FINAL
Model Report for Hangman (Latah) Creek TMDL Model Project

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Executive Summary

This report describes the work product for the Hangman (Latah) Creek TMDL modeling project which began mid-July 2006. Hangman (Latah) Creek, located in eastern Washington and Northern Idaho, drains a 672 square mile watershed and is included on Washington State's 303(d) list of impaired waters. The impairment listing results from non-attainment of water quality standards for ammonia, dissolved oxygen (DO), pH, temperature, turbidity, nutrients, and fecal coliform. For this TMDL modeling project, CDM supported a stakeholder group, comprised of local, state, tribal, and federal environmental agencies, to assimilate existing data, select a GIS-based, publicly available, water quality model for watershed and receiving water parameterization, and development of the model to be suitable for simulating Total Daily Maximum Load (TMDL) scenarios. TMDL parameters included in this study were phosphorus and total suspended sediment.

The first project milestone was to collect and summarize existing data and their sources (**Technical Memorandum #1 – Appendix A**). To accomplish this, CDM met with the stakeholder group to collect recent studies and data generated for the Hangman (Latah) Creek Watershed, discuss objectives for the TMDL model and conduct a photo survey of key geographic and site specific areas within the watershed. Other data requisitions included spatially referenced GIS layers, meteorology, hydrology, and water quality data from sampling stations within the watershed. These data were reviewed and downloaded from local, state, tribal, and federal agency websites. Findings from the data collection effort indicated that although the watershed has been studied extensively, many of these studies have not focused on collecting data specific for the TMDL modeling input.

After initial data collection efforts, CDM outlined a modeling approach based on the quality and quantity of data available for the watershed relative to the capabilities of several publicly available watershed and receiving water models in order for the stakeholder group to make an informed selection (**Technical Memorandum #2 – Appendix B**). Based on it's ability satisfy most of the key modeling criteria and objectives outlined by the client/stakeholder group, the Watershed Analysis Risk Management Framework (WARMF) model was selected.

With the selection of the WARMF model and an outlined approach, CDM prepared a Quality Assurance Project Plan (QAPP) to establish modeling objectives and develop controls for data input, model calibration, validation, and usability (**Appendix C**).

Initial development of the WARMF model involved import of key watershed layers, such as soil and land use surveys using GIS software. Additionally, GIS extensions, such as Spatial Analyst and ArcHydro, were used to analyze 10 meter DEM data to partition the entire Hangman (Latah) Creek watershed into 36 subwatersheds (catchments) and import hydrology parameters including slope, stream segment width, and aspect into the WARMF model. The average catchment size in the WARMF model is approximately 12,000 acres. Once the catchment and river segments were defined, the GIS layers for soil, land use, and river bank erosion areas

were used to set initial parameter inputs for each catchment and river segment in the WARMF model. These parameters were later refined during the calibration process.

WARMF model development continued with input of the following time-series data spanning eight water years from 1998 to 2005:

- Meteorological data from four stations within, or near the watershed;
- Hydrologic and water quality data from 11 stations located on the main stem and five major tributaries within the watershed;
- Point Source Data from six Waste Water Treatment Plants within the watershed.

When additional, model specific, data are collected, these catchments can easily be refined into a higher level of sub-catchment delineation if the stakeholder group decides that this would improve TMDL analyses results.

At the conclusion of model development, CDM proceeded to calibrate the Hangman Creek WARMF Model (HCWM) to the observed input data for five stations within the watershed where hydrology and water quality data were sufficient. These stations included:

1. Hangman Creek at the Mouth
2. Hangman Creek at Duncan
3. Rock Creek at the Mouth
4. Hangman Creek at Bradshaw
5. Hangman Creek at Tekoa

Given the resource constraints and limited "model-specific" detail of existing input data, the hydrology and water quality calibration results are good to very good and fit within observed data ranges.

Hydrology calibration results are presented for Hangman (Latah) Creek watershed at the mouth and the four upstream locations. These hydrology calibration results show a good correlation between average daily observed flow and average daily calibrated flow. In general, the model predicts periods of high flow and low flow well. Simulated cumulative runoff volume is slightly lower than the observed conditions before 2001 and slightly higher in more recent years.

For water quality calibration, time series plots of simulated and observed TSS and TP were compared at the mouth of Hangman Creek. Additionally, a sliding interval baseflow separation data analysis tool was employed to classify flows as "wet" (30% or greater than the baseflow) fraction, or "dry" (baseflow conditions) to compare water quality calibration for different hydrologic conditions at the five calibration locations in box and whisker plots. Generally, the simulated TSS and TP

concentrations compare equally to observed values at the mouth of Hangman Creek and the four upstream/tributary calibration stations.

In its current state, the HCWM allows the stakeholder group to:

- Effectively predict estimated daily nutrient concentrations and loads from the entire Hangman (Latah) Creek watershed (**Table E-1**);
- Focus similar predictions on four upper watershed areas (**Table E-1**)**;**
- Develop numeric targets for pollutant reductions;
- Recommend practices to reduce the impact of pollutant load sources, and
- Develop implementation plans.

Table E-1
Distribution of Pollutant Sources for TSS and TP

Hangman Creek at the Mouth

Source Category	TSS (kg/d)	TP (kg/d)
Deciduous	0.6	0.00
Coniferous	5,430	3.76
Mixed Forest	84	0.25
Cropland / Pasture	36,700	15.80
Rangeland	7,450	3.07
Forested Wetland	9	0.02
Non-forested Wetland	15	0.02
Barren	5	0.00
Residential	3,200	1.18
Comm./Industrial	491	0.14
General Nonpoint Sources	3,050	0.00
Stream Bank Erosion	74,700	13.80
Type 1 Septic System	-	5.23
General Point Sources	-	6.93
TOTAL	131,134	50.20

Hangman Creek at Duncan

Source Category	TSS (kg/d)	TP (kg/d)
Deciduous	0.8	0.00
Coniferous	6,170	3.88
Mixed Forest	115	0.30
Cropland / Pasture	48,300	17.40
Rangeland	7,670	2.79
Forested Wetland	11	0.02
Non-forested Wetland	17	0.01
Barren	4	0.00
Residential	2,450	0.96
Comm./Industrial	637	0.16
General Nonpoint Sources	471	0.00
Stream Bank Erosion	739	0.12
Type 1 Septic System	-	5.96
General Point Sources	-	5.16
TOTAL	66,585	36.77

Hangman Creek at Rock Creek Mouth

Source Category	TSS (kg/d)	TP (kg/d)
Deciduous	0.2	0.00
Coniferous	1,880	1.30
Mixed Forest	40	0.10
Cropland / Pasture	25,400	11.30
Rangeland	3,120	1.43
Forested Wetland	3	0.00
Non-forested Wetland	7	0.00
Barren	0	0.00
Residential	1,360	0.62
Comm./Industrial	141	0.05
General Nonpoint Sources	6	0.00
Stream Bank Erosion	0	-
Type 1 Septic System	-	1.56
General Point Sources	-	2.14
TOTAL	31,958	18.51

Hangman Creek at Bradshaw Road

Source Category	TSS (kg/d)	TP (kg/d)
Deciduous	0.8	0.002
Coniferous	5,580	2.76
Mixed Forest	111	0.22
Cropland / Pasture	30,700	6.17
Rangeland	5,770	1.41
Forested Wetland	9	0.02
Non-forested Wetland	13	0.01
Barren	6	0.001
Residential	1,440	0.36
Comm./Industrial	623	0.10
General Nonpoint Sources	401	0.00
Stream Bank Erosion	1,160	0.14
Type 1 Septic System	-	3.64
General Point Sources	-	2.32
TOTAL	45,813	17.14

Hangman Creek at Tekoa

Source Category	TSS (kg/d)	TP (kg/d)
Deciduous	0.3	0.001
Coniferous	6,980	2.99
Mixed Forest	59	0.18
Cropland / Pasture	16,600	3.68
Rangeland	4,880	1.19
Forested Wetland	13	0.02
Non-forested Wetland	18	0.01
Barren	9	0.001
Residential	1,620	0.36
Comm./Industrial	189	0.03
General Nonpoint Sources	64	0.00
Stream Bank Erosion	15	0.00
Type 1 Septic System		3.41
WWTP Effluent		2.50
TOTAL	30,447	14.38

Note: Source characterization is cumulative. The mouth results account for everything. Bradshaw accounts for Tekoa, etc... A net loss in some source sediments are a result of downstream settling.

Ultimately, the Hangman Creek TMDL model can be expanded and refined by the stakeholder group as the model is updated with "model-specific" data collection efforts and input from interest groups to direct TMDL modeling scenarios that will address effective planning and management decisions regarding the beneficial uses within the Hangman (Latah) Creek watershed.

Section 1
Introduction

1.1 Watershed Description

The Hangman (Latah) Creek watershed is located in eastern Washington and northern Idaho. It encompasses approximately 672 square miles and is tributary to the Spokane River. **Figure 1** shows the physical and political boundaries of the watershed in addition to the perennial streams within its boundaries.

The watershed's headwaters are in Idaho at a mean elevation of approximately 3,600 feet mean sea level (ft-msl). The watershed elevations decline to roughly 1,700 ft msl at the mouth. Land use within the watershed is estimated at 64 percent agricultural, 28 percent forested and 8 percent urban residential, with the majority of urban residential existing in the lower reaches near the mouth within the City of Spokane metropolitan area.

Based on Washington State's 303(d) listing, water quality in certain segments of Hangman Creek is impaired as indicated by water quality parameters including: ammonia, dissolved oxygen (DO), pH, temperature, turbidity, nutrients, and fecal coliform. In addition, the ongoing Spokane River TMDL process has identified Hangman Creek as a significant source of phosphorus in early spring that depresses DO and influences algae blooms in the lower reaches of the Spokane River and Long Lake.

1.2 Purpose of Preliminary Hangman (Latah) Creek TMDL Modeling Project

The purpose of the Hangman (Latah) Creek TMDL modeling project was to satisfy the following objectives:

- Identify and assemble available datasets for landscape and water quality (instream) modeling
- Select the appropriate model or models for watershed and instream modeling based on publicly available modeling software, available data, water quality standards and client/stakeholder input.
- Construct a preliminary model from available datasets and information for TMDL modeling of phosphorus and total suspended sediment (acting as a surrogate measure for turbidity)
- Calibrate the preliminary model to the discharge point (mouth) of the 672 square-mile watershed and four spatially distributed subwatershed locations.
- Develop model input parameters and conduct a sensitivity analysis on these input parameters

- Provide instruction to the client team on using the model for future model development, maintenance, and application of TMDL allocation scenarios.

1.3 Report Overview

This report provides a summary of the Hangman (Latah) Creek TMDL model construction, calibration, model parameter sensitivity and recommendations for filling data gaps and future model supported management scenarios. It contains the following:

Section 2: TMDL Model Construction –provides details on the selected Watershed Analysis Risk Management Framework (WARMF) model inputs and assumptions used during model construction to address data gaps.

Section 3: WARMF Calibration – provides model parameters in the WARMF software, which were modified for the hydrology and water quality calibration. Also includes a summary of the WARMF parameter sensitivity analysis.

Section 4: WARMF Maintenance Recommendations and Future Scenarios – provides a discussion regarding data gaps, additional calibration efforts and future scenarios to address water quality effects of nonpoint source and point source loadings in the watershed.

Section 5: References – provides a list of references used in the report.

Project memorandums and reports leading up to WARMF model construction are included as appendices to this report. These include:

Appendix A - Data Bibliography for the Hangman (Latah) Creek Watershed

Appendix B - Modeling Approach for Hangman (Latah) Creek TMDL Project

Appendix C - Modeling Quality Assurance Plan for Hangman (Latah) Creek

Appendix D – Includes a working copy of the WARMF model for Hangman (Latah) Creek TMDL Project with a complete set of current calibrated input parameters.

Section 2
Hangman (Latah) Creek TMDL Model Construction

2.1 WARMF Subcatchment Development

Based on client/stakeholder participation and input during the August 16, 2006 conference call, CDM utilized ArcHydro®, an ESRI GIS extension tool, to delineate subcatchments within the watershed for use in development of the Watershed Analysis Risk Management Framework (WARMF) model. This process resulted in the separation of the Hangman (Latah) Creek watershed into 36 subwatersheds, 23 more than the coarser delineation that can be downloaded from the Washington State Department of Ecology (WDOE) (http://www.ecy.wa.gov/services/gis/data/data.htm).

ESRI Spatial Analyst® was used to calculate an area weighted slope and aspect for each of the 36 subcatchments. The subcatchment layer was converted to a geographic coordinate system (latitude/longitude) to be correctly imported into WARMF. Attributes of the GIS layer were linked to WARMF subcatchment specific parameters including, area, slope, and aspect.

Spatial Analyst was also used to calculate upstream and downstream elevations, length, and slope for each of the rivers generated by ArcHydro to connect nested subcatchments. For each river segment, ArcHydro develops a hydrologic network by including the subcatchment name which the river segment drains and the river segment directly downstream. The river shapefile was converted to a geographic coordinate system and imported into WARMF. Attributes of the GIS layer were linked to specific WARMF river segment parameters, including the drainage network parameters, eliminating the need to set up tributary connections and many physical river characteristics within the model Graphical User Interface (GUI).

Figure 2 shows the additional Hangman Creek subcatchments and the Dynamic Elevation Model (DEM) delineated river segments after importing into WARMF. This level of spatial discretization is appropriate given the location and number of monitoring stations with relevant flow and water quality data. Future applications of WARMF in the Hangman (Latah) Creek watershed can provide a higher level of subcatchment discretization if it is decided that this would significantly improve the TMDL analyses results.

Summary statistics for the modeled Hangman Creek subcatchments are:

Minimum catchment size = 576 acres
Maximum catchment size = 27,785 acres

The average catchment size = 12,000 acres

2.2 WARMF Model Inputs

After importing GIS data that delineated the watershed's boundary conditions, including subcatchment and rivers into the WARMF model, CDM began to enter land use information and time series plots of available meteorological, hydrology, water quality, point sources and other unique subcatchment and river parameters into the WARMF model database. The input data, processes and assumptions involved in entry into the WARMF model format are described below.

2.2.1 Land Use

GIS land use coverages from the 1992 USGS National Land Cover Dataset (NLCD) were imported into the WARMF model. The more recent 2001 NLCD land use coverage was not complete for a quarter of the upper watershed within Washington State. However, 2001 land use coverage were available for the developing residential urban areas in the lower watershed where the most significant changes in land use have occurred since the 1992 survey. Prior to WARMF input, the 1992 and 2001 land cover datasets were merged, where more recent data replaced older data. This single comprehensive land cover layer was imported into WARMF using the linkages between NLCD cover types and WARMF land use categories (**Table 1**). **Table 1** also shows the land use distribution within each of the 36 subcatchments. The subcatchment locations listed on **Table 1** are shown on **Figure 2**.

2.2.2 Meteorological

The following meteorological data fields are required by WARMF:

- Precipitation (cm)
- Minimum Temperature (˚C)
- Maximum Temperature (˚C)
- Cloud Cover (0 to 1)
- Dewpoint Temperature (˚C)
- Air Pressure (mbar)
- Wind speed (m/s)
- Data Source (added by CDM to track the source used as a surrogate for the missing meteorological records)

The available data from the following weather stations within or near the watershed were converted to metric units and daily time steps as necessary for input into the model:

- Spokane Airport
- Rosalia
- Plummer
- Coeur d'Alene (CDA) Tribe Farm

The period of record selected for WARMF meteorological data input spanned eight water years from 1998 to 2005 and established the time period for all of the other time series inputs described below. This eight year period was selected for the following reasons:

1. It provides a recent weather pattern that remains relevant for future TMDL modeling scenarios.
2. It is consistent with the period of record most of the discharge and water quality data within the watershed is available.
3. It had the least amount of data gaps of the four available weather stations
4. It covers dry (below average annual precipitation), as well as wet (above average), and average annual precipitation years.

For the 1998-2005 period of record, the Spokane Airport station contains a complete data set for the meteorological data fields required by WARMF. The CDA Tribal Farm Station near Tekoa had data for all of the WARMF meteorological data fields except for cloud cover. The Rosalia and Plummer stations only had data for precipitation and min/max air temperature. In these cases, the missing WARMF data field parameters were supplemented with Spokane Airport data.

Missing data took the form of a blank, "M", "null", or "-" value. These values were deleted and replaced with a value from the nearest station as a surrogate for the data gap. Spokane Airport had some minimal data gaps that were replaced by an average of the days before and after.

The available cloud cover data were listed as "Sky Conditions" and used the following labeling system:

CLR: Clear below 12,000 Ft.
FEW: Few; >0/8 - 2/8 sky cover
SCT: Scattered; 3/8 - 4/8 sky cover
BKN: Broken; 5/8 - 7/8 sky cover
OVC: Overcast; 8/8 sky cover

The following numeric values were assigned to each abbreviation to be used in the Cloud Cover category:

CLR: 0.0
FEW: 0.25
SCT: 0.50
BKN: 0.75
OVC: 1.0

After each label, a base height in hundreds of feet is listed. These values were ignored. Sometimes multiple values were listed as in the following example:

"BKN045 BKN070 OVC200"

The "worst case" was selected for these values and the OVC value of 1.0 was used.

2.2.3 Observed Hydrology

US Geological Survey

Hydrology data were downloaded from the USGS National Water Information System Web Interface for the mouth of Hangman (Latah) Creek, Station 12424003 (URL: http://waterdata.usgs.gov/nwis/sw/). The daily time-step flow data for the 1998-2005 water year period were converted to cubic meters per second and input into the WARMF model. The USGS station data has minimal data gaps and provides the most complete and continuous daily discharge record for the watershed to-date. No flow is listed on certain days when there was ice blockage in the stream channel.

CDA Tribe Data

Additional daily hydrology data for the upper watershed were received from the CDA Tribes on September 11, 2006. Receipt of the hydrology data from the tribe was delayed due to processing, tabulation, and QA/QC review of the field data. The CDA Tribe provided numerous stations with daily discharge data, however only six[1] were selected and input into the WARMF model because many of the CDA monitoring stations had minimal data points, were located on a small tributaries streams and not relevant for the scale of this initial model calibration effort, or the monitoring stations had significant data gaps during the 1998-2005 period established for the WARMF simulation. That aside, data from these stations will provide useful information for a refined WARMF model when sufficient information is collected to focus on smaller subcatchments for site specific TMDL loading assessments.

Values with a "less-than" (<) qualifier were entered as the value so that they could be compared to simulated data (i.e. "<0.3 cms" was set to "0.3 cms"). Some data were listed as "dry" or "standing pools". These values were entered as "0 cms".

[1] These stations include: Hangman Creek at the Stateline, Indian Creek at Pow Wow, Little Hangman at Stateline, Moctileme at Mouth, North Fork Rock Creek at Hwy 58, and Lower Sheep Creek

Spokane County Conservation District (SCCD)
Additional daily hydrology data for five SCCD stations in the upper watershed were entered into the WARMF model. Due to the schedule constraints of the modeling project there was insufficient time necessary for calibrating the upper watershed subcatchments and river segments connected with these data for the Draft report. Since submittal of the draft, CDM received an extension and additional funding to calibrate upper watershed subcatchments and river segments to observed daily discharge data from four of the five SCCD stations[2].

Although generally complete for the 1999-2005 period of record, the daily discharge records for all of the stations except Tekoa have several data gaps (left blank in the WARMF model observed dataset) for several months.

2.2.4 Observed Water Quality

Observed water quality data for comparison with WARMF model output results came predominantly from Washington State Department of Ecology (WDOE) online EIM database and USGS water quality data collected at the mouth of Hangman (Latah) Creek, Station 12424003 (URL: http://waterdata.usgs.gov/nwis/sw/).. The data were imported into MS Excel and reduced to all total phosphorus/phosphorus[3] (TP) and total suspended sediment (TSS) using pivot table techniques. Many EIM stations provided very few TP and TSS monitoring results. The following stations were processed for incorporation into the WARMF model, either because they had a significant amount of data (more than 10 samples) or because there was no other sampling done in the area. For river segments with multiple water quality monitoring locations, data from the most downstream sampling location were used.

WDOE Monitoring Station locations:

- Hangman Creek at Bradshaw Rd
- Hangman Creek at Duncan
- Hangman Creek at WA/ID State Line
- Hangman Creek at Mouth, USGS Site (Additional USGS data used)
- Little Hangman Creek at Tekoa
- Rattler Run Creek at Mouth

CDA Tribe Data:

[2] The SCCD stations calibrated in the WARMF model include: Hangman Creek at Duncan, Rock Creek at the Mouth, Hangman Creek at Bradshaw Rd., and Hangman Creek at Tekoa
[3] Phosphorus values in the EIM database were entered into WARMF as Total Phosphorus

- Hangman Creek at WA/ID State Line
- Lower Sheep Creek
- Little Hangman Creek at State Line
- North Fork Rock Creek at Hwy 58
- Moctileme Creek at Mouth

The latitude and longitude coordinate locations were supplied for the WDOE EIM data and other station information were approximated from CDA Tribe or other GIS supplied information. The CDA Tribe data had some notation such as the less than (<) symbol before the listed data. Values with a "less-than" (<) qualifier were entered as the value so that they could be compared to simulated data (i.e. "<0.3 cms" was set to "0.3 cms").

2.2.5 Point Sources

Point source input data were provided by CDA Tribe and WDOE from their Water Permit Life Cycle System (WPLCS) database and manual paper copies of daily water quality discharge monitoring reports from the following Waste Water Treatment Plants (WWTPs) identified in the watershed:

- Cheney
- Spangle
- Rockford
- Fairfield
- Tekoa
- Tensed

The WARMF model point sources included both TP and daily flow volume. TSS was determined to be negligible from the WWTPs and therefore no TSS point sources were included in the model. Many of the WWTP discharge permits do not require TP monitoring, so TP data were minimal. Only two stations, Cheney and Spangle, had TP data recorded. TP data for *Rockford*, *Fairfield*, and *Tekoa* were taken from the "The Hangman (Latah) Creek Water Quality Summary", WDOE Public Data File No. 05-01, March 2005, p. 12. The point source data were provided on a monthly or sporadic interval instead of the daily time-step used by WARMF. WARMF simulates the point sources during days with missing data as equal to the most recent measurements; therefore more data could significantly improve the model results.

Total phosphorus data were recorded in milligrams per liter (*mg/l)* and WARMF point source input required the units to be kilograms per day (*kg/D)*. The following conversion was used:

$$[\text{Discharge}]\left[\frac{\cancel{m^3}}{\cancel{s}}\right][\text{Total Phosphorus}]\left[\frac{\cancel{mg}}{\cancel{L}}\right]\left[\frac{1000\cancel{L}}{\cancel{m^3}}\right]\left[\frac{86400\cancel{sec}}{day}\right]\left[\frac{kg}{1x10^6\cancel{mg}}\right]=$$

$$[\text{Discharge}][\text{Total Phosphorus}]\left[86.4\frac{kg}{day}\right]$$

Figure 2 shows the point source locations and where they were input in the WARMF river segments.

2.2.6 Subcatchment and River Segment Parameters

In addition to the time-series data described above, WARMF included parameter inputs for each of the subcatchments and river segments. These inputs are summarized below.

Subcatchment Parameters

Physical Data - Width

The width of the subcatchment is the representative width parallel to the length of the river banks. Therefore, the length of each river segment in each subcatchment has been doubled to represent the length of the banks on either side of the river segment. This accounts for a hydrologic flowpath on each river bank for each subcatchment.

Soil Layers

Thickness, Field Capacity, Initial Moisture, Saturated Moisture, and Horizontal and Vertical Conductivity were estimated for three soil layers based on soil series data obtained from the United States Department of Agriculture Conservation Survey (USDA-NRCS) (http://soildatamart.nrcs.usda.gov/Default.aspx). Initial estimates for these parameters were calculated for each subcatchment by using ArcGIS to union the soil series map layers and associated soil properties with the subcatchment layer.

These average values were input into the WARMF GUI for each subcatchment. Original estimates were modified during the calibration process as discussed in **Section 3**. Table 2 lists the range of baseline soil properties in order of greatest sensitivity to least that were input into the WARMF model prior to calibration. The table also compares the baseline ranges to a refined range after final calibration of the 5 watershed areas and their associated catchments.

Sediment

Soil Erosivity Factor (Kw) and Surface Particle Content were estimated for each subcatchment using the same approach described above. These parameters, shown in **Table 3,** were input into WARMF for each subcatchment and unchanged during model calibration.

River Segment Parameters

In addition to Point Source information, river segments in WARMF required the following sediment information input for each river segment:

- Initial Sediment Depth, m
- Bed Diffusion Rate, m^2/d
- Detachment Velocity Multiplier
- Detachment Velocity Exponent
- Vegetation Factor
- Bank Stability Factor
- Bed Particle Contact (%)

The initial sediment depth within the stream was taken to be 1m in near the mouth of the Hangman (Latah) Creek, 0.5m in the canyon areas, and 1.5m in the Palouse areas. These values were based on information for river segments described in "Spokane County Proper Functioning Condition Stream Inventory and Assessment" (SCCD 2005) and the "Latah Creek Instream Flow Study" (Hardin-Davis, Inc. 2003).

The Bed Diffusion Rate was left as the default parameter of 0.0002 m^2/d based on WARMF guidelines. The Detachment Velocity Multiplier was left as the default values of $1x10^{-6}$. The Detachment Velocity Exponent was used as a calibration parameter and adjusted between a value of 1 and 2.

The Vegetation and Bank Stability Factors were used as calibration parameters. Initial values were developed based on the length and height of erosion along each river segment and photos provided in the "Spokane County Proper Functioning Condition Stream Inventory and Assessment" (SCCD, 2005). All river segments without documented erosion problems were given a value of 0 for both riverbank erosion factors.

CDM input values for the Bed Particle Content into WARMF based on properties found in the interactive online NRCS Web Soil Survey. Each river segment was found in the online interactive map and the adjacent surface soils data tables were extracted.

The predominant surface soil (or in some cases predominant surface *soils*, if more than one had about an equal percentage) were used. The Soil Survey also provided the clay content of that soil. Soil unit information was compared to the Soil Texture Classification triangle, for a rough estimate of the fractions of clay, silt, and sand in the predominant soil(s). These values were also compared to the surrounding soil in each subcatchment and the sand and silt values were adjusted slightly in some cases. **Table 4** shows the sediment parameters input for each stream segment in the WARMF model.

Section 3
Hangman (Latah) Creek TMDL Model Calibration

3.1 WARMF Model Calibration Overview

Calibration involves minimization of deviation between measured field conditions and model output by adjusting parameters of the model. Data required for this step are a set of known input values along with corresponding field observation results. If the model is calibrated properly, the model predictions will be acceptably close to the field predictions. However, the capability of any model to accurately depict water quality conditions is directly related to the accuracy of input data and the accuracy and completeness of observed data available for comparison. Model calibration is critical for using the Hangman (Latah) Creek WARMF model (HCWM) in predicting water quality when addressing future changes or improvements to current water quality conditions throughout the watershed.

The HCWM was calibrated based on available existing data and will be explained throughout the remainder of this section. For the hydrology calibration, simulated average daily flows were compared to historical average daily flows and model parameters were adjusted accordingly so that there was a close match between observed and predicted flows. For the water quality calibration, observed total phosphorus and total suspended sediment concentrations were compared to what the HCWM predicted and model parameters were adjusted accordingly to achieve a acceptable match between observed and predicted concentrations.

3.2 Hydrology Calibration

The purpose of the hydrology calibration is to develop a model that predicts runoff similar to historical data in the watershed during a variety of climactic conditions. Hydrologic calibration is critical for any further use of the model for subsequent water quality predictions and TMDL analyses. The period of time for the calibration simulation includes the water years of 1998 through 2005 (Oct 1 to Sep 30).

Five stations were selected for hydrology calibration based on sufficient quantity and spatial distribution of the data. The locations WARMF model hydrology calibration focused on are listed below in upgradient order within the watershed.

Hangman Creek at the Mouth

Hangman Creek at Duncan

Rock Creek at the Mouth

Hangman Creek at Bradshaw Road

Hangman Creek at Tekoa

Despite the absence of calibration for other upper watershed stations with less data that were provided by the client/stakeholder group, CDM has input these data into the final HCWM for future calibration efforts as discussed in Sections 2 and **4**.

3.2.1 Hydrology Calibration Locations

In order to calibrate the HCWM to observed hydrology, the simulated and observed river flows were compared at the five gauging stations listed above. **Figure 2** shows the USGS stream flow gage location at the mouth and the four SCCD gauging stations selected for calibration. **Figure 2** also shows stations with data provided by the client/stakeholder group that were input into the final HCWM, but not calibrated. The period of record for each gage is detailed in **Appendix A**.

3.2.2 Hydrology Calibration Parameters

Provided below is a discussion of the WARMF model parameters that were modified so that HCWM predicted, or modeled stream flow, matched observed stream flow throughout the watershed. Calibration parameters provided by the WARMF software are either applied to the entire watershed or on a subcatchment basis. The parameters that were modified for the entire watershed include:

- *Open Area Melting Rate* – the rate at which snow melts in that fraction of each land use that is open in winter
- *Forested Area Melting Rate* – the rate at which snow melts in that fraction of each land use that is not open in winter
- *Snow Melting Temperature* – the temperature at which snow melts (+/- 2° C)

The snow melt coefficients listed above are what control the shape of the hydrograph during snow melt periods (early spring). Higher melting rates and lower snow melting temperatures result in higher peaks and steeper recessional limbs following the wet season.

In addition to the parameters that were applied to the entire watershed, the following subcatchment specific parameters were modified for the hydrology calibration.

- *Average Temperature Lapse* – the average amount subtracted from the temperature in the meteorological file to account for regional variations in temperature due to orographic effects
- *Detention Storage* – the percent of surface water that is not available for surface runoff because it is stored within the watershed

- *Soil Layer Thickness* – the average thickness of each of the three soil layers
- *Initial Soil Moisture* – the initial volume fraction of water in each soil layer
- *Soil Moisture Field Capacity* – the volume fraction of water in each soil layer that does not flow out of the soil
- *Soil Saturation Moisture* – the maximum volume fraction of water in each soil layer
- *Horizontal Hydraulic Conductivity* – the ratio of velocity to hydraulic gradient and indicates the permeability of the soil
- *Root Zone Distribution* – the ratio of plant roots and associated soil water transpiration between the different soil layers

Generally, more flashy hydrographs are developed by reducing the volume of storage available within the soil layers, therefore reducing soil layer thickness resulted in higher peak flows. Similarly, reducing the available water content (AWC), the difference between the field capacity and saturated moisture content, increased runoff volumes, by reducing the amount of water stored in the soil layers that is available for plant transpiration. Vertical hydraulic conductivity in the surface soil layer is very low, as shown by the SSURGO data and in discussions with WDOE staff. Reducing this parameter also contributed to flashier hydrologic simulation results.

3.2.3 Hydrology Calibration Results

In order to assess the hydrology calibration efforts, calculations were completed for each calibration location of basic statistics and several different error measures, including relative error (RE), root mean square error (RMSE), and two measures of fit (Nash, 1970; McMahon, 1994), referred to as NS and MH, respectively. The following equations show how the different error measures use the simulated (x) and observed (c) hydrographs to assess the accuracy of the calibration for (n) timesteps:

$$RE = \frac{\sum (x - c)}{n}$$

Table 5 present summary statistics from each calibrated subwatershed including

$$RMSE = \sqrt{\frac{\sum (x - c)^2}{n}}$$

mean daily flow, maximum daily flow, and distribution of runoff volume by season

$$NS = 1 - \left(\frac{\sum (x - c)^2}{\sum (c - \bar{c})^2} \right)$$

and weather condition, and error measures including RE, RMSE, NS, and MH to

$$MH = 1 - \left(\frac{\sum \left(\sqrt{x} - \sqrt{c} \right)^2}{\sum (\sqrt{c} - \sqrt{\bar{c}})^2} \right)$$

portray the accuracy of the hydrologic calibration.

Hydrology calibration results are presented for Hangman (Latah) Creek watershed at the mouth and the four upstream locations. **Figure 3** shows the cumulative runoff volume of simulated and observed runoff for each of the calibration locations. This calibration result shows that model is able to estimate runoff volumes for long term simulations, including multiple years with varying climactic conditions. **Figure 4** includes annual time series plots of simulated and observed daily runoff for each year in the calibration period for each of the calibration locations..

Figures 3 and 4 show a good correlation between average daily observed flow and average daily calibrated flow (top graph in each figure). In general, the model predicts periods of high flow and low flow well. Simulated cumulative runoff volume is slightly lower than the observed conditions before 2001 and slightly higher in more recent years.

3.2.4 WARMF Parameter Sensitivity Summary

The impact of changes to different parameters on the accuracy of the hydrologic calibration can be determined by performing a model sensitivity analysis. There are many different approaches to conducting a sensitivity analysis of wide ranging complexity. For the HCWM, a qualitative sensitivity analysis was performed by evaluating changes in mean daily flow, maximum daily flow, and goodness of fit measures resulting from different parameter sets. The sensitivity analysis showed that the most sensitive parameters in the HCWM were the soil layer thickness and saturated moisture content. The sensitivity analysis revealed that simulated wet weather runoff rates are predominantly controlled by saturation excess surface runoff, whereby the soil storage capacity is exceeded and additional rainfall over pervious areas generates overland flow. When the layer thickness and soil water holding capacity parameters are decreased, simulated event flows are increased. Groundwater exfiltration from the soil layers provides a greater fraction of runoff during inter-event periods.

Field capacity and initial moisture were identified as moderately sensitive parameters. Soil layer thickness and water holding capacity parameters (field capacity, saturated moisture) provided the model with increased storage in the soil, which tended to attenuate peak flow. Large storage volumes in the soil layers also resulted in more baseflow. Based on observations at the USGS gauge, the flashy character of this watershed was best approximated by setting the soil layer thickness slightly lower than the SSURGO data suggested.

The surface runoff parameters for overland flow roughness and detention storage were relatively insensitive, showing very little impact upon the simulation results. The daily time step of the WARMF hydrologic model limits the precision of overland

flow estimates. However, these parameters may be much more sensitive for short term single storm event simulations requiring a smaller time step.

The vertical and horizontal hydraulic conductivity parameters did not significantly impact simulation results, with exception to the first soil layer. Vertical conductivity into the first soil horizon was a parameter that controlled infiltration excess over pervious areas. Since the soils in the Hangman (Latah) Creek watershed are known to have a very hard surface horizon, this parameter was able to be adjusted to levels were it can be highly sensitive (<200 cm/d).

3.3 Water Quality Calibration

3.3.1 Total Suspended Solids

Total Suspended Solids concentrations increase during runoff events due to erosion of surface soils in subcatchments and well as increased scour of stream beds and banks. Erosion of soils from the upstream watershed is a function of land use type and the soil erosivity parameter. The soil erosivity for each subcatchment was determined by averaging the SSURGO data for the different soil series. This was not changed during water quality calibration.

Soil erosion parameters related to land use types are include rainfall detachment, flow detachment, and cropping factors. Higher values for these parameters indicate a greater potential for soil particle detachment from the land surface. The cropping factor was used as the primary TSS calibration parameter. This factor can be varied by month of the year for different land use types, and therefore higher erosion rates during periods of greater exposed soil conditions can be simulated. Also, it has been found that erosion increases when soils are frozen due to greater channelization of overland flow within rills (Froese et. al., 1999). This was accounted for by assigning a relatively higher cropping factor during the winter months.

Higher concentrations of TSS have been observed in the lower reaches of Hangman Creek in relation to the upper watershed, due to significant stream bed and bank scour. The model accounts for this process as a function of streamflow velocity, particle size, and several calibration coefficients. Streambed scour is simulated as a power function of the velocity above the critical particle shear velocity. The coefficient and exponent in this function were adjusted to simulate increased bed scour in the lower reaches of Hangman Creek. Channel bank scour is a function of average daily streamflow velocity raised to the third power. The coefficient in this function was also employed as a calibration parameter to increase simulated TSS concentrations in the lower reaches of Hangman Creek.

3.3.2 Total Phosphorus

Total Phosphorus concentrations are highly correlated to simulated TSS due to adsorption of phosphate onto sediment within subcatchments. The adsorption

isotherm parameters control this process. During dry weather, TP concentrations in stream are controlled primarily by wastewater treatment plant effluent, septic systems, and leaching from the soil matrix. The initial soil water phosphate concentration was used as a calibration parameter and was found to impact dry weather concentrations for the entire period of record. A constant concentration of 3 mg/l was estimated for septic system effluent and actual WWTP effluent data from several plants was used to simulate this TP input to Hangman Creek

3.3.3 Results

Figures 5 and 6 show a time series of simulated and observed TSS and TP at the mouth of Hangman Creek, respectively. TSS results are shown on a logarithmic scale due to the wide range of values. Generally, the simulated TSS and TP concentrations are comparable to observed values at the mouth of Hangman Creek. Calibration of TSS and TP at four other locations upstream of this location was conducted; however time series plots are not included due to the very small size of the observed sample data sets.

To compare the results of the water quality calibration for different hydrologic conditions, a sliding interval baseflow separation data analysis tool was employed (**Figure 7**). Days when event driven runoff was 30% or greater than the baseflow fraction were classified as "wet". All other days were considered "dry" or representative of baseflow conditions. The simulation results are compared to observed values for wet and dry conditions for each of the five calibration locations in box and whisker plots for both TSS and TP (**Figures 8 and 9**).

Based on this initial WARMF model development and calibration, the distribution of pollutant sources for TSS and TP in each of the five calibrated subwatersheds are summarized in **Table 6**. This distribution of sources, including subcatchment land uses, septic systems, WWTPS, and other in-stream source categories can be modified by adjusting WARMF parameters following additional source characterization studies in the Hangman (Latah) Creek watershed. This water quality modeling effort found the greatest sources of TSS in the watershed to be agricultural runoff from the upper watersheds, and in stream bed and bank scour primarily simulated in the lower reaches of Hangman Creek. TP loads were primarily attributed to agricultural runoff as well as septic systems, WWTPs, runoff from residential landscape areas, natural soil leaching in coniferous forest areas and stream bank erosion.

3.4 Calibration Summary

Accurate input data and field measurements are important to model calibration.

There is uncertainty in both of these items and it is not possible to achieve a close match at all locations at all times. The current HCWM model should be considered a work in progress and while the model is adequately set up to evaluate potential

scenarios within the watershed, further data collection efforts and calibration refinement are needed in the near future. Specific areas of improvement identified during this model development and calibration effort are discussed in the following section.

Section 4
Hangman (Latah) Creek TMDL Model Recommendations and Future Scenarios

This section discusses data gaps in the model and provides recommendations for collecting information to refine the WARMF model for future TMDL management scenarios.

4.1 Data Gaps

Although the objective to develop a preliminary model for determining the loading and delivery of phosphorus and sediment from the Hangman (Latah) Creek watershed to its discharge into the Spokane River has been achieved, by addressing the following data gaps, the Hangman (Latah) Creek Watershed client/stakeholder group will be able to further the functionality of the TMDL model. Current data gaps include:

- Lack of current and future land use data for entire watershed;
- Incomplete meteorological data records in the upper watershed in comparison with the data available near the mouth;
- Lesser amount of observed water quality monitoring data for tributaries within the upper watershed in comparison to the data available near the mouth;
- Inclusion of the periphyton module to address observed phosphorus assimilation;
- Insufficient phosphorus loading data from WWTPs located in the watershed.

The portions of the watershed missing recent land use information are in the upper southwest portions of the watershed. Because this land use has not drastically changed since the 1992 survey, this gap in recent land use is not as critical as other areas at this time.

Future land use coverage can be prepared using local Land Use Plans or zoning maps to estimate urbanization in the watershed. Agricultural agencies can typically provide estimates of future crop acreages and cropping practices.

As explained in **Section 3,** the HCWM under predicts periods of high and low flow well at the mouth when compared to observed historical flow. Further refinement and calibration of the upper SCCD and CDA station data may require additional analysis and interpolation of missing meteorological data in the upper watershed. Inclusion of a dry weather run-off module or modifying the HCWM to include runoff from irrigation in urban areas should eliminate this condition.

The amount of observed water quality data for Hangman Creek is greater in downstream portions of the watershed (at the mouth) than in the upstream portions. While the amount of data is sufficient for this preliminary model development and calibration effort, as the TMDL stakeholder group begins to assess how to utilize the HCWM to initiate development of TMDLs within the watershed, more specific data collection in specific areas of the watershed will be required. If the model is to be used for just one tributary within the watershed, more spatial data within the single tributary may be necessary for a more refined calibration of the HCWM in the areas of concern.

4.2 Model Maintenance

The following model maintenance and updates are recommended:

- Run a meteorological model such as CLIDATA to interpolate and synthesize missing meteorological records in the upper watershed.
- Increase monitoring frequency (possibly instrument) of WWTP discharge and phosphorous concentration.
- Further calibration of Total Phosphorus
- Incorporation of periphyton module to address observed phosphorus assimilation during dry weather periods
- Incorporate a more accurate estimate of septic system distribution between the subcatchments
- Development of the TMDL module and assigning water quality limited segments

4.3 Future Scenarios

After fulfilling the recommended model maintenance tasks, the WARMF model may be used for future scenarios to determine loads of TSS and TP within the Hangman (Latah) Creek watershed. Three scenarios to evaluate may include:

- Changing land use
- Changes in watershed management due to various BMP implementation
- Increase of point source discharges

Section 5
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Tables

Table 1
Land Use by Subcatchment

Subcatchment		Land Cover																				Grand Total
		11	21	22	23	24	31	41	42	43	51	52	71	81	82	83	84	90	91	92	95	
		Open Water	Developed, Open Space	Developed, Low Intensity	Developed, Medium Intensity	Developed, High Intensity	Barren Land	Deciduous Forest	Evergreen Forest	Mixed Forest	Dwarf Scrub	Scrub/Shrub	Grasslands/Herbaceous	Pasture/Hay	Row Crops	Small Grains	Fallow	Woody Wetlands	Palustrine Forested Wetland	Palustrine Scrub/Shrub	Emergent Herbaceous Wetland	
1	Acres	1	1,436	2,545	548	123			1,664			510	1,732	213	105			4			10	8,892
	Percent of Total	0.0%	16.1%	28.6%	6.2%	1.4%			18.7%			5.7%	19.5%	2.4%	1.2%			0.0%			0.1%	100%
2	Acres		414	674	35		1		3,525			947	1,553	117	414						15	7,695
	Percent of Total		5.4%	8.8%	0.5%		0.0%		45.8%			12.3%	20.2%	1.5%	5.4%						0.2%	100%
3	Acres	8	658	1,469	406	1	1	1	6,761			2,530	3,932	307	2,149			16			47	18,285
	Percent of Total	0.0%	3.6%	8.0%	2.2%	0.0%	0.0%	0.0%	37.0%			13.8%	21.5%	1.7%	11.8%			0.1%			0.3%	100%
4	Acres	8	275	255	29		1	0	4,731	17	990	1,121	2,650	59	3,454	1,802	537		2		17	15,947
	Percent of Total	0.1%	1.7%	1.6%	0.2%		0.0%	0.0%	29.7%	0.1%	6.2%	7.0%	16.6%	0.4%	21.7%	11.3%	3.4%		0.0%		0.1%	100%
5	Acres	167	432	1,027	564	58	2		6,785			2,516	4,060	977	5,608			70			351	22,618
	Percent of Total	0.7%	1.9%	4.5%	2.5%	0.3%	0.0%		30.0%			11.1%	18.0%	4.3%	24.8%			0.3%			1.6%	100%
6	Acres		181	103	0				1,160			1,138	1,364	53	2,407			2			1	6,409
	Percent of Total		2.8%	1.6%	0.0%				18.1%			17.8%	21.3%	0.8%	37.6%			0.0%			0.0%	100%
7	Acres	1	33	61	30		2	1	1,176	3	67	491	582	91	336	18	4		0	0	2	2,900
	Percent of Total	0.0%	1.1%	2.1%	1.0%		0.1%	0.0%	40.5%	0.1%	2.3%	16.9%	20.1%	3.2%	11.6%	0.6%	0.2%		0.0%	0.0%	0.1%	100%
8	Acres	2	178	40	111			1	3,312	6	506	939	787		1,846	5,510	1,437	5	2		5	14,686
	Percent of Total	0.0%	1.2%	0.3%	0.8%			0.0%	22.6%	0.0%	3.4%	6.4%	5.4%		12.6%	37.5%	9.8%	0.0%	0.0%		0.0%	100%
9	Acres	0	9	7	17		0		388	3	318	141	441	35	11	13	14		2			1,398
	Percent of Total	0.0%	0.6%	0.5%	1.2%		0.0%		27.7%	0.2%	22.7%	10.1%	31.5%	2.5%	0.8%	1.0%	1.0%		0.1%			100%
10	Acres	4	2		3		0	0	163	2	207		88	85		20	14		1	1		591
	Percent of Total	0.6%	0.3%		0.5%		0.0%	0.1%	27.6%	0.4%	34.9%		14.9%	14.3%		3.5%	2.4%		0.2%	0.1%		100%
11	Acres	17	14	19	102		7	0	7,142	19	1,062	1,783	4,326	618	939	736	619	27	1		70	17,503
	Percent of Total	0.1%	0.1%	0.1%	0.6%		0.0%	0.0%	40.8%	0.1%	6.1%	10.2%	24.7%	3.5%	5.4%	4.2%	3.5%	0.2%	0.0%		0.4%	100%
12	Acres	13	110		193		1	1	538	2	1,272		701	20		6,408	2,723		1	0		11,984
	Percent of Total	0.1%	0.9%		1.6%		0.0%	0.0%	4.5%	0.0%	10.6%		5.8%	0.2%		53.5%	22.7%		0.0%	0.0%		100%
13	Acres	31	201	12	202		4	3	2,394	128	2,428	375	1,114	199	662	17,004	3,734	1	13	0		28,505
	Percent of Total	0.1%	0.7%	0.0%	0.7%		0.0%	0.0%	8.4%	0.4%	8.5%	1.3%	3.9%	0.7%	2.3%	59.7%	13.1%	0.0%	0.0%	0.0%		100%
14	Acres	3	309	200	239		1	3	4,024	131	1,228	1,845	365	13	4,164	11,343	4,462	31	2		70	28,432
	Percent of Total	0.0%	1.1%	0.7%	0.8%		0.0%	0.0%	14.2%	0.5%	4.3%	6.5%	1.3%	0.0%	14.6%	39.9%	15.7%	0.1%	0.0%		0.2%	100%
15	Acres	2	79		28		0	0	42	5	163		48			1,131	351					1,850
	Percent of Total	0.1%	4.3%		1.5%		0.0%	0.0%	2.3%	0.3%	8.8%		2.6%			61.1%	19.0%					100%
16	Acres	29	3		90		1	4	953	39	2,929		1,180	651		10,134	3,036		4	1		19,052
	Percent of Total	0.2%	0.0%		0.5%		0.0%	0.0%	5.0%	0.2%	15.4%		6.2%	3.4%		53.2%	15.9%		0.0%	0.0%		100%
17	Acres	0			36			0	22	5			17			3,280	1,333					4,694
	Percent of Total	0.0%			0.8%			0.0%	0.5%	0.1%			0.4%			69.9%	28.4%					100%
18	Acres	0	55	18	94			1	1,532	10	167	353	53	5	1,198	5,943	4,322	14			5	13,771
	Percent of Total	0.0%	0.4%	0.1%	0.7%			0.0%	11.1%	0.1%	1.2%	2.6%	0.4%	0.0%	8.7%	43.2%	31.4%	0.1%			0.0%	100%
19	Acres	4	134		157			1	12	1	99		59			5,879	2,466					8,812
	Percent of Total	0.0%	1.5%		1.8%			0.0%	0.1%	0.0%	1.1%		0.7%			66.7%	28.0%					100%
20	Acres	3	113		292		3	3	211	39	1,111		419			16,772	7,985		0			26,951
	Percent of Total	0.0%	0.4%		1.1%		0.0%	0.0%	0.8%	0.1%	4.1%		1.6%			62.2%	29.6%		0.0%			100%
21	Acres	1	17	10	208			1	1,385	223	576	47	87	4	1,056	12,142	6,470	7				22,234
	Percent of Total	0.0%	0.1%	0.0%	0.9%			0.0%	6.2%	1.0%	2.6%	0.2%	0.4%	0.0%	4.7%	54.6%	29.1%	0.0%				100%
22	Acres	3	251	50	120		3	7	4,358	826	417	1,595	451	94	3,167	7,141	4,186	4		0	38	22,711
	Percent of Total	0.0%	1.1%	0.2%	0.5%		0.0%	0.0%	19.2%	3.6%	1.8%	7.0%	2.0%	0.4%	13.9%	31.4%	18.4%	0.0%		0.0%	0.2%	100%
23	Acres		55		68			3	875	134	789		397			4,509	941					7,770
	Percent of Total		0.7%		0.9%			0.0%	11.3%	1.7%	10.1%		5.1%			58.0%	12.1%					100%
24	Acres		210	56	60			1	4,633	1	0	1,330	58	31	3,716	3,771	2,458	40			70	16,436
	Percent of Total		1.3%	0.3%	0.4%			0.0%	28.2%	0.0%	0.0%	8.1%	0.4%	0.2%	22.6%	22.9%	15.0%	0.2%			0.4%	100%
25	Acres	0	103		55			1	11	5	41		52			1,141	387					1,796
	Percent of Total	0.0%	5.7%		3.1%			0.1%	0.6%	0.3%	2.3%		2.9%			63.5%	21.5%					100%
26	Acres	2	46		92			2	50	5	941		250			4,720	1,672			0		7,781
	Percent of Total	0.0%	0.6%		1.2%			0.0%	0.6%	0.1%	12.1%		3.2%			60.7%	21.5%			0.0%		100%
27	Acres	1	103		130			2	73	13	7					7,171	4,695					12,195
	Percent of Total	0.0%	0.8%		1.1%			0.0%	0.6%	0.1%	0.1%					58.8%	38.5%					100%
28	Acres	2	52	24	13		1		1,642			391	19	8	1,810	1,778	977	38			16	6,772
	Percent of Total	0.0%	0.8%	0.4%	0.2%		0.0%		24.3%			5.8%	0.3%	0.1%	26.7%	26.3%	14.4%	0.6%			0.2%	100%
29	Acres		291	114	37				5,439	27	3	1,267	102	3	5,298	2,009	1,617	33			96	16,339
	Percent of Total		1.8%	0.7%	0.2%				33.3%	0.2%	0.0%	7.8%	0.6%	0.0%	32.4%	12.3%	9.9%	0.2%			0.6%	100%
30	Acres		122	50				1	5,022			1,006	48	1	1,598			38			27	7,913
	Percent of Total		1.5%	0.6%				0.0%	63.5%			12.7%	0.6%	0.0%	20.2%			0.5%			0.3%	100%
31	Acres		141	112	3				1,350			606	83		3,098			54			110	5,557
	Percent of Total		2.5%	2.0%	0.1%				24.3%			10.9%	1.5%		55.8%			1.0%			2.0%	100%
32	Acres		189	65					3,131			2,119	62	6	1,162			36			31	6,801
	Percent of Total		2.8%	1.0%					46.0%			31.2%	0.9%	0.1%	17.1%			0.5%			0.5%	100%
33	Acres		157	29				2	4,944			2,614	759	11	1,292			81			104	9,993
	Percent of Total		1.6%	0.3%				0.0%	49.5%			26.2%	7.6%	0.1%	12.9%			0.8%			1.0%	100%
34	Acres		247	78				1	4,564			1,616	217	19	611			26			42	7,421
	Percent of Total		3.3%	1.1%				0.0%	61.5%			21.8%	2.9%	0.3%	8.2%			0.4%			0.6%	100%
35	Acres		186	41					9,784			2,386	471	4	157			37			51	13,119
	Percent of Total		1.4%	0.3%					74.6%			18.2%	3.6%	0.0%	1.2%			0.3%			0.4%	100%
36	Acres	2	4		23			1	199	4	1,097		241	5		2,049	737		4			4,365
	Percent of Total	0.0%	0.1%		0.5%			0.0%	4.5%	0.1%	25.1%		5.5%	0.1%		46.9%	16.9%		0.1%			100%

Table 2. Comparison between original and modified soil parameters used in Hangman (Latah) Creek WARMF TMDL model.

Sensitivity: Greatest ← → Least

Subwatershed Name	Subcatchment IDs in each Subwatershed	Soil Layer	Soil Thickness (cm)			Saturation Moisture			Field Capacity			Hydraulic Conductivity (cm/day)		AWC		Hydraulic Conductivity (µm/s)		Horizontal Hydraulic Conductivity (cm/day)	Vertical Hydraulic Conductivity (cm/day)
			Precalibration Ranges (SSURGO)[1]		Final Calibration [2]	Precalibration Ranges (SSURGO)[1]		Final Calibration [2]	Precalibration Ranges (SSURGO)[1]		Final Calibration [2]	Precalibration Ranges (SSURGO)[3]		Final Calibration [2]				Final Calibration [2]	Final Calibration [2]
			Min	Max		Min	Max		Min	Max		Min	Max	Min	Max	Min	Max		
Hangman Creek at Mouth	1, 2, 3, 4, 5, 6, 7, 9, 11, 12	1	8	152	11	0.21	0.65	0.48	0.01	0.47	0.37	26	795	0.07	0.60	3	92	200	200
		2	0	144	23	0.13	0.64	0.45	0.00	0.46	0.36	8	2592	0.04	0.60	0.91	300	240	375
		3	0	119	37	0.14	0.63	0.44	0.09	0.45	0.32	8	2592	0.04	0.33	0.91	300	200	200
Hangman Creek at Duncan	16, 19, 36, 10	1	8	152	12	0.21	0.65	0.45	0.01	0.44	0.32	26	242	0.07	0.30	3	28	110	450
		2	0	124	21	0.17	0.64	0.49	0.05	0.46	0.30	8	242	0.07	0.25	0.91	28	240	500
		3	0	119	75	0.14	0.62	0.54	0.09	0.42	0.30	8	2592	0.05	0.25	0.91	300	40	80
Rock Creek at Mouth	8, 13, 14, 15, 17, 18, 21	1	8	152	12	0.21	0.67	0.54	0.01	0.47	0.40	26	795	0.02	0.30	3	92	300	150
		2	0	137	40	0.14	0.64	0.45	0.05	0.46	0.33	2	795	0.02	0.25	0.21	92	2800	1100
		3	0	127	55	0.16	0.49	0.50	0.08	0.33	0.32	26	2592	0.03	0.25	3	300	110	227
Hangman Creek at Bradshaw	20, 23	1	8	99	10	0.21	0.63	0.52	0.12	0.40	0.41	26	78	0.07	0.30	3	9	120	70
		2	13	119	12	0.17	0.64	0.55	0.08	0.41	0.35	8	242	0.09	0.25	0.91	28	200	300
		3	0	119	25	0.14	0.62	0.50	0.05	0.42	0.35	8	2592	0.05	0.25	0.91	300	200	340
Hangman Creek at Tekoa	22, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35	1	3	109	12	0.21	0.67	0.57	0.05	0.48	0.33	24	795	0.02	0.30	2.82	92	55	40
		2	13	137	43	0.11	0.64	0.55	0.03	0.46	0.31	2	795	0.02	0.25	0.21	92	470	400
		3	0	127	106	0.11	0.49	0.50	0.00	0.38	0.28	2	793	0.03	0.25	0.21	91.74	300	200

[1] Initial precalibration ranges were averaged for each subcatchment.
[2] Final calibration includes grouping of subcatchments into five subwatersheds.
[3] Hydraulic Conductivity values from SSURGO were listed as Saturdated Hydraulic Conductivity (Ksat). These values were applied to both the horizontal (Kh) and vertical (Kv) conductivity inputs into the WARMF model.

Table 3
WARMF Subcatchment Sediment Input Parameters

Subcatchment ID	Sand (%)	Silt (%)	Clay (%)	Kw
1	45	43	12	0.26
2	48	39	13	0.24
3	44	42	14	0.27
4	42	44	14	0.25
5	28	52	20	0.32
6	38	46	16	0.3
7	54	36	10	0.24
8	34	50	16	0.29
9	42	43	15	0.24
10	45	42	13	0.27
11	31	50	19	0.27
12	22	56	22	0.31
13	25	56	19	0.33
14	18	62	20	0.35
15	22	59	19	0.33
16	21	57	22	0.32
17	16	61	23	0.32
18	18	60	22	0.34
19	15	60	25	0.32
20	15	60	25	0.35
21	18	60	22	0.36
22	16	62	22	0.4
23	25	52	23	0.26
24	14	62	24	0.39
25	14	62	24	0.36
26	15	61	24	0.34
27	11	63	26	0.38
28	14	63	23	0.38
29	16	61	23	0.4
30	22	60	18	0.39
31	17	62	21	0.41
32	20	61	19	0.42
33	24	58	18	0.36
34	26	58	16	0.37
35	24	59	17	0.37
36	30	50	20	0.3

Table 4
WARMF River Segment Sediment Input Parameters

Name	River	Clay	Silt	Sand	Initial Sediment Depth (m)	Initial Bank Stability Values	Soil Type	
Hangman Creek Mouth	634	10	25	65	1	0.0020	McB	Loamy Sand
Marshall Creek	635	5	35	60	1	0.0003	MaC, McB	Loamy Sand
Stevens Creek	636	6	34	60	1	0.0003	PsA	Sandy Loam
Hangman Creek	637	5	30	65	1	0.0027	PsA, SzE	Sandy Loam
Hangman Creek	638	12	43	45	1	0.0015	SoE	Speigle very stony silt loam
California	639	12	48	40	1	0.0003	BfD, HvD	Bernhill Very Stony Silt Loam
Hangman Creek	640	15	45	40	0.5	0.0010	HxC, NcA	
Hangman Creek	641	15	45	40	0.5	0.0010	HxC, NcA	
Marshall Creek	642	10	10	80	1	0.0003	HvC, HxC, MaC	Rocky Complex and Loamy Sand
Marshall Creek	643	11	49	40	1	0.0003	HsB	
Mica Creek	644	15	55	30	1.5	0.0003	NcA, BfD	Silt Loam
Rock Creek mouth	645	12	48	40	0.5	0.0030	HvD, BfD	
Rock Creek	646	20	65	15	1.5	0.0003	Ca	Silt Loam
Spangle Creek	647	15	45	40	0.5	0.0003	HsB (Hesseltine stony silt loam), Ca (Caldwell silt Loam)	
Rock Creek	648	22	65	13	1.5	0.0003	Ca	Silt Loam
North Fork Rock Creek	649	20	65	15	1.5	0.0003	Ca, NcA	Silt Loam
Rock Creek/Rose Creek	650	22	65	13	1.5	0.0003	Cald, Cald-Thatuna	Silt Loam
Hangman Creek	651	15	65	20	0.5	0.0007	HvD, NcA	Silt Loam
Rattler Run	652	20	60	20	1.5	0.0003	PcE (Palouse Very Rocky), Ca (Caldwell)	Silt Loam
Rock Creek	653	22	60	18	1.5	0.0003	Ca, NaC (Naff Silt Loam)	Silt Loam
Hangman Creek	654	21	69	10	1.5	0.0005	Caldwell and Naff	Silt Loam
Cove Creek	655	21	59	20	1.5	0.0003	Caldwell and Naff	
Little Hangman	656	22	65	13	1.5	0.0003	Cald Silt Loam	
Moctileme Creek	657	22	65	13	1.5	0.0003	Cald Silt Loam	
Hangman Creek	658	22	65	13	1.5	0.0004	Ca	
Little Hangman	659	22	65	13	1.5	0.0003	Caldwell	
Lolo Creek	660	20	65	15	1.5	0.0003	Latahco, Latahco-Luvell Silt Loam	
Hangman Creek	661	22	65	13	1.5	0.0003	Cald Silt Loam	
Hangman Creek	662	21	65	14	1.5	0.0003	Cald, Latahco	
Hangman Creek	663	20	65	15	1.5	0.0003	Latahco-Luvell Silt Loam	
Mission Creek	664	20	65	15	1.5	0.0003	Latahco-Luvell Silt Loam	
Sheep Creek	665	10	70	20	1.5	0.0003	Porret and Moctileme Silt Loam	
Hangman Creek	666	8	65	27	1.5	0.0003	Moctileme Silt Loam	
Mineral/Smith Creek	667	8	65	27	1.5	0.0003	Moctileme Silt Loam	
Hangman Creek	668	15	65	20	1.5	0.0003	Porret Silt Loam	
Courtney Canyon	669	5	10	85	0.5	0.0003	BkD (Berhill Very Rock Complex)	

Table 5
WARMF Hydrology Calibration Summary Statistics

Hangman Creek at the Mouth

Evaluation Criteria	Simulated	Observed
Mean Daily Flow (cfs)	177	177
November to April	334	323
April to October	66	73
Maximum Day Flow (cfs)	5,086	5,440
Absolute Error	2.58	
Relative Error	0.01	
RMSE Error	6.45	
Nash-Sutcliff 1970 Criteria	68%	
McMahon 1994 Criteria	75%	

Hangman Creek at Duncan

Evaluation Criteria	Simulated	Observed
Mean Daily Flow (cfs)	120	120
November to April	209	216
April to October	57	52
Maximum Day Flow (cfs)	4,329	3,483
Absolute Error	2.09	
Relative Error	-0.01	
RMSE Error	5.71	
Nash-Sutcliff 1970 Criteria	51%	
McMahon 1994 Criteria	71%	

Hangman Creek at Rock Creek Mouth

Evaluation Criteria	Simulated	Observed
Mean Daily Flow (cfs)	41	41
November to April	82	83
April to October	11	12
Maximum Day Flow (cfs)	1,279	2,358
Absolute Error	0.85	
Relative Error	-0.02	
RMSE Error	2.81	
Nash-Sutcliff 1970 Criteria	39%	
McMahon 1994 Criteria	66%	

Hangman Creek at Bradshaw Road

Evaluation Criteria	Simulated	Observed
Mean Daily Flow (cfs)	77	79
November to April	144	147
April to October	30	31
Maximum Day Flow (cfs)	2,871	3,156
Absolute Error	1.59	
Relative Error	-0.04	
RMSE Error	4.09	
Nash-Sutcliff 1970 Criteria	52%	
McMahon 1994 Criteria	66%	

Hangman Creek at Tekoa

Evaluation Criteria	Simulated	Observed
Mean Daily Flow (cfs)	72	74
November to April	121	133
April to October	37	32
Maximum Day Flow (cfs)	2,900	3,130
Absolute Error	1.57	
Relative Error	-0.06	
RMSE Error	4.230	
Nash-Sutcliff 1970 Criteria	40%	
McMahon 1994 Criteria	57%	

Table 6
Distribution of Pollutant Sources for TSS and TP

Hangman Creek at the Mouth

Source Category	TSS (kg/d)	TP (kg/d)
Deciduous	0.6	0.00
Coniferous	5,430	3.76
Mixed Forest	84	0.25
Cropland / Pasture	36,700	15.80
Rangeland	7,450	3.07
Forested Wetland	9	0.02
Non-forested Wetland	15	0.02
Barren	5	0.00
Residential	3,200	1.18
Comm./Industrial	491	0.14
General Nonpoint Sources	3,050	0.00
Stream Bank Erosion	74,700	13.80
Type 1 Septic System	-	5.23
General Point Sources	-	6.93
TOTAL	131,134	50.20

Hangman Creek at Duncan

Source Category	TSS (kg/d)	TP (kg/d)
Deciduous	0.8	0.00
Coniferous	6,170	3.88
Mixed Forest	115	0.30
Cropland / Pasture	48,300	17.40
Rangeland	7,670	2.79
Forested Wetland	11	0.02
Non-forested Wetland	17	0.01
Barren	4	0.00
Residential	2,450	0.96
Comm./Industrial	637	0.16
General Nonpoint Sources	471	0.00
Stream Bank Erosion	739	0.12
Type 1 Septic System	-	5.96
General Point Sources	-	5.16
TOTAL	66,585	36.77

Hangman Creek at Rock Creek Mouth

Source Category	TSS (kg/d)	TP (kg/d)
Deciduous	0.2	0.00
Coniferous	1,880	1.30
Mixed Forest	40	0.10
Cropland / Pasture	25,400	11.30
Rangeland	3,120	1.43
Forested Wetland	3	0.00
Non-forested Wetland	7	0.00
Barren	0	0.00
Residential	1,360	0.62
Comm./Industrial	141	0.05
General Nonpoint Sources	6	0.00
Stream Bank Erosion	0	-
Type 1 Septic System	-	1.56
General Point Sources	-	2.14
TOTAL	31,958	18.51

Hangman Creek at Bradshaw Road

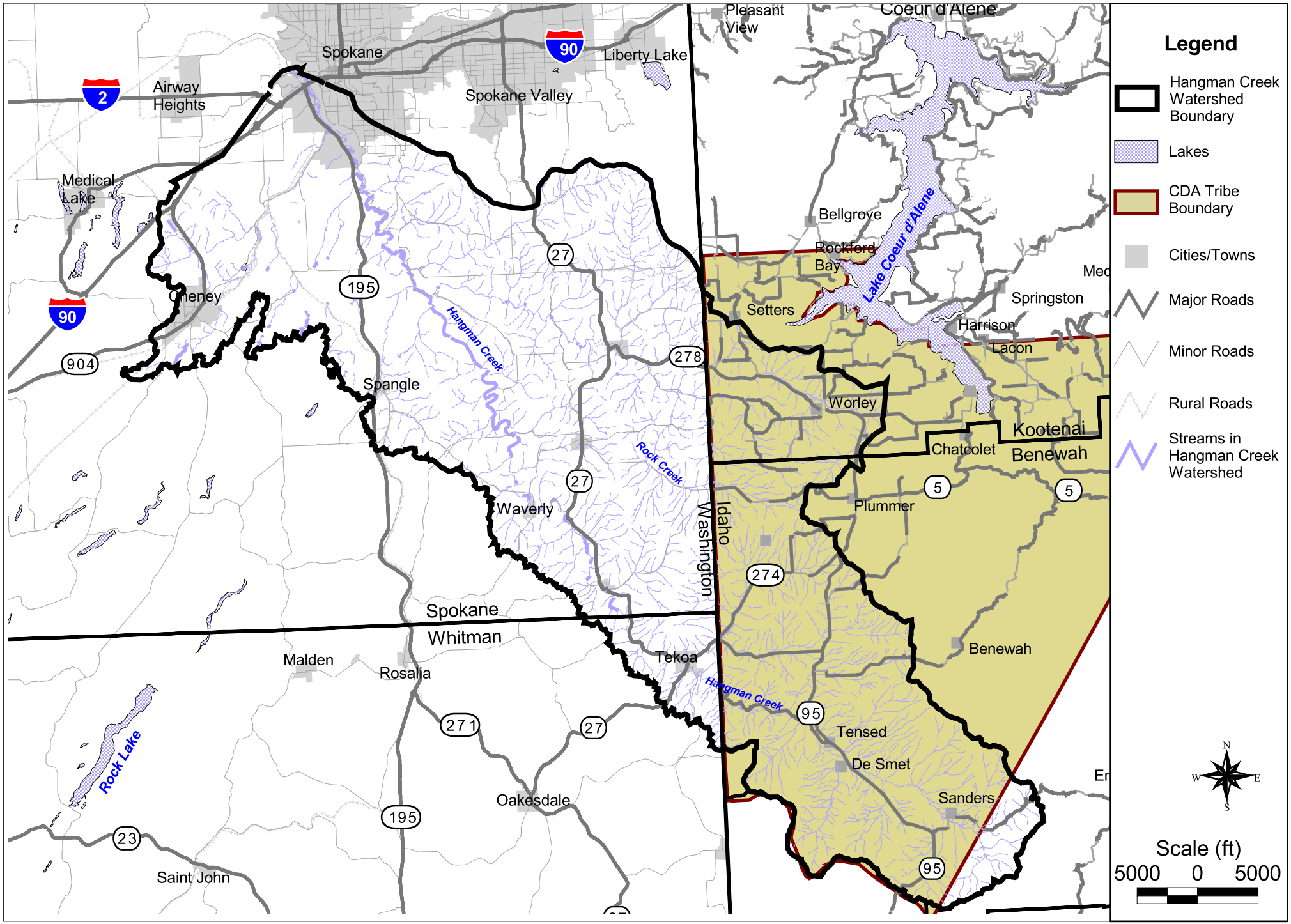
Source Category	TSS (kg/d)	TP (kg/d)
Deciduous	0.8	0.002
Coniferous	5,580	2.76
Mixed Forest	111	0.22
Cropland / Pasture	30,700	6.17
Rangeland	5,770	1.41
Forested Wetland	9	0.02
Non-forested Wetland	13	0.01
Barren	6	0.001
Residential	1,440	0.36
Comm./Industrial	623	0.10
General Nonpoint Sources	401	0.00
Stream Bank Erosion	1,160	0.14
Type 1 Septic System	-	3.64
General Point Sources	-	2.32
TOTAL	45,813	17.14

Hangman Creek at Tekoa

Source Category	TSS (kg/d)	TP (kg/d)
Deciduous	0.3	0.001
Coniferous	6,980	2.99
Mixed Forest	59	0.18
Cropland / Pasture	16,600	3.68
Rangeland	4,880	1.19
Forested Wetland	13	0.02
Non-forested Wetland	18	0.01
Barren	9	0.001
Residential	1,620	0.36
Comm./Industrial	189	0.03
General Nonpoint Sources	64	0.00
Stream Bank Erosion	15	0.00
Type 1 Septic System		3.41
WWTP Effluent		2.50
TOTAL	30,447	14.38

Note: Source characterization is cumulative. The mouth results account for everything. Bradshaw accounts for Tekoa, etc... A net loss in some source sediments are a result of downstream settling.

Figures



CDM

Hangman (Latah) Creek TMDL Modeling
Final Model Report

Figure 1
Hangman (Latah) Creek Watershed

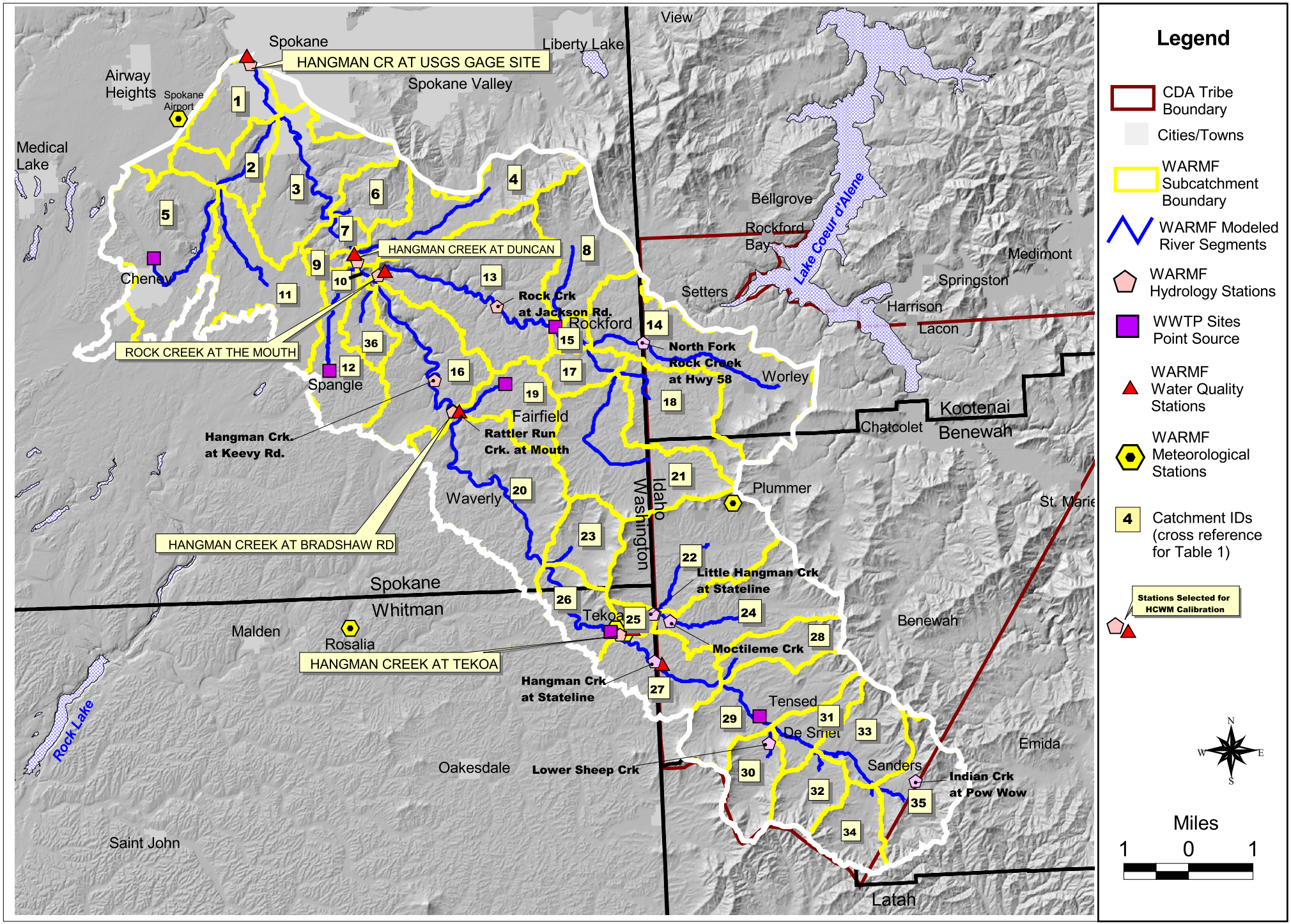
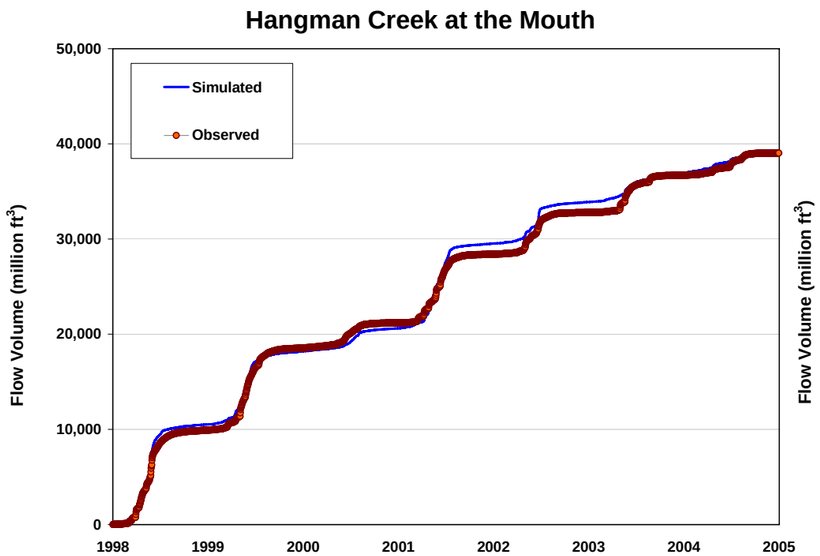
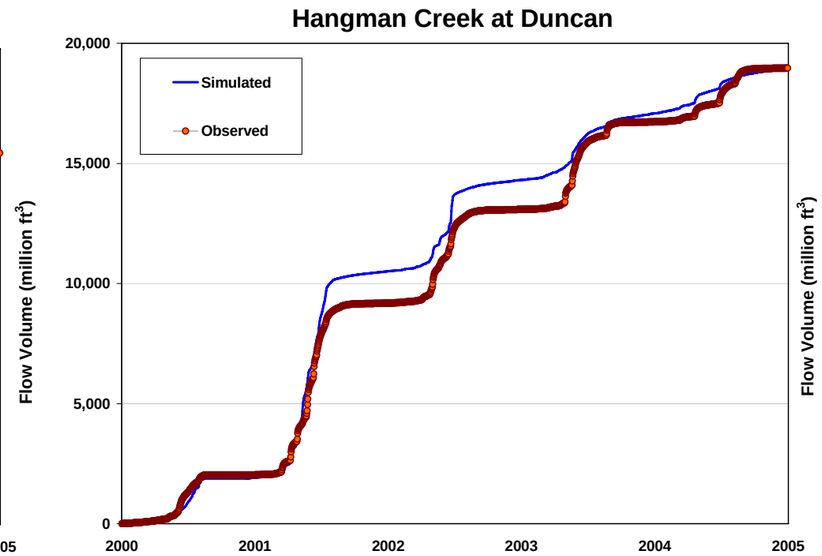
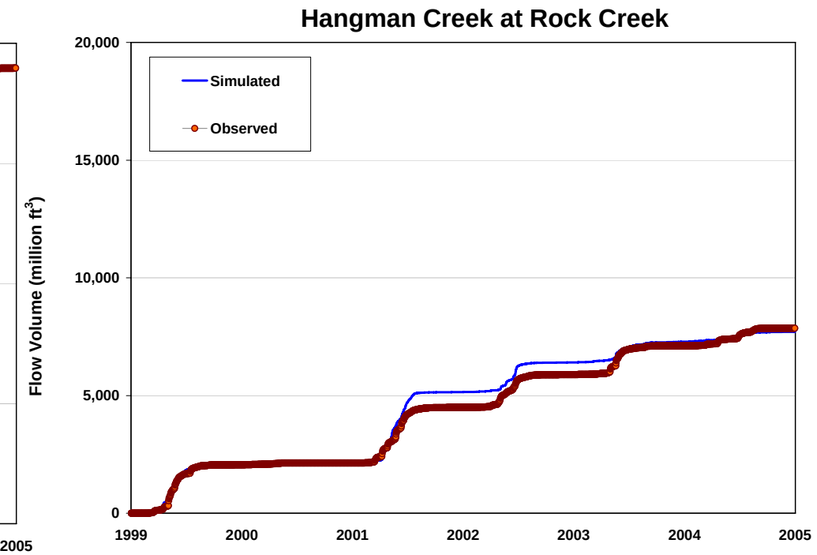
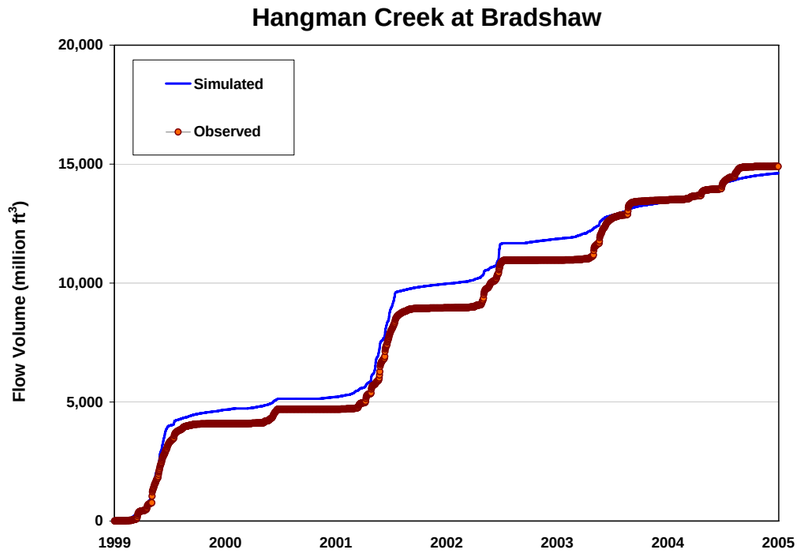


Figure 2
WARMF Model
Subcatchments, River Segments and Input Stations









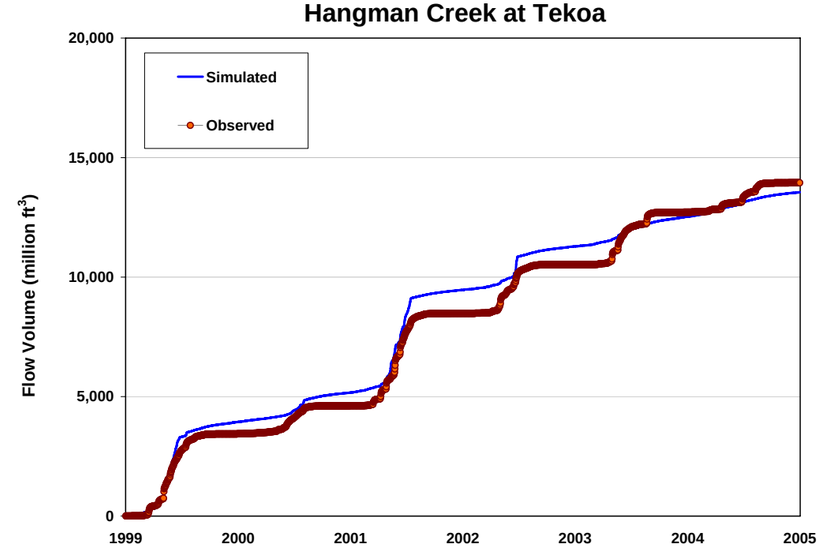
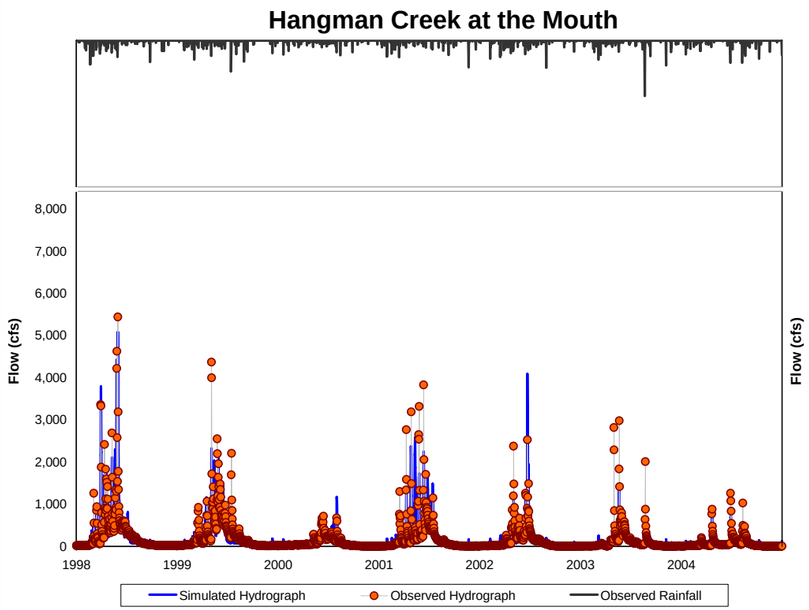
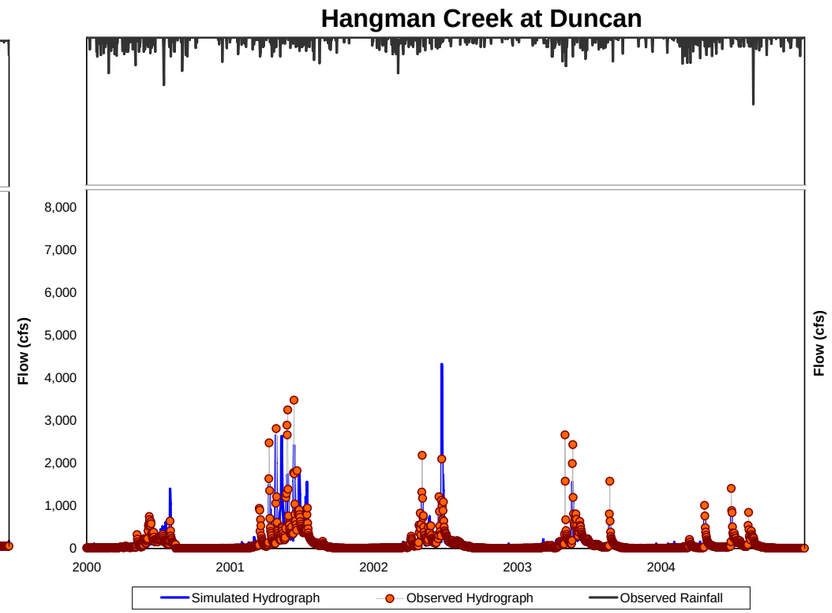
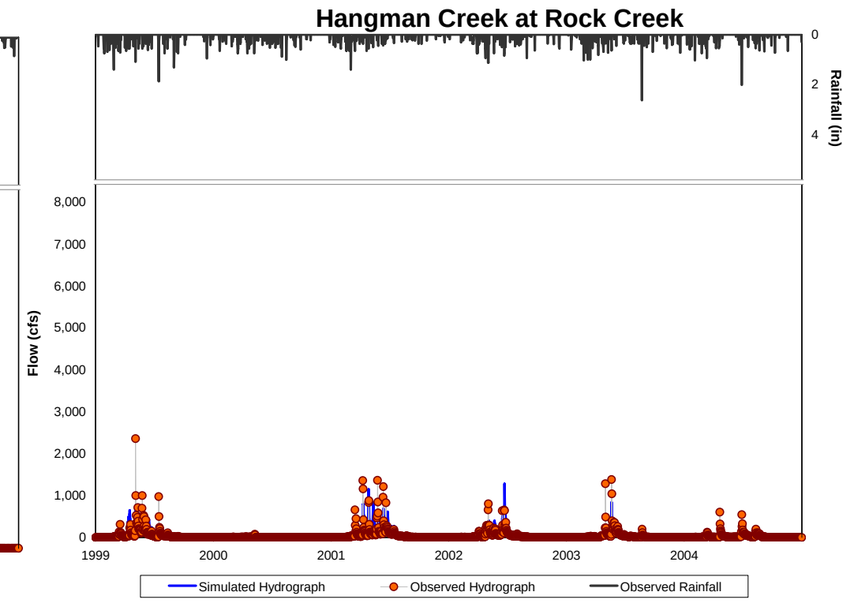
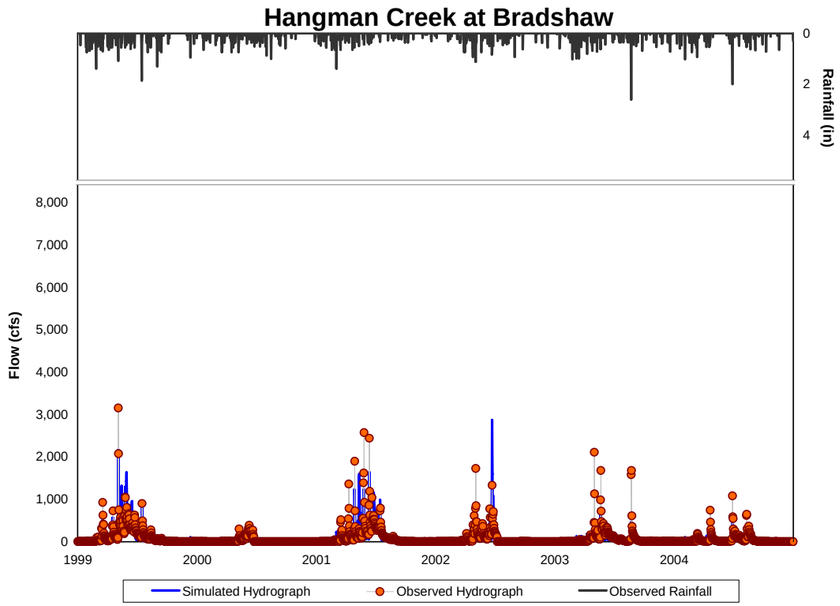


Figure 3
Cumulative Runoff Volume Plots
Simulated and Observed









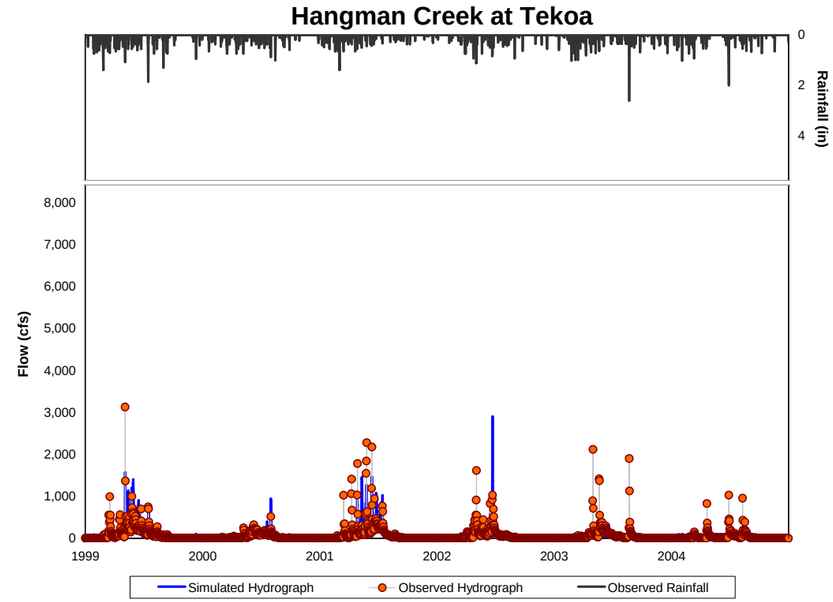


Figure 4
Time Series Plots
Simulated and Observed Hydrographs

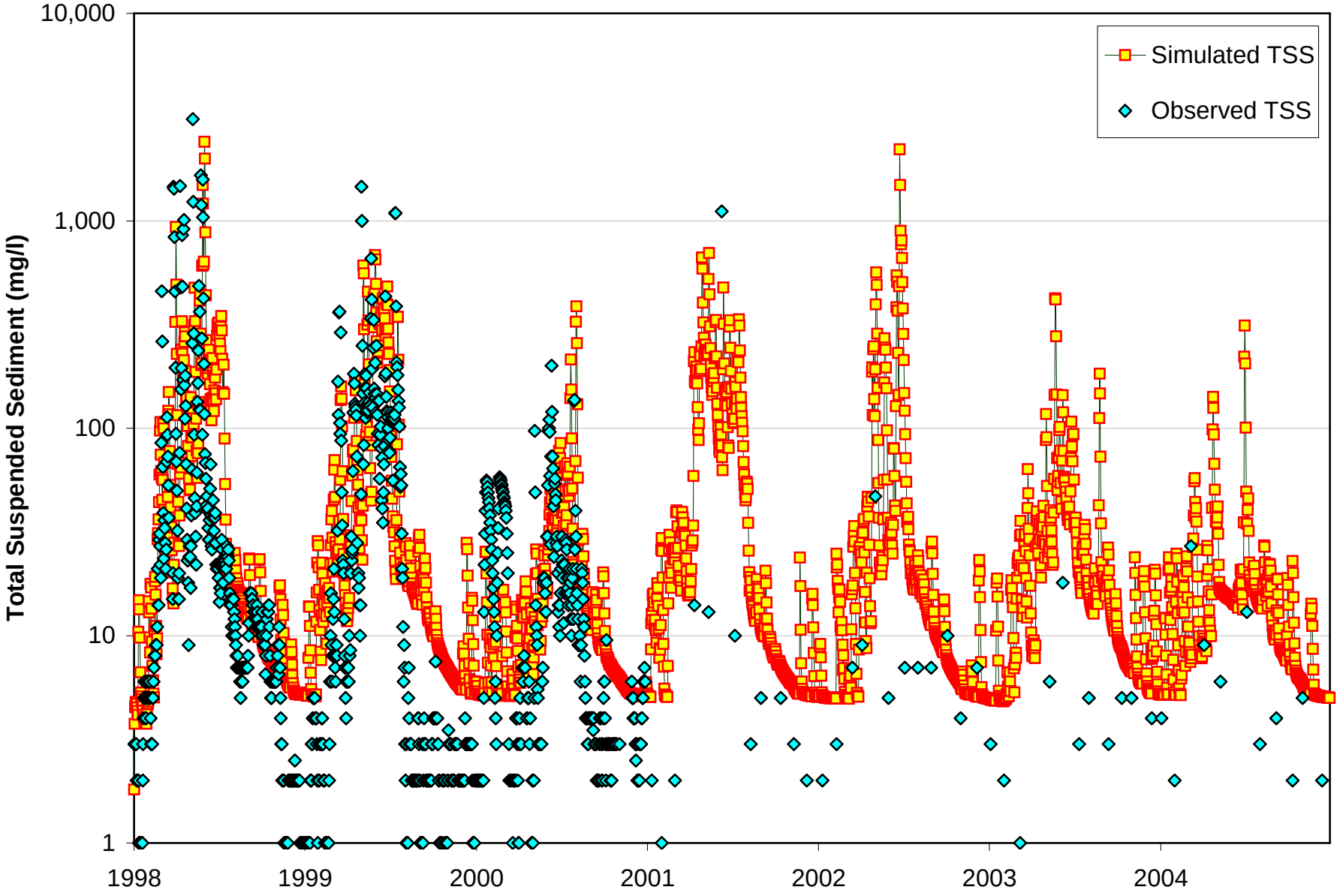
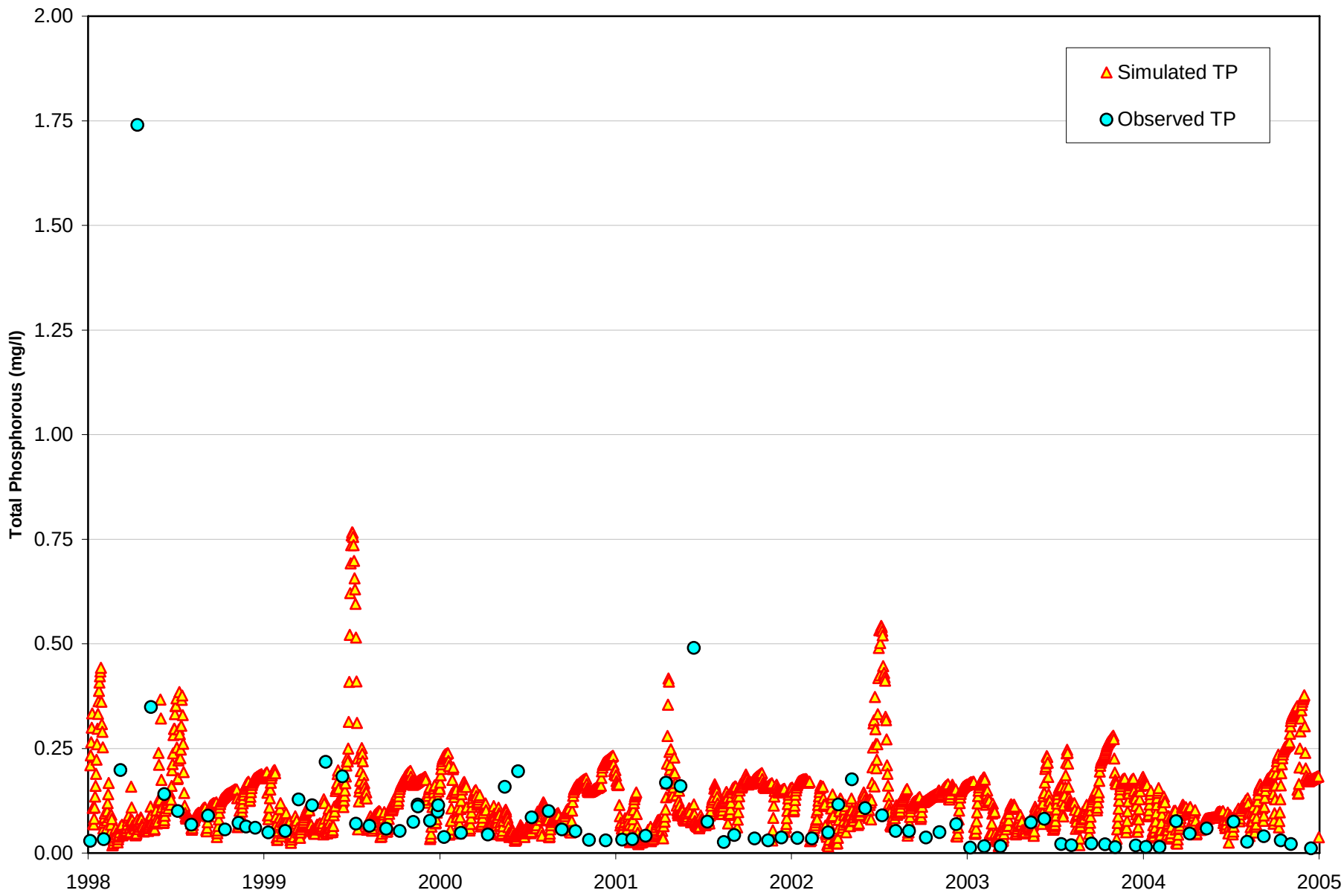


Figure 5
TSS - Hangman Creek Mouth
Simulate vs. Observed



CDM

Hangman (Latah) Creek TMDL Modeling
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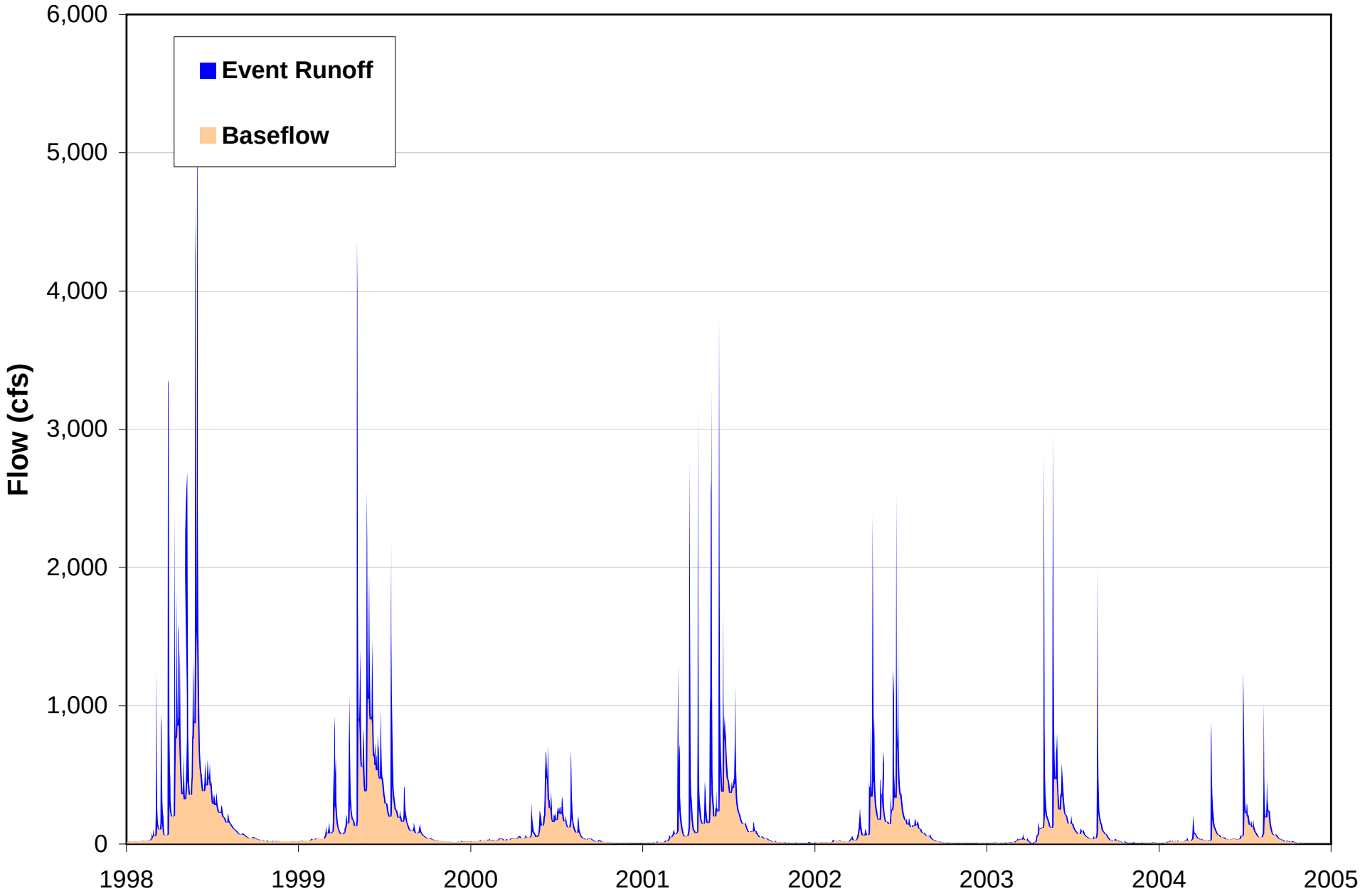
Figure 6
TP - Hangman Creek Mouth
Simulated vs. Observed



CDM

Hangman (Latah) Creek TMDL Modeling
Final Model Report

Figure 7
Baseflow Separation for
Wet vs Dry Water Quality Calibration

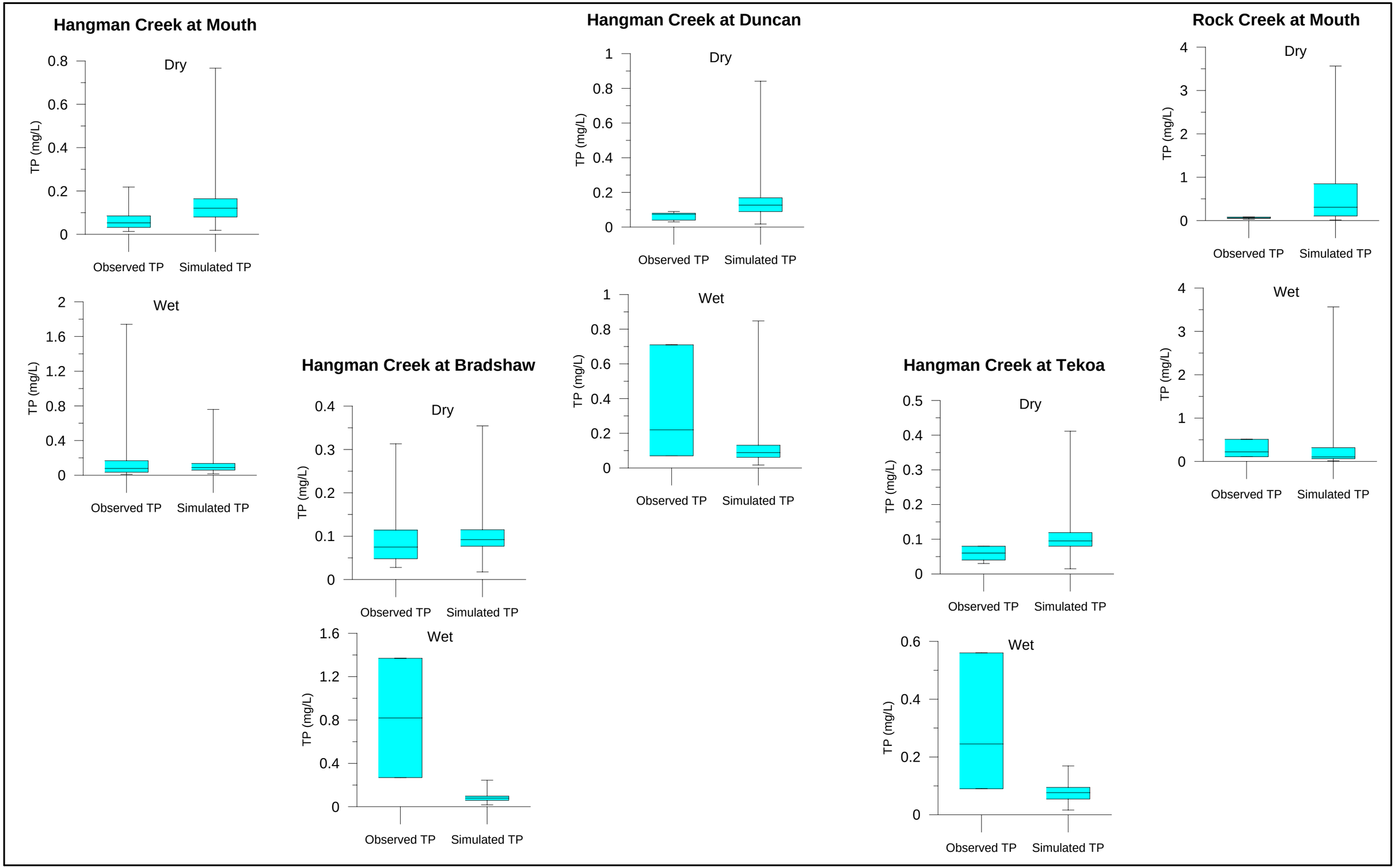


Figure 8
Box and Whisker Plots of TP
Wet vs. Dry Water Quality Calibration

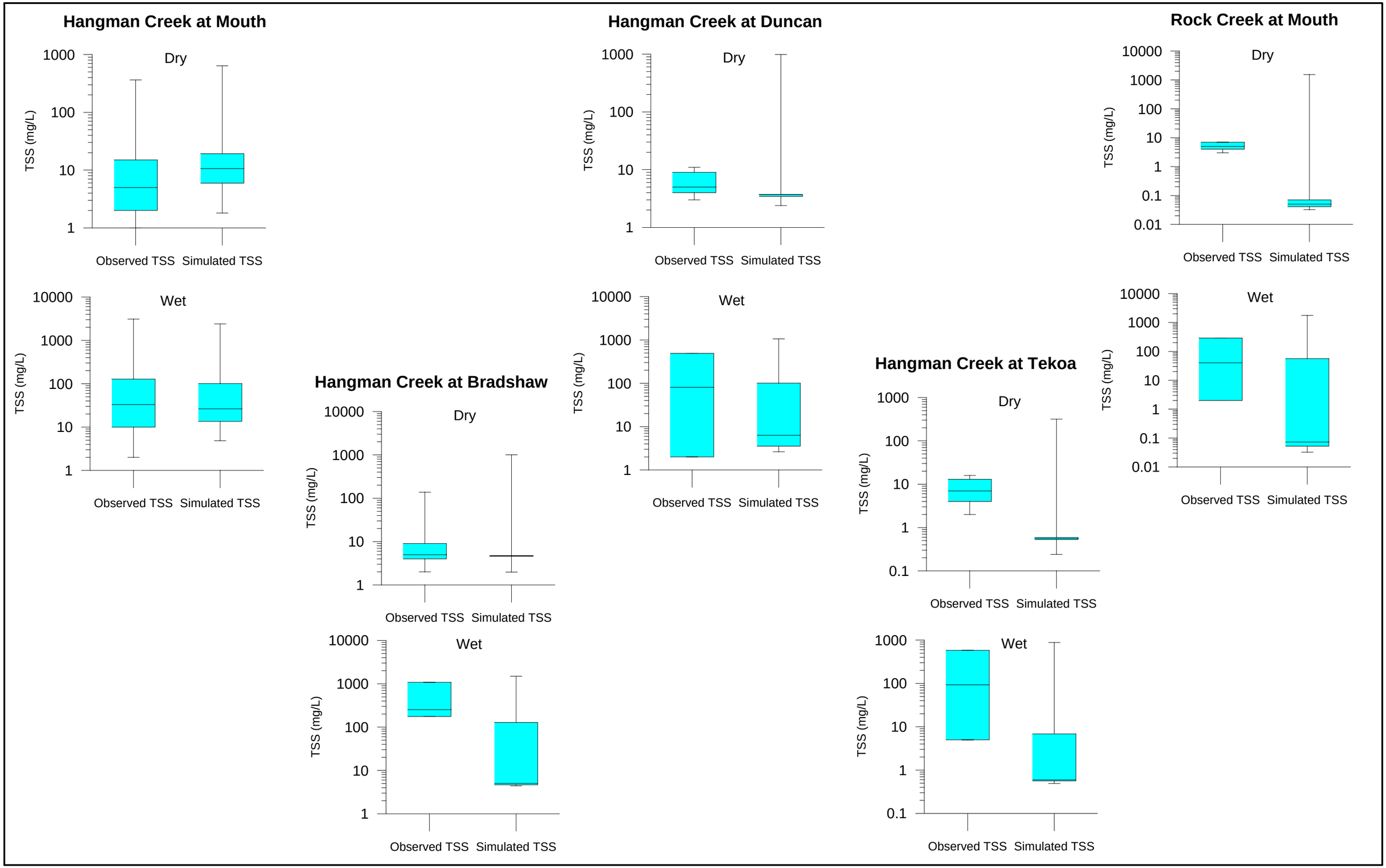


Figure 9
Box and Whisker Plots of TSS
Wet vs. Dry Water Quality Calibration

Appendix A

Technical Memorandum #1 – Data Bibliography

Appendix B

Technical Memorandum #2 – Modeling Approach

Appendix C
Modeling Quality Assurance Project Plan

Appendix D
Hangman (Latah) Creek WARMF Model CD