	8	0	0	0	2	0	2	1	0	0	1	2	0	0	0	63
28-Sep	27.5	7	1	0	4	3	0	0	0	3	0	2	0	0	0	0	0	0	2	3	25
29-Sep	32.7	13	11	1	7	1	0	0	0	4	0	0	1	0	0	0	0	0	1	0	39
30-Sep	26.8	7	6	0	3	0	0	1	0	0	1	1	3	0	0	1	0	0	1	0	24
3-Oct	24.4	4	3	0	2	0	0	0	0	3	0	0	0	0	0	1	0	0	2	0	15
4-Oct	33.0	32	20	3	13	6	0	0	0	12	1	3	0	0	1	0	0	0	0	1	92
5-Oct	26.2	15	6	0	4	3	0	0	0	4	0	0	1	0	0	0	0	0	0	0	33
6-Oct	32.0	26	15	0	6	1	0	0	0	0	0	0	2	0	0	1	0	0	0	1	52
7-Oct	26.3	23	17	1	7	1	0	0	0	4	0	1	1	0	0	0	0	0	0	1	56
10-Oct	26.2	14	10	1	5	12	0	0	0	7	0	0	0	0	0	1	1	0	0	0	51
11-Oct	33.5	23	14	0	6	11	1	2	0	13	0	0	0	0	0	0	0	0	0	2	72
12-Oct	27.6	6	7	1	4	2	2	0	0	1	0	1	1	0	0	0	0	1	0	0	26
13-Oct	33.9	34	28	4	11	16	1	2	0	13	2	0	1	0	0	0	0	1	0	5	118
Total	**905.3**	**582**	**342**	**12**	**199**	**85**	**4**	**15**	**2**	**88**	**4**	**24**	**21**	**3**	**2**	**9**	**6**	**15**	**18**	**41**	**1472**

Appendix 2. Review of raptor collision potential by fall migrants along the proposed Burch Mountain Transmission line, EDM International.

Burch Mountain Raptor Collision Risk Analysis

Submitted to:

Chelan County PUD

January 2006

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1.0 INTRODUCTION

In 2005, EDM International, Inc. (EDM) partnered with Chelan County Public Utility District (Chelan County PUD) to develop a study design to monitor migrating raptors at Burch Mountain. The objectives of the study were to combine visual observations with vertical and horizontal radar to identify future transmission line spans where migrating raptor flight paths might intersect with the proposed line. The following report includes background information on avian interactions with power lines and results from the completed migration study. Recommendations for wire-marking also are included for select spans.

2.0 BIRD COLLISIONS

Birds face collision threats from power lines, television towers, radio and cellular telephone towers and related wires, wire fences, wind turbines, cars, aircraft, trains, etc. Although birds often exist near power lines without significant collision risks, problems occur in localized areas where certain factors exist. To understand why birds fly into power lines, the activities resulting in the collisions need to be identified and different factors analyzed.

2.1 Structure Configuration

Burch Mountain is adjacent to Chelan Ridge, which concentrates migrating raptors. As the migrants pass over Burch Mountain, they may encounter portions of the proposed transmission line. Collision risk increases when power line conductors are placed at different elevations on a structure. A horizontal configuration minimizes the potential collision zone (APLIC 1994). The proposed Chelan County PUD 230 kV transmission line is of horizontal construction with all 3 conductors at the same elevation supported by steel poles (Figure 1). This will allow birds to cross over or under all 3 primary conductors by making only one flight adjustment.

Visual pollution is an important component of transmission line design and sometimes nonspecular (nonreflective) conductor is used to blend wires into the background. However this also makes wires difficult to see by migrating and local birds. The Chelan County PUD 230 kV transmission line wires are secular (reflective) and will provide greater contrast with the landscape than nonspecular conductor.

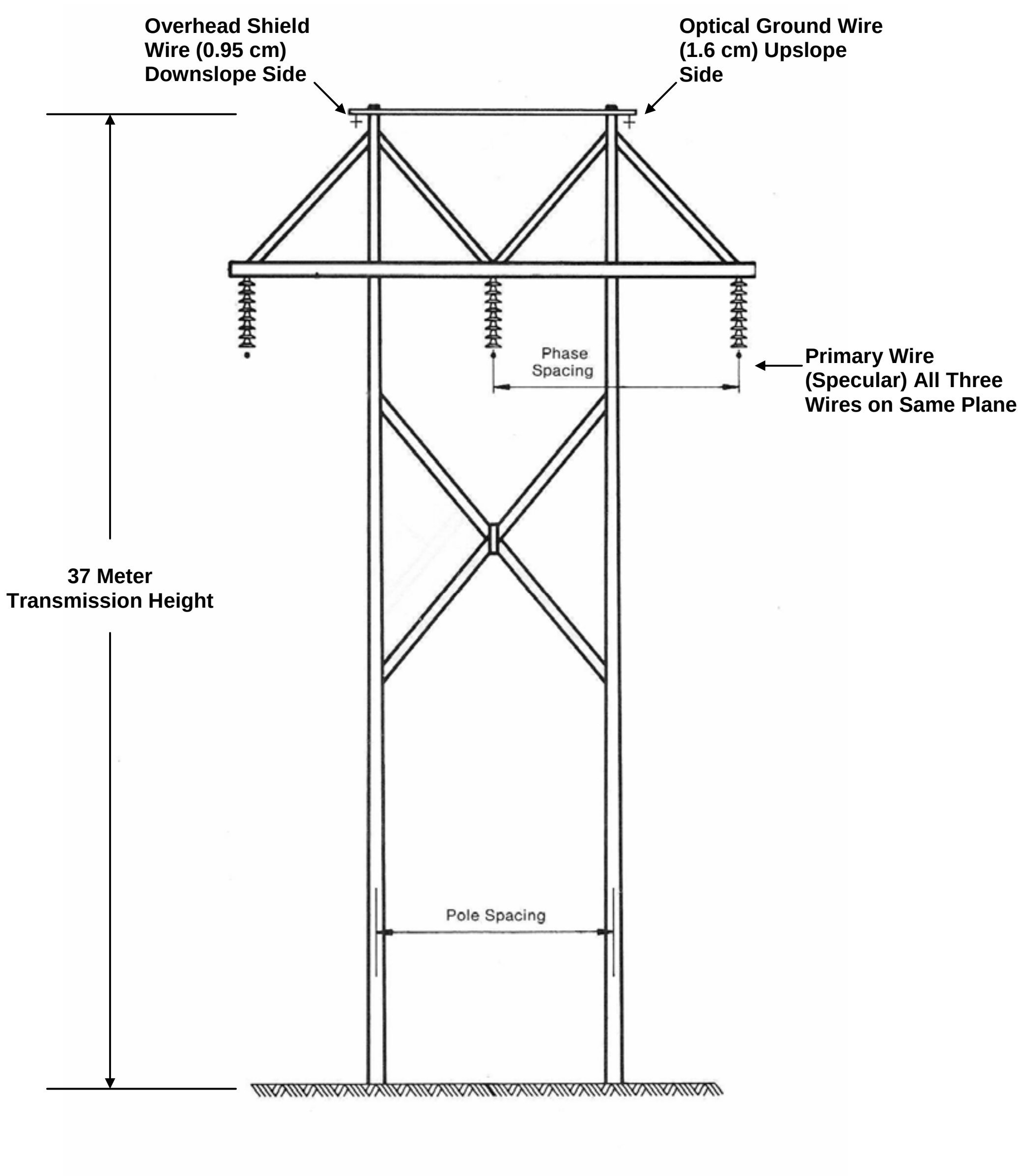

Figure 1 Typical 230 kV H-Frame Construction

2.2 Overhead Shield Wires

Overhead shield wires are frequently located above the transmission conductors. These conductors are grounded and are used to shield lightning from striking the transmission conductors. Overhead shield wires are typically smaller than transmission conductors and several reports have stressed reduced shield wires are more likely to cause bird collisions (APLIC 1994). There are eyewitness accounts of birds managing to avoid phase conductors in time, only to crash into the overhead shield wires, which were thinner and less visible (Crowder 2000).

The proposed Chelan County PUD 230kV transmission line will be constructed with 2 overhead shield wires (Figure 1). Two types of wire will be used. A standard diameter (0.95 cm) shield wire will be used on the eastern or downslope side of all the structures. An optical ground wire (1.6 cm) that contains fiber optic cables will be placed on the western or upslope side of the structures. The larger wire will be positioned on the upslope side so that it is the first wire encountered by migrating birds coming from the north. Since the fiber optic cable is almost two times larger in diameter, it is expected to be more visible to local and migrating raptors.

2.3 Weather

Inclement weather is the most frequently described factor affecting bird collisions (APLIC 1994). The most important weather conditions are related to visibility and reduced flight control in high winds.

Thunderstorms are usually considered too violent to be used for migrating raptors (Kerlinger 1989). Violent updrafts subject migrating birds to below-freezing temperatures, precipitation, and low oxygen partial pressure (Kerlinger 1989). However raptors sometimes turn towards an oncoming storm front to take advantage of the rising air displaced by the falling rain (Smith 1985). Rain almost always suppresses migration (Newton 1990). Haugh (1972) found that red-tailed hawks had a greater tendency to interrupt migration when weather conditions were poor and radar studies have shown that birds migrate more often without precipitation than with precipitation (Richardson 1978).

Another weather factor that can deter migration is fog. In a northern California study, red-tailed hawk and accipiter migration was negatively correlated with fog (Hall et al. 1992). Richardson (1978) in a review of migration notes a number of papers in which autumn hawk migration is suppressed by extensive rain or fog due to a lack of thermals (Broun 1939, Mueller and Berger 1961, Beaman and Galea 1974).

Visibility was recorded hourly at the site. Passage rates were highest during periods of unlimited visibility (defined as visibility greater than 30 km). Although precipitation only occurred on five days at the Burch Mountain site, passage rates were lower than average during these periods of light precipitation. The tendency to interrupt migration during inclement weather minimizes collision risks. Problems could still occur if birds encounter these conditions unexpectedly after initiating migration.

2.4 Wind

Wind direction and wind speed can either be of assistance or a hindrance to migration. In fall, large western raptor counts are often correlated with following winds and low barometric pressure or during periods of warm fair weather (Hoffman 1985). Increasing wind speed can be a benefit to migration by producing updrafts and creating ridge lift, but at the same time if wind speed is too strong thermals can be disrupted and thus impede migration (Hall et al. 1992, Richardson 1978).

High winds reduce flight control, contributing to potential power line collisions (APLIC 1994). Migration at the Burch Mountain site was disrupted during a period of high wind. The lowest passage rate recorded at the Burch Mountain site was 4 detected birds on September 28th. This day also recorded the highest mean wind speed of the fall migration season. The tendency to interrupt migration during strong winds minimizes collision risks. Problems could still occur if birds encounter these conditions unexpectedly after initiating migration.

2.5 Time of Day

Poor visibility is an important collision factor and birds crossing power lines before sunrise or after dusk have greater difficulty seeing wires (APLIC 1994). Migration magnitude and altitude are closely tied to the time of day. In general, raptors migrate in greater numbers on rising air as temperatures increase throughout the day. This is supported by visual observations and radar tracking at the Burch Mountain site. Raptor migration was lowest during the early morning hours, increased through midday, then declined into the afternoon. The bulk of raptors migrated between 10:00 am and 2:00 pm (83.8%) with only 5.5% moving before 10:00 am and 11.1% after 2:00 pm.

Additionally, early morning raptor migration was monitored September 20-22 beginning at 8:00 pm. No migrants were observed prior to 9:00 am on these days although the daily passage rates for September 20 and 22 were higher than average.

2.6 Flight Elevation

Raptors use two different methods for migrating long distances, powered flight and gliding flight. Powered flight and gliding flight are used to varying degrees by different species. For example, the most common species detected at Burch Mountain is the sharp-shinned hawk, which uses powered flight more than red-tailed hawks (Kerlinger 1989).

In gliding flight raptors utilize ridgelines and thermals to soar for long distances. When horizontal wind is deflected upward by a ridgeline an updraft occurs. Raptors use these updrafts by soaring in circles in the updraft gaining altitude and then gliding in their general migratory direction or by continually gliding through the updraft without necessarily gaining altitude. Raptors utilize thermals in a similar way. Thermals are created when temperature and pressure gradients are formed so that warm air rises and is replaced by cooler air. Thermals can extend to hundreds or thousands of meters (Kerlinger 1989). Radar studies indicate that when using thermals in temperate areas, raptors typically fly at altitudes between 300 and 800 meters (Newton 1990). Birds sometimes migrate at these high altitudes to take advantage of strong stable winds. Lower temperatures at higher altitudes may also prevent overheating during labored flight.

Flight elevation near power lines is an important collision factor. Accordingly, radar was used to measure the flight altitudes of raptors in the Burch Mountain study area. Radar-measured flight altitudes of common raptors observed at the Burch Mountain study area are listed in Table 1.

Table 1 Burch Mountain Radar-Measured Mean Flight Altitudes

Species	Sample Size	Mean Altitude (m)
Sharp-shinned hawk	97	177
Coopers hawk	81	223
Accipiter Species	27	389
Golden eagle	48	410
Red-tailed hawk	47	149

The mean altitudes recorded for all species are greater than the 37 meter estimated transmission pole-top height. The vast majority of the 332 confirmed migration crossings detected by radar (91.5%) passed above the proposed 37 meter estimated pole-top height. The radar detected only 28 confirmed crossings (8.5%) below the pole-top height over the 32 days of observations (Table 2). The predominant crossings were by accipiters, consisting of 8 sharp-shinned hawks and 8 Cooper's hawks.

Table 2 Number of Crossings below the Proposed Pole-Top Height Detected by Radar

Species	Number
Accipiter Species	16
Golden eagle	2
Merlin	1
Red-tailed hawk	6
American kestrel	2
Osprey	1

Visual observations of migrant crossings below pole-top height were collected independently. For the visual observations, only 4.7% (n = 58) of the migrating raptors that crossed the vertical plane of the proposed line (n = 1,235) were below pole-top height (Table 3). Like the radar study, the predominant species were accipiters, consisting of 35 sharp-shinned hawks, 7 Cooper's hawks, and 8 unidentified accipiters.

Table 3 Number of Migrant Raptors below the Proposed Pole-Top Height Detected by Visual Observations

Species	Number
Accipiter Species	50
Golden eagle	1
Merlin	4
Northern Harrier	1
Red-tailed hawk	2

Spans 5 to 11 had the greatest number of observed migrating birds, with 75.4% of all species crossings. Within this proposed line section, Spans 6 and 7 accounted for 51.7% of all 58 observed migrants passing below the pole-top height. Although proposed span 6 is the shortest span in the study area, it had the greatest number of below pole-top migrants (n = 14).

2.7 Local Raptor Use

Raptors observed perching and or hunting in the vicinity of the line were not classified as migrants to reduce the potential of inflating the number of migrating raptors observed (HawkWatch 2005). These birds were observed crossing the line multiple times in a relatively short duration. A total of 193 raptor line crossings were recorded for these species. The majority of local raptors crossing the proposed transmission line were above pole-top height (69.9%). It is expected that local birds will habituate to new facilities, adjusting their flight patterns to new obstacles in their daily areas (Harmata et al. 1997). Most the repeated line crossings were by red-tailed hawks (28%), followed by golden eagle (26.4%), sharp-shinned hawk (20.7%), and Cooper's hawk (8.3%).

2.8 Physiology and Behavior

Size and maneuverability are important factors in evaluating species' vulnerability to collisions with overhead wires (Bevanger 1998). Soaring and slow-flying species can be expected to be less vulnerable to collision hazards than fast, strong flyers (i.e. species with high wing loading). As discussed in Olendorff and Lehman (1986), raptors have the following physical and behavioral attributes which decrease their susceptibility of collision:

1. Raptors have keen eyesight.
2. Many raptors soar or use relatively slow flapping.
3. Most raptors are maneuverable in flight.
4. Raptors learn to use utility structures and likely become conditioned to wires.
5. Unlike waterfowl, raptors do not fly in restrictive flocks.

Generally, raptors are infrequently involved in collisions although they spend extensive periods of time in the air relative to other species (Bevanger 1994). In a retrospective study of raptor collisions conducted in 1986 by Olendorff and Lehman, raptor collision mortality information was sought from a variety of sources including ornithological journals. A total of 88 records were reviewed and the most commonly reported species were peregrine falcons (27%), bald eagles (17%), golden eagles (10%), red-tailed hawks (8%) and ospreys (8%). No accipiters were recorded.

Although raptors are agile flyers with excellent eyesight, they may be more susceptible to colliding with power lines when preoccupied or distracted (e.g., territorial defense, prey pursuit) (Olendorff and Lehman 1986; Thompson 1978). Except for critically endangered species (e.g. California condor), collisions with power lines are likely a low level, random, and insignificant mortality factor for raptor populations (Olendorff and Lehman 1986).

Both the Burch Mountain radar study and observational studies denote the most common migratory species as accipiters (Table 4). The field observations detected 1,135 accipiters (77.1%) and the radar study yielded 205 confirmed accipiters (62%). Accipiters inhabit woodlands and have short rounded wings and long tails. They are built for rapid maneuverable flight among branches inside the forest. Accipiters feed on many bird species by surprising them with quick bursts of speed. Based on their morphology and preference for forested areas, the three accipiter species are not at a high risk of collision.

Table 4 Species Detections by Observers and Radar

Species	Observations	Radar
Accipiters (3 spp.)	1135	205
Golden eagle	88	48
Buteo (2 spp.)	89	49
Falcons (5 spp.)	59	10
Bald eagle	2	0
Unidentified Eagle	4	0
Turkey Vulture	6	3
Osprey	18	6
N. Harrier	15	6
Unknown	56	5

Buteos and golden eagles were the second most numerous detected species. Buteos or soaring hawks, and eagles have broad wings, wide tails and are built for soaring. Based on their morphology, these species are not at a high risk of collision although incidents are reported in the literature (Olendorff and Lehman 1986). Power line surveys in Colorado, Montana, and Alaska also confirm both bald and golden eagle collisions (Harness et al. 2003).

The fourth largest raptor group is represented by 5 falcon species. Falcons have pointed wings and long tails. They are built for rapid flight and mainly feed on bird species by diving from high altitudes to catch birds in midair. Although falcons are agile fliers, some species such as the peregrine falcon can be vulnerable to collisions because of their hunting behavior (attaining high speeds when following prey near the ground) (Olendorff and Lehman 1986).

2.9 Age

Age of birds may influence the risk of collision. Young birds unfamiliar with power lines and new terrain are more vulnerable than older experienced birds (APLIC 1994). Observations yielded age classifications for 227 migrating accipiters, 62 eagles, and 48 buteos. Fifty percent of the accipiters were juvenile birds. Fifty-five percent of the eagles were sub-adults and 25% of the buteos were juveniles.

3.0 ELECTROCUTION

Negative power line interactions can occur when raptors collide or are electrocuted by power lines. Electrocutions occur when birds are large enough to span the distance between wires or between an energized component and a ground. Suggested Practices for Raptor Protection on Power Lines – The State of the Art in 1996 recommends 60 inches of separation to prevent eagle contacts (APLIC 1996). The proposed 230 kV H-frame line will be constructed with National Electrical Safety Code (NESC) conductor clearances. The NESC requires greater clearances above the ground and between conductors as voltages increase.

The proposed new line exceeds the minimum eagle separation recommendations with a phase-to-pole (ground) separation of approximately 8 feet and a vertical separation of approximately 11 to 15 feet. With this separation, the proposed facilities will not pose an electrocution threat to any birds. Even an adult female eagle with a maximum wingspan of 90 inches will have adequate clearance. The use of suspension insulators also contributes to safety for large perching birds and eagles because the conductors are safely suspended under the arms (Figure 1).

4.0 POSITIVE INTERACTIONS

Raptors and power lines interact in several ways. Positive interactions occur when power structures provide perching and hunting sites. Many raptors spend considerable time hunting from utility structures because this technique uses little energy. When raptors have a choice of hunting techniques, they often select a method that uses the least amount of energy (Newton 1979). Raptors will likely use portions of the proposed line for hunting in the treeless areas of Burch Mountain.

Another positive interaction is the use of power structures as nesting sites. The availability of suitable nest sites can limit raptor populations in both diurnal raptors and nocturnal species (Newton 1979). Transmission and distribution power lines in treeless regions have increased the availability of nesting sites with positive results for eagles, hawks, and falcons. In the northwest, ospreys have benefited from the use of power line structures and preferentially choose utility structures near water upon which to construct their nests (Henny and Kaiser 1996). There is an unoccupied golden eagle nesting territory on Eagle Rock. It is unknown if eagles will use the transmission H-structures for nesting but the added perch sites could provide increased foraging success. This in turn could increase future nesting success for eagles and other species.

5.0 WIRE MARKING

One of the most effective ways to reduce collision mortality is to mark overhead shield wires to make them more visible. Overhead shield wires are the wires most often struck by birds (Scott et al. 1972, Brown et al. 1987, Faanes 1987, Savereno et al. 1996). Marking devices should not be installed on electrically energized conductors with a voltage of 230 kV because of ozone deterioration (Hurst 2004). The ozone destroys the chemical properties and makes marking devices brittle, reducing their service life. Marking devices will also create radio and television interference when installed on higher voltage conductors (Hurst 2004). This is not a problem on overhead shield wires.

Devices that physically enlarge the wire commonly act as wind-catching objects, encouraging icing in winter and increasing the risk of wire and power breaks due to line tension and stress loads. The attachment of devices also may cause physical damage through abrasion to the conductors. This is a concern for both primary energized wires and overhead shield wires. Prior to installing any devices, engineering should review the devices to be installed.

5.1 Wire Marking Products

Although several products are available to mark power lines there have been very few rigorous experimental designs to test their effectiveness. Additionally there are very few studies comparing various products. Following is a discussion of the various products available to mark overhead shield wires and their advantages and disadvantages.

5.1.1 Flapper

The Flapper (Photo 1) was designed in South Africa in partnership with Preformed Line Products, ESKOM and the Endangered Wildlife Trust (EWT). The Flapper is distributed by Kaddas and is designed to securely grip wires up to a diameter of 18mm with a locking plastic jaw. The Flapper can be installed and removed from the ground (Photo 2) and has been UV stabilized and is available in red, white, and black. Black and white flappers provide maximum contrast. The advantage of the Flapper is the movement of the swinging plate helps make a line more visible than simply increasing the line profile.


Photo: Kari Spire

Photo 1 White Flapper


Photo: Kari Spire

Photo 2 Flapper Installation

The Flapper is in use in Africa and is effective at reducing collisions. However, ESKOM has experienced problems with the device shifting (van Rooyen 2005, Kruger 2004). Flappers installed on 345kV shield wires in Colorado in 2002 were revisited in 2005. Similar to the problems noted in Africa, many of these devices had broken flappers and/or shifted (EDM 2005).

5.1.2 BirdMARK Bird Flight Diverter and FireFly

Photo 3 BirdMARK Bird Flight Diverter

The BirdMARK (Photo 3) is distributed by P&R Industries and is designed to securely grip wires up to a diameter of 70mm with a strong spring-loaded clamping jaw. The clamping jaw is also used with several other P&R products designed specifically for power lines.

The BirdMARK can be installed and removed from the ground without interrupting power. The manufacturer claims the BirdMARK will stay in position even in a Force 8 gale. The swinging roundel is available in either orange or red-and-white.

Recently this product line was expanded to include the FireFly. The FireFly uses the same clamp but the circular plate has been replaced with a rectangular plate. The rectangular plate includes a reflective and fluorescent reflective surface (Photo 4 and Photo 5).

Photo 4 FireFly During the Day

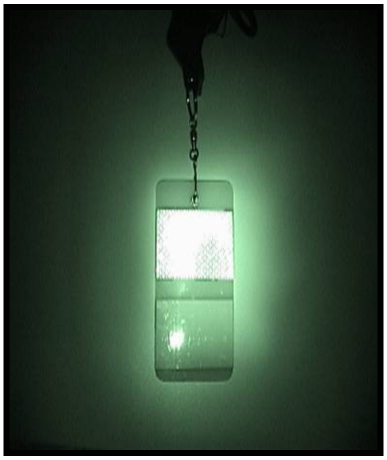

Photo 5 FireFly at Night

The advantage of the BirdMARK and FireFly is the movement of the swinging plate helps make a line more visible than simply increasing the line profile. In areas where vandalism is a constant problem with overhead power lines, a marking system resembling a target might create problems. Unfortunately, no studies on the effectiveness of the BirdMARK or FireFly were found in the scientific literature although it would appear the device should be similarly effective as the Flapper. Problems with breaking/missing plates have been noted in California with the FireFly (EDM 2005).

5.1.3 Bird Flight Diverter

The Bird Flight Diverter (BFD) was developed in Europe during the 1970's (Figure 2). The BFD is made from a high impact standard grey PVC and is UV stabilized.

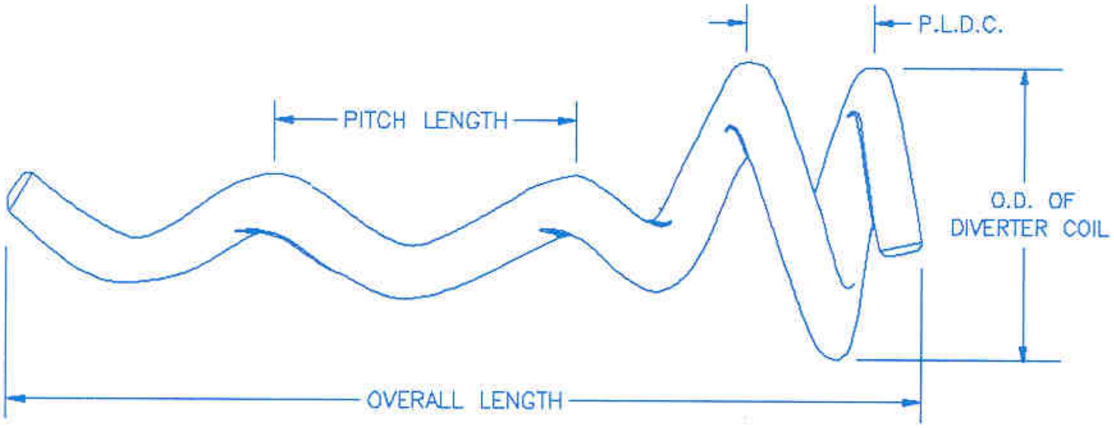

Figure 2 Bird Flight Diverter Manufactured by Dulmison (made from high impact PVC and UV stabilized)

The Dulmison BFD is available in a variety of colors and different sizes to accommodate a conductor ranging from 0.44 to 3.08 cm (Photo 6).

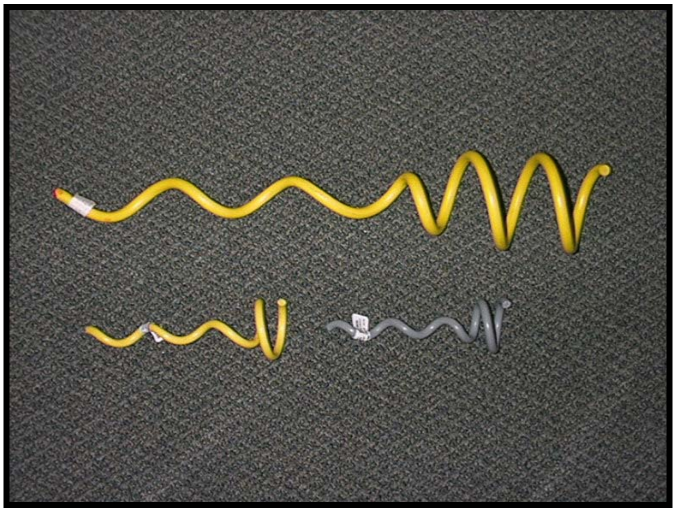

Photo 6 Bird Flight Diverters for Small and Larger Wires

The BFD has been shown to be effective when installed on transmission overhead shield wires in Europe. Typical spacing ranges from 5 to 10 meters in Europe. In North

America, the BFD has also shown to be effective in reducing waterfowl collisions with overhead shield wires (Crowder 2000). The spacing of the BFDs in Crowder's 1998-2000 study was 6 meters (20 feet) apart. The BFD is believed to be effective because its profile makes the wires more visible.

The BFD colors may fade after long periods of exposure but should not become brittle or lose their elastic properties. ESKOM has used the Preformed Line Products - Bird Flight Diverter in South Africa for years with no reports of mechanical failure although some red PVC devices have faded (van Rooyen 2005).

5.1.4 Swan Flight Diverter

The Swan Flight Diverter (SFD) is similar to the BFD but includes four 17.8 cm spirals (Photo 7). The SFD is made from a high impact standard grey PVC and is UV stabilized. The Dulmison SFD is available in a variety of colors and is available in different sizes to accommodate conductors ranging from 0.44 to 3.08 cm.

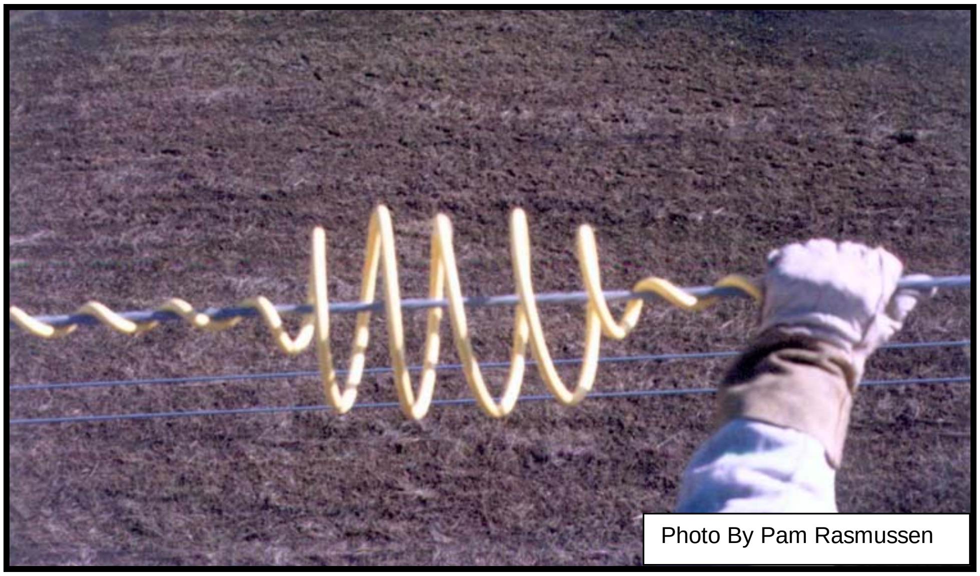

Photo By Pam Rasmussen

Photo 7 Swan Flight Diverters being Placed on a Shield Wire

The SFD has been shown to be effective when installed on transmission overhead shield wires in North America. In the early 1990's Northern States Power Company addressed a problem where endangered trumpeter swans were colliding with a power line during the winter months in a small bay on the St. Croix River in Hudson, Wisconsin. Yellow SFDs were installed to make the shield wires more visible in low light and poor visibility conditions. The SFDs were installed May of 1996 on a 15-meter spacing staggered on each parallel shield wire, resulting in an appearance of 7.6-meter spacing. As of 2005, no additional collisions or deaths have been documented (Rasmussen 2005).

In Indiana, the SFD has also shown to be effective in reducing waterfowl collisions with overhead shield wires (Crowder, 2000). The spacing of the SFDs in Crowder's 1998-2000 study was 6 meters (20 feet) apart (Photo 8). The close spacing was required to compare the effectiveness of the SFD to the BFD.


Photo By Michael Crowder

Photo 8 Swan Flight Diverters Installed at a 6-Meter Interval in Indiana

The SFD colors may fade after long periods of exposure but should not become brittle or lose their elastic properties.

5.1.5 Spiral Vibration Dampers

Spiral Vibration Dampers (SVD) are manufactured from solid PVC into a helix (Figure 3). The purpose of the damper is to reduce high frequency aeolian vibration. The SVD is designed to provide the action/reaction motion to oppose the natural vibration of cable by gripping a conductor tight at one end; loosely on the opposite end. The vibration is often inducted by low velocity winds of 4.5 – 2.9 kmph.

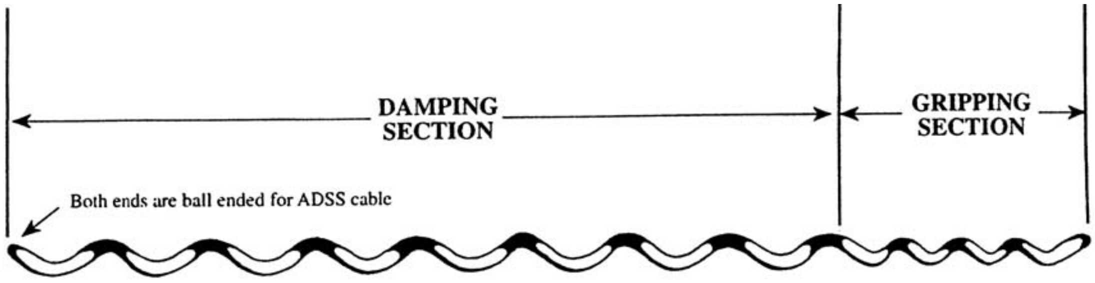

Figure 3 Spiral Vibration Damper

The Dulmison SVD is made from a high impact standard UV stabilized PVC. The SVD is also available in a variety of colors. There are also different sizes available to accommodate a conductor ranging from 0.44 to 1.9 cm.

SVDs were used in the San Luis Valley in Colorado to mitigate crane collisions. Coverage of the wires was 27.5% of each span, reducing collisions by 61%. The SVD colors may also fade after long periods of exposure but should not become brittle or lose their elastic properties. Tri-State has used the Dulmison and Preformed spiral vibration dampers for approximately 16 years without any failures (Dille 2005). The dampers are easy to install however after several years they do become brittle and will break if they need to be removed (Dille 2005).

5.2 Marker Spacing

The space between wire markers varies depending upon a number of factors including the size of marker, species, and bird concentrations. The optimal way to install markers is to stagger them to minimize the number of devices required. In the collision studies documented in “Mitigating Bird Collisions with Power Lines: The State of the Art in 1994” the BFD reduced collisions from 86-89% when spaced 5 meters apart and 57-58% when spaced 10 meters apart. The larger BFD (Catalog BFD-7) reduced collisions 65-74% when spaced 15 meters apart. The SVD reduced collisions 61% when 27.5% on the span was covered. Northern States Power Company eliminated swan collisions using yellow SFDs at staggered 15-meter spacing, resulting in an appearance of 7.5-meter spacing.

It is important to note the reported collision reduction levels are complied from a variety of sources and are not directly comparable due to varying methodologies, environments, and bird species. Also, none of the studies specifically addressed raptor collisions.

The optimal diverter placement is to stagger the devices midway between each other to reduce the number of markers. A significant portion of the cost associated with installing any marker is getting the proper placement of the devices. When stringing the conductors it is important to mark where the diverter is to be placed rather than to perform measurements when the wires are in the air. This is more critical when installing markers with a helicopter or tall crane than when using a pull cart.

5.3 Maintenance and Reliability

Given today’s pressures to ensure reliability, it is imperative that utilities exercise due diligence when seeking to implement solutions to such problems. Care must be exercised in solving problems to avoid creating additional problems that could lead to degradation of facility availability by promoting either forced or scheduled outages. Thus, utilities should exercise caution by using solutions with a proven track record or by thoroughly testing potential solutions before implementing them on critical facilities.

Although active devices (e.g., Flapper, BirdMARK, FireFly) have been shown to effectively reduce collisions, passive PVC devices have proven to be effective in the long-term. Tri-State has used spiral vibration dampers for approximately 16 years without any failures (Dille 2005) and Northern States Power has successfully used the Swan Flight Diverters since 1996 with no maintenance problems (Rasmussen 2005). Likewise, Northwest Energy has used the BFD's for over 6 years with no shifting or other maintenance problems (Milodragovich 2005).

6.0 PROJECT CONCLUSIONS

6.1 Projects Risks

Collisions with the proposed line are expected to be minimal due to the following line configuration factors:

1. Horizontal configuration.
2. Specular (reflective) conductor.
3. A larger optical ground wire on the upslope side to make it more visible to fall migrating raptors.

Additionally the radar and visual study results support minimal risks due to the following observations:

1. Migration was highest during periods of good lighting and visibility.
2. Raptors reduced their migration during high winds and rain.
3. The vast majority of migrating raptors passed above the proposed 37 meter estimated pole-top height.
4. Accipiters, buteos, eagles and falcons were recorded in small numbers below the proposed pole-top height.
    a. Radar: 28 birds passed below the pole-top height.
    b. Visual: 58 birds passed below the pole-top height.

Although buteos, eagles and falcons have been recorded in the literature as occasional victims of collision, raptor collisions with power lines are typically a random, low-level, and biologically inconsequential mortality factor for raptors (Olendorff and Lehman 1986). Raptors are at lower risk due to the following physical and behavioral attributes which decrease their susceptibility of collision:

1. Raptors have keen eyesight.
2. Many raptors soar or use relatively slow flapping.
3. Most raptors are maneuverable in flight.
4. Raptors learn to use utility structures and likely become conditioned to wires.
5. Unlike waterfowl, raptors do not fly in restrictive flocks.

The exception is in the case of critically endangered species, of which none were detected in the project area. Additionally, it is expected that local birds will habituate to new facilities, adjusting their flight patterns to new obstacles in their daily areas (Harmata et al. 1997).

The proposed transmission line project will not pose an electrocution risk due to the phase-to-phase and phase-to-ground clearances.

6.2 Overhead Static Marking

Although the mean below pole-top passage rate (migrants/hr ± SE) for spans 6 and 7 were low with 0.02 and 0.06 ± 0.02 migrants/hr respectively, these spans are recommended because 51.7% of the 58 migrants observed passing below the proposed pole-top height are at these two spans. These spans also fall within Spans 5 to 11 where 75.4% of all observed species crossings (above and below pole-top) were recorded. Marking the shield wires on these two spans during construction will further minimize collision risks and this is preferable to retrofitting lines at a later date.

6.3 Marker Type and Spacing

Although swinging plates were tested in the San Luis Valley of Colorado and successfully reduced collisions (APLIC 1994), utilities using the Flapper have experienced problems with the devices slipping on the wires. The BirdMARK and FireFly appear to have solved this problem by using a high strength spring and padded grip but no data are available on their effectiveness. FireFlys and Flappers also have experienced problems with deteriorating plates (EDM 2005).

It is important to select mitigating measures that will need minimal maintenance. Until test data are available demonstrating the Flapper, BirdMARK, and FireFly plates are aerodynamically stable and that the devices will stay in place during high winds, passive devices should be sought for this project. Given the remote location of this line, and the difficulty of accessing overhead shield wires, active type devices are not recommended.

Passive marking devices include the SVD, BFD, and SFD. These products have all been demonstrated to reduce collisions with waterfowl, cranes, bustards, and swans (APLIC 1994). There are very few comparative studies testing the effectiveness of various marker devices. The exception is one study by Crowder (2000) comparing the SFD and BFD in their effectiveness to reduce waterfowl collisions at an Indiana wetland. There was no significant difference between the SFD and BFD based upon the number of dead birds per search (Crowder 2001). There are no studies on which marker type is most effective for raptors.

Passive devices are recommended for the Chelan County PUD 230kV line because they are manufactured from a high impact PVC that possesses excellent strength and long-term durability. Given the diurnal nature of the migrating raptors and their good vision, the preferred marking type is the BFD. These devices are smaller than the SFD and will reduce potential wind and ice loading issues.

Although these devices are available in a variety of colors, there is a general consensus that these devices work because they increase the profile of the line, not because of their color (APLIC 1994). However, the BFD should be ordered in yellow to maximize contrast with the horizon during low light. The BFDs should be installed on a 10m staggered interval for spans 6 and 7 on the static and optical ground wire. This will give the appearance of 5m spacing from the side.

6.4 **Maintenance**

Given the long-term effectiveness of PVC devices, the BFDs should be inspected minimally on a 3-year cycle during routine line patrols. If a BFD is discovered to be missing/damaged during routine patrols it should be replaced during the next scheduled maintenance. The conservative spacing resulting in an appearance of a 5m interval allows for an occasional missing device while still increasing the line's profile. If multiple devices are missing on an individual overhead shield wire they should be replaced. If there is a need to delay replacements, an evaluation of the collision risk at that particular span should first be assessed. This decision should be coordinated with the U.S. Fish and Wildlife Service and Washington Department of Fish and Wildlife and their biological expertise sought.

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