APPENDIX H

WEPP MODEL

Mt. Ashland Ski Area Expansion

Erosion Rates and Sediment Yield Predictions Using the WEPP Model

FEIS Appendix H

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Introduction and Background

Estimated sediment yields presented in the Mt Ashland Ski Expansion FEIS were derived from the *Water Erosion Prediction Project (WEPP)* soil erosion model. WEPP is a physically based model that has been adapted to forestlands and forest management activities including road construction, timber harvest disturbances and forest fires. The model was developed by a team of government scientists from the Agricultural Research Service, Forest Service, Natural Resource Conservation Service, Bureau of Land Management and Geological Survey. Of the erosion models, WEPP is the most suitable for predicting the effects of forest practices on soil erosion and sediment yields in mountainous terrain where erosion rates are unknown (pers. com. Walt Megahan 2004).

There are several interfaces to the WEPP model that were used to evaluate site-specific disturbances for each alternative presented in the Mt Ashland Ski Expansion EIS. *Disturbed WEPP* (Elliot and others 2000) was used to predict erosion and sediment yields from ski run construction and *WEPP: Road* (Elliot and others1999) interface was used for construction of parking lots, roads, trails, terminals and footings for towers and buildings. These web-based interface programs and supporting documentation are accessible at:

http://forest.moscowfsl.wsu.edu/fswepp.

The WEPP model uses soil texture, slope gradients, slope lengths, soil cover, vegetative community, climate data and disturbance type to determine erosion rates and sediment yields through a defined buffer. The WEPP model was used to evaluate alternatives in the FEIS by simulating each site-disturbing activity through the program and summarizing the predicted sediment yields by each alternative and watershed (See Section 5, Effects on Soils - Erosion and Sedimentation). It was also used to reconstruct the sediment yield history from the original ski area development to the present.

The methods and assumptions used in these analyses are presented below.

Limitations of the WEPP Model

First and second year sediment yield rates from *WEPP: Road*: The *WEPP: Road* model does not account for the high erosion rates that typically occur during the first two years after disturbance (Megahan and Kidd, 1972, Megahan, 1974; Ketcheson and others 1999). See *WEPP: Road* discussion below for how this was compensated for in this analysis.

Downslope sediment yield from *WEPP: Road*. The WEPP model was developed for application on agricultural and rangelands and has been adapted to forest lands. Components of the model, particularly the hydrologic components, work reasonably well on the original target areas but have limitations when applied to forestlands, particularly forest roads. Also, only a profile template is available for application on forestlands at the present time; the watershed template is presently unavailable.

The simple profile template assumes an impermeable subsurface layer, does not calculate subsurface flow interception by cutslopes, and does not provide for lateral inflow or outflow or variable source area effects. All of these processes are important on forestlands. Most of these limitations have minimal effect on erosion and sediment transport within the area of disturbance but can become problematic when calculating sediment transport through downslope buffer areas, especially below forest roads.

To illustrate, WEPP often predicts the occurrence of saturated conditions below road cross drain culverts that results in continued downslope erosion and sediment transport regardless of buffer width. In some cases, erosion is predicted to increase with increasing buffer width. Such results are not supported by observations in the area (Letters to Ashland RD 6/4/03, 8/22/03 and 9/11/03) and in granitic soils of the Idaho Batholith (pers. com. Megahan 2004). See *WEPP: Road* discussion below for how this was compensated for in this assessment.

Erosion from Mass Movement, Gully, Channel Erosion: Does not predict sediment yields from within gully or channels or from mass movement events.

Methods and Assumptions

Methods and Assumptions Used for Determining Sediment Yields by Alternative

For each FEIS alternative, a map was created that displayed the proposed disturbances; stream courses; and contour intervals. From these maps "sediment yield mapping units" were delineated based on the type of disturbance and the proximity of the disturbance to a stream course. Only those disturbances within 300 feet of a stream course were delineated. For each sediment yield mapping unit, site factors were entered into either the *Disturbed WEPP* or *Road: WEPP* interface programs depending on the type of disturbance being proposed. Site factors include slope gradients, slope lengths, soil cover, vegetative community, and geomorphic features that affect direction of overland flow. Results for both *Disturbed WEPP* and *Road: WEPP* were reported as sediment entering a channel through a buffer. All values were converted to cubic yards of sediment and summarized by alternative and by watershed (see FEIS Chapter IV).

The WEPP model is considered the most appropriate, state-of-the-art erosion prediction model currently available for forested terrain. The *Disturbed WEPP* and *WEPP: Road* model evaluates erosion and sediment delivery potential from disturbed forested terrain and forest roads, respectively. True erosion rates are highly variable due to large variations in local topography, climate, soil properties and vegetative properties. The WEPP model reports a sediment yield in absolute amounts. The supporting WEPP documentation indicates that the accuracy of the output figures is at best, plus or minus 50% (Elliot and others1999).

Disturbed WEPP - Input Variables

Variables Common to all Runs:

WEPP Version: The most current version (v2004.02.18) of *Disturbed WEPP* was used for all computer runs.

Simulation: 100 years of simulation.

Climate: The Medford WB AP OR Weather Station, located near Medford Oregon (42.37^{o}N, 122.87^{o}W) was used as the primary climate station for the WEPP model. The 65 years of climate data from this station was modified using the USDA FS *ROCK: Clime* program to best describe the climate of the Mt Ashland study area. The climate program is included in the WEPP program and for this analysis the mean monthly precipitation, number of wet days and monthly maximimum and minimum temperatures were obtained from the Big Red Mountain SNOTEL station (http://www.wrcc.dri.edu) to modify the Medford Weather Station data to conditions at MASA. The Big Red Mountain SNOTEL station is located 7.5 miles to the west of Mt Ashland and is similar in elevation (6,250 feet) and topography (a north aspect slope just off the ridgeline) to the study area. It is assumed to have very similar weather to the Mt Ashland study area. A summary of 12 years of daily temperature and precipitation is summarized in Table H-1.

Table H-1. Summary of SNOTEL Data Used in WEPP Models - 1990 -2002

Month	Maximum Temperature (^{o}F)	Minimum Temperature (^{o}F)	Precipitation (inches)	Number of Wet Days*
January	34.7	25.4	8.98	14.5
February	36.3	25.6	6.85	14.3
March	40.1	25.5	7.15	16.1
April	44.9	28.0	5.49	12.3
May	51.6	33.8	3.48	9.2
June	55.2	36.2	2.65	5.7
July	68.2	48.6	0.72	3.0
August	65.0	45.5	0.71	1.3
September	64.1	46.6	0.61	1.9
October	50.7	37.0	2.96	7.1
November	39.0	29.1	7.31	13.4
December	34.5	25.1	8.66	13.6

*The number of wet days are days where appreciable precipitation was recorded

Soil Texture: *Disturbed WEPP* uses four textural classes – clay loam, silt loam, sandy loam and loam. Most soils in the study area fall into the sandy loam textural class.

Site Specific Variables

Disturbed WEPP has two overland flow elements – an upper and lower. The user can assign site factors associated with a particular disturbance to the "upper element" and site factors associated with a buffer zone in the "lower element" below the disturbance. Using the elements in this manner simulates the effects that a buffer separating a disturbance from a stream course will have on sediment yields.

Vegetation Treatment: *Disturbed WEPP* describes a range of forest and rangeland conditions in 8 "vegetation treatment" categories. For each sediment yield mapping unit, one of 8 vegetative treatments were assigned to the "upper element" and "lower element" (buffer area below disturbance). Table H-2 displays the vegetative treatments that were assigned to each proposed disturbance.

Table H-2.
General Assumptions for % Cover, Vegetation Treatment and % of Area Disturbed for Upper and Lower Elements for First, Second and Third Year After Disturbances

			Upper Element (Disturbance)		Lower Element (Buffer)	
Disturbance Activity	**% of Area in Disturbance Activity**	**Years After Disturbance**	**Vegetation Treatment**	**% Cover**	**Vegetation**	**% Cover**
Ski Run - Pile and Burn	5	1	High Intensity Fire	20	Forest 20 Years	95
		2		50		
		3		75		
Ski Run - Excavator	5	1	Skidtrail	10	Forest 20 Years	95
		2		50		
		3		75		
Ski Run - Helicopter Yarding	100	1	Forest 5 Years	80	Forest 20 Years	95
		2		85		
		3		90		

Cover (%): *Disturbed WEPP* is very sensitive to changes in ground cover. For this analysis, ground cover is the percentage of the soil surface covered by the basal area of plants, plus litter and rock fragments in direct contact with the soil. Cover % after disturbance was predicted for each disturbance activity for the upper and lower elements and these assumptions are shown in Table H-2.

For most disturbances, first year % ground cover is low which results in high sediment yields often observed in the first year. Second and third year erosion and sediment yield rates decline rapidly over the initial high first year values because of regrowth in vegetation or the armoring of the soil surface with rock fragments.

In this analysis, it is assumed that under worst-case scenarios, there will be no mitigation measures in place the first year after disturbance. Second and third year scenarios assume that mitigation measures are in place and fully functioning.

To account for the change in sediment yields, each sediment yield mapping unit is run for the first, second and third year using increasingly more soil cover for the second and third years to account for mitigation measures, soil armoring and vegetation regrowth.

Rock (%): This is the percent rock fragment in the soil profile. It is applied to the upper and lower elements and based on descriptions of coarse fragment percentages from the updated landtype map.

Horizontal Length (ft): Slope length factors are used in both upper and lower elements. The horizontal length of the upper element is the length of the disturbance directly upslope from the buffer. This is considered the "disturbance length".

The horizontal length of the lower element is the distance directly below the disturbance (lower portion of the upper element) to a channel or gully. This can also be considered the width of the buffer. All lengths were measured on the horizontal from GIS maps.

Gradient (%): There are two slope gradients entries for each upper and lower element. The first entry for the upper element is the slope gradient at the top of the disturbance and the second entry is the slope gradient at the center of the disturbance. The first entry for the lower element is slope gradient at the center of the buffer and the lower entry is the slope gradient at the bottom of the buffer. Slope gradients for this analysis were calculated from contour intervals.

Area of Disturbance: Area of the disturbance was measured in acres using a dot grid.

Multiple Disturbances: Some sediment yield mapping units have more than one disturbance. For instance, a ski run might be helicopter yarded, piled and burned, as well as have impacts associated with excavator work. Each of these disturbances was treated separately in *Disturbed WEPP*. Since some activities only cover a small portion of the mapping unit, the sediment yield values were multiplied by the estimated area of disturbance (see "% of Area in Disturbance Category" in Table H-2).

Results

Disturbed WEPP displays sediment yields for 100, 50, 20, 10 and 5 year return intervals. It also displays sediment yield for an average year. Usually the average falls between the 2 and 3 year return interval for erosion and sediment yield data. For this analysis, the average sediment yield rates were used for comparing alternatives. These values were converted to cubic yards per acre and then multiplied by the area of the sediment yield mapping unit to obtain average yields for each disturbance. For circumstances where the disturbances did not cover the entire sediment mapping unit (e.g., pile and burn and excavator disturbances), the percent of area assumed to be in this type of disturbance was multiplied by the acreage of the sediment yield map unit.

WEPP: Road - Input Variables

Variables Common to all Runs:

WEPP Version: v2004.02.18XXX was used for all *WEPP: Road* computer runs

Simulation: 100 years of simulation.

Climate: Same as *Disturbed WEPP*.

Soil Texture: Same as *Disturbed WEPP*.

Site Specific Variables

Road Design: There are four road design options for *WEPP: Road* – 1) insloped, bare ditch, 2) insloped, vegetated or rocked ditch, 3) outslope, unrutted and 4) outsloped, rutted. Outslope unrutted was used to assess footings for towers and buildings, construction of ski trails requiring cuts and fills, reconstruction of existing roads, and construction of gabion walls and parking lots.

Road Surface: *WEPP: Road* allows for three road surface types - 1) native, 2) graveled and 3) paved. For ski trails (with cuts and fills), terminals, footings (for towers and buildings) and *all first year* construction of parking lots or access road, the "native surface" were used for first year simulations. After the first year "paved surface" was used for parking lots and "graveled surface" was used for access roads.

Traffic Level: There are three traffic levels – 1) high, 2) low and 3) no traffic. For construction of ski trails, footings for towers, buildings, and gabion walls a "no traffic" level was applied. A "low traffic level" was applied to access road reconstruction sites and a "high traffic" level was applied to parking lots.

% Rock: The percent rock fragment in the soil profile. It is based on descriptions from the updated landtype map.

Road Gradient: Slope gradients were obtained from typical road, tower and parking lot cross sections.

Road Lengths: The length of a road sections or construction section being evaluated.

Road Widths: Road widths were obtained from typical cross sections for road, tower, parking lot, and access road sites.

Fill Gradients and Lengths: Fill gradients and lengths were obtained from typical cross sections for towers, parking lot, and roads.

Buffer Gradients and Lengths: Slope gradients were measured from contour lines on alternative maps for slopes within each buffer section. Buffer lengths were not used in *WEPP: Road* (see Results section below) but since *WEPP: Road* requires a minimum of 1.5' to run the program, this value was entered into the length field.

Results

Sediment Delivery. *WEPP: Road* reports out sediment yields in two forms – sediment leaving the road prism termed "Road Prism Erosion" and sediment entering a channel termed "Sediment Leaving Buffer". As previously stated, a limitation to the *WEPP: Road* program is that it overestimates sediment delivery rates at MASA. This is based on personal communications with Walt Megahan (pers. com. Megahan 2004), onsite observations of buffer zones in the Mt. Ashland area after summer thunderstorms (letters on file at the Ashland Ranger District) and a considerable body of research summarized in the Washington Road Surface Erosion Model Manual (Dube and others 2004), located at:

(http://www.dnr.wa.gov/forestpractices/adaptivemanagement).

For this assessment, the sediment delivery table (Table H-3) developed for the Washington Road Surface Erosion Model Manual (WARSEM) was used in this assessment to calculate the estimated quantity of sediment delivered to streamcourses. For example, if a disturbance was separated from a stream channel by a 35 foot forested buffer, the pounds of "road prism erosion" calculated from *WEPP: Road* would be multiplied by 0.7 (or 70%) to give the amount of sediment that would enter the streamcourse.

Table H-3 was based on research from roads with culverts and therefore the values are somewhat higher than what would be expected from the proposed construction activities considered in the FEIS which were designed not to concentrate water (the exception is the parking lot dips). Therefore the sediment delivery rates presented in Table H-3 represent higher than expected, or worst case values.

Table H-3. Sediment Delivery/Distance Relationship

Distance Streamcourse from Culvert or Concentrated Water (ft.)	Average Percent of "Road Prism Erosion" Delivered
0	100
35	70
70	50
105	35
140	25
175	18
210	10
245	4
280	3
315	2
350	1

(from Dube and others 2004)

First and Second Year Erosion Rates. Compared to long-term erosion rates, the erosion rates that occur during the first two years after road construction are generally much greater (Ketcheson et al. 1999, Megahan 1974, Megahan and Kid 1972). A summary of research findings indicates that first year and second year erosion rates following construction are approximately 10 and 2 fold over the long-term erosion rates (*WARSEM*). To reflect these findings, the calculated sediment yields for each disturbance were multiplied by 10 for first year, and 2 for second year results.

Sediment Yields from Original Ski Area Construction - Methods and Assumptions

Reconstructing the sediment delivery history of the Mt Ashland Ski Area as documented in FEIS Chapter III was based on interpretating soil disturbance from four sets of aerial photographs taken in 1966, 1975, 1993 and 1998 and simulating these disturbances using the WEPP erosion model. For this process, aerial photographs were scanned at very high resolution so that fine erosional features, like gullies, tractor paths, and ground cover, could be detected.

Disturbance areas were described in WEPP input variable terms (as discussed above) and run through the *Disturbed WEPP* or *WEPP: Road* model to obtain annual sediment rates for first, second and third year after disturbance. These predicted annual rates were summarized for each decade and are displayed in Chapter III, Figure III-2. Since there were no aerial photographs taken during the 1980's, the rates stated for that period were obtained by averaging the rates from 1970 and 1990.

FEIS Figure III-2 does not include erosion from gullies and channels, which in the Cottonwood Watershed and to a lesser extent in the Ashland Watershed, would have been very high during the 1960s through the 1980s. After that period of time, implementation of restoration projects and the natural reestablishment of vegetation on the disturbed sites and gullies would have reduced runoff and gully erosion substantially.

Comparison of Estimated Sediment Yields

The WEPP model is often used to compare *relative* sediment yields of proposed alternatives without ground truthing, however it was important for this analysis to determine how well the *absolute* rates of sediment yields predicted by the WEPP model compared to actual collected sediment rates to understand the actual impacts to downstream resources, especially the potential impacts to Reeder Reservoir in the Ashland Creek Watershed.

This section compares sediment values obtained from a 6-year sediment monitoring project to estimated sediment yields derived from using the WEPP model for that same time period. The results of this comparision serve to verify the accuracy of the WEPP model used in this analysis.

Surface Erosion Monitoring Project

In the late 1970s, watershed specialists for the RRNF installed two sediment basins on the East Fork Ashland Creek just below the ski area. In the fall from 1978 through 1983, watershed personnel measured and removed sediments that accumulated in these dams. Near the end of this period, the Forest and District watershed specialists presented their findings and recommended discontinuing the program "feeling that (they) had learned enough and that funding was not sufficient to continue it" (USDA FS 1983).

The general findings from this report as presented in the July 2003 DEIS were recently updated by Dr. Walt Megahan using additional data from surveys conducted in 1984 (USDA FS 1987), and data from personal files (pers. conversation with Brazier) is summarized in Table H-4 below.

Two sediment dams were originally constructed and monitored; the sediment dam on Pumphouse Creek was not included in Table H-4 due to the uncertainty of the data from this structure. Data from the Windsor Sediment Dam were adjusted for overflow and leaks by assuming that the actual sediment yield could be twice as much as measured due to overflow and leakage. This was a conservative assumption made in the original report but applied only to those years when the errors occurred.

The data were further adjusted for trap efficiency to account for sediment that would have been carried over the spillway as a suspended load. Based on trap efficiency studies conducted in the Idaho Batholith, a trap efficiency of 70% was considered reasonable for this analysis (pers. com. Megahan 2004). Values obtained for "Adjusted for Trap Efficiency" are based on "Adjusted for Overflow or Leaks" values divided by 0.7.

The sediment yield in Table H-4 rates are somewhat higher than those reported out in the July 2003 DEIS due to the 70% increase in trap efficiency and inclusion of data taken in 1983-84.

Table H-4. Sediment Yield Data for MASA

	Sediment Yield (cubic yards)		
Year	Raw Data	Adjusted for Overflow or Leaks	Adjusted forTtrap Efficiency
1978-79	10+	20	28.6
1979-80	1.7	3.4	4.9
1980-81	0	0	0
1981-82	11.3	22.6	32.3
1982-83	8.6	8.6	12.3
1983-84	28.3 - 33.3	33.3	47.6
		Average	21

Comparison of Yields From WEPP Modeling to Surface Erosion Monitoring

To compare actual sediment yields (from the Surface Erosion Monitoring) to predicted yields (from WEPP modeling), the 1975 aerial photographs were digitized at very high resolution and disturbance areas were delineated and described within the small watershed above the Windsor Sediment Dam. These disturbances were simulated through the WEPP program and sediment values summarized. Under this analysis, WEPP predicted an average annual sediment rate of 14.7 cubic yards for that period of time, which is 6.3 yards less than the average annual sediment obtain from monitoring the Windsor sediment dam.

As previously stated, The WEPP model accuracy is considered to be +/- 50 percent at best. Applying this range of accuracy to the sediment rate of 14.7 cubic yards would create a range of sediment rates predicted by WEPP to be between 7.3 to 22 cubic yards per year. The actual average annual sediment yield from the Windsor Chair Sediment Dam is within the high end of this accuracy range and suggests that the WEPP generated sediment yield values calculated for the FEIS are realistic.

Probabilities of Extreme Erosion Events

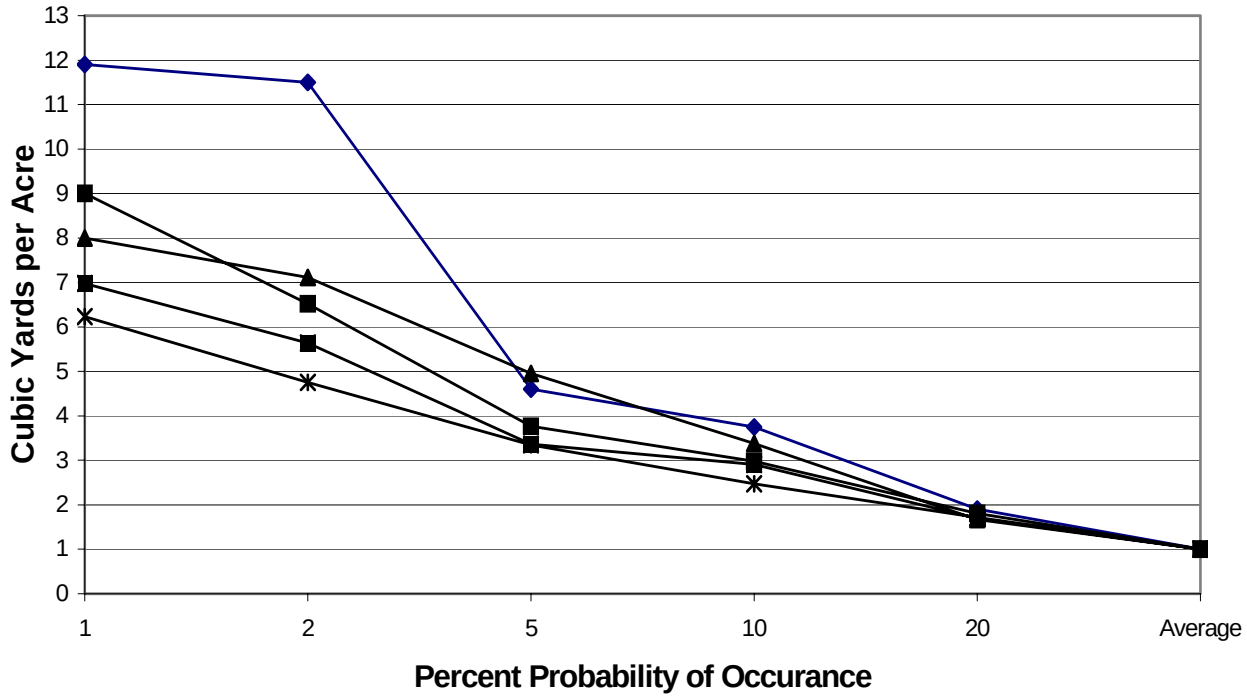
All sediment yield values displayed in FEIS Chapter IV are reported as averages and therefore represent the estimated rates that would occur on an average year. Sediment yields measured over time are characterized by a few rare, large events and many more moderate to small events producing a frequency distribution that is skewed to the left. The average value represents the mean of all simulated annual sediment yields over a 100-year period.

Although useful for comparison purposes, the average does not provide a measure of the risk of extreme storm patterns with subsequently higher sediment yields. The relationship between sediment values from average years and those from extreme years are shown in Figure H-1. The graph is based on *Disturbed WEPP* simulations and shows the range of expected sediment yield values, where the “average” outputs values have been normalized to equal 1 cubic yard of sediment per year to show the relationship with more extreme storm years. While the simulations give slightly different curves, the relationships of annual probability of occurance to sediment yields are very similar.

Five examples are shown in Figure H that demonstrate the range of high and low sediment yields, based on 35 simulations for extreme storm Years. Figure H-1 can be used to illustrate the magnitude of change for extreme storm patterns and extreme water years. For example, a storm year predicted to occur once in 100 years (or 1 percent probability of occurance) is predicted to produce between 6 and 12 fold the amount of sediment of an average year. A storm year that occurs once in 10 years (or 10 percent probability of occurance) is predicted to produce between 2.5 and 4 times the sediment of an average year.

WEPP: Road does not give sediment distribution values for years with extreme erosion events, however the relationship shown in Figure H-1 should be similar for sediment yields originating from roads.

Figure H-1. Relationship of Sediment Yields and Probability of Occurence For Extreme Storm Years



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