Predicting Sediment Delivery from Small Catchments in the Western Cascades of Oregon Using the U.S.F.S. Disturbed WEPP Model

Barbara A. Geren
M.S. Candidate, Resource Geography
Oregon State University Department of Geosciences

And

Dr. Julia A. Jones
Professor, Oregon State University Department of Geosciences

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57600 McKenzie Hwy
McKenzie Bridge, OR 97413
541-822-3381

Questions about this report should be directed to:
Barbara Geren: gerenb@geo.oregonstate.edu
Dr. Julia Jones: jonesj@geo.oregonstate.edu
Dave Kretzing: dkretzing@fs.fed.us

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Executive Summary

The U.S. Forest Service on the Willamette National Forest currently employs the "Disturbed Water Erosion Prediction Project" (WEPP) model to determine potential suspended sediment delivery from timber harvests or other treatment scenarios given user-defined hillslope parameters. At the time of this study there was no known calibration or testing of the model's accuracy in steep, dissected terrain such as that of the Western Cascades of Oregon.

This analysis used the simplified web-based version of FSWEPP to predict suspended sediment output from three small catchments located on the H.J. Andrews (HJA) Research Forest. Basins were either clear-cut, 25% patch-cut, or in old-growth control conditions. Inputting long-term site data from on-the-ground measurements, WEPP model fields were populated with the most basin-representative information possible.

Four different model simulation strategies compared suspended sediment delivery both within individual basin scenarios, and also between the three basins.

Results indicated that WEPP tended to over-estimate suspended sediment outputs across the treated basin scenarios relative to long-term ground data. A crude Analysis of Variance (ANOVA) f-test compared the differences in total mean suspended sediments delivered or predicted within each basin. Subsequent numbers suggested that at least two of the basins' means were significantly different between various model scenarios as well as the Andrews dataset.

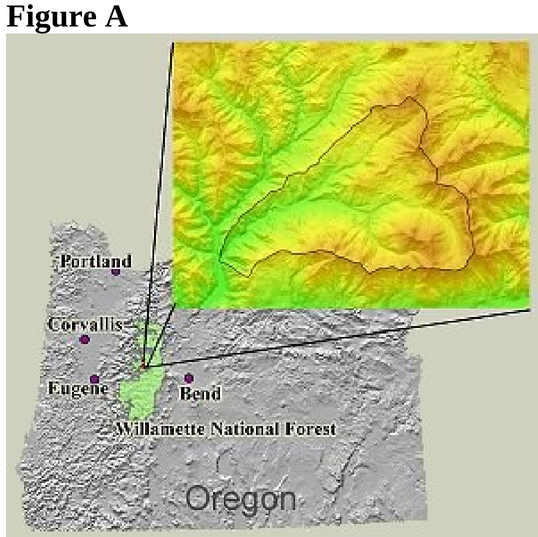
Though Disturbed WEPP was ultimately not a convincing prediction tool in this investigation, the study provided both background and foundation for further model testing and calibration. Given the wealth of long-term data available from the HJA, the model may merit further ground-testing and calibration against the backdrop of this climate and terrain.

Key words: suspended sediment delivery, Water Erosion Prediction Project, Disturbed WEPP, H.J. Andrews Research Forest, predictive models, erosion rates

Introduction and Purpose

This study involved an analysis of the United States Forest Service's (U.S.F.S.) model, Disturbed Water Erosion Prediction Project (Disturbed WEPP) simplified web-based version 2000.12.20. The model was applied to obtain suspended sediment yield predictions resulting from timber harvests in the Cascade Mountains of the Pacific Northwest. WEPP is currently in use by U.S.F.S. to assess the potential impacts of pending or proposed timber sales. The intent here was to provide feedback not only on WEPP's general predictive performance with relation to real, site-specific data, but also to offer relevant information for program and model designers. Besides specific, catchment-level suspended sediment yield comparisons, this assessment

Figure A



From the H.J. Andrews Website:
http://www.fsl.orst.edu/lter/about.cfm?topnav=2 (April 13, 2006)

includes comments on ease of use and overall effectiveness of the model's parameters and input variables.

Table A

Characteristics of Study Catchments at the H.J. Andrews LTER Site			
NAD 1927 UTM 10	**Watershed 1 (WS1)**	**Watershed 2 (WS2)**	**Watershed 3 (WS3)**
Boundaries - (Decimal Degrees)			
North Boundary	44.208517	44.213385	44.219943
West Boundary	-122.256831	-122.243976	-122.241949
South Boundary	44.199017	44.206178	44.208031
East Boundary	-122.235813	-122.229741	-122.224022
WEPP Input Variables - Constant from Cascadia R.S. Climate			
Latitude	44.38	44.38	44.38
Longitude	-122.50	-122.50	-122.50
Elevation - Meters			
Minimum	457	548	418
Maximum	1027	1078	1080
WEPP Input Variable (mean) - Meters	742	813	749
Mean Annual Precipitation - mm	2300	2300	2300
Area-Hectares	95.9	60.3	101.1
Aspect -Degrees Azimuth	286	318	313
Percent Slope	59	53	52
Channel Length - Meters	2808	1861	2771
Treatment - HJA Description			
	100% Clearcut 1962-1966; Slash Burned 1966; Re-seeded/Fill-in Planted, 1967,1968	Undisturbed Control; Completely Forested Old Growth, 400 to 500-Year Stands of Douglas Fir and Hemlock	25% Patch Cut in 3 Patches (5, 9, 11 hectares) 1962-1963; Slash Burned 1963; Significant Debris Flows in 1964 and 1996
Roads	None *	None	1.65 miles, 6% of Area, 1959

* Small portions of road passing through Eastern and Western-most corners of WS not included in this study's calculations;
Values for portion through Eastern-most corner can be viewed on Road Network Table.
Data Sources: Da Shepherd (2004, H.J. Andrews Experimental Forest Metadata Report); Grant (2005, HS03 Abstract); Lutz & Halpern (2006).

Forecasting abilities of WEPP were tested against real, on-the-ground data from the H.J. Andrews (H.J.A.) Research Forest located on the Willamette National Forest in the Cascade Mountain Range of central Oregon (see Figure A). This assessment included approximately thirty years of suspended sediment yield data from small catchment studies within the Long Term Ecological Research (LTER) program at the Andrews. Suspended sediment yields from three basins were compared with WEPP predictions after the same treatments and basin characteristics were assigned within the model. Equivalent H.J.A. reference basins included: Watershed 1 (WS1), clear-cut and slash burned; Watershed 2 (WS2), control, and; Watershed 3 (WS3), 25% partial-cut and slash burned. Specific characteristics of each catchment can be viewed in Table A.

Methodology:

Table B

Treatment 1 ➔ (clear-cut;**WS1**)
- Run model with treatment
- Run without treatment to observe natural erosion rates and sediment yields

Treatment 2 ➔ (partial-cut;**WS3**)
- Run model with treatment
- Run without treatment to observe natural erosion rates and sediment yields

Control ➔ (no harvest; **WS2**)
- Run model with treatment
- Run without treatment to observe natural erosion rates and sediment yields

The WEPP model investigated here can be found under the "Disturbed WEPP" header at http://forest.moscowfsl.wsu.edu/fswepp/. Differences in sediment yields resulting from distinct harvest treatments were considered in the manner illustrated by Table B, employing both the WEPP modeling website, as well as data sets from the H.J.A.

Sediment yield predictions from different treatments both between and within watersheds were compared to each other and to data from the H.J.A. sites. This also allowed for some potential calibration of expected outputs from natural processes verses harvest treatments.

The remainder of this report describes how values were obtained to fulfill WEPP's user input fields according to interpretations of model parameters. This is followed by a more detailed explanation of Table B above that lists the final model scenarios simulated for comparative analysis. Next is a review of the results of these scenarios and subsequent consideration of possible errors and oversights. The report ends with suggestions and comment about the model interface and possible improvements that could be made.

Although all efforts were made to provide the most accurate and precise data and explanations, it is highly recommended that the original Andrews data sources be consulted directly for any related inquiries or further calibrations. For more in-depth model explanations, WEPP technical documentation is also accessible via the website mentioned above.

1. Customizing Climate Parameters for WEPP Input

A. Model Input Procedure

In order to capture the most accurate representation of climate in the three study basins, custom climate parameters were created and incorporated into the Disturbed WEPP model via the "RockClime Climate Generator" option.

This entailed selecting the "Custom Climate" option and then choosing the "Oregon" region and selecting "Show Me the Climates". The climate "Cascadia R S" was selected for modification. Modifiable parameters included the following variables: mean maximum monthly temperature; mean minimum monthly temperature; mean monthly precipitation; and monthly number of wet days.

It also appeared possible to customize elevation, latitude, and longitude points. However, the PRISM model influenced these respective values such that changing any one of the values led to changes in the other two as well as changes in precipitation rates. Though the generation and use of estimated climate values from PRISM were optional from this screen, whenever possible in situ climate data were utilized as input. The final elevation, latitude, and longitudinal coordinates that were used appeared similar to Cascadia R S parameters, which are listed earlier in Table A. The option to "Adjust Temperature for Lapse Rate" was not selected, since actual temperature values were used. Also, it did not appear that actual elevations could be simultaneously input when specifying temperature.

B. Data Sources & Methods

The meteorological station located on Watershed 2 (CS2MET) of the H.J.A. collected these actual catchment-level climate data. This particular station has been compiling data since February 2, 1958, and data estimates were available extending back to October 1, 1957 (Da Shepherd 2004 at ClimDB & HydroDB website). Throughout this time period, air temperature instruments employed included: a Cole Parmer hygrothermograph chart (1958-1997); a Belfort hygrothermograph chart (1997-1998); a Campbell Model HMP35C probe (1998 to present); and a Campbell Scientific CR21X data logger (1998 to present) (Da Shepherd 2004 at ClimDB & HydroDB website). Precipitation instrumentation included a Belfort Universal Recording Rain Gage, Cat No. 5-780, and a Non-Recording Precipitation Gage Cat NO. 5-400 (Da Shepherd 2004 at ClimDB & HydroDB website). Although the meteorological station located at the HJA headquarters (PRIMET) was another viable option, CS2MET was selected both for its closer proximity to the watersheds in question, as well as its longevity of data history.

Data sets from CS2MET regarding monthly minimum and maximum temperatures, as well as monthly precipitation, were downloaded from the ClimDB and HydroDB (2005) website. The mean numbers of wet days per month were obtained from data sets by McKee et al (2005) accessed via the LTER website. Using Excel, monthly maximum and minimum temperatures were totaled and averaged for all years such that monthly mean temperatures were obtained for the period of October 1957 to July 2005. Air temperature data from the period of August 1999 through February 2000 were omitted due to possible errors. Precipitation was also averaged on a monthly basis for this time period. No similar errors in precipitation data were apparent. Any data flagged as estimated were incorporated into input calculations. Results utilized as input values for all four climate variables can be viewed in Table 1.1. Latitude, longitude, and elevation parameters could not be set for each specific basin. Instead, built-in values for Cascadia R S were set at 44.38° N, 122.50°W. Actual values for the watersheds can be viewed in Table A entitled "Characteristics of Study Catchments".

Table 1.1

CS2MET (WS2) Climate Station: October 1957 - July 2005	* Mean Maximum Temperatures by Month	* Mean Minimum Temperatures by Month	Mean Precipitation by Month	Mean Number of Precipitation Days by Month
Month	**Celsius**	**Celsius**	**mm**	**# of Days**
January	3.89	-0.48	357.83	20.21
February	5.74	0.31	265.18	17.48
March	8.15	1.00	248.98	19.15
April	12.8	2.69	169.53	17.56
May	18.68	5.73	119.32	13.35
June	23.28	8.87	65.01	9.04
July	28.42	10.78	16.36	3.56
August	26.98	10.74	32.96	4.40
September	19.73	8.09	74.31	7.34
October	12.8	4.66	164.46	12.50
November	7.02	1.76	358.00	19.21
December	3.99	-0.28	381.73	20.04

Data Source: HydroDB & ClimDB (Accessed 12/18/2005)

***** Data from 1999 August through February 2000 omitted due to possible error; data averaged without these values.

2. Customizing Soil Parameters for WEPP Input

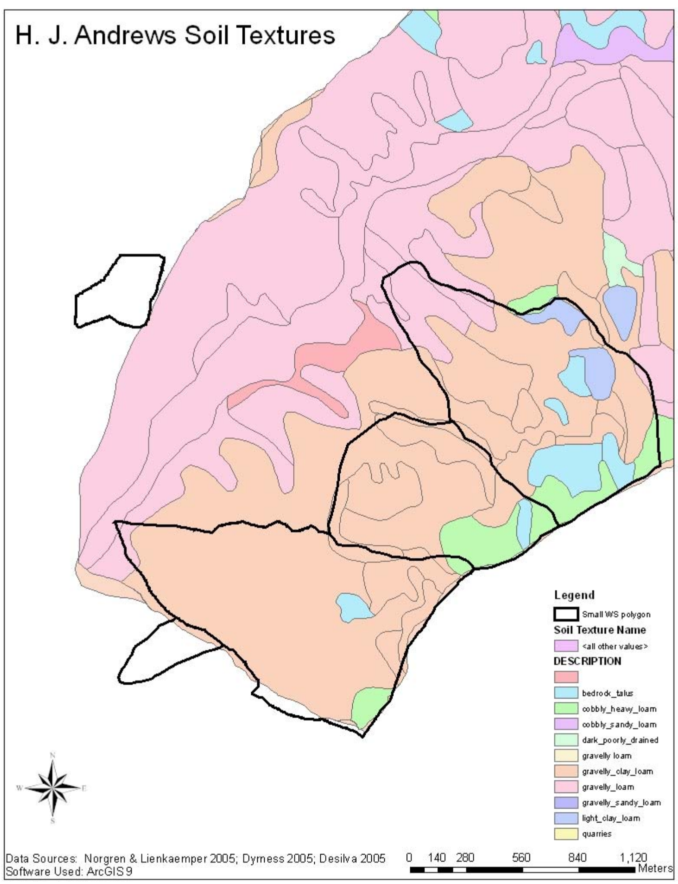
A. Model Input Procedure

WEPP model input parameters only allowed the following four soil choices based on texture: clay loam, silt loam, sandy loam, and loam. A "Universal Soil Classification Code" followed general soil descriptions for these choices (Elliot 2000). However, neither field was particularly helpful in determining appropriate soil texture choices, even when in possession of actual soil types for the given study area.

After entry of the requested parameters (soil texture in addition to other input fields), the model calculated 24 soil variables including: percentages of clay, silt, and sand, critical shear, erodability, porosity, and hydraulic conductivity (Alberts et al 1995). Unfortunately, neither the ability to manipulate, nor the appropriate selection of parameters in order to adequately achieve desired soil variables was immediately evident or intuitive from the given menu of choices. Furthermore, the model internally altered all soil properties depending on selected combinations of soil texture and vegetation treatment (Alberts et al 1995). Consequently, soil conditions could not be held constant if vegetation treatments were changed. Therefore, a more exact and extensive study of soil properties derived from varying vegetation/texture combinations was not explored.

In an attempt to mitigate for these model qualities, each treatment scenario was accompanied by a subjective analysis of its impacts on soil properties to the particular chosen texture. Appropriate adjustments were then made. Due to the sensitivity of soil texture to cover and vegetation selections, changes in soil texture were only adjusted after the former selections were finalized. Ultimately however, this issue became a moot point because the model seemed to best represent constituent percentages in the *loam* category regardless of the treatment type. More discussion of these adjustments follows.

Figure 2.1



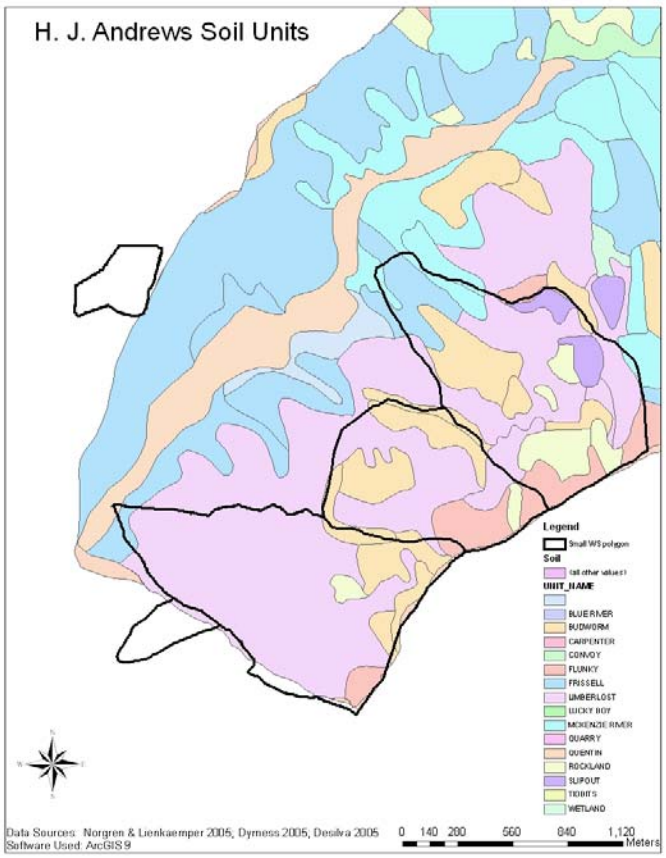
B. Data Sources & Methods

Swanson & James (1975) described the geologic and geomorphic characteristics of the steep, dissected landscape of the H.J. Andrews Research Forest. Bedrock of volcanic origin underlies the Andrews in three distinct geologic formations: Little Butte, Sardine, and Pliocascade that roughly correspond to lower, middle, and higher elevations, respectively. Furthermore, glacial, fluvial, and mass wasting processes have contributed to soil formation and parent materials of breccias, tuffs, and colluviums. (Swanson & James 1975).

Extensive soil surveys conducted and mapped on the H.J. Andrews Research Forest by

Dyrness in 1964 were then modified and updated to GIS format by Norgren in 1994 (Dyrness 2005, SP001; Norgren & Lienkaemper 2005). Utilizing these data sets, it appeared that the predominant soil texture present in all three watersheds was generally classified as gravelly-clay-loam (Dyrness 2005, SP001; Norgren & Lienkaemper 2005). Stone content was estimated to range from 35% to 50% (Dyrness 1969). Results of the soil units and soil textures can be viewed in Figures 2.1 and 2.2.

Figure 2.2



Further soil characteristics were also obtained and a cursory compilation was made from the list of more detailed profiles on the Dyrness LTER site (Dyrness 2005, SP001). For this analysis, only the topmost A1 soil horizon was utilized to estimate percent ranges of clay, silt, and sand. These properties are listed in Table 2.1 along with respective soil series and families that can be correlated with Figures 2.1 and 2.2. Although other physical and chemical descriptions were also available for most all soil units on the Andrews study sites, only texture percentages were compared to WEPP prediction outputs.

The WEPP input selection for "Vegetation Treatment" affecting soil texture was given priority for reasons discussed above. The resultant soil parameters output for each of the four soil texture options were then subjectively compared to each other in *only* with regards to percentages of clay, silt, and sand. Next, these percentages were analyzed with respect to the aggregated Andrews data in an attempt to determine the best representation of the watersheds' soil properties related to texture. Ultimately, "Loam" (rather than clay-loam) was selected as the appropriate texture for all runs in all scenarios. It appeared that "Loam" characteristics – rather than "Clay-loam" – retained the closest representative percentages of sand and clay present in the output soil profile.

Patch-cuts in WS 3 were located on several different soil types that did not necessarily represent the watershed as a whole, nor the soil texture generalized for all three watersheds. Because of the method in which WEPP defined soil properties, even more attention was given to the soil properties selected and displayed for this particular watershed. Nonetheless, "Loam" was still selected as the best representation of this watershed for reasons described above. However, rock percentages were adjusted, and they are discussed further in the corresponding sections.

Table 2.1

Soil Series	Soil Family	Soil Texture	% Sand	% Silt	% Clay
Watershed 1					
Limberlost	Pachic Halumpbrepts	Fine-Loamy	42.1-44.5	35.1-37.4	20.1-20.5
	Typic Halumpbrepts				
Budworm	Pachic Halumpbrepts	Fine-Loamy	31.4-39.1	36.4-54.3	14.3-27.3
	Umbric-Hapludalfs				
	Typic Dystrochrepts				
Frissel	Lithic Dystrochrepts	Loamy-Skeletal	41.2	42.7	16.1
Soil from Andesite Colluvium	Typic Halumpbrepts	Loamy-Skeletal	49.0	35.3	15.7
Rockland		Bedrock Talus			
Watershed 2					
Budworm	Typic Halumpbrepts	Fine-Loamy	36.5	37.2	26.3
Frissel	Typic Dystrochrepts	Fine-Loamy	18.5-42.9	35.5-49.4	17.1-32.2
	Typic Halumpbrepts				
	Fluventic Dystrochrepts				
Limberlost-Stony Phase	Typic Halumpbrepts	Loamy-Skeletal	64.7	19.4	16.0
Limberlost	Typic Dystrochrepts	Fine-Loamy	24.7-41.7	33.2-45.9	25.1-26.6
	Pachic Halumpbrepts				
Soil from Andesite Colluvium	Typic Halumpbrepts	Fine-Loamy	34.9-59.4	22.5 -41.0	16.5-25.8
		Loamy-Skeletal			
Rockland		Bedrock Talus			
Watershed 3					
Limberlost	Pachic Halumpbrepts	Fine-Loamy	35.3 - 43.5	34.4-41.1	22.1-24.1
	Typic Halumpbrepts	Loamy-Skeletal			
Flunky/Zango	Lithic Dystrochrepts	Loamy-Skeletal	33.4-63.7	27.7-45.8	8.6-20.8
	Pachic Halumpbrepts				
Budworm	Aquic Halumpbrepts	Fine-Loamy	36.7	40.3	22.9
Budworm- Stony Phase	Typic Halumpbrepts	Loamy-Skeletal	37.6-43.6	34.3-38.5	22.2-23.9
Frissel	Typic Dystrochrepts	Fine-Loamy	35.9	41.4	22.7
Frissel- Stony Phase	Typic Halumpbrepts	Loamy-Skeletal	61.7	19.2	19.1
Soil from Andesite Colluvium	Typic Dystrochrepts	Loamy-Skeletal	43.8	53.1	23.1
Blue River	Pachic Halumpbrepts	Loamy-Skeletal	54.2	34.7	11.0
McKenzie River	Typic Haplohumults	Clayey-Mixed	27.2	44.8	28.0
	Ultic Hapludalfs	Clayey-Mixed	31.3	43.5	25.3
McKenzie River – Stony Phase	Ultic Hapludalfs	Clayey-Mixed	34.1	44.4	21.5
Slipout	Aquic Halumpbrepts	Fine-Loamy	30.6- 50.9	26.3-48.1	21.3-22.8
Soil from Andesite Colluvium	Typic Halumpbrepts	Coarse-Loamy	59.3	27.1	13.6
Rockland		Bedrock Talus			

Data Source: (Dyrness 2005; Norgren & Lienkaemper 2005)

3. Customizing Vegetation Treatments for WEPP Input

A. Model Input Procedure

Disturbed WEPP offered eight “Vegetation Treatment” classes that varied in terms of vegetation types, stem spacing, height, soil conditions, etc. Recommendations within the “Vegetation Treatment” description text were given by Disturbed WEPP for appropriate treatment selection and application to harvesting and prescribed burning conditions.

For this project, treatment applications followed those recommended in Table 4, and Example 3 in the Disturbed WEPP Technical Documentation (Elliot 2000, pp. 9, 16). Clear-cuts were treated with the “5-Year-Old Forest” selection, and broadcast slash burning was treated as a “Low Severity Fire”. Both “Tall-grass and Short-grass Prairie” conditions were employed to represent regeneration stages after burning. WEPP also assumed its “20-Year-Old Forest” option offers the maximum level of cover and erosion control that can be offered by mature vegetation (Elliot 2000, 5). Therefore, this option was used to represent old-growth conditions.

B. Data Sources & Methods

Figure 3.1
Watershed 1 – Clearcut

(LTER website 2005)

Prior to logging, Watersheds 1, 2 and 3 consisted of old-growth conifers in the 300 to 500-year-old and 125-year-old age and class ranges, with subcanopies and understories that included conifers and hardwoods (Halpern 1989). Watersheds 1 and 3 had been studied extensively with regards to vegetation cover and ground conditions (Dyrness 1973, Halpern 1989, and Halpern 2005). In 1962 prior to logging, data on the two watersheds were collected, and sampling continued through the slash-burning phase into present time (Dyrness 1973, 2005; and Halpern 1989, 2005). Between 1962 and 1966, WS1 was completely clear-cut via skyline yarding; slash was broadcast burned in 1966 (Halpern 1989; Da Shepherd 2004 at ClimDB & HydroDB website). In the winter of 1962, 25% of WS3 was harvested in three patches, while slash was broadcast burned in September 1963 (Halpern 1989; (Da Shepherd 2004 at ClimDB & HydroDB website). Figures 3.1 to 3.3 illustrate each of these experimental basins.

Figure 3.2
Watershed 2 – Old Growth

(LTER website 2005)

In order to represent processes of harvesting, burning, and regeneration within Disturbed WEPP, vegetation treatments types were entered in the series shown in Table 3.4. Resulting yearly averages from each run were displayed and totaled. This decision was based on examples from the model literature indicating each of these phases could be assumed to occur for approximately one year and progressed in a series

(Elliot 2000, pp. 9, 16). Subsequent model runs presumed no buffer zones. Treatments and burn severity were also generally homogenized across the entire watershed. However, uniform treatment conditions and effects were not necessarily found on the ground (Halpern 2005, Personal Communication).

Figure 3.4
Watershed 3 – Patch-cut

(LTER website 2005)

Actual "Percent Coverage" input values – as distinct from "Vegetation Treatment" – for harvested watersheds were selected in concert with efforts to represent vegetation treatments and regeneration changes through time. All inputs can be viewed in Table 3.4. More discussion of how coverage values were interpreted can be found in the "Percent Coverage" section of this report. Although separate simulations of individual vegetation treatments could be made for each individual "Percent Coverage" value, such was beyond the scope of this particular study.

Finally, because only 25% of WS3 was cut, WEPP was run as described below; predicted totals for the model basin were then multiplied by 0.25. Next, WS3 was simulated as if no disturbance occurred using the "20-Year-Old Forest" selection and other correlating inputs, which were true for the remaining 75% of the watershed not harvested. These output data were multiplied by 0.75. Lastly, sum totals from these two scenarios indicated sediment prediction results for WS3 patch-cut by 25%.

Control simulations for all three catchments were represented by the "20-year-old Forest" treatment selection run for 30 years in the method using the series of averages, and for 42 years in the single scenario comparisons. More discussion of the simulation strategy appears the respective section of this report.

Table 3.4

∆ Multiple Scenarios and Resulting Averages Simulated in WEPP Representing Catchment Regeneration after Control, Clear-cut, and Burn Treatments

Year	Years after Disturbance	Treatment Series and Temporal Duration	* Estimated % Cover (1 - % Bare Ground) (Halpern 2005)	Average Upland Erosion Rate Based on 2 Year Return Period (tons/hectare)	Average Sediment Yield/Output Leaving Profile Based on 2 Year Return Period (tons/hectare)	Sum of Upland Erosion + Sediment Output	Ψ Calibrated % Cover	Average Upland Erosion Rate Based on 2 Year Return Period (tons/hectare)	Average Sediment Yield/Output Leaving Profile Based on 2 Year Return Period (tons/hectare)	Sum of Upland Erosion + Sediment Output
Watershed 1 -- 100% Clearcut, Slash Burned										
Scenario A: 30-Year Simulation Representing Temporal Regeneration by Combining Yearly Average Sediment Predictions from Multiple Treatment Scenarios										
1962	0	20-Year Old Forest	⊥ 96	0.21	0.21	0.42	α ⊥ 96	0.21	0.21	0.42
1963	1	Five Year Old Forest	88	0.52	0.52	1.04	α 88	0.52	0.52	1.04
1964	2	Five Year Old Forest	88	0.52	0.52	1.04	α 88	0.52	0.52	1.04
1965	3	Five Year Old Forest	88	0.52	0.52	1.04	α 88	0.52	0.52	1.04
1966	0	Low Severity Fire	46	297.02	297.02	594.04	86	11.67	11.62	23.29
1967	1	Short Grass Prairie	45	206.93	206.93	413.86	92	5	5	10
1968	2	Tall Grass Prairie	52	25.97	25.97	51.94	77	2.19	2.19	4.38
1969	3	Shrub-dominated Rangeland	51	0.47	0.44	0.91	74	0.15	0.14	0.29
1970	4	Five-Year Old Forest	60	2.79	2.79	5.58	90	0.49	0.49	0.98
1971-1980	5-15	Five-Year Old Forest (Yearly Avg. x's 10)	*76	10	10	20	90	4.9	4.9	9.8
1981-2003	16-38	20-Year Old Forest (Yearly Avg. x's 23)	*93	4.83	4.83	9.66	α 93	4.83	4.83	9.66
1962-2003	42	20-Year Old Forest *(Yearly Avg. x's 42)*; Simulated for 30 Years	96	8.82	8.82	17.64	α 96	8.82	8.82	17.64
Sum of Average Outputs from Each Scenario				**558.6**	**558.57**	**1117.17**		**39.82**	**39.76**	**79.58**
Scenario B: 42-Year Simulation Representing Temporal Regeneration from Single Treatment Scenario										
1962-2003	42	Control; 20 Year Old Forest, Simulated for 42 Years	96	0.16	0.16	0.32	α 96	0.16	0.16	0.32
1962-2003	42	Low Severity Fire, Simulated for 42 Years	46	295.46	295.46	590.92	86	10.95	10.95	21.9
Average Yearly Sediment Yield *x's 42 Years*			**Control**	**6.72**	**Burn**	**12409.32**	**Control**	**6.72**	**Burn**	**459.9**
Watershed 2 -- Control										
Scenario A: 30-Year Simulation Representing Temporal Regeneration by Combining Yearly Average Sediment Predictions from Multiple Treatment Scenarios										
1962-2003	42	20-Year Old Forest *(Yearly Avg. x's 42)*; Simulated for 30 Years	97	17.22	17.22	**34.44**	α 97	17.22	17.22	**34.44**
Scenario B: 42-Year Simulation Representing Temporal Regeneration from Single Treatment Scenario										
1962-2003	42	Control; 20 Year Old Forest, Simulated for 42 Years	97	0.36	0.36	**0.72**	α 97	0.36	0.36	**0.72**
Average Yearly Sediment Yield *x's 42 Years*			**Control**	**15.12**			**Control**	**15.12**		
Watershed 3 -- 25% Clearcut, Slash Burned										
Scenario A: 30-Year Simulation Representing Temporal Regeneration by Combining Yearly Average Sediment Predictions from Multiple Treatment Scenarios										
1962	0	20-Year Old Forest	⊥ 97.3	0.24	0.23	0.47	α⊥ 97.3	0.24	0.23	0.47
1963	1	Five Year Old Forest	84	0.69	0.69	1.38	90	0.54	0.54	1.08
1964	0	Low Severity Fire	71	38.1	38.1	76.2	90	9.33	9.33	18.66
1965	1	Short Grass Prairie	72.1	21.82	21.82	43.64	91	5.57	5.57	11.14
1966	2	Tall Grass Prairie	69.6	3.14	3.14	6.28	78	2.11	2.11	4.22
1967	3	Shrub-dominated Rangeland	71.9	0.19	0.17	0.36	75	0.18	0.17	0.35
1968	4	Five-Year Old Forest	72.6	1.23	1.23	2.46	90	0.54	0.54	1.08
1969-1978	5-15	Five-Year Old Forest (Yearly Avg. x's 10)	*78	9.1	9.1	18.2	α 90	5.4	5.4	10.8
1979-2003	16-41	20-Year Old Forest (Yearly Avg. x's 25)	*94	6.25	5.75	12	α 94	6.25	5.75	12
1962-2003	42	20-Year Old Forest *(Yearly Avg. x's 42)*; Simulated for 30 Years	⊥ 97.3	10.08	9.66	19.74	α 97.3	10.08	9.66	19.74
Initial Sum of Average Outputs from Each Scenario *Without Adjustment for Patch-Cut*				**90.84**	**89.89**	**180.73**		**40.24**	**39.3**	**79.54**
Totals x's 0.25				**22.71**	**22.47**	**45.18**		**10.06**	**9.83**	**19.89**
Patch-cut Adjusted Sum of Averages ((Total x's 0.25)+ 0.75 x's 20-Year Old Forest)				**30.27**	**29.72**	**59.99**		**17.62**	**17.07**	**34.69**
Scenario B: 42-Year Simulation Representing Temporal Regeneration from Single Treatment Scenario										
1962-2003	42	Control; 20 Year Old Forest, Simulated for 42 Years	97.3	0.18	0.17	0.35	97.3	0.18	0.17	0.35
1962-2003	42	Low Severity Fire, Simulated for 42 Years	71	38.23	38.23	76.46	90	8.8	8.76	17.56
Average Yearly Sediment Yield *x's 42 Years*			**Control**	**7.14**	**Burn**	**406.77**	**Control**	**7.14**	**Burn**	**97.335**

∆ All runs except for "Control" and "Low Severity Fire Simulated for 42 Years" were simulated for 30 years; soil texture was held constant as "loam" for all scenarios; See accompanying graphs for illustration of data highlighted in green.
⊥ Cut occurred in fall, data probably collected in summer. This data offers before-cut perspective on vegetation treatment and cover values.
α No new additional vegetation calibration needed to achieve ≅ 93-94% cover range; cover already sufficient, or same calibration occurred in a separate cell.
* Cover % is the average of range of estimated values (1-bare ground) obtained from Halpern (2005 Unpublished Data) for each time period.
Ψ Value from 30-year vegetation calibration that adjusted the approximated % cover to the ≅ 93-94% range after 30 years regeneration.
Data Sources: Halpern 2005; Dyrness 1973; Elliot 2000, Disturbed WEPP, Da Shepherd 2004.

4. Customizing Percent Coverage for WEPP Input

A. Model Input Procedure

Disturbed WEPP utilized user input value of percent coverage along with climate predictions, rock cover, and vegetation treatment to calculate the following biomass conversion ratio:

Ratio = 8.17 * exp (0.031 * Cover - 0.0023 * Precipitation) (Elliot 2000)

Due to the number of changing variables involved in this prediction, WEPP offered a “Calibrate Vegetation” option that could be selected for a minimum of 10 years. The resultant calibration gave the average percent cover predicted for the selected period of time, which could then be arbitrarily adjusted for final input as needed (Elliot 2000). Unfortunately, WEPP offered no clear, exact definition or description of what this “Cover %” specifically entailed, other than “surface residue cover” (Elliot 2000, 2). A later explanation in the Disturbed WEPP documentation detailed how it affected and was affected by vegetation, climate, and rock percentages, but this remained somewhat vague (Elliot 2000, 9). On the other hand, the accompanying technical document (Stott 1995, Arnold 1995) was very detailed, but still failed to make user input considerations clear for novice users or seasoned botanists. This was of significant importance in this study, as WEPP suspended sediment output was extremely sensitive to changes in percent cover (Elliot 2000).

For the purposes of this study, “Cover %” was interpreted as anything not bare ground or mineral soil. This was distinct from data that might reflect vegetation cover or canopy cover, as it included residual cover like slash and rocks, and was not directly related to understory. In addition to running simulations under this assumption using corresponding Andrews data, multiple scenarios were simulated with predicted percentage cover values from the 30-year “calibrated vegetation” option. Inputs were adjusted within the selected treatment types in order to reflect /predict cover of approximately >90% after 30 years of set simulation.

Figure 4.1

Winter 1973 PLANT SUCCESSION IN THE OREGON CASCADES 59

TABLE 2. Cover and frequency values for all plant species encountered on permanent milacre plots in three clear-cut units during the growing seasons of 1962 (before logging), 1963 (first year after logging), and 1964–68 (after slash burning)

	1962		1963		1964		1965		1966		1967		1968	
PLANT SPECIES	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.
	Per cent													
TOTAL OF TREE, SHRUBS, AND HERB LAYER COVER (net)	69.6		10.3		15.2		49.3		53.4		62.5		79.5	
GROUND CONDITION														
Moss	21.5	77.8	1.9	11.7	0.7	4.0	1.9	9.8	3.4	17.5	1.7	9.7	1.9	7.5
Litter	93.8	99.6	80.9	97.8	64.9	92.4	65.2	93.1	63.2	95.3	66.6	96.2	67.9	91.3
Bare Ground	2.7	7.5	16.0	35.7	29.0	55.7	27.9	53.0	30.4	60.3	28.1	56.5	27.4	50.8
Stones	2.8	15.5	3.2	16.8	6.1	30.4	6.3	31.0	6.2	32.2	5.3	27.7	4.6	24.0

[a]Value less than 0.05.
[b]Present in trace amounts.

(Dyrness 1973)

B. Data Sources & Methods

Figure 4.1 indicates total percentages of vegetation cover, bare ground, and rock specifically for WS3 (Dyrness 1973). Later vegetation data for both WS1 and WS3 further compiled by Halpern were also utilized to estimate cover percentages entered into WEPP (Halpern 2005, Unpublished Data). Coverage values for the control Watershed 2, which remained in old growth, were assumed to be similar to pre-harvest and burn values found in the previously old-growth-covered WS1 and WS3.

Andrews data of primary use for the WEPP model included the total percent cover, the percent of bare ground, and the percent of stones. For WEPP input purposes, the percent of surface not classified as bare ground by Halpern or Dyrness was interpreted as "Cover %". To reiterate, this was distinct from data that reflected vegetation or canopy cover, as it included residual cover like slash and rocks, and was not directly related to understory. Bare ground in the case of the Andrews data was defined by "the absence of fine litter on the soil surface and the ability to see mineral soil beneath the herb layer…" (Halpern, Personal Communication 1/8/06). Consequently, this value correlated to both the Halpern (2005, unpublished data) and Dyrness (1973) data in the form of 1-% of bare ground values displayed in Figure 4.1.

Percent stone values were excluded from this input field since bare ground was devoid of stones in the Andrews bare ground measurements (Halpern, Personal Communication 1/8/06). Rock cover percentages were therefore already incorporated into WEPP coverage percents by the data collection method described above. In the case of the Andrews data, stones were defined as >7.0 cm (Halpern, Personal Communication 1/8/06). Percent rock data is further discussed regarding input for percent rock in a separate portion of this report.

Actual input coverage values for the harvested watersheds were changed in concert with efforts to represent vegetation regeneration via a series of treatment changes through time. All of these quantities can be viewed in Tables 3.4 or 9.1 reproduced in other sections.

Furthermore, available percent coverage data only considered the harvested and burned portions of H.J.A. basins and not the catchments as a whole (Halpern 2005, Personal Communication 12/05). In addition, burn severities across study plots and patch cuts within WS3 were not constant (Dyrness 1973). For this study, treatments and burn severity were generalized as the same across the entire watershed.

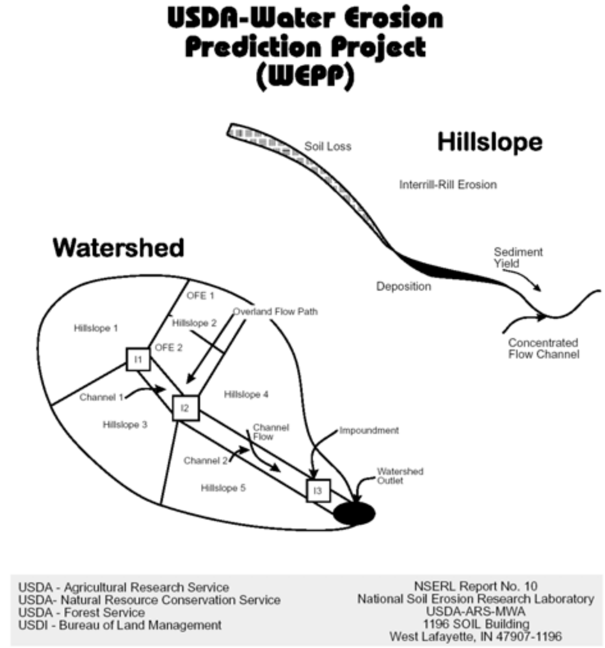
5. Customizing Gradient and Horizontal Length Parameters for WEPP Input

A. Model Input Procedure

In an attempt to capture the most accurate representation of gradients and horizontal lengths in the three study areas, custom parameters were estimated for each basin and incorporated into the Disturbed WEPP model via the "Gradient Percent" and "Horizontal Length" options.

WEPP divided hillslopes into upper and lower regions such that each section had two slope inputs and one horizontal length input (Elliot 2000). Figure 5.1 illustrates this hillslope division. Essentially, slopes must be entered for the top of the hill (in this case, the ridgeline of the catchment); the bottom of the hillslope (here, the stream channel served as a general reference); and the centers of the respective sections (in this study, visually selected samples were taken from what appeared as geographic center bands of the watershed and representative slope ranges for several hillslope section). Although the initial slope input for WEPP must equal zero when starting at the top of the basin hillslope (Elliot 2000), actual slope estimates for this region were also calculated.

Figure 5.1.

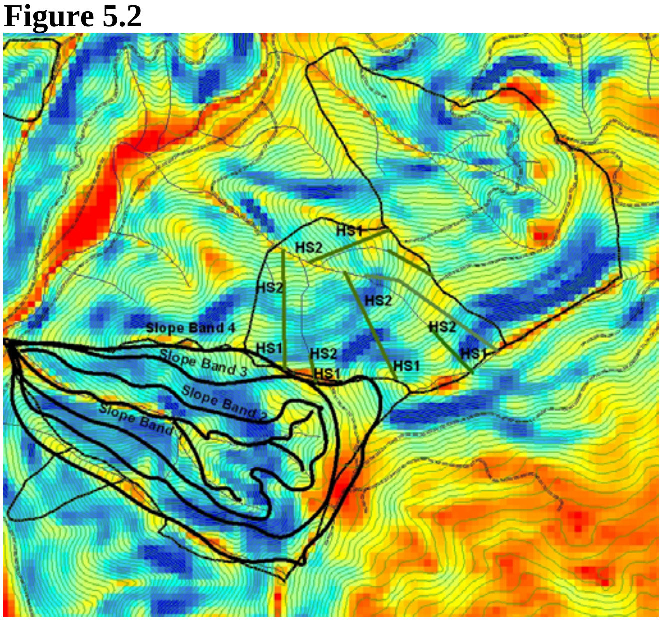


Elliot 2000

B. Data Sources & Methods

Actual slope values and horizontal watershed lengths were estimated from samples subjectively chosen utilizing Arc GIS 9 software and 30 meter DEM's obtained from Lienkaemper (30 DEM, Watershed Boundaries, & Stream Network 2005; Valentine 2005) and Desilva (Administrative Boundary 2005) at the H.J. Andrews online LTER site (http://www.fsl.orst.edu/lter/data/abstract.cfm?dbcode= GI002; HF014; HF013; & GI006, respectively).

Figure 5.2



Sample slope data points were visually selected along four estimated geographical ranges representing the section gradients described above. Figure 5.2 illustrates this selection process with heavy black lines representing the slope bands, and heavy green lines illustrating horizontal lengths taken from a planar perspective. Slope values are shaded in ascending order from lower red through yellow to green, and the highest, blue. The four bands of slope values were then separately averaged so that headwater feeder stream slopes were averaged with

Table 5.1

Slope Gradient and Horizontal Hillslope Length Estimates	Watershed 1	Watershed 2	Watershed 3
% Slope gradient with respect to bottom of hillslope			
Lowest Elevation	30.65	39.3	32.07
Middle Lowest Elevation	67.38	59.95	53.83
Middle Highest Elevation	70.66	60.03	61.08
Highest Elevation	31.48	31.47	33.15
Average planar length of each hillslope section, top to bottom; (Section 1 = Section 2) in meters			
Upper Hillslope	153.31	208.61	188.76
Lower Hillslope	153.31	208.61	188.76

Data Source: (Lienkaemper, DEMs, watershed boundaries, & stream network 2005; Desilva 2005, Admin. Boundaries; Valentine 2005).
Software Used: Arc GIS 9 & MS Excel

values from further down the watershed. Gradient percentages can be viewed in Table 5.1. These numbers are also within the range presented in Table A.

Horizontal planar lengths from the top of the ridgeline to the bottom stream channel were estimated using the same DEM information. Again, ridgelines, stream channels, and visually estimated geographic middle bands were used as reference points. Sample line segments extending from the ridgeline to the bottom of the hillslope were visually selected to include shorter segments from the feeder streams, as well as longer segments from portions of the basin further downstream. These total lengths were then averaged and divided in half to obtain two equal upper and lower section lengths. Again, methods can be seen in Figure 5.2 and results used in WEPP input fields can be viewed in Table 5.1. The highest elevation equaled zero in accordance with the WEPP documentation instructions (Elliot 2000).

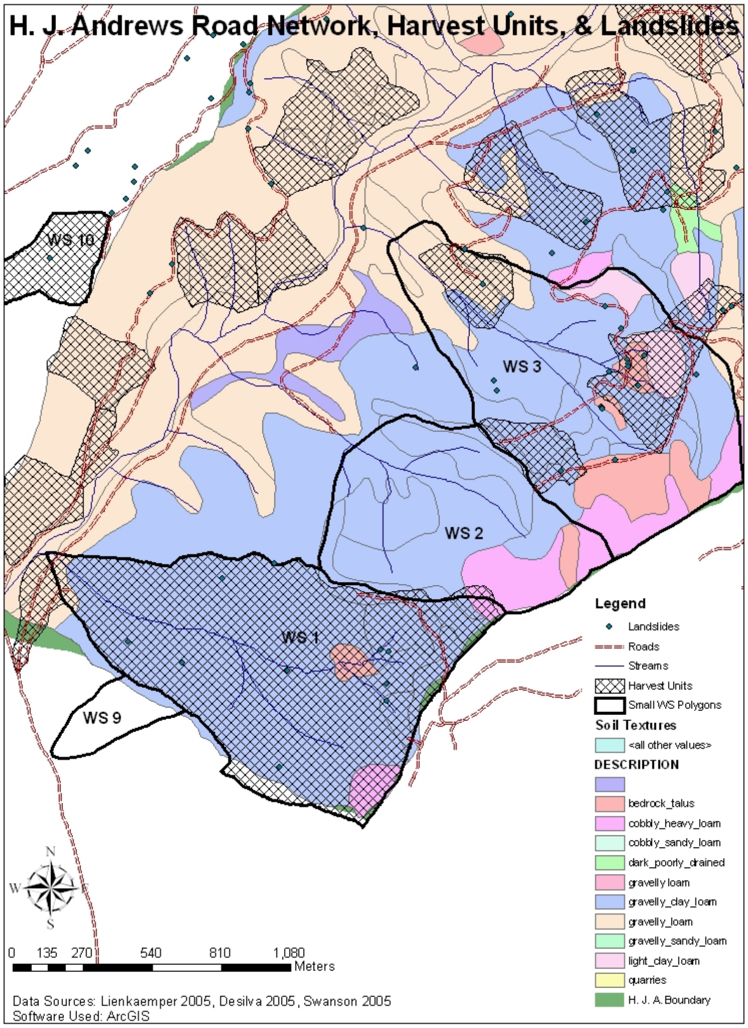
6. Customizing Percentage of Rock for WEPP Input

A. Model Input Procedure

Disturbed WEPP offered a "Rock %" input field representing the percentage of rock fragments per volume located in the soil (Elliot 2000). There was a distinction drawn between surface cover that might include rocks and this particular input field. Rock content values directly reduced the hydraulic conductivity of the soil parameters and were limited to a 50% ceiling regardless of whether higher values were input by the user (Elliot 2000).

B. Data Sources & Methods

Figure 6.1



Rocks as surface cover were included via the "Coverage %" field discussed in its respective section of this report, and were thus assumed to be incorporated into the calculations made utilizing bare soil values from the Andrews data sets of Halpern (2005, Unpublished Data) and Dyrness (1973). These surface rock percentages were therefore ignored for this particular field of input.

Extensive soil surveys conducted and mapped on the H.J. Andrews Research Forest by Dyrness in 1964 were then modified and updated to GIS format by Norgren in 1994 (Dyrness 2005, SP001; and Norgren & Lienkaemper 2005, SP026). Utilizing these data sets, it appeared that the predominant soil texture present in all three watersheds was generally classified as gravelly-clay-loam (Dyrness 2005, SP001; Norgren & Lienkaemper 2005, SP026). Stone content was estimated to range from 35% to 50% (Dyrness 1969). Results of the soil textures can be viewed in Figure 6.1.

Table 6.1

% Rock Entered in WEPP		
	Upper Slope	Lower Slope
WS1	45	40
WS2	50	45
WS3	50	45

As mentioned previously, patch-cuts in WS 3 were located on several different soil textures that did not necessarily represent the watershed as a whole, nor the rock percentages that were generalized for all three watersheds. Rock contents on the eastern and northern-most patch cuts may have exceeded the 50% ceiling, as these textures were characterized as bedrock talus and/or coarser gravelly loam rather than the gravelly clay loam of the rest of the watershed. Figure 6.1 also illustrates these characteristics. Taking into consideration the above conditions, Table 6.2 indicates the values input into WEPP for this field.

7. Correcting for Landslide and Road Sediment Contributions

A. Landscape Contributions

I. Model Input Procedure

Because the intent of this analysis was to isolate sediment output generated specifically from timber harvests, ideally mass failure and landslide contributions would be minimized to the greatest extent possible. However, WEPP did not offer any input or adjustment options for isolating such events that may have occurred on the model hillslope of interest.

In order to capture predicted natural sediment erosion in the absence of harvest, two scenarios were simulated for each of the cut basins, WS1 and WS3. This allowed some comparison between a control data represented by the "20-year Forest" vegetation selection simulated for 42 years and the appropriate harvest treatment within basins. As a third comparative approach, control sediment outputs were also subtracted from the experimental treatment output predictions in ensuing sections of this report. Outputs between the two cut watersheds and the control watershed, WS2, were also compared.

II. Data Sources & Methods

Landslide data was obtained (Swanson 2005, GE012) and overlaid onto DEM data (Desilva 2005, GI006; and Norgren & Lienkaemper 2005, SP026). Landslides did occur in two of the three study catchments during the time span studied. Visual observation revealed that the bulk of the landslide activity occurred in harvested areas and was particularly concentrated in WS3 near soils labeled as bedrock talus. Slides can be viewed in Figure 6.1 represented by green points.

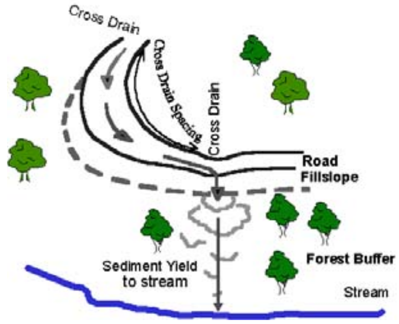
Unfortunately, it was not possible to specifically exclude from the Andrews suspended sediment data the possible sediment yield contributions from these landslides. However, from map 6.1 it is possible to see there was a visible correlation between landslides, roads, and harvested forest areas, particularly as WS2 had not registered a slide in the time frame of Swanson's 1953 to 1996 data inventory. This may indicate that debris flows and landslides are more important sediment delivery processes in this terrain than the overland erosion rates predicted by WEPP. More discussion of debris flows and Andrews suspended sediment data is included in the "Comparative Results" section of this report.

B. Customizing Road Parameters for Potential RoadWEPP, Cross-Drain, and Disturbed WEPP Integration

Disturbed WEPP did not offer any input fields to describe road impacts on sediment production. Instead, RoadWEPP and CrossDrain prediction models dealt with sediment yields originating from roads that may have been constructed during harvest. Road Batch is a third option from the WEPP suite of predictive models, but it is not discussed here.

Though initially intended, this project did not utilize either model to obtain sediment output predictions for analysis in conjunction with Disturbed WEPP or H.J. Andrews data. This was due to the lack of site-specific suspended sediment data from such isolated sources on the H.J.A. at the discrete scale and time period explored in this report. Source-specific sediment yield data for WS3 may have been available on the LTER website for the time period after the 1950's road construction and prior to the 1962 harvest. Road sediment data was available at a broader scale for the Lookout Creek Basin as a whole (Wemple 1996), but not at an appropriate scale for this study. Though not incorporated into this analysis, the following discussion is provided to inform a future investigation should further research be desired.

Figure 7.B.1

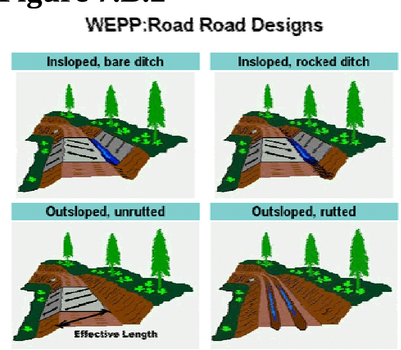


(Elliot 1999 CrossDrain)

I. Model Input Procedure

Several input fields in both road models could exploit data either already obtained for other portions of this study, or by the same methods discussed in respective sections. A more detailed explanation of either of these models is available in the RoadWEPP (Elliot et. al. 1999, RoadWEPP) and CrossDrain (Elliot et. al. 1999, X-DRAIN) technical documentation listed in the "References" section of this report. Figures 7.B.1 & 7.B.2 illustrate of some the pertinent input fields.

Figure 7.B.2



Elliot 1999. Road WEPP

II. Data Sources & Methods

The only roads with probable significant contributions to suspended sediment yields on the H.J.A. were those located on WS3 in the three patch-cut areas. Although a tiny portion of the road network also extended into the very eastern and western-most corners of the WS1, these could be effectively ignored and were assumed to have little contribution to the overall sediment output of the watershed (Jones 2005, Personal Communication). Foot trails on WS2 were also excluded from consideration, though Road WEPP did offer an option for their analysis.

"On the H.J. Andrews, road gradients are in the 6-8% range, with the road fill [gradients] possibly well over 50% - perhaps as much as 70-80%…For road width, 20 m is the average effective width of the road, including the fill and the cut. The actual width of the road surface is about 1/3 of that [or] - 7m" …Roads are insloping, gravel surface, with ditch relief and stream-crossing culverts in the small watersheds... Culvert spacing is about 100 m…" (Jones 2005, Personal Communication). Further details about the road network on these specific watersheds can be viewed in the Table 7.B.1 below.

The segments of road known to have stream crossings or harvested buffers may be of particular importance in assigning correct RoadWEPP or CrossDrain input field values. Best efforts should be made to follow examples in the technical document and to divide up segments so that buffer lengths and road segments are adjusted accordingly (Elliot 1999, Road WEPP, p. 12). Table 7.B.1 suggests a scheme towards this end.

Table 7.B.1

***Estimated* Road Network Values for the H.J. Andrews Research Forest**

Watershed	Date Constructed	Road & Segment	Status	Total Road Length (m)	Average Road Gradient (%)	Average Buffer Length (m)	Average Buffer Gradient (%)
Watershed 1	1966	**East-Most**	*Not significantly within watershed	650.74	29.75	330.37	44.66
Watershed 2	NA		Foot paths excluded from study	NA	NA	NA	NA
Watershed 3	1959	**South-Most**	Buffer to stream harvested	1019.16	6-8%	224.99	40.9
		Middle, SW Segment	* # Abandoned	420.15	6-8%	172.90	48.54
		Middle, NE Segment	#	879.16	6-8%	116.61	54.25
		North-Most	*Abandoned; Buffer to stream harvested	179.96	6-8%	121.43	42.01
WS 3 Totals & Averages				2498.43	6-8%	158.98	46.43

* Segments may not be significantly contributing sediment sources, and therefore may be either excluded or adjusted accordingly in the scenarios.
# This segment contains a stream crossing

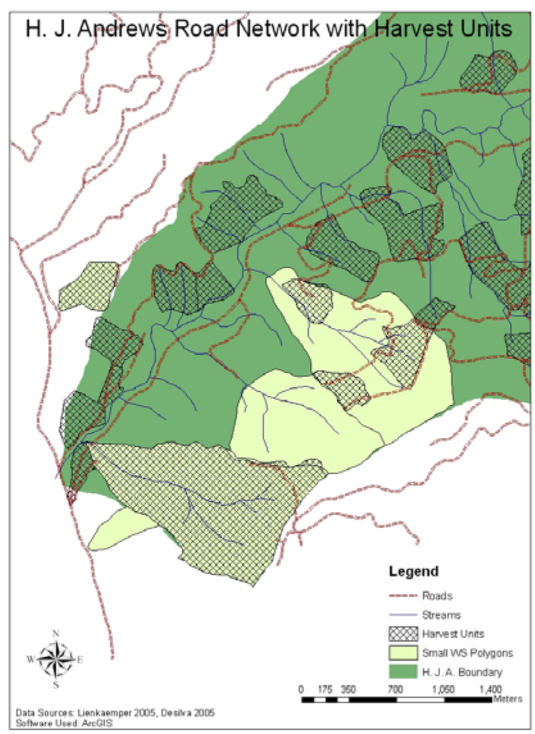
Data Sources: Lienkaemper 2005, HF014, DH001, HF013; Desilva 2005, GI006; and Jones 2005, Per. Com.)
Software Used: ArcGIS 9, MS Excel

Notable assumptions imbedded in Road WEPP that could limit the accuracy of resultant predictions included buffer surface coverage at 100% from the litter of 20-year-old forests (Elliot 1999, Road WEPP). This could be pertinent particularly in two of the patch-cuts on WS3, which may not have had vegetated buffers. Additionally, insloped bare-ditch conditions that were applicable to new roads assumed no rutting, which may or may not be the case in reality.

Limitations in CrossDrain might arise from the inability to utilize custom climate parameters set previously for "Disturbed WEPP" inputs. This could create a lack of continuity with the overall landscape representation created in the WEPP model. Furthermore, if roads drained directly into established channels, then CrossDrain was not the most appropriate modeling tool (Elliot 1999, CrossDrain), which may have been the case in a section of the mid-elevation road in WS3.

Furthermore, as displayed in Figure 7.B.3, the middle and southern-most roads in WS3 ran parallel to each other at different elevations, and in one segment provided the top and bottom borders of the patch-cut. This may have influenced or exacerbated suspended sediment effects differently than in harvest

Figure 7.B.3



patches without more than one road border. Buffer lengths and gradients of the higher elevation road were sometimes intercepted by lower road surfaces. These stacked spatial conditions probably caused cumulative impacts on sediment production, but could not be reflected in either model. Hence, neither model seemed to address in a completely satisfactory manner the exact ground conditions present at the two relevant H.J.A. basins.

8. Andrews Suspended Sediment Data

A. Data Sources & Methods

Original suspended sediment site data for Watersheds 1, 2, and 3 were obtained from the H.J. Andrews LTER website and were derived from the long-term projects of both Gordon Grant (2005, HS03) and Richard L. Fredriksen (2005, CF002).

Spanning the period between 1955 and 1988, Grant's study included all three basins and utilized an approach described as follows. Sampling methodology involved the collection of suspended sediment grab-samples taken during the rising, peak, and falling intervals of each storm. These were supplemented by additional grab-sampling at least every three weeks for most water years throughout the duration of the study. During this research period, at least three different filtration techniques were employed to measure quantities and concentrations of suspended sediments. Since the termination of collection, these datasets have been updated several times (Grant 2005, Abstract HS03).

The specific data column extracted from Grant's data for use in the WEPP comparative analysis was labeled "CUYLDEND" and involved the cumulative storm and non-storm sediment yields from the beginning of the water year to the end of the last time interval prior to the start of the next water year (November 1). The metadata refers to these columns as 76-83 under format 4, and all measurements are in KG/HA (Grant 2005, HS03). This did not include bedload data. It is noteworthy that the last sample from the final year of data collection, 1988, was collected in June rather than November for all three catchments. Therefore, these values do not constitute a complete water year.

Fredricksen's dataset spans from 1981 to 2004 for WS2, and from 2003-2004 for WS1. The 2003-2004 water year encompasses a completely different time period, from May 2003 to May 2004. The sampling design described in the Fredricksen dataset was based on a battery-powered in-house sampler that collected stream water proportional to the stream flow rate. "Twenty proportions equaled the discharge increases of 1/20th of the expected maximum discharge… and with each proportional increase, the number of samples taken in the base time period increased by one" (Fredriksen 2005, Abstract CF002). Fredriksen's dataset, with the exception of one extremely high sampling value, tended towards lower totals than those of the Grant data for the years of overlapping coverage discussed below. This difference was not statistically confirmed, and could be due in part to the variation in sampling techniques and timing.

The Fredriksen sediment data set overlapped Grant's from roughly 1981 to 1988 and then extended into 2004 for WS2. For these related years, suspended sediment values were calculated as an average between both dataset's totals in corresponding water years. Grant, Fredricksen, and averaged data were then used to analyze an almost continuous time span of suspended sediment values for WS2 from the period of 1955 to 2004. Only discontinuous data from 1988 to 2003 was located for WS1, and WS3 data was not located for dates after 1988. Finally, it is also notable that data was calculated by water year, which began on November 1 of each year in the Grant data, and ended September 30 in the Fredricksen set.

9. Choice and Execution of Representative Simulations in WEPP Model

A. Model Input Procedure

At first blush, with relevant site information from the H.J. Andrews providing a framework for variable inputs, it seemed running various scenarios in this model and extracting germane output would be a straightforward process. However, this was not the case. Though somewhat helpful guides, the examples provided in the technical documentation (Elliot 2000) pertaining to specific model applications were difficult to interpret for questions explored in this study. Because of this and issues related to percentages of cover discussed earlier, multiple simulations were developed for each basin.

Results from these runs were construed via two approaches. For explanatory purposes and as a reference, the table from the vegetation treatments portion of this report is duplicated here. All values are given in metric units.

B. Data Sources & Methods

Both methods described below have two associated subcategories that merit a brief and prior explanation. The selection criteria to obtain values in the column "Calibrated % Cover" (green) and "Estimated % Cover" (orange) are described in their respective previous sections. Resulting suspended sediment yields from *calibrated* inputs are the only amounts used in comparisons with actual site data in all cases.

As illustrated in the table, inputting groundcover measurements from the basins produced sediment yields from the models that were astronomically higher than those from calibrated cover entries. Though calibrated cover also predicted higher yields than actually occurred in the basins – which are discussed in greater detail elsewhere – these values are highlighted in green and graphed later in this report.

For comparative analyses, the first approach taken to generate relevant WEPP values incorporated treatment-specific yearly averages (also described as the "two-year return period" of the run). These were obtained from 30-year simulation requests, which the literature suggested were adequate to achieve such values (Elliot 2000). Yearly representative treatment averages were then arranged to correspond with actual harvest sequences that occurred at the Andrew's basins. Both resulting erosion rates and sediment yields are listed in Table 9.1 under "Scenario A". "Calibrated % Cover" sediment yield values were then later graphed alongside the actual suspended sediment values recorded for each basin at the Andrews.

A second methodology utilized single treatment types of "low severity fire" and "20-year-old Forest" (control) that tested the model's predictive capacity for sediment output during regeneration over a 42-year period. Therefore, a 42-year simulation request was made, rather than the 30 years previously discussed. Though the "low severity fire" treatment did not occur for this exact amount of time at H.J.A., this duration was sufficient for valid comparisons. "Scenario B" in Table 9.1 illustrates results from this approach.

To graph outputs from these runs, the toggle link, "extended output", at the end of the general WEPP html overview screen was selected, and 42 years of data generated from each simulation were downloaded to an Excel file. Because this study focused on off-site effects, only yearly suspended sediment yield data with the units of kilograms per meter were extracted. These values were re-coupled with the corresponding year of occurrence in the prediction (i.e. years1-42, or 1962-2003). These numbers were then converted to kilograms per hectare for each year using a coefficient calculated from the width needed to achieve 10000 m^2 (one hectare) and the given total length of the hillslope entered earlier in the model. WEPP generated the erosion rates and suspended sediment yields based on a one-meter cross-section along the total given length of the hillslope, so the conversion was this simple process:

- Given the WEPP output of some number of kilograms per 1 meter width;
- Length (L) and area (A) were known: Hillslope Input Length & 10,000 m^2= 1 hectare;
- Width (W) must then be a constant to achieve the given one hectare area;
- W Coefficient= $W^c = \frac{A=10,000\ m^2}{L=\text{Hillslope length}}$
- So, W^c * WEPP-generated kg's/meter of width = Number of kg/ha

Specific data values and coefficients can be viewed in Appendix A of this report.

Table 9.1

∆ Multiple Scenarios and Resulting Averages Simulated in WEPP Representing Catchment Regeneration after Control, Clearcut, and Burn Treatments

Year	Years after Disturbance	Treatment Series and Temporal Duration	* Estimated % Cover (1 - % Bare Ground) (Halpern 2005)	Average Upland Erosion Rate Based on 2 Year Return Period (tons/hectare)	Average Sediment Yield/Output Leaving Profile Based on 2 Year Return Period (tons/hectare)	Sum of Upland Erosion + Sediment Output	Ψ Calibrated % Cover	Average Upland Erosion Rate Based on 2 Year Return Period (tons/hectare)	Average Sediment Yield/Output Leaving Profile Based on 2 Year Return Period (tons/hectare)	Sum of Upland Erosion + Sediment Output
Watershed 1 -- 100% Clearcut, Slash Burned										
Scenario A: 30-Year Simulation Representing Temporal Regeneration by Combining Yearly Average Sediment Predictions from Multiple Treatment Scenarios										
1962	0	20-Year Old Forest	⊥ 96	0.21	0.21	0.42	α ⊥ 96	0.21	0.21	0.42
1963	1	Five Year Old Forest	88	0.52	0.52	1.04	α 88	0.52	0.52	1.04
1964	2	Five Year Old Forest	88	0.52	0.52	1.04	α 88	0.52	0.52	1.04
1965	3	Five Year Old Forest	88	0.52	0.52	1.04	α 88	0.52	0.52	1.04
1966	0	Low Severity Fire	46	297.02	297.02	594.04	86	11.67	11.62	23.29
1967	1	Short Grass Prairie	45	206.93	206.93	413.86	92	5	5	10
1968	2	Tall Grass Prairie	52	25.97	25.97	51.94	77	2.19	2.19	4.38
1969	3	Shrub-dominated Rangeland	51	0.47	0.44	0.91	74	0.15	0.14	0.29
1970	4	Five-Year Old Forest	60	2.79	2.79	5.58	90	0.49	0.49	0.98
1971-1980	5-15	Five-Year Old Forest (Yearly Avg. x's 10)	*76	10	10	20	90	4.9	4.9	9.8
1981-2003	16-38	20-Year Old Forest (Yearly Avg. x's 23)	*93	4.83	4.83	9.66	α 93	4.83	4.83	9.66
1962-2003	42	20-Year Old Forest *(Yearly Avg. x's 42)*; Simulated for 30 Years	96	8.82	8.82	17.64	α 96	8.82	8.82	17.64
Sum of Average Outputs from Each Scenario				**558.6**	**558.57**	**1117.17**		**39.82**	**39.76**	**79.58**
Scenario B: 42-Year Simulation Representing Temporal Regeneration from Single Treatment Scenario										
1962-2003	42	Control; 20 Year Old Forest, Simulated for 42 Years	96	0.16	0.16	0.32	α 96	0.16	0.16	0.32
1962-2003	42	Low Severity Fire, Simulated for 42 Years	46	295.46	295.46	590.92	86	10.95	10.95	21.9
Average Yearly Sediment Yield *x's 42 Years*			**Control**	**6.72**	**Burn**	**12409.32**	**Control**	**6.72**	**Burn**	**459.9**
Watershed 2 -- Control										
Scenario A: 30-Year Simulation Representing Temporal Regeneration by Combining Yearly Average Sediment Predictions from Multiple Treatment Scenarios										
1962-2003	42	20-Year Old Forest *(Yearly Avg. x's 42)*; Simulated for 30 Years	97	17.22	17.22	**34.44**	α 97	17.22	17.22	**34.44**
Scenario B: 42-Year Simulation Representing Temporal Regeneration from Single Treatment Scenario										
1962-2003	42	Control; 20 Year Old Forest, Simulated for 42 Years	97	0.36	0.36	**0.72**	α 97	0.36	0.36	**0.72**
Average Yearly Sediment Yield *x's 42 Years*			**Control**	**15.12**			**Control**	**15.12**		
Watershed 3 -- 25% Clearcut, Slash Burned										
Scenario A: 30-Year Simulation Representing Temporal Regeneration by Combining Yearly Average Sediment Predictions from Multiple Treatment Scenarios										
1962	0	20-Year Old Forest	⊥ 97.3	0.24	0.23	0.47	α⊥ 97.3	0.24	0.23	0.47
1963	1	Five Year Old Forest	84	0.69	0.69	1.38	90	0.54	0.54	1.08
1964	0	Low Severity Fire	71	38.1	38.1	76.2	90	9.33	9.33	18.66
1965	1	Short Grass Prairie	72.1	21.82	21.82	43.64	91	5.57	5.57	11.14
1966	2	Tall Grass Prairie	69.6	3.14	3.14	6.28	78	2.11	2.11	4.22
1967	3	Shrub-dominated Rangeland	71.9	0.19	0.17	0.36	75	0.18	0.17	0.35
1968	4	Five-Year Old Forest	72.6	1.23	1.23	2.46	90	0.54	0.54	1.08
1969-1978	5-15	Five-Year Old Forest (Yearly Avg. x's 10)	*78	9.1	9.1	18.2	α 90	5.4	5.4	10.8
1979-2003	16-41	20-Year Old Forest (Yearly Avg. x's 25)	*94	6.25	5.75	12	α 94	6.25	5.75	12
1962-2003	42	20-Year Old Forest *(Yearly Avg. x's 42)*; Simulated for 30 Years	⊥ 97.3	10.08	9.66	19.74	α 97.3	10.08	9.66	19.74
Initial Sum of Average Outputs from Each Scenario *Without Adjustment for Patch-Cut*				**90.84**	**89.89**	**180.73**		**40.24**	**39.3**	**79.54**
Totals x's 0.25				**22.71**	**22.47**	**45.18**		**10.06**	**9.83**	**19.89**
Patch-cut Adjusted Sum of Averages ((Total x's 0.25)+ 0.75 x's 20-Year Old Forest)				**30.27**	**29.72**	**59.99**		**17.62**	**17.07**	**34.69**
Scenario B: 42-Year Simulation Representing Temporal Regeneration from Single Treatment Scenario										
1962-2003	42	Control; 20 Year Old Forest, Simulated for 42 Years	97.3	0.18	0.17	0.35	97.3	0.18	0.17	0.35
1962-2003	42	Low Severity Fire, Simulated for 42 Years	71	38.23	38.23	76.46	90	8.8	8.76	17.56
Average Yearly Sediment Yield *x's 42 Years*			**Control**	**7.14**	**Burn**	**406.77**	**Control**	**7.14**	**Burn**	**97.335**

∆ All runs except for "Control" and "Low Severity Fire Simulated for 42 Years" were simulated for 30 years; soil texture was held constant as "loam" for all scenarios; See accompanying graphs for illustration of data highlighted in green.
⊥ Cut occurred in fall, data probably collected in summer. This data offers before-cut perspective on vegetation treatment and cover values.
α No new additional vegetation calibration needed to achieve ≅ 93-94% cover range; cover already sufficient, or same calibration occurred in a separate cell.
* Cover % is the average of range of estimated values (1-bare ground) obtained from Halpern (2005 Unpublished Data) for each time period.
Ψ Value from 30-year vegetation calibration that adjusted the approximated % cover to the ≅ 93-94% range after 30 years regeneration.
Data Sources: Halpern 2005; Dyrness 1973; Elliot 2000, Disturbed WEPP, Da Shepherd 2004.

10. Comparative Results and Analysis

Based on a visual inspection of the graphs that follow (Figures 10.1, 10.2, and 10.3), it appeared that WEPP generally over-estimated the suspended sediment output across all three basin treatments. The most glaring over-estimate occurred in the low-severity fire scenario simulated for Watershed 1. However, the series of yearly averages designed to represent corresponding in situ treatments was closer to real suspended sediment numbers for this catchment. It also did not appear that correcting for controlled, naturally occurring sediment yield made any significant difference in improving the accuracy of the model predictions.

For WS2 (Figure 10.2), the 20-year old forest scenario seemed to do a fair job of estimating the total suspended sediment for the basin, though WEPP's peak value was much lower than the actual maximum output. Concurrently, most of the rest of the values generally trended above actual measurements.

After adjusting WEPP yield numbers in order to better capture a patch-cut basin, WS3 predictions were moderately within range of the actual outputs (Figure 10.3). Though the peak was again underestimated, numbers trended similarly to WS1 and frequently overestimated values relative to Andrews data. This model overestimation occurred despite the inclusion of mass movements and debris flow events in the basin data sets.

The following statistical discussion merits this disclaimer: the tools applied below were employed strictly to provide a crude comparison of overall averages and may not have been the most appropriate or rigorous statistical techniques available.

A brief one-way classification analysis of variance (ANOVA) f-test was conducted to determine whether or not an equal means model would adequately describe the comparison of values across all data sources and model predictions. The values utilized were the total treatment or basin averages over the entire duration of the study or model simulation. In theory, overall model results would be similar to those obtained from the three sites. Graphic results and statistical summaries are displayed separately below for each watershed. It is notable that even with a natural log transformation, neither the equality of spreads nor the normalcy of distribution could be adequately adjusted to meet some of the necessary model assumptions.

Before performing a natural log transformation, data points that were predicted as zero were adjusted to 0.001. This allowed an ANOVA to be performed on points that would have otherwise been infinitely incalculable. Furthermore, WS3 graphs are displayed with and without the major outlier, though ANOVA results are given with the inclusion of the outlier point. The water year in which the point seems to have occurred is 1965, which was probably the same 1964 debris event that destroyed the bedload facility referenced in the Grant data (2005, Abstract).

Figure 10.1

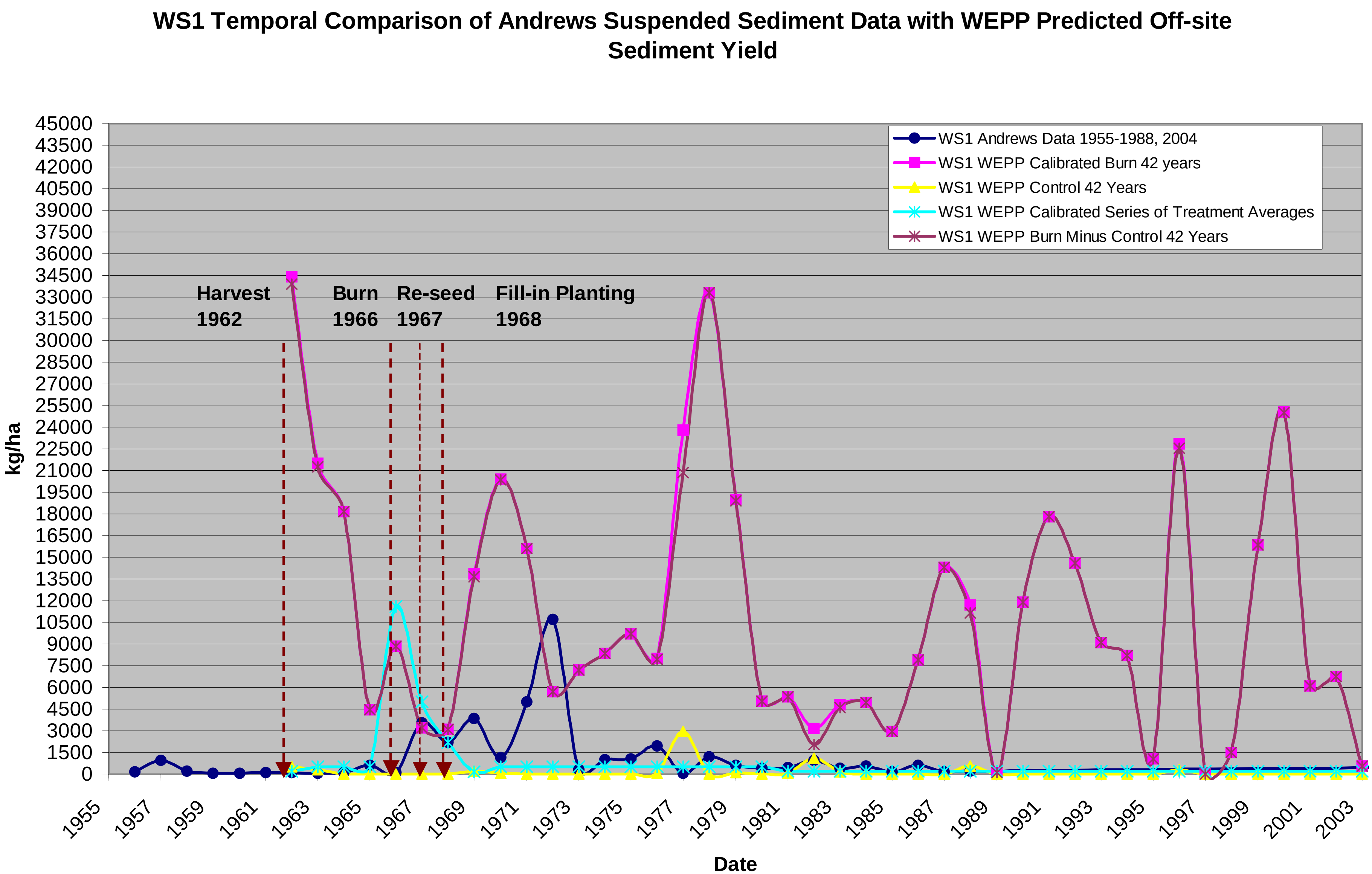

WS1 Temporal Comparison of Andrews Suspended Sediment Data with WEPP Predicted Off-site Sediment Yield
kg/ha
Date
Harvest 1962
Burn 1966
Re-seed 1967
Fill-in Planting 1968
WS1 Andrews Data 1955-1988, 2004
WS1 WEPP Calibrated Burn 42 years
WS1 WEPP Control 42 Years
WS1 WEPP Calibrated Series of Treatment Averages
WS1 WEPP Burn Minus Control 42 Years
45000
43500
42000
40500
39000
37500
36000
34500
33000
31500
30000
28500
27000
25500
24000
22500
21000
19500
18000
16500
15000
13500
12000
10500
9000
7500
6000
4500
3000
1500
0
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003

Figure 10.2

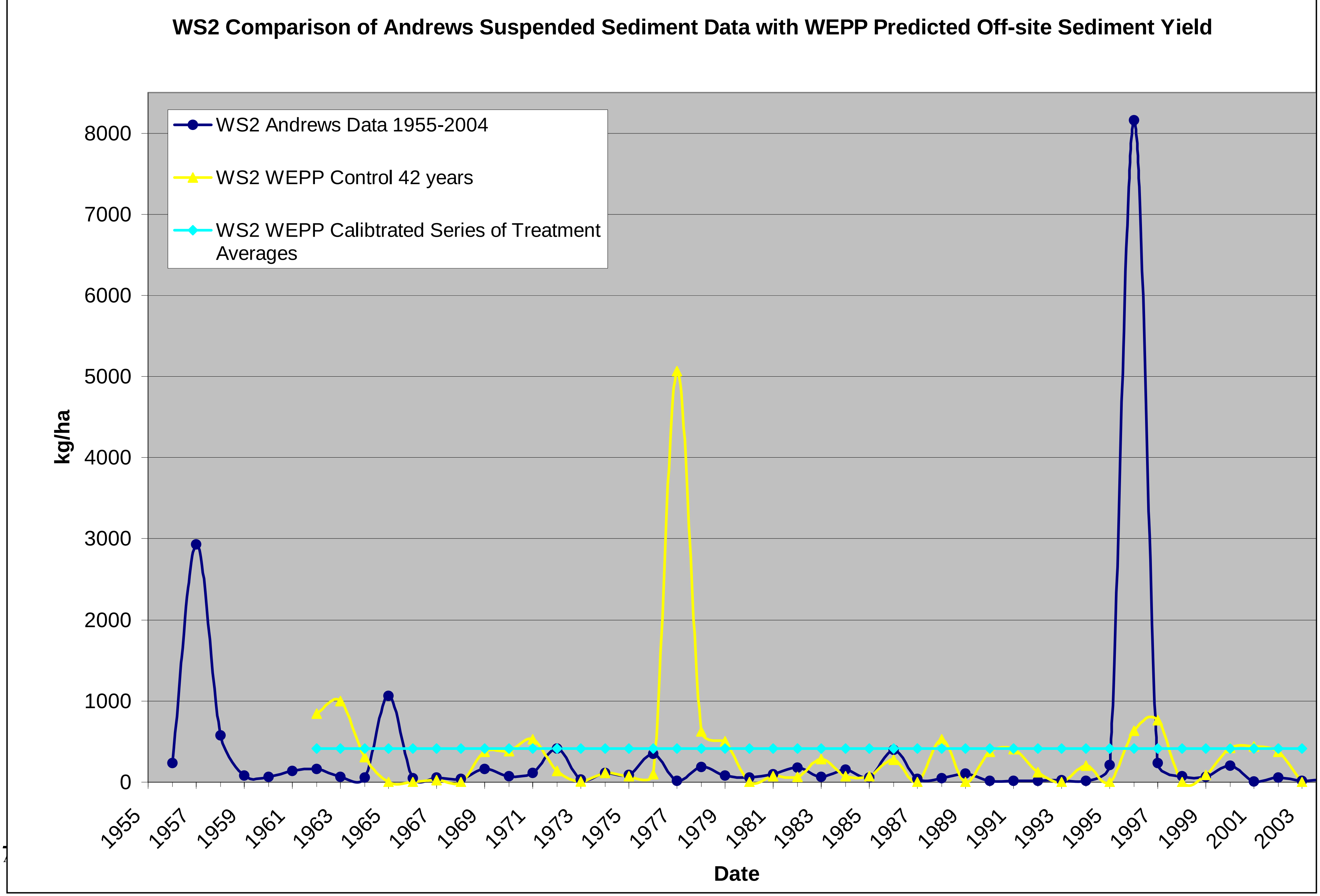
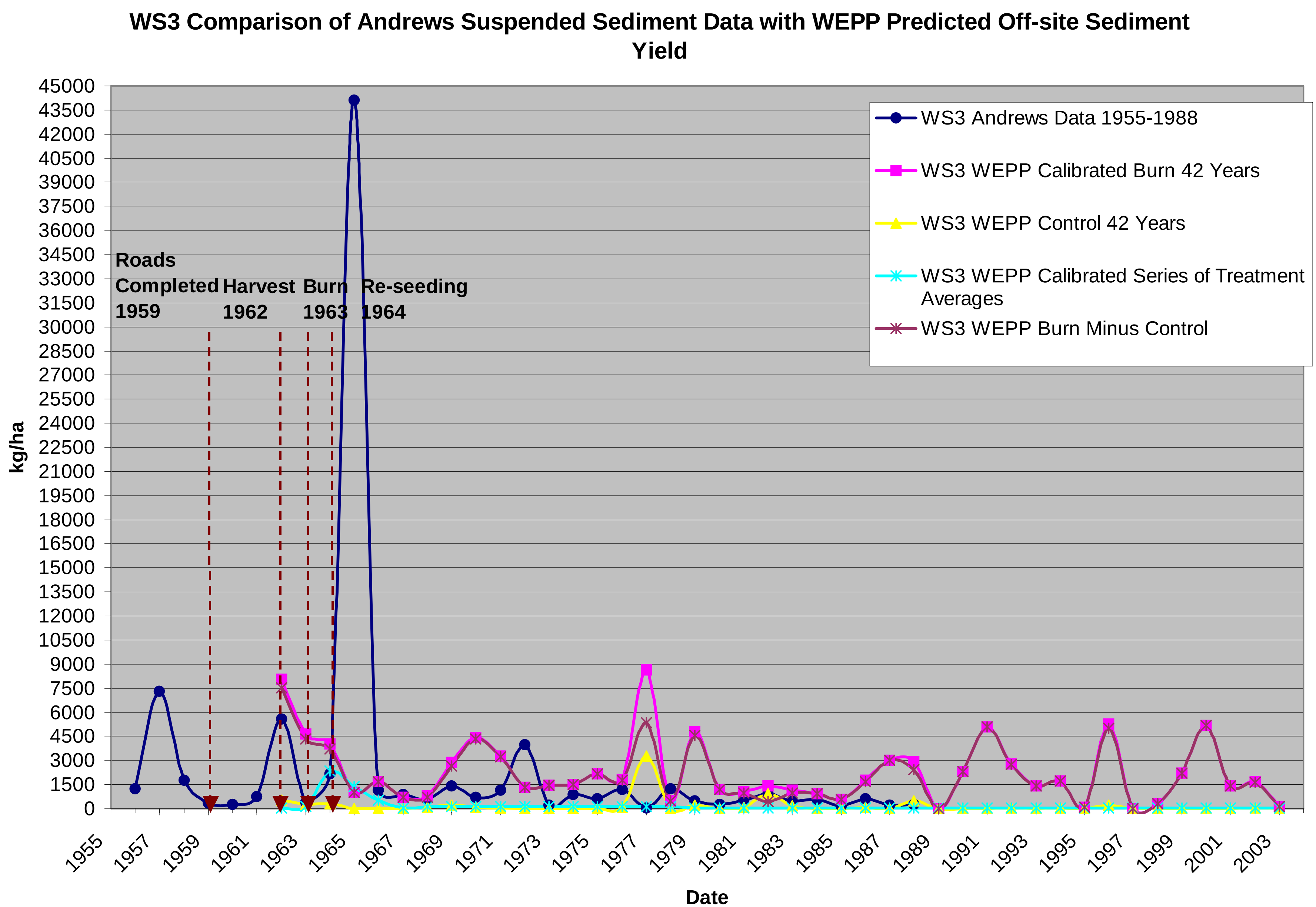
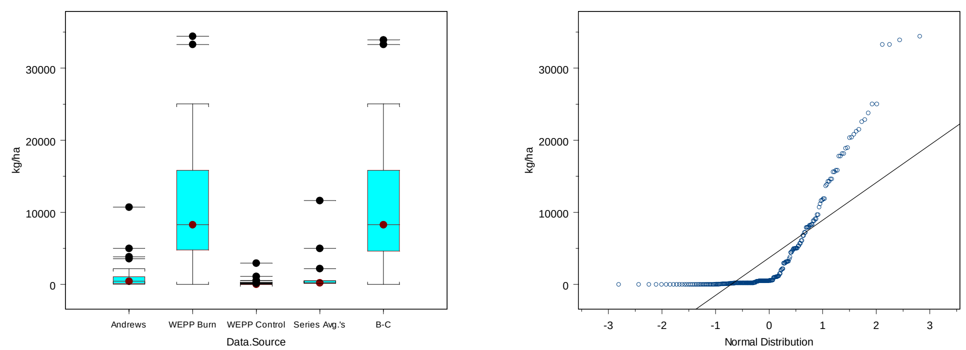

WS2 Comparison of Andrews Suspended Sediment Data with WEPP Predicted Off-site Sediment Yield
WS2 Andrews Data 1955-2004
WS2 WEPP Control 42 years
WS2 WEPP Calibtrated Series of Treatment Averages
kg/ha
8000
7000
6000
5000
4000
3000
2000
1000
0
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
Date

Figure 10.3

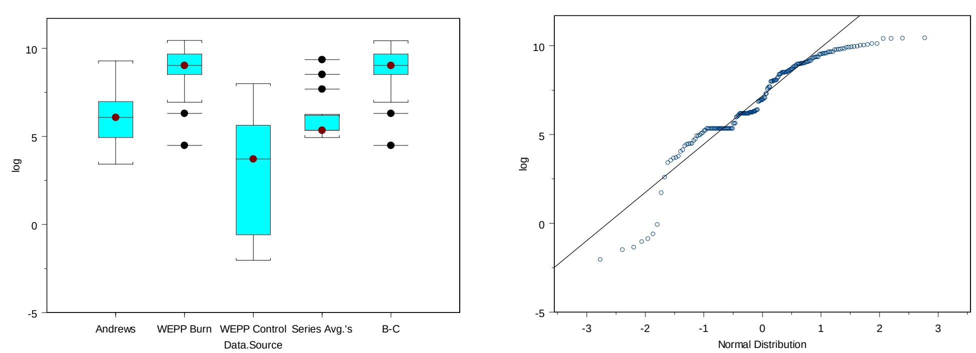

WS3 Comparison of Andrews Suspended Sediment Data with WEPP Predicted Off-site Sediment Yield
kg/ha
Date
Roads Completed 1959
Harvest 1962
Burn 1963
Re-seeding 1964
WS3 Andrews Data 1955-1988
WS3 WEPP Calibrated Burn 42 Years
WS3 WEPP Control 42 Years
WS3 WEPP Calibrated Series of Treatment Averages
WS3 WEPP Burn Minus Control

From the non-transformed data for WS1, given the relatively large f-statistic (39.81) and the very small p-value (P≈0, two-sided test), this evidence strongly suggested there was a statistically significant difference in means between one or more of the 5 groups tested. The log transformed data seemed to further support this with a larger f-statistic (79.96) and the very small p-value (P≈0, two-sided test). The grand average for WS1 was 4902.8 from non-transformed calculations, with a pooled standard deviation of 32,377,891. For the transformed data, the grand average after back-transformation was a factor of 214.22 with a back-transformed pooled standard deviation of 17767.03. See figures 9.4-9.6 for more details.

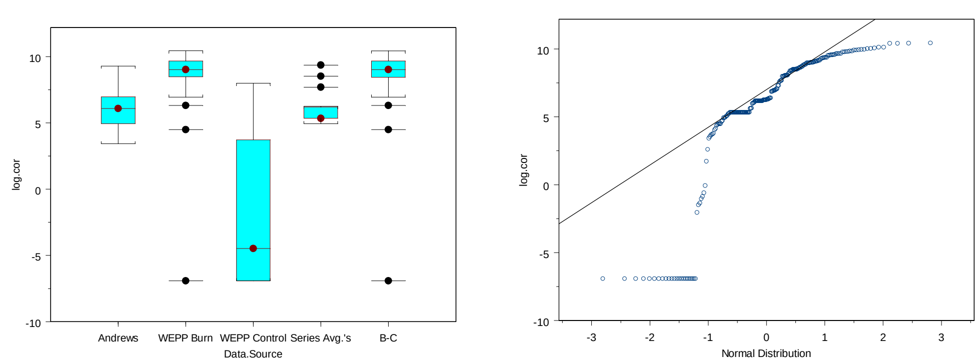
Figure 10.4



WS1 Box plots and Normal QQ plots without transformation.



WS1 Box plots and Normal QQ plots with natural log transformation



WS1 Box plots and Normal QQ plots with natural log transformation AND zero values adjusted to 0.001 for ANOVA input

Table 10.5

*** Analysis of Variance Model ***
aov(formula = kg.ha ~ Data.Source, data = WS1SPlus, qr = T, na.action = na.exclude)

Terms:

	Data.Source	Residuals
Sum of Squares	5156449064	6378444550
Deg. of Freedom	4	197

Residual standard error: 5690.157
Estimated effects may be unbalanced

Type III Sum of Squares

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
Data.Source	4	5156449064	1289112266	39.81458	0
Residuals	197	6378444550	32377891		

Tables of means
Grand mean
4902.8

Data.Source

	Andrews	WEPP Burn	WEPP Control	Series Avg.'s	B-C
	1155	10954	149	737	10805
rep	34	42	42	42	42

***WS1** ANOVA results using original, non-transformed data.*
1-pf(39.81458,4,197); p=[1] 0
Given the large F-Statistic and the very small p-value(P≈0, two-sided test), this evidence strongly suggested there was a statistically significant difference in means between one or more of the 5 groups tested in WS1.

Conversely, the small f-statistic (0.0485) and the large p-value (P≈0.9526668, two-sided test) from the non-transformed data for WS2 provided evidence that strongly suggested there was little statistically significant difference in means between one or more of the 3 groups tested in WS2. However, the larger f-statistic and the small p-value (P≈0.00002, two-sided test), of the log-transformed data seemed to contradict the non-transformed results and strongly suggested there was some statistically significant difference in means between one or more of the 3 groups tested in WS2. Departures from normalicy and equal spread may have explained these conflicting results. The grand average for WS2 was 375.94 from non-transformed calculations, with a pooled standard deviation of 744711.8. For the transformed data, the grand average after back-transformation was a factor of 100.103 with a back transformed pooled standard deviation of 611.723. See figures 9.7-9.9 for more details.

In WS3, a somewhat smaller f-statistic (4.93) resulted in a small p-value (P≈0.0008336908, two-sided test), which suggested strong evidence there was a statistically significant difference in means between one or more of the 5 groups tested in WS3. The log-transformed data coincided with these findings, yielding a larger f-statistic (42.17398) and a very small p-value (P≈0.0, two-sided test). The grand average for WS3 was 1389.7 from non-transformed calculations, with a pooled standard deviation of 10959685. For the transformed data, the grand average after back-transformation was a factor of 128.93 with a back-transformed pooled standard deviation of 14222.78. See figures 9.10-9.12 for more details.

Table 10.6

*** Analysis of Variance Model ***
aov (formula = log.cor ~ Data.Source, data = WS1SPlus, qr = T, na.action = na.exclude)

Terms:

	Data.Source	Residuals
Sum of Squares	3129.580	1927.662
Deg. of Freedom	4	197

Residual standard error: 3.128112
Estimated effects may be unbalanced

Type III Sum of Squares

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
Data.Source	4	3129.580	782.3950	79.95791	0
Residuals	197	1927.662	9.7851		

Tables of means
Grand mean
5.3674

Data.Source

	Andrews	WEPP Burn	WEPP Control	Series Avg.'s	B-C
	6.039	8.535	-1.978	5.851	8.518
Rep	34.000	42.000	42.000	42.000	42.000

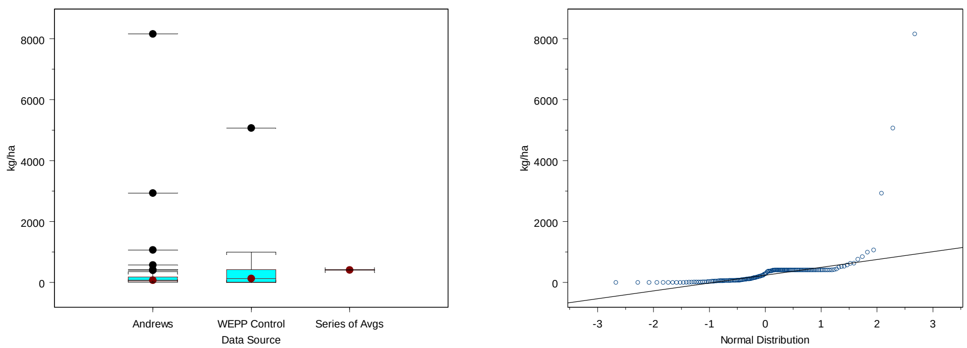
***WS1** ANOVA results using natural log transformed data with zero values adjusted to 0.001 prior to transformation*.
1-pf(79.95791,4,197); p= [1] 0
Given the large F-Statistic and the very small p-value($P \approx 0$, two-sided test), this evidence strongly suggested there was a statistically significant difference in means between one or more of the 5 groups tested in WS1.

Though ANOVA was applied to this study, it was not the most appropriate statistical tool for these data, and was used only to provide a very crude description of relationships between these numbers. Several assumptions were violated that complicated the application of simple statistical methods. Given the serial properties of these data, multiple comparisons issues, the probable lack of independence among WEPP parameters, and multiple other influencing variables, this was probably a case for some sort of multivariate linear regression analysis. Employing these more robust and sophisticated tools was beyond the scope of this investigation but warrants future consideration for model testing and calibration purposes.

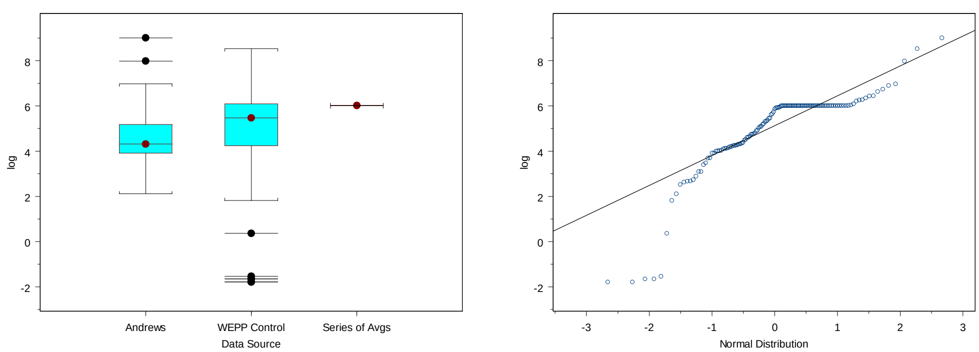
Additionally, it would be inappropriate to draw any causal inferences or inferences to a broader population of basins, as neither random sampling techniques nor true treatment experiments were applied in this study. It did appear that in this particular dissected terrain and set of climate and topographical conditions, WEPP failed to reflect the actual suspended sediment outputs with any significant degree of accuracy. This was not necessarily surprising given the WEPP accuracy of predicted runoff at plus or minus 50% (Elliot 2000).

Finally, to afford a further perspective on the possible relationships between model predictions and the H.J.A. data, simple regression plots are also provided using non-transformed data and corresponding years in 10.13 through 10.18.

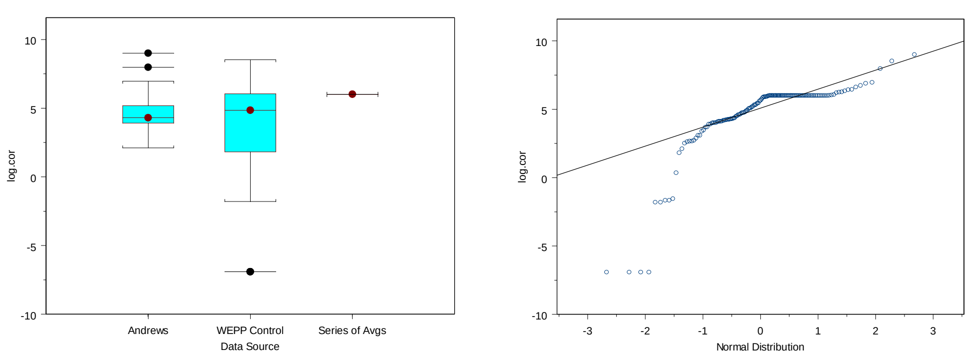
Figure 10.7



WS2 Box plots and Normal QQ plots without transformation.



WS2 Box plots and Normal QQ plots with natural log transformation



WS2 Box plots and Normal QQ plots with natural log transformation AND zero values adjusted to 0.001 for ANOVA input

Table 10.8

*** Analysis of Variance Model ***
aov(formula = kg.ha ~ Data.Source, data = WS02SPlus, qr = T, na.action = na.exclude)

Terms:

	Data.Source	Residuals
Sum of Squares	72249	96812536
Deg. of Freedom	2	130

Residual standard error: 862.9669
Estimated effects may be unbalanced

Type III Sum of Squares

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
Data.Source	2	72249	36124.6	0.04850814	0.9526668
Residuals	130	96812536	744711.8		

Tables of means
Grand mean
375.94

Data.Source

	Andrews	WEPP Control	Series of Avgs
	357.08	363.90	410.00
Rep	49.00	42.00	42.00

***WS2** ANOVA results using original, non-transformed data*.
1-pf(0.04850814,2,130); p= [1] 0.9526668
Given the small F-Statistic and the large p-value (P≈0.9526668, two-sided test), this evidence strongly suggested there was little statistically significant difference in means between one or more of the 3 groups tested in WS2.

Table 10.9

*** Analysis of Variance Model ***
aov(formula = log.cor ~ Data.Source, data = WS02SPlus, qr = T, na.action = na.exclude)

Terms:

	Data Source	Residuals
Sum of Squares	155.2363	834.1163
Deg. of Freedom	2	130

Residual standard error: 2.533038
Estimated effects may be unbalanced

Type III Sum of Squares

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
Data.Source	2	155.2363	77.61814	12.09706	0.00001520227
Residuals	130	834.1163	6.41628		

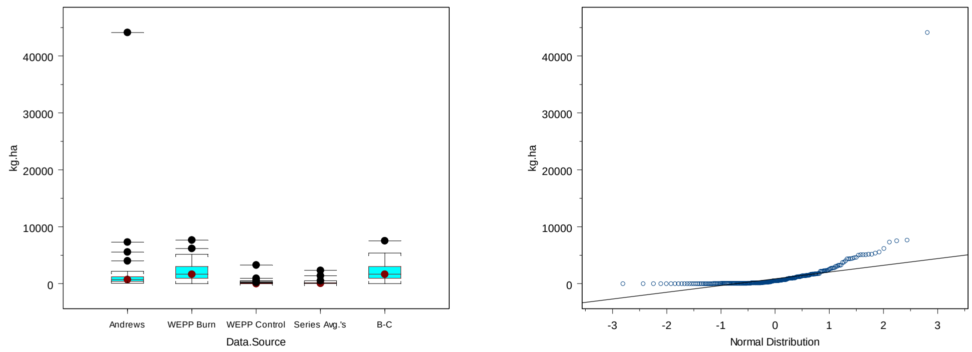
Tables of means
Grand mean
4.6062

Data.Source

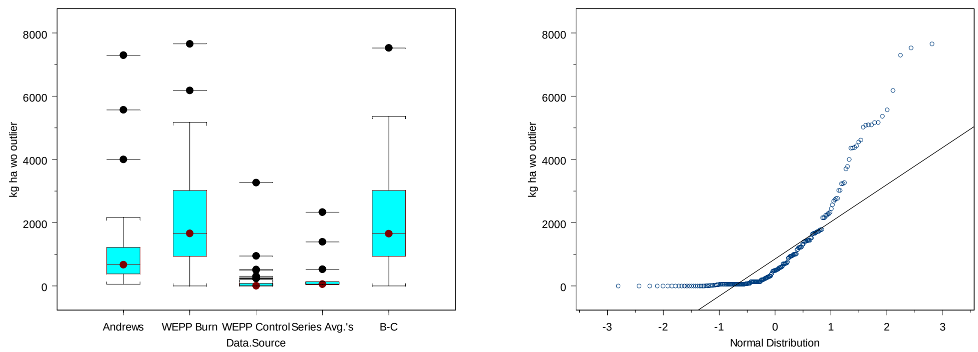
	Andrews	WEPP Control	Series of Avgs
	4.515	3.303	6.016
Rep	49.000	42.000	42.000

WS2 *ANOVA results using natural log transformed data with zero values adjusted to 0.001 prior to transformation.*
1-pf(12.09706,2,130); p= [1] 0.00001520227
Given the larger F-Statistic and the small p-value (P≈0.00002, two-sided test), this evidence seemed to contradict the non-transformed results and strongly suggested there was some statistically significant difference in means between one or more of the 3 groups tested in WS2.

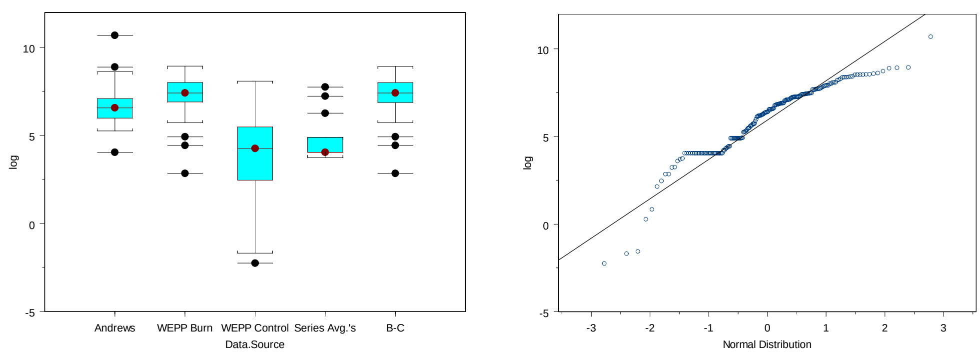
Figure 10.10



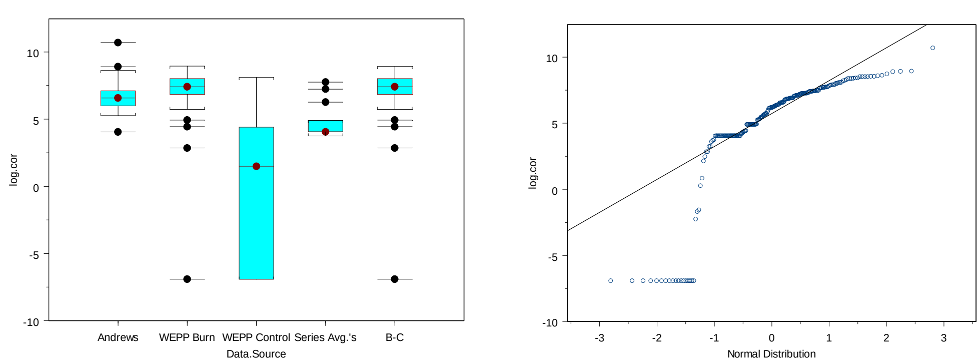
WS3 Box plots and Normal QQ plots without transformation.



WS3 Box plots and Normal QQ plots without transformation *and without outlier*.



WS3 Box plots and Normal QQ plots with natural log transformation including outlier.



WS3 Box plots and Normal QQ plots with natural log transformation AND zero values adjusted to 0.001 for ANOVA input

Table 10.11

*** Analysis of Variance Model ***
aov(formula = kg.ha ~ Data.Source, data = WS3DataB, qr = T, na.action = na.exclude)

Terms:

	Data.Source	Residuals
Sum of Squares	215943462	2148098258
Deg. of Freedom	4	196

Residual standard error: 3310.541
Estimated effects may be unbalanced

Type III Sum of Squares

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
Data.Source	4	215943462	53985865	4.925859	0.0008336905
Residuals	196	2148098258	10959685		

Tables of means
Grand mean
1389.7

Data.Source

	Andrews	WEPP Burn	WEPP Control	Series Avg.'s	B-C
	2501.9	2189.9	171.7	176.4	2147.0
Rep	33.0	42.0	42.0	42.0	42.0

***WS3** ANOVA results using original, non-transformed data*.
1-pf(4.925859,4,196); p=[1] 0.0008336908
Although a somewhat smaller F-Statistic, given the small p-value (P≈0.0008336908, two-sided test) this evidence strongly suggested there was a statistically significant difference in means between one or more of the 5 groups tested in WS3.

Table 10.12

*** Analysis of Variance Model ***
aov(formula = log.cor ~ Data.Source, data = WS3DataB, qr = T, na.action = na.exclude)

Terms:

	Data.Source	Residuals
Sum of Squares	1613.176	1874.275
Deg. of Freedom	4	196

Residual standard error: 3.09235
Estimated effects may be unbalanced

Type III Sum of Squares

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
Data.Source	4	1613.176	403.2941	42.17398	0
Residuals	196	1874.275	9.5626		

Tables of means
Grand mean
4.8593

Data.Source

	Andrews	WEPP Burn	WEPP Control	Series Avg.'s	B-C
	6.689	6.932	-0.350	4.505	6.912
Rep	33.000	42.000	42.000	42.000	42.000

WS3 *ANOVA results using natural log transformed data with zero values adjusted to 0.001 prior to transformation.*
1-pf(42.17398,4,196); p=[1] 0
Given the larger F-Statistic and the small p-value (P≈0.0, two-sided test), this evidence this evidence strongly suggested there was a statistically significant difference in means between one or more of the 5 groups tested in WS3.

Figure 10.13

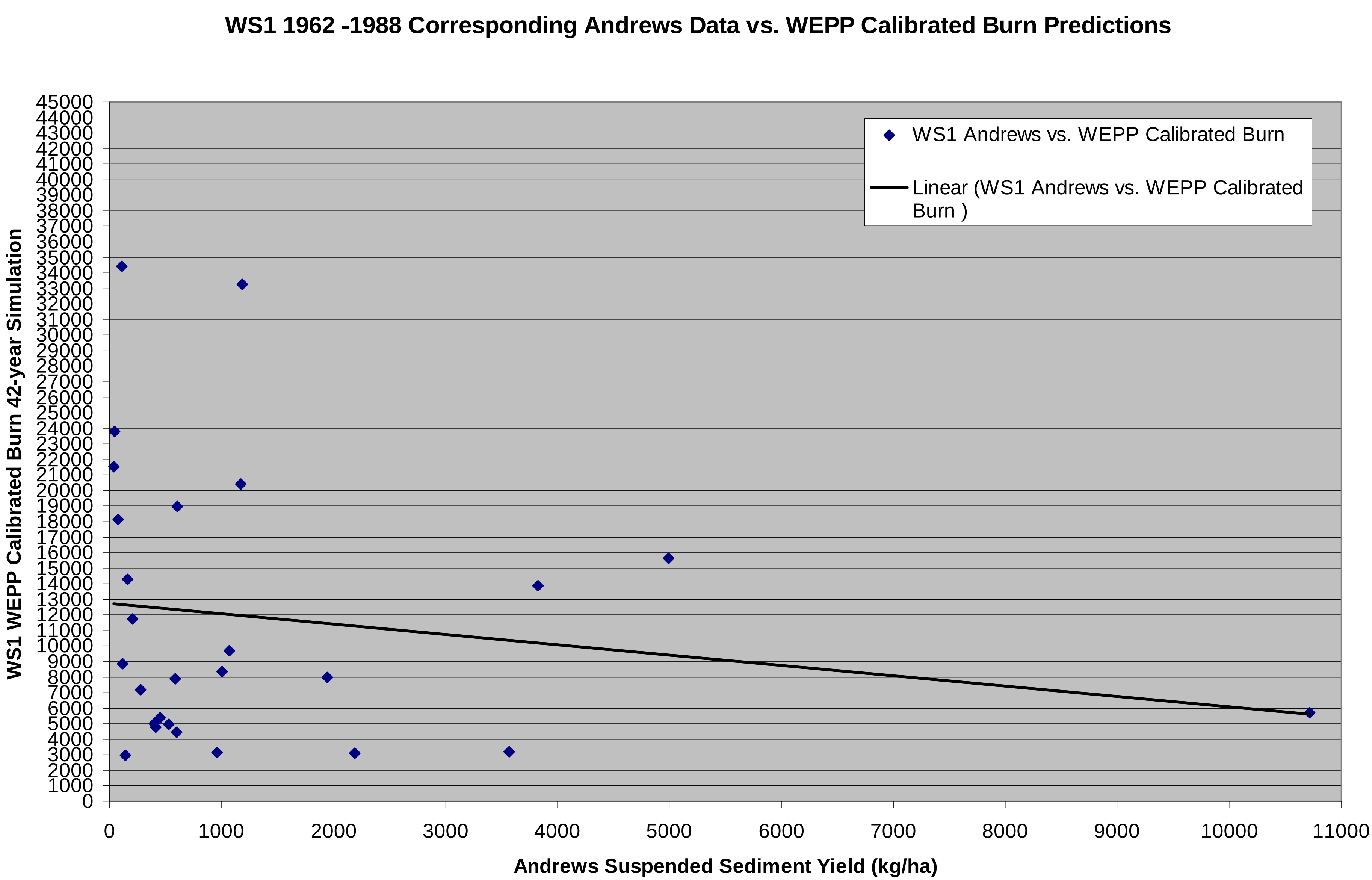

WS1 1962 -1988 Corresponding Andrews Data vs. WEPP Calibrated Burn Predictions
WS1 Andrews vs. WEPP Calibrated Burn
Linear (WS1 Andrews vs. WEPP Calibrated Burn)
WS1 WEPP Calibrated Burn 42-year Simulation
Andrews Suspended Sediment Yield (kg/ha)
45000
44000
43000
42000
41000
40000
39000
38000
37000
36000
35000
34000
33000
32000
31000
30000
29000
28000
27000
26000
25000
24000
23000
22000
21000
20000
19000
18000
17000
16000
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000

Figure 10.14

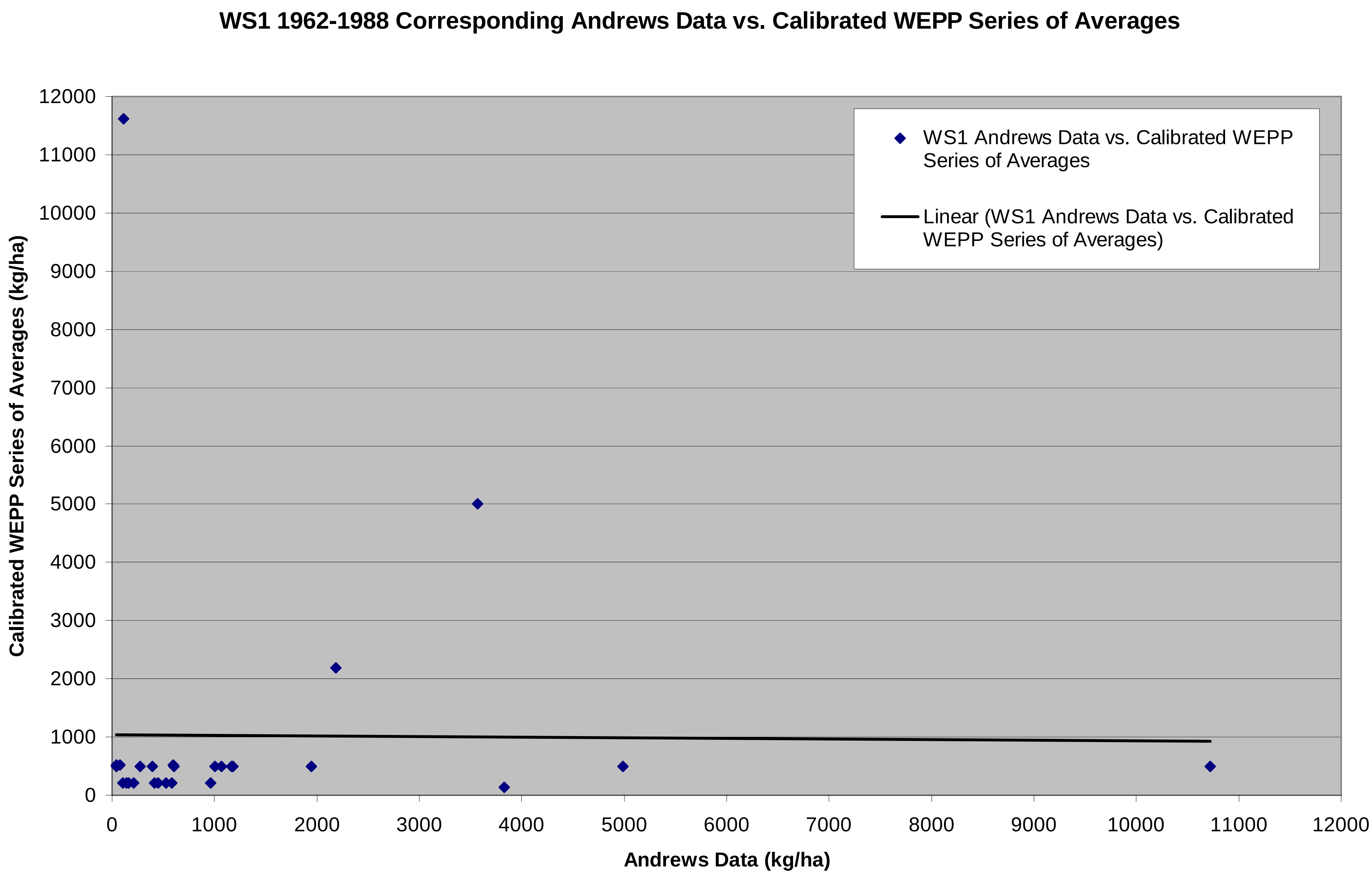

WS1 1962-1988 Corresponding Andrews Data vs. Calibrated WEPP Series of Averages
Calibrated WEPP Series of Averages (kg/ha)
Andrews Data (kg/ha)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
WS1 Andrews Data vs. Calibrated WEPP Series of Averages
Linear (WS1 Andrews Data vs. Calibrated WEPP Series of Averages)

Figure 10.15

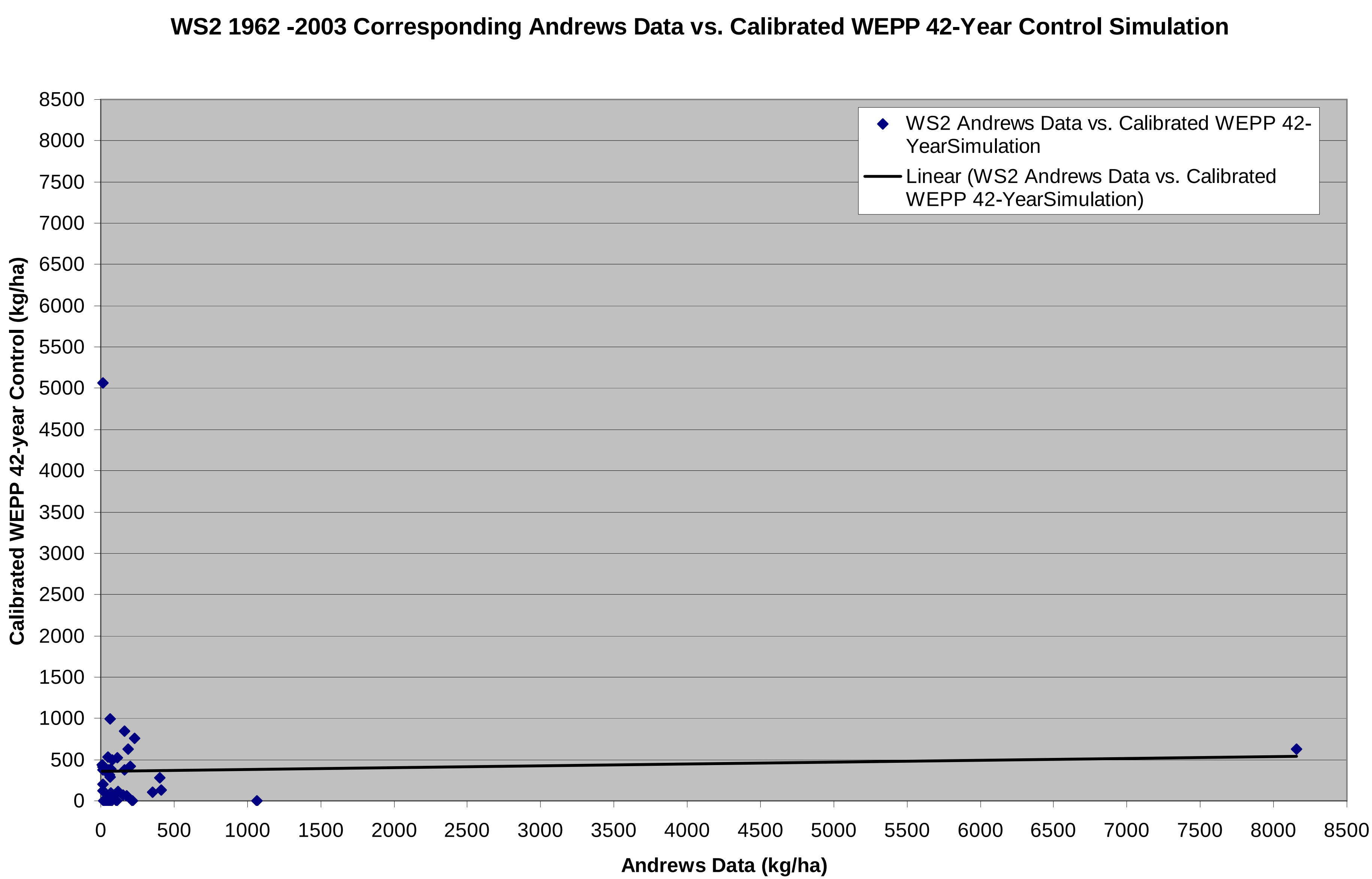

WS2 1962 -2003 Corresponding Andrews Data vs. Calibrated WEPP 42-Year Control Simulation
WS2 Andrews Data vs. Calibrated WEPP 42-YearSimulation
Linear (WS2 Andrews Data vs. Calibrated WEPP 42-YearSimulation)
Calibrated WEPP 42-year Control (kg/ha)
Andrews Data (kg/ha)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
7500
8000
8500

Figure 10.16

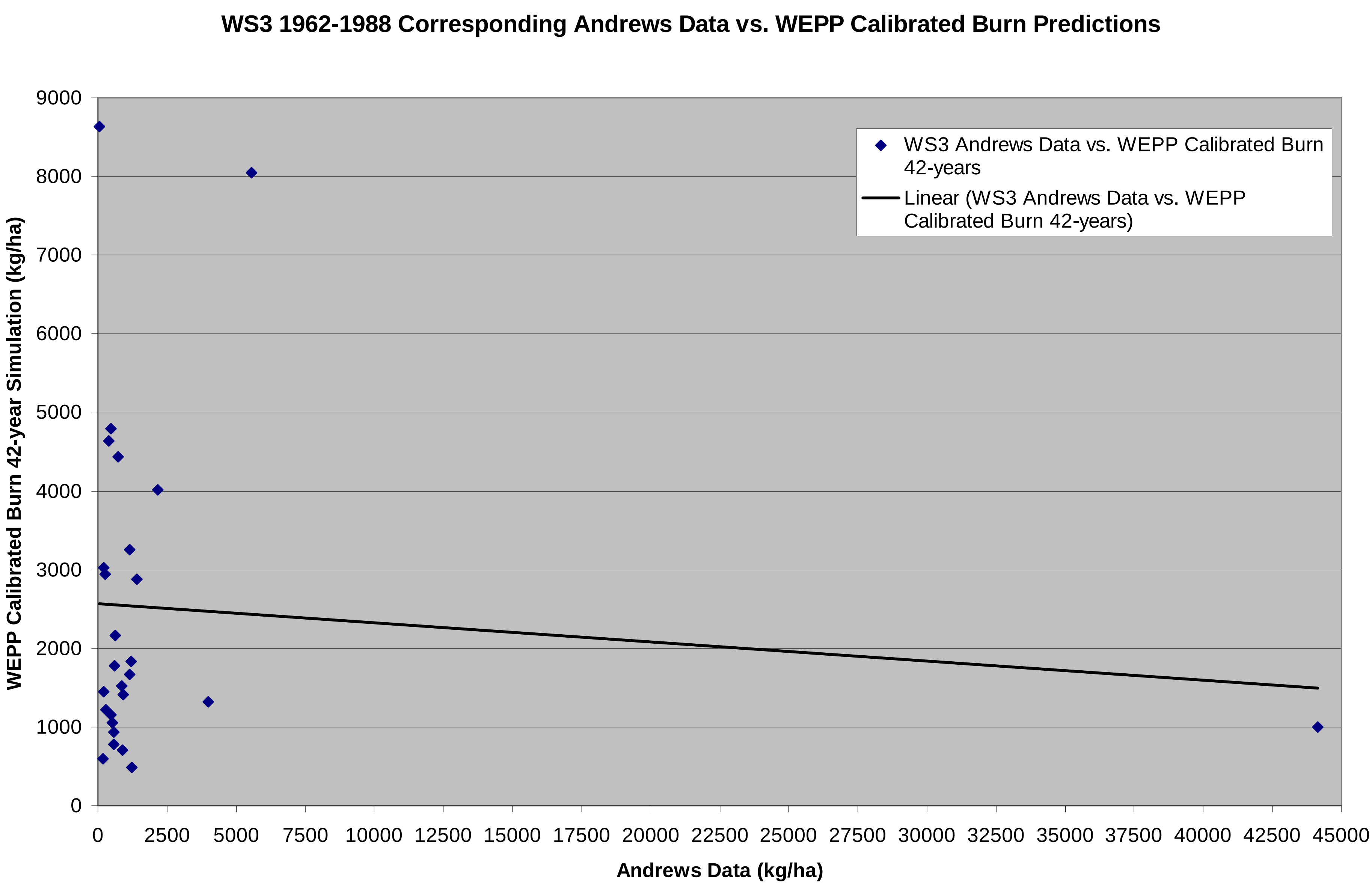
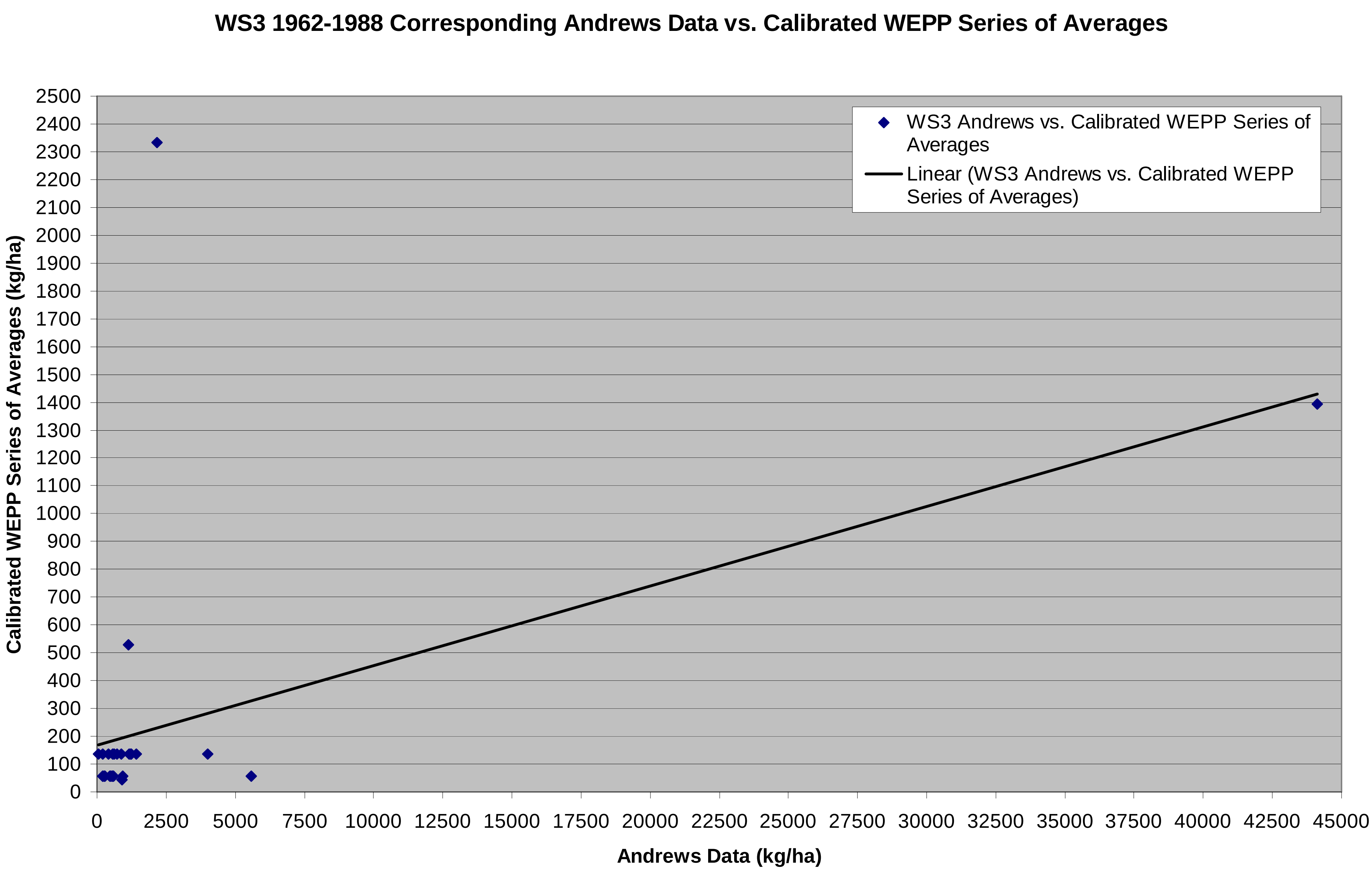

WS3 1962-1988 Corresponding Andrews Data vs. WEPP Calibrated Burn Predictions
WEPP Calibrated Burn 42-year Simulation (kg/ha)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
WS3 Andrews Data vs. WEPP Calibrated Burn 42-years
Linear (WS3 Andrews Data vs. WEPP Calibrated Burn 42-years)
0 2500 5000 7500 10000 12500 15000 17500 20000 22500 25000 27500 30000 32500 35000 37500 40000 42500 45000
Andrews Data (kg/ha)

Figure 10.17


WS3 1962-1988 Corresponding Andrews Data vs. Calibrated WEPP Series of Averages
WS3 Andrews vs. Calibrated WEPP Series of Averages
Linear (WS3 Andrews vs. Calibrated WEPP Series of Averages)
Calibrated WEPP Series of Averages (kg/ha)
Andrews Data (kg/ha)
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
2300
2400
2500
0
2500
5000
7500
10000
12500
15000
17500
20000
22500
25000
27500
30000
32500
35000
37500
40000
42500
45000

An excellent and relevant study by Grant and Wolff (1991) evaluated the long-term suspended sediment data from WS1, 2, & 3, and their conclusions warrant mention in relationship to the intentions of this project and the WEPP predictive model.

Figure 10.18

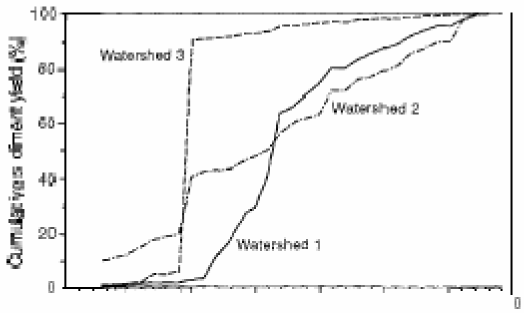


FIG. *2 Cummulative sediment yields for Watersheds 1, 2, and 3 for WY* 1958-1988.

(Grant & Wolff 1991)

For WS1, average annual sediment production was about 12 time the pretreatment rates, with a predicted decline to average pre-harvest levels by 1996. In WS3, post-treatment yields were about 27 times those of WS2 and 4 times that of WS1 over the same time period. However, excluding WY 1965, WS3 yields were lower than WS1. This may be explained by the timing of storm events relative to the timing of harvest completion and burning in each watershed (Grant and Wolff 1991). These results can be viewed in Figure 10.18.

Their analysis of sediment delivery trends also concluded that in steep dissected terrain such as the Western Cascades, multiple factors complicated the extrapolation of any volume predictions. Extreme and episodic events dominated sediment yield processes in these watersheds and must therefore be considered in long-term monitoring of land use effects in order to more fully capture patterns of sediment production (Grant & Wolff 1991).

Grant and Hayes (qtd. in Swanson & Jones 2002) further described the effects of timber harvesting on both the hydrologic regime and sediment supply characteristics of a treated basin. Small increases in stream discharge related to harvesting and road networks translated into significantly higher levels of sediment delivery to streams. Their results from this phenomenon in WS1 are displayed in Figure 10.19. Though peak flows increased after harvest, this result was dwarfed by a corresponding increase in sediment supply (Grant & Hayes in Swanson & Jones 2002).

10.19

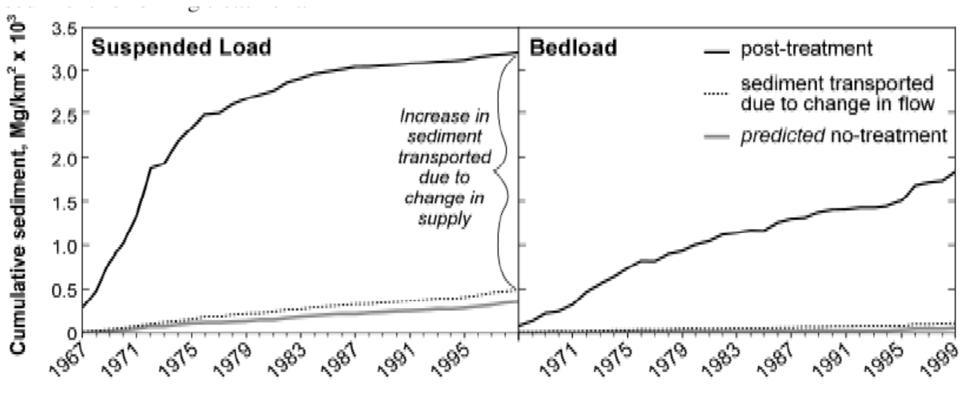


Figure 4.2. Watershed 1 sediment yield after clearcut and prescribed fire for water years 1967-1999.

(Grant & Hayes in Swanson & Jones 2000)

11. Errors and Assumptions

In all instances, best efforts were made to represent in situ data regarding the H.J. Andrews as accurately as possible. However, decimal degree values may project misleading precision, as most of the variables were estimated or averaged from data previously collected in the field by other researchers. This averaging of the averages and researcher lack of familiarity with many of the variables must be considered in the interpretation of these results.

When completing the Disturbed WEPP input fields, extensive time was given to proper interpretation of variables and their components. That being said, due to the vagueness of the accompanying technical documentation and limitations on the scope of this study, entered values may not have correctly correlated with the variable sought by the model. While much of the Andrews data corresponded well enough with the input fields indicated, “Percent Cover” offered one example in which the relationship could be described as tenuous at best. For this reason, extra simulations were run utilizing the “Calibrate Vegetation” option. More discussion of potential errors or assumptions is broken into respective sections below.

Because the intent of the project focused only on sediment output from timber- harvested areas, the initial desire was to limit suspended sediment yields that derived from mass wasting and road hydrology. Unfortunately, the scope of this study did not allow for the calculation of road or landslide-specific contributions to the site-specific sediment yield data obtained from Andrews’s sources. It is remained unclear if a breakdown of such data existed for any of the basins at the scale currently investigated in this piece. Therefore, accurate extraneous values could not be eliminated from the suspended sediment ground-data totals. Fortunately, this was likely an issue almost exclusively limited to Watershed 3. Furthermore, even with the potential inclusion of landslide and mass-wasting sources, WEPP still over-predicted sediment output relative to the H.J.A. amounts. Greater discussion of the nature and contribution of debris flows and landslides was addressed in the “Comparative Results and Analysis” portion of this report. As mentioned, slides and debris flows attributed to the highest suspended sediment values, yet WEPP’s predictions went above even these included data.

A. Climate:

As mentioned in the input section of this report, climate values may have been impacted by the inability to enter precise coordinates for each watershed in conjunction with elevation. Because of the fluidity of impacts to multiple fields with the entry of a single custom variable, no lapse rate adjustment was chosen. This may have had relevance based on the elevation of the watershed. Custom elevations were included.

Again, climate data was obtained via an averaging of the averages of weather data, which may or may not have been the most statistically rigorous method to employ. Fortunately, this probably had little real impact because of the stochastic climate data generated by the model based on triangulated information from other weather stations that occurred in an obscure manner not well explained.

A brief cursory review of standard climate input figures compared to real Andrews data was conducted. WEPP approximations under Cascadia R S consistently underestimated average maximum temperatures used from the Andrews CS2MET, while minimum monthly averages were inconsistently related. The mean monthly precipitation and mean number of wet days were also consistently lower for the standardized values compared to CS2MET data. Parameters were customized to the greatest extent possible, but could have been unknowingly internally modified.

In addition, unless the 450 mm maximum precipitation values is a misprint in the technical documentation (Elliot 2000, p 9), this ceiling renders the model inapplicable to climates such as the Andrews, whose watersheds receive average annual precipitation around the 2300mm range (Da Shepherd 2004 at ClimDB & HydroDB website).

Finally, in one simulation there appeared to be no data generated for one of the years (36) in a 42 year run (Simulation for WS1, Burn Scenario run for 42 years). This omission was neither evident in the output screen nor noted in either the html or extended data report. The extent of this error's impact on the results as a whole is unknown. It was unclear as to whether there was simply zero output for the year, or alternately, a glitch. Furthermore, it is not clear whether or not such a mistake was perpetuated in other simulations.

B. Soil

In this model, selected soil textures characterized the entire hillslope – or in this case, basin. However, represented catchments and hillslopes were not homogenous, particularly as illustrated in WS3 where one of the harvests occurred in an area labeled as bedrock talus. For this reason, it was an extreme oversimplification to select one representative texture whose properties changed with each vegetation treatment. A more accurate approach may have broken the basins into progressively smaller units adjusting input field qualities accordingly. However, such detail was beyond the scope of this study.

Actual Andrews data characterized the majority of all three watersheds as gravelly clay loam. However, the description and definition in the WEPP literature did not seem clearly correlated with the Andrews' description of clay loam. In WEPP, "loam" appeared as best fit in all scenarios based solely on relative comparisons of percent clay, sand, and silt. This evaluation was a somewhat arbitrary method, but other soil properties generated by the model besides the above three proved to be moving targets for comparison. Further analysis of soil selections was beyond the scope of this study.

C. Vegetation Treatment

WEPP contained several built-in assumptions (Elliot 2000) that may or may not have held true for the steep, dissected terrains of the Western Cascades. While simple examples were given in the documentation regarding the appropriate method of application for WEPP (Elliot 2000), clarification was still lacking for disturbance regimes such as those experience by the Andrews. For this reason, multiple scenarios were simulated, and results were listed in table form (9.1). Formatting tables in this manner attempted to facilitate assessments and alternative outcomes derived from different treatments. However, this large number of simulations and predictions contributed to an over-abundance of data that tended to obscure the comparisons sought between WEPP results and data from the H.J.A.

As to the input of the data itself, burn severity, cover percents, and vegetation treatments were all assumed constant and homogenous, though there were indications this may not have been the case (see pertinent sections of this report) (Dyrness1973). Besides the calculations made for WS3, watersheds were considered homogenous and without buffers. Studies providing cover data for these basins were only conducted on harvested and burned areas, and not the catchment as a whole (Halpern 2005, Personal Communication 12/2005). Hence, all information for vegetation treatment and vegetation cover on WS2 was extrapolated from values for the other two watersheds. Finally, a more extensive analysis of the model's internal adjustments to actual vegetation characteristics in each class was not conducted.

D. Percent Cover

As mentioned in the discussion section of this report, this input field offered the most difficultly for proper interpretation and the most room for error. If this domain was incorrectly interpreted to include any value *not* defined as bare ground, then erroneous data was used. However, corresponding "Calibrated Vegetation" scenarios were also simulated such that cover values were entered to achieve a 93-94 % range by 30 years of prediction. Towards this end, no clear manner existed to employ actual watershed cover data because of extreme sensitivity in the model.

The "desired cover conditions" (Elliot 2000, pp.7, 9) mentioned in the technical documentation could only be interpreted as future resulting ground conditions after treatment. These cover conditions were also influence by other stochastic variables supposedly incorporated into the predictive simulation, and were therefore imminently unknown. By executing the model in this trial and error fashion, unnecessary subjectivity was introduced into outputs at the very commencement of the study. Later sediment predictions could be influenced by somewhat capricious assumptions on the part of the user at the onset of field inputs.

Finally, some of the input field data for WS2 was extrapolated from values obtained for WS1 & WS3. Data points were also in some cases pulled from graphs and were estimated from position rather than extracted from raw data.

E. Gradients and Horizontal Lengths

These averages were visually selected, and therefore were not a statistically perfect form of sampling. For horizontal lengths, best estimates were taken along visually discerned flow paths. Limitations arising from 30 m DEM's and the researcher's knowledge of Arc GIS 9 also could have resulted in inexact numbers. However, average slope conditions were still in the range of those real values listed in the attributes Table A.

Furthermore, some of the sample horizontal lengths actually intersected road cuts. Two segments of roads in WS3 ran parallel to each other and uphill of the stream network they both eventually crossed. This likely impacted stream network lengths and hydrologic connectivity (Wemple et al 1996).

F. Percent Rock

Though extensive data on exact percent of rock per volume may have been available from the H. J. Andrews LTER site, its exact use and representation was beyond the scope of this study. Estimations were made using the high end of the 35-50% range listed in the Andrews metadata (Da Shepherd 2004 at ClimDB & HydroDB website). It was assumed that the upper hillslopes of the watershed would be of higher rock content based on a visual analysis of the soils maps listed in that section. These estimates impacted the hydraulic conductivity of the soil (Elliot 2000), but the extent was not analyzed.

G. Sediment Inputs from Landslides and Roads

Neither landslides, mass failures, nor road inputs were excluded from the Andrews suspended sediment data. Isolation and elimination of sediment values from an exclusive harvest source were therefore impossible. As such, comparisons to the WEPP predictions must be considered in this light. However, this issue was probably mostly limited to the WS3 basin, which was the only to experience significant road construction (Jones 2005). Significant debris flows did occur on WS1 in the 1964 storm, and several smaller slides that did not become flows prior to 1972 also occurred on WS1 (Grant 2005).

H. Andrews Suspended Sediment Data

Interpretation and comparisons within these datasets were complicated by variations in sampling methods and techniques within and between each H.J.A. project. Differences in grab sampling verses proportional sampling, changes in filtration calibers and techniques, and adjustments to the water year were just a few examples that may have added unnecessary variation to this assessment. These factors must be taken into consideration in evaluating the precision of comparisons set forth in this report. All efforts were made to keep assessments as consistent and accurate as possible.

Fortunately, because WEPP does not seem to distinguish between water years and calendar years, complications with this particular factor may not necessarily be relevant. The different techniques used probably had no bearing either, since the predictions from WEPP were so much higher than the ground data.

Furthermore, it was notable that the 1988 water year was incomplete for all basins, but these values were incorporated into the calculation of averages while reconciling the overlapping datasets from the years of 1981 to 1988 for WS2. Fredriksen’s dataset, with the exception of one extremely high sampling value, tended towards lower totals than those of the Grant data for the years of overlap mentioned. This could be due in part to the difference in sampling techniques and timing of sample collection related to one particular storm.

I. Generation of WEPP Simulations and Subsequent Data Extraction for Comparison

Only values from the calibrated vegetation simulations were extracted and graphed. Therefore, the vegetation cover percentages may not reflect the real groundcover characteristics measured for the catchments during the given year. However, as illustrated by the earlier table (9.1) in values highlighted by orange, entering actual cover percentages from the Andrew's data resulted in predicted values that were well above those actually observed, as did the calibrated entries, though not to as great an extent.

Additionally, onsite erosion rates were suspiciously and consistently equal to suspended sediment yield in the "offsite effects" portion of the WEPP output report. The reason these values were almost always similar was unknown. One possible explanation was because no buffer was included, since none was mentioned in any of the Andrews literature. This seemed to indicate an assumption that *all* of the sediment shown to be detaching from all upland erosion rates and locations (sheet erosion) was remaining in solution and moving offsite. This could be one explanation for the higher yields predicted by the model, but this is only conjecture. Accompanying literature was too vague for a confident interpretation of why this occurred and the exact relationship between the two values given and those captured at the Andrews basins.

Finally, though the "low severity fire" treatment at H.J.A.'s WS1 and WS3 did not occur during the exact times for which it was run in WEPP (38 vs. 42 years), the duration simulated was sufficient for valid comparisons. WEPP was also simulated to run until 2003 and not 2004, but temperatures in the climate section were averaged to the year 2005. It is doubtful even these small cumulative discrepancies had much overall impact on the model outcomes relative to the Andrews data.

J. Results and Statistical Analysis

It cannot be stressed too strongly that the statistical analysis performed here was for cursory informational purposes only. A more appropriate analysis involving more rigorous and robust statistical tools would make a stronger case for any appropriate inferences or specific relationships between the compared model simulations and results.

12 Utilizing WEPP

As a tool for roughly estimating the potential impact of harvest on sediment output, the simplified web-based version of the FSWEPP offered some insight. Its creators at least attempted to make its implementation somewhat user-friendly. Links were available to general technical documentation, as well as more specific model discussions. However, the performance and understanding of the model was not as seamless as it could be on various fronts. Besides the applicable difference in major erosion producing processes (debris flows and landslides) on the H.J.A. as compared to overland erosion rates predicted by WEPP, there were user input as well as output interpretation issues that could be addressed more effectively.

Though technical documentation was available for most fields of the model, much of it was either too vague or too technical for novice users. Even more advanced users with accurate and pertinent ground data will probably find the accompanying discussions of assumptions and the explanations of variables frustrating in the least.

Below are comments regarding specific input fields of Disturbed WEPP. It is followed by a discussion of methods for communicating WEPP's predictive outputs.

A. Input Selections: Comments and Suggestions:

I. Climate

Although straightforward in appearance, Disturbed WEPP climate input was not the simple task that it should have been. To begin, no access to a general map was readily available to help facilitate identification of nearby climate station locations until one was already selected. Unfortunately, after selection the resultant map only indicated the location of that particular station and not its position relative to other possible alternatives. This seemed counter-intuitive for a user only generally familiar with a desired study location wanting to search for the closest or most representative climate station, which may or may not be one and the same

Additionally, there was no easily identifiable option to modify custom climates already created, unless the user employed the browser's go-back button at the time of the initial custom template entry. In general, the input procedure was somewhat awkward and inefficient to navigate. Furthermore, the integration with PRISM was probably useful, but the ability to adjust latitude, longitude, and elevation to an exact location was misleading. A more visible warning should be listed on this screen indicating that any changes to latitude, longitude, or elevation results in changes to, or the resetting of, any of the previously modified custom climate parameter columns in the input section following this data field.

Furthermore, the existence of long-term climate data and continuously monitored weather stations at several locations in the H.J. Andrews Research Forest could provide important additional assets and information to the model. It was not apparent that these stations were incorporated into the network of weather stations utilized to triangulate and predict climate conditions. Consideration should be given to taking advantage of the data provided by these untapped resources.

Finally, unless the 450 mm maximum precipitation values is a misprint in the technical documentation (Elliot 2000, p 9), this ceiling renders the model inapplicable to climates such as the Andrews, whose watersheds receive average annual precipitation around the 2300 mm range.

II. Soils

Though extensive soil data was available for all three watersheds, it was difficult to represent the information correctly in the model. Section 2 regarding soil inputs covered a brief discussion of these difficulties. Due to the cascading manner in which inputs affected each other, it was difficult to truly customize soil characteristics for the watersheds. Nor was it possible to keep any of the input variables constant so that changes in resultant outputs driven by individual adjustments could be discerned.

As with much of the documentation related to this model, explanations and descriptions of model assumptions fell short for a non-technical user. A less-technical but more specific description of how to take soil properties into consideration and how to compensate for their changing conditions with each treatment option would contribute greatly to the effective utilization of this model.

III. Vegetation Treatment

The exact method of analyzing sediment response functions as a result of vegetation selection is unclear. Although the examples provided in the Disturbed WEPP documentation (Elliot 2000) were helpful in assisting the user in the proper method of setting up a scenario for analysis, they were equally confusing. On one hand, it seemed apparent that starting with the "Low Severity Fire" selection would suffice for the ground conditions on the Andrews at the time of the initial disturbance. It could then be interpreted that from this entry condition into the future, vegetation treatments, percentages of cover, and erosion rates would adjust themselves accordingly and reflect the entire cumulative process and its evolution through time. However, this seemed to contrast with the strategy later employed in Example 3 (Elliot 2000, p 16), which created separate treatments for each time period in the regeneration process. Because of this conflicting approach, this study employed both methods with confusing comparative results. Again, clarity in technical documentation would greatly assist new users in quicker comprehension and interpretation of the model's returns.

IV. Percent Cover

Of all inputs into the Disturbed WEPP model, this was the most frustrating to accurately represent utilizing relevant, on-the-ground data. The technical documentation accompanying this portion of the model was insufficient to fully convey both the precise meaning of the variable, and the exact manner in which it was or should be considered for input purposes. For a novice user as well as an accomplished botanist, the documentation was either too technical or too vague in the extreme.

Furthermore, as it was one of the most sensitive and influential variables in the model, it seemed antithetical to simply adjust it via trial and error in order to project "desired cover…conditions" (Elliot 2000, pp.7, 9). These desired cover conditions, which one could only interpret as future resulting ground conditions after treatment, were also influence by other variables, and therefore imminently unknown. In essence, ground cover predictions were an essential component of the desired output, but were requested as an input based on speculation of what might be too low or too high for after-harvest treatments in any given year. By executing the model in this fashion, unnecessary subjectivity was introduced into outputs at the commencement of the simulation such that later sediment predictions could be influenced by somewhat capricious assumptions on the part of the user.

V. Percent Gradients and Horizontal Lengths

The fields in this portion of the model were fairly straightforward to populate. However, a visual illustration included in the general technical document would be a beneficial addition to the explanation. Furthermore, clearer suggestions or recommendations on how to characterize an entire catchment besides individual hillslopes would be useful.

VI. Percent Rock

Once more, selection of appropriate input values would benefit greatly from a clearer, more robust explanation of this variable. Although fairly straight forward to enter from a per volume perspective, there was no immediately evident way to discern this variable's exact impact on soil texture and the other properties it was stated to affect.

VII. Exclusion of Landslides and Mass Failures or Road Contributions

Predictions or analyses of such events were not noted possibilities considered in WEPP outcomes. Considering the visible correlation between harvest areas and landslides, such an input or output field would be an interesting addition to the Disturbed WEPP repertoire.

VIII. Integration with Road WEPP or CrossDrain

Despite the proximity and allusions to both of these sister models, there was no apparent way to link either the inputs or the results of Disturbed WEPP and their fields in order to achieve any type of cumulative, basin-level perspective. Considering that some sort of road network usually accompanies harvesting, it would be beneficial to allow the user to toggle between these outputs, and to combine the values of both models if appropriate and so desired.

B. WEPP Predictions, Outputs, and Results: Comments and Suggestions:

One major drawback to the output and results set-up of this model was that the extended output file did not easily identify several of the user inputs utilized or entered in creating the predictions. Therefore, it was imperative to label each file comprehensively and also to save the general html page in order to refer back to the originally determined criteria. This was particularly cumbersome when generating multiple comparisons and or seeking trends from specific changes to input fields. Furthermore, reading the file and extracting the data was an onerous process, as no brief summaries or graphs were available besides the general html output screen. Better labeling and a brief summary column of yearly averages at the beginning of the data set would have improved this layout. Finally, the ability to save searches, inputs, and results accessible from more than a single computer address may result in more universal ease of use.

Discussion and Conclusions

While simplified web-based version of the U.S. Forest Service's Disturbed Watershed Erosion Prediction Project offered some predictive capacity to assess sediment yields from various types of timber-harvest activities, there were numerous drawbacks as well.

Though probably more realistic than not, the way in which model parameters functioned as “moving targets” dependent on input from other fields made ground-testing the model very difficult. In order to measure and calibrate model accuracy in steep, dissected terrain, the use of real suspended sediment data as well as other site-data resources from the H.J. Andrews LTER Forest merits more research. This report was meant to serve as a starting point for further model testing, as it provided multiple data sources for input fields and cursory results from such entries. Though beyond the scope of this study, more rigorous statistical analyses may be able to provide a calibration factor for use in this landscape as well as insights into future model designs or modifications.

Finally, in landscapes and climates such as that of the H.J. Andrews, the Disturbed WEPP model may not be the most appropriate or relevant tool for predicting and describing dominant sediment delivery events and processes. Overland erosion processes are not as significant as large storm events or debris flows at the H.J.A., as these events often produced the most sediment delivery in the basins (Grant & Wolff 1991). Furthermore, despite the inclusion of these inputs in the Andrews data, WEPP nevertheless overestimated offsite sediment yields from the basin. Ultimately, in this instance WEPP may be a more useful tool for comparing treatment scenarios as opposed to determining specific sediment delivery volume.

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See also: http://lterweb.forestry.oregonstate.edu/climhy//temp/AND.pdf
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We would appreciate a copy of any publication that cites our data.
Please send to: Don Henshaw
Forestry Sciences Lab
3200 Jefferson Way
Corvallis OR 97331

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Appendix A: Data Summaries

Watershed 1: Extracted & Compiled Suspended Sediment Yield Data

Note: Water Year begins November 1 for Grant Data; Ends September 30 for Fredricksen Data; Not Applicable to WEPP

WEPP Conversion Constant to get kg/ha from kg/m : 32.6136 from length= 306.62 m and area = L* ?w=10000m^2; so 10000/306.62 = 32.6136

Andrews Data: Combined Grant & Fredriksen Data			WEPP Burn Scenario Calibrated 42-Year Run			WEPP Contol 42-Year Run			WEPP Calibrated Yearly Average Yields for Series of Treatments at 30-Year Run		WEPP Calibrated Burn Minus Control	
Year	kg/ha		Year	kg/m	kg/ha	Year	kg/m	kg/ha	Year	kg/ha	Year	kg/ha
1955		1	1962	1055.209	34414.16	1962	15.811	515.6536	1962	210	1962	33898.51
1956	146.317	2	1963	659.526	21509.52	1963	8.575	279.6616	1963	520	1963	21229.86
1957	972.942	3	1964	556.823	18160	1964	0	0	1964	520	1964	18160
1958	190.174	4	1965	135.935	4433.33	1965	0	0	1965	520	1965	4433.33
1959	57.407	5	1966	271.095	8841.384	1966	0	0	1966	11620	1966	8841.384
1960	30.828	6	1967	98.749	3220.56	1967	0.013	0.423977	1967	5000	1967	3220.136
1961	90.48	7	1968	95.539	3115.871	1968	0	0	1968	2190	1968	3115.871
1962	106.637	8	1969	424.849	13855.86	1969	5.741	187.2347	1969	140	1969	13668.62
1963	39.667	9	1970	626.128	20420.29	1970	1.932	63.00948	1970	490	1970	20357.28
1964	79.424	10	1971	478.896	15618.52	1971	0.029	0.945794	1971	490	1971	15617.58
1965	596.894	11	1972	174.803	5700.955	1972	0	0	1972	490	1972	5700.955
1966	115.597	12	1973	220.86	7203.04	1973	0	0	1973	490	1973	7203.04
1967	3566.724	13	1974	255.499	8332.742	1974	0	0	1974	490	1974	8332.742
1968	2186.495	14	1975	296.692	9676.194	1975	0.011	0.35875	1975	490	1975	9675.835
1969	3826.601	15	1976	244.579	7976.602	1976	1.076	35.09223	1976	490	1976	7941.509
1970	1169.212	16	1977	729.071	23777.63	1977	90.484	2951.009	1977	490	1977	20826.62
1971	4988.031	17	1978	1020.478	33281.46	1978	0	0	1978	490	1978	33281.46
1972	10718.73	18	1979	582.018	18981.7	1979	2.626	85.64331	1979	490	1979	18896.06
1973	277.126	19	1980	154.243	5030.42	1980	0	0	1980	490	1980	5030.42
1974	1002.669	20	1981	164.8	5374.721	1981	1.259	41.06052	1981	210	1981	5333.661
1975	1066.315	21	1982	96.988	3163.128	1982	33.678	1098.361	1982	210	1982	2064.767
1976	1943.5	22	1983	146.43	4775.609	1983	5.069	165.3183	1983	210	1983	4610.291
1977	44.158	23	1984	152.318	4967.638	1984	0	0	1984	210	1984	4967.638
1978	1182.395	24	1985	90.645	2956.26	1985	0	0	1985	210	1985	2956.26
1979	607.295	25	1986	242.37	7904.558	1986	0	0	1986	210	1986	7904.558
1980	396.345	26	1987	438.257	14293.14	1987	0	0	1987	210	1987	14293.14
1981	448.396	27	1988	359.301	11718.1	1988	16.863	549.9631	1988	210	1988	11168.14
1982	961.458	28	1989	2.738	89.29604	1989	0	0	1989	210	1989	89.29604
1983	413.256	29	1990	364.976	11903.18	1990	0	0	1990	210	1990	11903.18
1984	525.795	30	1991	545.614	17794.44	1991	0	0	1991	210	1991	17794.44
1985	139.839	31	1992	448.335	14621.82	1992	0.017	0.554431	1992	210	1992	14621.26
1986	585.3	32	1993	278.789	9092.313	1993	0	0	1993	210	1993	9092.313
1987	158.436	33	1994	252.024	8219.41	1994	0.416	13.56726	1994	210	1994	8205.843
*1988	209.213	34	1995	31.798	1037.047	1995	0	0	1995	210	1995	1037.047
2004	428.92	35	1996	700.769	22854.6	1996	8.713	284.1623	1996	210	1996	22570.44
Average	1155.076	36	1997		0	1997	0	0	1997	210	1997	0
Standard Deviation	2055.565	37	1998	45.798	1493.638	1998	0.004	0.130454	1998	210	1998	1493.507
* Not taken in November,		38	1999	485.425	15831.46	1999	0	0	1999	210	1999	15831.46
Taken in June,		39	2000	767.481	25030.32	2000	0.173	5.642153	2000	210	2000	25024.68
Incomplete Water Year		40	2001	186.539	6083.708	2001	0.008	0.260909	2001	210	2001	6083.447
Data Sources: Grant (2005),		41	2002	207.663	6772.638	2002	0.007	0.228295	2002	210	2002	6772.41
and Fredricksen (2005)		42	2003	16.823	548.6586	2003	0	0	2003	210	2003	548.6586
			Average	344.0701	10954.19	**Average**	4.583452	149.4829	**Average**	736.6667	**Average**	10804.71
			Standard Deviation	263.8618	8674.456	**Standard Deviation**	14.97579	488.4145	**Standard Deviation**	1890.66	**Standard Deviation**	8550.532

Watershed 2: Extracted & Compiled Suspended Sediment Yield Data

Note: Water Year begins Nov. 1 for Grant Data; Ends Sept. 30 for Fredricksen Data; Not Applicable to WEPP

WEPP Conversion Constant to get kg/ha from kg/m :

23.9682 from length= 417.22 m and area = L* ?w=10000m^2; so 10000/417.22 = 23.9682

Andrews Data: Combined Grant & Fredriksen Data			**WEPP Contol 42-Year Run**			**WEPP Calibrated Yearly Average Yields for Series of Treatments at 30-Year Run**	
Year	kg/ha		Year	kg/m	kg/ha	Year	kg/ha
1955		1	1962	35.356	847.4196792	1962	410
1956	236.127	2	1963	41.546	995.7828372	1963	410
1957	2930.239	3	1964	12.95	310.38819	1964	410
1958	574.565	4	1965	0	0	1965	410
1959	79.701	5	1966	0.009	0.2157138	1966	410
1960	61.872	6	1967	0.923	22.1226486	1967	410
1961	138.152	7	1968	0.06	1.438092	1968	410
1962	161.711	8	1969	15.626	374.5270932	1969	410
1963	61.77	9	1970	15.989	383.2275498	1970	410
1964	56.796	10	1971	21.889	524.6399298	1971	410
1965	1067.065	11	1972	5.593	134.0541426	1972	410
1966	50.188	12	1973	0.258	6.1837956	1973	410
1967	55.43	13	1974	4.837	115.9341834	1974	410
1968	40.846	14	1975	2.959	70.9219038	1975	410
1969	163.233	15	1976	4.212	100.9540584	1976	410
1970	70.752	16	1977	211.494	5069.130491	1977	410
1971	115.304	17	1978	26.108	625.7617656	1978	410
1972	412.386	18	1979	20.897	500.8634754	1979	410
1973	32.544	19	1980	0	0	1980	410
1974	117.519	20	1981	3.137	75.1882434	1981	410
1975	89.212	21	1982	2.629	63.0123978	1982	410
1976	351.775	22	1983	11.918	285.6530076	1983	410
1977	12.518	23	1984	2.88	69.028416	1984	410
1978	185.113	24	1985	3.008	72.0963456	1985	410
1979	77.858	25	1986	11.458	274.6276356	1986	410
1980	60.398	26	1987	0.008	0.1917456	1987	410
1981	100.371	27	1988	22.12	530.176584	1988	410
1982	177.732	28	1989	0.008	0.1917456	1989	410
1983	66.177	29	1990	15.748	377.4512136	1990	410
1984	153.521	30	1991	16.984	407.0759088	1991	410
1985	54.695	31	1992	5.131	122.9808342	1992	410
1986	401.3275	32	1993	0.007	0.1677774	1993	410
1987	40.1985	33	1994	8.533	204.5206506	1994	410
1988	50.3255	34	1995	0	0	1995	410
1989	105.54	35	1996	26.344	631.4182608	1996	410
1990	13.92	36	1997	31.758	761.1820956	1997	410
1991	14.6	37	1998	0.007	0.1677774	1998	410
1992	14.48	38	1999	3.838	91.9899516	1999	410
1993	22.17	39	2000	17.571	421.1452422	2000	410
1994	15.42	40	2001	18.353	439.8883746	2001	410
1995	214.54	41	2002	15.525	372.106305	2002	410
1996	8158.21	42	2003	0	0	2003	410
1997	232.96		**Average**	15.18264	363.9006205	**Average**	410
1998	74.62		**Standard Deviation**	32.91066	788.8092735	**Standard Deviation**	0
1999	67.08						
2000	203.57						
2001	8.28						
2002	55.83						
2003	18.06						
2004	29.99						
Average	357.0753						
Standard Deviation	1218.79						

Data Sources: Grant (2005) and Fredricksen (2005)

Data Sources: Average of Grant and Fredricksen Yearly Totals

Watershed 3: Extracted & Compiled Suspended Sediment Yield Data

Note: Water Year begins November 1 for Grant Data; Ends September 30 for Fredricksen Data; Not Applicable to WEPP
WEPP Conversion Constant to get kg/ha from kg/m: 26.4887 from length= 377.52 m and area = L* ?w=10000m^2; so 10000/377.52 = 26.4887

Andrews Data: Combined Grant & Fredriksen Data			WEPP Burn Scenario Calibrated 42-Year Run				WEPP Contol 42-Year Run			WEPP Calibrated Yearly Average Yields for Series of Treatments at 30-Year Run		
Year	kg/ha		Year	kg/m	Total kg/ha	.25 Burn + .75Control kg/ha	Year	kg/m	kg/ha	Year	Total kg/ha	.25 Burn + .75Control kg/ha
1955	NA	1	1962	1155.98	30620.4	8043.373	1962	19.544	517.6952	1962	230	57.5
1956	1226.236	2	1963	668.893	17718.1	4637.529	1963	10.47	277.3367	1963	540	135
1957	7296.32	3	1964	570.607	15114.6	4010.641	1964	11.677	309.3085	1964	9330	2332.5
1958	1784.308	4	1965	150.775	3993.83	998.4584	1965	0	0	1965	5570	1392.5
1959	359.487	5	1966	251.953	6673.91	1668.477	1966	0	0	1966	2110	527.5
1960	245.222	6	1967	105.839	2803.54	702.6326	1967	0.088	2.331006	1967	170	42.5
1961	760.089	7	1968	109.569	2902.34	781.708	1968	2.825	74.83058	1968	540	135
1962	5568.096	8	1969	411.61	10903	2875.309	1969	7.528	199.4069	1969	540	135
1963	401.283	9	1970	661.523	17522.9	4438.572	1970	2.912	77.13509	1970	540	135
1964	2163.818	10	1971	488.857	12949.2	3256.269	1971	0.955	25.29671	1971	540	135
1965	44128.64	11	1972	198.849	5267.25	1316.813	1972	0	0	1972	540	135
1966	1142.112	12	1973	218.349	5783.78	1445.945	1973	0	0	1973	540	135
1967	893.125	13	1974	229.096	6068.46	1517.114	1974	0	0	1974	540	135
1968	574.619	14	1975	325.809	8630.26	2158.558	1975	0.05	1.324435	1975	540	135
1969	1407.809	15	1976	268.809	7120.4	1830.78	1976	2.551	67.57267	1976	540	135
1970	719.36	16	1977	933.811	24735.4	8636.144	1977	123.438	3269.712	1977	540	135
1971	1157.354	17	1978	73.647	1950.81	487.7033	1978	0	0	1978	540	135
1972	3999.677	18	1979	696.806	18457.5	4790.468	1979	8.864	234.7958	1979	230	57.5
1973	216.764	19	1980	183.802	4868.68	1217.169	1980	0	0	1980	230	57.5
1974	873.051	20	1981	151.459	4011.95	1053.966	1981	2.566	67.97	1981	230	57.5
1975	626.442	21	1982	105.335	2790.19	1408.927	1982	35.808	948.5074	1982	230	57.5
1976	1207.724	22	1983	153.011	4053.06	1156.185	1983	7.194	190.5597	1983	230	57.5
1977	57.318	23	1984	141.608	3751.01	937.753	1984	0	0	1984	230	57.5
1978	1234.026	24	1985	89.394	2367.93	591.9827	1985	0	0	1985	230	57.5
1979	466.113	25	1986	258.672	6851.89	1774.14	1986	3.079	81.55871	1986	230	57.5
1980	285.259	26	1987	456.455	12090.9	3022.725	1987	0	0	1987	230	57.5
1981	532.772	27	1988	387.532	10265.2	2940.411	1988	18.831	498.8087	1988	230	57.5
1982	916.584	28	1989	2.608	69.0825	17.27063	1989	0	0	1989	230	57.5
1983	482.375	29	1990	345.384	9148.77	2293.57	1990	0.321	8.502873	1990	230	57.5
1984	563.609	30	1991	768.702	20361.9	5090.479	1991	0	0	1991	230	57.5
1985	193.64	31	1992	418.47	11084.7	2798.776	1992	1.389	36.7928	1992	230	57.5
1986	604.928	32	1993	216.738	5741.11	1435.356	1993	0.004	0.105955	1993	230	57.5
1987	203.906	33	1994	260.902	6910.95	1747.228	1994	0.981	25.98541	1994	230	57.5
*1988	270.762	34	1995	12.782	338.579	84.64464	1995	0	0	1995	230	57.5
Average	2501.904	35	1996	767.535	20331	5263.874	1996	9.117	241.4975	1996	230	57.5
Standard Deviation	7632.694	36	1997	0	0	0	1997	0	0	1997	230	57.5
* Not taken in November,		37	1998	46.542	1232.84	308.3483	1998	0.007	0.185421	1998	230	57.5
Taken in June,		38	1999	336.981	8926.19	2231.547	1999	0	0	1999	230	57.5
Incomplete Water Year		39	2000	780.411	20672.1	5176.879	2000	0.446	11.81396	2000	230	57.5
		40	2001	213.992	5668.37	1417.251	2001	0.008	0.21191	2001	230	57.5
		41	2002	249.39	6606.02	1681.999	2002	1.535	40.66015	2002	230	57.5
		42	2003	20.875	552.952	138.2379	2003	0	0	2003	230	57.5
			Average	330.6991	8759.79	2318.696	**Average**	6.48067	171.6644	**Average**	705.714	176.428571
			Standard Deviation	275.8648	7307.3	2027.174	**Standard Deviation**	19.7875	524.1453	**Standard Deviation**	1611.79	402.946519

Appendix B: WEPP Output Pages