SE GROUP

TECHNICAL MEMORANDUM

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TO:	White Pass MDP FEIS Project File
FROM:	SE Group
CC:	
DATE:	9/21/2006
RE:	White Pass MDP WEPP Modeling Analysis

A modeling study was conducted in order to quantify sediment production due to changes in land cover associated with the proposed projects of the White Pass MDP. SE Group utilized the US Department of Agriculture – Agricultural Research Service Water Erosion Prediction Project (WEPP) model to compute sediment *detachment* for the various land cover types within each affected sub-watershed. The model was used to compute detachment only, and did not account for routing and buffering (which reduce actual yields to the stream system). Because the analysis did not account for factors that can result in the removal and deposition of sediment from water before reaching a surface water body, it represents a conservative analysis (i.e., it overestimates the contribution of sediment to the Upper Clear Fork Cowlitz and Upper Tieton sub-watersheds).

SE Group evaluated two modeling methodologies for application of the WEPP model to the White Pass project:

1) GeoWEPP: a GIS-enabled version of WEPP, which accounts for routing of detached sediment through a digital elevation model (DEM) derived stream channel network. Because GeoWEPP accounts for routing, its results can be considered an estimate of sediment yield.

2) Hillslope WEPP/GIS analysis: the hillslope version of the WEPP model is run for all combinations of representative land cover and slope combinations encountered within each DEM grid cell to compute a sediment detachment rate for each cell within the DEM grid. The results from WEPP are then input into a GIS database. The WEPP-computed detachment rates are summed over all DEM grid cells to produce an overall estimate of sediment detachment within the White Pass Study Area. This methodology does not account for routing of sediment within the watershed. After detachment, sediment may undergo a series of processes of re-deposition, filtration and re-entrainment and transport before reaching a water body. These processes tend to reduce actual *yields* of sediment to water bodies. Thus the results of the hillslope/GIS

methodology produce a somewhat conservative estimate of sediment production via detachment only, and not a result representing actual sediment yield and transport by surface waters.

SE Group conducted a preliminary modeling exercise in GeoWEPP in order to evaluate its potential effectiveness and suitability for application to the White Pass project by using it to compute sediment yields for Alternative 1 in the Upper Clear Fork Cowlitz sub-watershed. A landcover grid for the Upper Clear Fork Cowlitz sub-watershed was obtained from the USGS National Landcover Database, and refined using site-specific data. Soils information was obtained and edge-matched from both the USDA-Natural Resources Conservation Service (NRCS) and the Gifford Pinchot National Forest. However, the WEPP soils database does not contain soils properties files for the mapped soils units within the vicinity of the White Pass SUP. Therefore, the soils textural data present within available mapping was used to select an appropriate soil type from within the Forest Service Disturbed generic WEPP soils database: a gravelly sandy loam forested soil.

The GeoWEPP model is paired with a DEM and channel network analysis model called TOPAZ (Topographic Parameterization).[1] The TOPAZ process is utilized to interactively derive a channel network. The terrain analysis process also derives sub-catchments – which are incorporated into the GeoWEPP modeling process as hillslopes. GeoWEPP cross-queries the derived sub-catchments against the GIS DEM, landcover, and soils database, and derives a set of representative WEPP hillslope model projects, one for each sub-catchment. Each hillslope model contains one management prescription, soils representation, and slope profile that is considered representative of the entire sub-catchment.

The GeoWEPP model is computationally demanding. The 2,520-acre GeoWEPP modeling catchment that contains the SUP within the Upper Clear Fork Cowlitz watershed required individual WEPP model runs for 178 individual sub-catchments, and over 20,000 distinct flowpaths. A 30-year GeoWEPP simulation for this scenario required over 14 hours to complete on a 3.0 GHz dual-processor system. Thus, opportunities to experiment with the outcomes of different modeling assumptions upon the results were limited.

For baseline sediment yield within the Upper Clear Fork Cowlitz sub-watershed, GeoWEPP modeling produced a background value of approximately 19 tons per acre per year. For a watershed that is dominated by mature forest, which typically has background sediment yield rates of less than 1 ton per acre, this was judged to be unrealistically high. SE Group examined the model inputs and outputs for several representative individual hillslopes in order to assess the reason that the GeoWEPP simulations were producing comparatively high predictions for background sediment production.

The results of this examination indicate that this behavior may be a result of what appear to be implausibly long and linear sub-catchment derivations from the TOPAZ model as applied to the DEM

[1] http://grl.ars.usda.gov/topaz/TOPAZ1.HTM. Last Accessed 8/2006.

and channel system for the White Pass vicinity. Figure 1, attached, shows the sub-catchments derived by TOPAZ for the White Pass GeoWEPP model.

As shown in the figure, the sub-catchments derived by TOPAZ tend to be rather linear in shape. The resulting hillslopes in WEPP are quite long (many are over 1,500 feet in horizontal length). As a result it appears that the individual WEPP hillslope models that comprise the overall GeoWEPP analysis generate unrealistically high sediment yields. The reason for this behavior may be seen in Figure 2 by examining the slope profile and detachment results for a single representative WEPP hillslope (the hillslope of interest is highlighted by the red arrow in Figure 1).

In Figure 2, the color scale ranges from green (no sediment detachment) to white (moderate sediment detachment) to red (high sediment detachment), for a hillslope with mature forested land cover. As shown in Figure 2, no sediment detachment occurs along the first two-thirds of the slope profile. Note that detachment begins in an area that is of moderately gentle slope, and then accelerates through the steeper zone of the hillslope. Reviewing the hillslope model output in detail reveals that the length of the hillslope being modeled permits high surface sheet flow velocities to be attained as runoff accumulates along the hillslope, resulting in detachment at the slope toe for almost every hillslope in the model, even those that are fully forested. The fact that no detachment occurs at the top two-thirds of the slope, even where (as in Figure 2), the very top of the slope is quite steep, suggests that it is the attainment of high sheet flow velocities that is contributing to sediment productions in the hillslope model, and not the combination of landcover and topography. The high sheet flow velocities are a direct result of the length over which flow can accumulate for a very long hillslope. Due to these factors, as well as the constraints placed on the ability to refine the model inputs caused by the length of time required to complete each model run, SE Group chose to perform representative runs of the WEPP hillslope model for each combination of landcover, soil, and slope, and then analyze these results spatially utilizing GIS, as described in approach (2), above. This process is outlined in more detail following.

The USDA Forest Service has developed a set of forest simulation parameters for WEPP based on model calibration and validation to observed forested watershed behavior. These custom WEPP parameters are described in *Water Erosion Prediction Project Forest Applications*.[2] The WEPP model is a process-based, continuous computation, distributed parameter erosion prediction model implemented as a computer numerical simulation.[3]

The model is based on numerical representations of the physical processes influencing runoff and sediment yield. Thus, it permits a simulation of various actual watershed processes, including: rainfall/snowfall, infiltration, runoff, soil moisture accounting, snow accumulation/melt, evapotranspiration, plant growth and litter decomposition, and sediment detachment and deposition. The

[2] Elliot, William J and David E. Hall, 1997
[3] USDA Forest Service, 2000

model parameters include rainfall amounts and intensity, soil textural properties, slope shape, steepness, and orientation, and soil erodibility parameters. Soils are represented in multiple layers with parameters describing texture, rock content, moisture, permeability, organic content, and cation exchange capacity. The model uses a statistically generated synthetic climate dataset to drive its simulations. The synthetic dataset is derived by applying a probabilistic model using statistical parameters computed from observed climate trends. High resolution climate data (including temperature, wind speed and direction, relative humidity, and solar radiation) is derived via a sophisticated spatial algorithm. The PRISM climate data modeling process interpolates these variables based on both geographic position and elevation, from proximal NOAA, BLM remote automated weather stations, and NRCS-SNOTEL climate stations. Appropriate forested soil types and textures were chosen for simulation within WEPP based on available NRCS and Gifford Pinchot National Forest soils mapping.

The WEPP model was executed over a simulation period of 30 years. The model simulations were driven by climatic data derived from the PRISM model, corresponding to average-year conditions.[4] The event-based model output includes rainfall events statistically generated by the USDA-ARS CLIGEN package to produce the synthetic climate dataset, and runoff events resulting from either rainfall or snowmelt. The climate stations and derived climate data utilized in the PRISM interpolation methodology, and their relative weighting factors, are outlined in the following tables:

Table 1:
Prism Climate parameters for WHITE PASS WA
46.54oN 121.55oE; 4323 feet elevation
43 years of record

Month	Mean Maximum Temperature (ºF)	Mean Minimum Temperature (ºF)	Mean Precipitation (in)	Avg Number of wet days
January	31.8	19.1	13.36	14.7
February	37.4	20.9	8.11	12.3
March	42.0	22.9	7.60	13.6
April	48.5	26.7	5.28	12.0
May	56.1	32.0	4.11	10.8
June	61.7	38.2	2.71	8.2
July	68.1	41.6	1.36	4.8
August	68.2	41.1	1.76	5.7
September	62.7	35.0	3.49	7.8
October	52.5	28.4	6.51	10.3
November	38.2	23.7	11.65	14.2
December	32.1	20.3	12.21	14.7
Annual			78.15	129.1

[4] http://www.ocs.orst.edu/prism. Accessed 8/2006.

Table 2:
Climate Stations Used for Interpolated Data

Station	Weighting	Station	Weighting
Wind Stations		**Solar Radiation and Max .5 P Stations**	
Stampede Pass, WA	35.8 %	Stampede Pass, WA	47.8 %
Yakima, WA	32.3 %	Olympia, WA	36.7 %
Toledo, WA	31.9 %	Pendelton, OR	15.5 %
Dewpoint Stations		**Time-to-Peak Stations**	
Stampede Pass, WA	40.2 %	Stampede Pass, WA	40.2 %
Yakima, WA	36.3 %	Yakima, WA	36.3 %
Portland, OR	23.5 %	Portland, OR	23.5 %

The WEPP analysis focused on the modeling sediment detachment for the existing and proposed landcover types within the White Pass SUP (including the proposed SUP expansion). Detailed land use coverage was developed in GIS, assigning land use amongst the categories outlined in Table 3:

Table 3:
Land Use Categories Utilized in WEPP

Land Class	WEPP Management Prescription
Graded	Skid Trail
Ski Trail	Tall Grass
Forest	Forest
Roads – Native Surface	Native Surface Road
Roads – Gravel	Gravel Road
Rock	Short Grass

The land cover classes outlined in Table 3 were analyzed against GIS raster grids of slope and soils texture.

Next, in order to derive a sediment detachment rate for each combination of soil, slope, and land cover type present, the WEPP hillslope module was run for each combination of land cover class, slope, and soils texture (including WEPP:Road for the roads) associated with the land use changes proposed to occur for each of the Action Alternatives. Two model scenarios were executed:

- A "Post-Disturbance" landcover that represents conditions immediately after implementing the landcover change;

- An "After Recovery" landcover, that models likely long-term rates of sediment detachment after sites have had 2-5 years to stabilize and re-vegetate. For the differing disturbance mechanisms, the change in landcover was represented as follows:

Table 4:
Disturbance Mechanism Representations in WEPP

Disturbance	Post-Disturbance WEPP Prescription	After Recovery (2-5 years) WEPP Prescription
Grading	Skid Trail	Short Grass
Clearing and Grading	Skid Trail	Short Grass
Flush Cutting	Short Grass	Tall Grass
Road Construction – Native Surface	Roads – Native Surface	Roads – Native Surface
Road Construction – Gravel	Roads – Gravel	Roads – Gravel

Each treatment prescription was modeled for a representative 200-foot hillslope. Model runs for each of the above three prescriptions were performed for each of several slope gradient “bins”, as described below:

- 0 - 10 percent slope gradient
- 10 - 20 percent slope gradient
- 20 - 30 percent slope gradient
- 30 - 40 percent slope gradient
- Greater than 40 percent slope gradient

The WEPP model was executed over a 30-year period to provide a dataset of sufficient length to compute averages sediment detachment characteristics. The sediment detachment predictions from this simulation period offer an average value for soil detachment over the 30-year period. In some years (i.e., years with low surface runoff) no erosion takes place, while in high-runoff years, erosion may exceed the reported average values. In addition, it is important to note that the WEPP documentation cautions that “At best, any predicted runoff or erosion value, by any model, will be within only plus or minus 50 percent of the [actual] value. Erosion rates are highly variable, and most models can predict only a single value. Replicated research has shown that observed values vary widely for identical plots, or the same plot from year-to-year. Also, spatial variability…of soil properties add[s] to the complexity of erosion prediction.”[5]

The results of the WEPP analysis are outlined in the following Table. Maps of the WEPP-calculated sediment detachment are shown attached in Figures 3 through 11.

[5] USDA Forest Service, 2000

Table 5:
WEPP Sediment Detachment Results

Sub-Watershed	Alternative	Soil Detachment (Tons/year)		Short-Term	Long-Term
		Post-Disturbance	After Recovery (2-5 years)	% Increase	% Increase
Upper Clear Fork Cowlitz	1	N/A	103.1	N/A	N/A
	2	126.5	107.2	23%	4%
	Mod. 4	173.1	113.3	68%	10%
	6	112.7	107.8	9%	5%
	9	131.8	106.6	28%	3%
Upper Tieton	1	N/A	133.6	N/A	N/A
	2	133.7	133.7	0.0%	0.0%
	Mod. 4	133.8	133.9	0.1%	0.2%
	6	133.8	133.7	0.1%	0.1%
	9	150.8	134.8	12.8%	0.8%

It is important to note that the output of the process provides an estimate of *soil detachment*, and not actual delivery to the stream system. Due to the processes described above, the detachment-only analysis likely over-estimates the amount of sediment produced to the lower watershed.

As shown in Table 5, the long-term percentage change in sediment detachment is fairly similar amongst the alternatives. Long-term changes for the Upper Clear Fork Cowlitz sub-watershed would be greatest under Modified Alternative 4 at a 10 percent increase above Alternative 1. This would be due primarily to grading associated with the ski-back road/egress extending from the base of proposed *Chair 7* in Hogback Basin, to the base of the existing *Paradise Chair*, and then down to the base of the existing *Pigtail Chair*. Long-term changes would be greater for the Upper Clear Fork Cowlitz sub-watershed than for the Upper Tieton due to the greater area of proposed change in land use associated with the development of the trail system within the Hogback Basin. Long-term impacts to the Upper Tieton sub-watershed would be greatest under Alternative 9 at a 0.8 percent increase above Alternative 1.

Larger differences between alternatives are evident in the short-term post-disturbance increases in sediment detachment. Modified Alternative 4 exhibits an almost 70 percent increase in short-term detachment, primarily associated with grading that would occur to facilitate the development of ski-way access corridor traversing from the Hogback Basin terrain pod back to the existing trail network. As shown in the detachment maps, this increase in detachment would occur in close proximity to several streams, increasing the risk that this alternative could result in sedimentation to surface waters. Under Alternative 9, a short-term increase of almost 13 percent would occur within the Upper Tieton sub-watershed due to grading, which would occur to create ski-ways, skier bridges, and 7 trails within the *PCT* terrain pod.

References

Elliot, W. J. and D. E. Hall. 1997. *Water Erosion Prediction Project (WEPP) forest applications.* Gen. Tech. Rep. INT -GTR-365. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

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