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Walla Walla Watershed Planning Area Prediction of Gaged Streamflows by Modeling

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Quality Assurance Project Plan

Walla Walla Watershed Planning Area
Prediction of Gaged Streamflows by Modeling

June 2010

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Abstract

The Washington State Department of Ecology (Ecology) is proposing a study during 2010 to evaluate Ecology streamflow monitoring gages in the Walla Walla River basin in Washington State. This area is also called the Walla Walla watershed planning area and is designated as Water Resource Inventory Area (WRIA) 32. It is located in southeast Washington State. Portions of the Walla Walla River basin in Oregon are not in WRIA 32.

To predict flows at Ecology stations, regression-based streamflow models will be developed and applied. Existing hydrologic models will also be evaluated for possible use to predict flows at Ecology flow monitoring stations.

The quality of all computer modeling tools applied will be evaluated, and recommendations will be made for use of the models for water management by Ecology and the Walla Walla Watershed Management Partnership. The Partnership is comprised of local and tribal government representatives and citizens.

Each study conducted by Ecology must have an approved Quality Assurance Project Plan. The plan describes the objectives of the study and the procedures to be followed to achieve those objectives. After completion of the study, a final report describing the study results will be posted to the Internet.

Background

Overview of the Watershed

The focus of this study is Water Resource Inventory Area 32 (WRIA 32 – see Figure 1), which is also referred to as the Walla Walla watershed planning area. The description of the basin below is summarized from the WRIA 32 Phase II, Level 1 Watershed Assessment (Economic and Engineering Services, 2002).

Geography

The Walla Walla River is a tributary of the Columbia River, with its mouth just south (downstream) of the mouth of the Snake River near Pasco, Washington. The headwaters of the Walla Walla basin lie in the Blue Mountains to the east. The basin area is 1758 square miles (1,295,000 hectares). Most of the basin (73%) is in the state of Washington, while the rest is in Oregon (Figure 2). WRIA 32 is the portion of the basin in Washington State.

The Walla Walla basin is diverse geographically and hydrologically. Its upper reaches are mountainous and forested, while the downstream low-lying areas are semi-arid and mostly agricultural.

Climate

Winters are cold (averaging 20 to 25° F, or -7 to -4° C) with rain and snow, especially in the mountains. Summers are hot (averaging 90 to 95° F, or 32 to 35° C) and dry. Elevations range from 300 feet (90 meters) at the mouth of the river to over 5,000 feet (1,500 meters) in the highest areas of the watershed.

The lower west end of the basin lies in the rain shadow of the Cascade Mountains with average precipitation of less than 10 inches (250 millimeters) per year. Precipitation increases towards the Blue Mountains in the east end of the basin, where precipitation averages 40-60 inches (1,000 to 1,500 millimeters) per year. This precipitation falls mainly in winter (October through March), with thunderstorms occurring rarely (about 11 days per year) during the summer. In the lower parts of the basin, precipitation comes mainly as rain, while the uplands receive both rain and snow. Snow depths during an average winter are typically less than a foot on the lowlands and several feet in the Blue Mountains.

Hydrology

Groundwater in the basin is found in two primary formations:

- A gravel aquifer consisting of shallow unconsolidated sediments in the central lowlands and valley bottoms. The gravel aquifers tend to be in continuity with the streams in the basin, with groundwater flow into or out of streams depending on the relative elevations of the water table and stream water surface.

- Deeper fractured basalt aquifers underlying the entire basin. The basalt aquifers support summer stream baseflows in the higher elevations, but otherwise tend to discharge regionally to the Columbia and Snake Rivers.

Snowmelt from the Blue Mountains often produces high flows in the spring for the Walla Walla and Touchet Rivers and other high elevation tributaries. Lower elevation tributaries are dominated by rainfall runoff in the wet season (typically November through May). During the dry season (typically June through October), the natural process governing flows is groundwater interactions. However, diversions of water (e.g., irrigation) are extensive in the basin and dominate streamflows in the summer throughout most of the basin.

Land Ownership, Land Use, and Water Use

Political jurisdictions in WRIA 32 include Walla Walla and Columbia Counties, the City of Walla Walla, and smaller cities and towns (College Place, Waitsburg, and Dayton). The Walla Walla basin is within the Usual and Accustomed fishing areas for the Confederated Tribes of the Umatilla Indian Reservation. Other local jurisdictions include the Columbia and Walla Walla County Conservation Districts, the Port of Walla Walla, and several Irrigation Districts. About 9% of the basin is federally owned, mostly U.S. Forest Service lands in the Blue Mountains.

The primary land use in the Walla Walla basin is agriculture (75% of the land area), primarily irrigated and dry land farming. About 11% of the basin area is rangeland, and 10% is forested. The remainder of the basin is urbanized. About two-thirds of the basin's population lives around Walla Walla and the other four incorporated areas. Population is expected to increase by 24% from 2000 to 2020.

Agriculture dominates water use in the Walla Walla basin. About 40,000 acres are irrigated for crops, using an estimated 92,500 acre-feet of water per year. About half the water used is surface water and the rest groundwater. Historically irrigation occurred mostly in the spring and fall when surface water is relatively abundant. Crop water needs in the summer are then provided with residual soil moisture and groundwater. Crops are chosen that respond well to this irrigation regime.

Current residential, commercial, and industrial water use has been estimated at about 17,000 acre-feet of surface water per year, while groundwater use is estimated at about 11,000 acre-feet per year. These water uses tend to have a steady base consumption rate throughout the year, with a seasonal increase during hot weather due to irrigation of landscape, lawn, and home gardens. Residential, commercial, and industrial water use is expected to increase with population growth.

Watershed Planning

The key group for watershed planning in WRIA 32 is the Walla Walla Watershed Management Partnership. The Partnership is described on its website (www.wallawallawatershed.org):

The Walla Walla Watershed Management Partnership is a public agency operating under [RCW 90.92 (2SHB 1580, Chapter 183, Session Laws of 2009)](). The Partnership is charged with piloting local water management in the Walla Walla Basin. Efforts leading up to the formation of the Partnership were made up of community members including landowners, local governments, conservation groups, tribes, state and federal agencies, and many other entities working to develop local solutions to the unique water issues in the Walla Walla Basin. The Partnership is currently in the process of beginning implementation of the ten-year pilot local water management program approved by last year's legislature.

The Partnership grew out of watershed planning that began in 1998 under RCW 90.82. The Walla Walla watershed planning group successfully completed Levels 1 through 4: Watershed Assessment, Watershed Studies, Watershed Plan, and Detailed Implementation Plan. In 2007 two reports from The Ruckelshaus Center provided the basis for a proposal, which in 2009 resulted in legislation creating the Partnership.

The Partnership focuses on activities to protect instream flows, water quality, and fish habitat. The Partnership Board administers the partnership, and there is also a Policy Advisory Group and a Water Resources Panel. Most of the affected stakeholder groups are represented in the Partnership. These groups include federal, state and local government; the Umatilla Tribe; conservation and irrigation districts; universities; water rights holders; environmental and other non-profit groups; and local citizens.

Another watershed group that works closely with the Partnership is the Walla Walla Basin Watershed Council (WWBWC). WWBWC is focused primarily on the Oregon part of the watershed, but has played a lead role in scientific studies of the watershed as a whole. These studies are evaluating:

- The interactions of groundwater and surface water in the hyporheic zones of streams using fiber optic temperature sensors.
- Shallow aquifers through the monitoring of 97 wells in the basin.
- Surface water flows and levels at 50 small-order spring, stream, and irrigation ditch locations in the basin.
- A surface water budget for the Walla Walla River.

Streamflow Gages and Models

Streamflow Measurement

The Washington State Department of Ecology (Ecology) has historically operated 26 flow monitoring stations (www.ecy.wa.gov/programs/eap/flow/shu_main.html, Table 1 and Figure 1). These stations consist of:

- Seven active *telemetry* gages providing real-time data.
- Three historical gages (discontinued in 2009) with *continuous* data.

- Six historical staff gages (discontinued in 2009) where *manual stage height* readings are collected infrequently (at least once per month) and converted to instantaneous flow values.
- Ten historical gages with continuous data that were operated seasonally for 1 to 3 years in support of Total Maximum Daily Load studies (Johnson et al., 2004; Joy and Swanson, 2005; Joy et al., 2007; Stohr et al., 2007).

Streamflow discharge is measured directly at all stations on a regular basis, and rating curves are developed and updated for determining flow from gage height data.

The U.S. Geological Survey (USGS) has gaged streamflow throughout the Walla Walla basin at a variety of sites historically and currently (USGS, 2009a; 2009b):

- Four active stations in WRIA 32. These are listed in Table 2. One station – Mill Creek at Five Mile Road Bridge – is partially funded by Ecology.
- Nine historical stations in WRIA 32 with continuous flow.
- Four historical stations in Oregon.

The USGS historical stations have no data after 1989 and will not be used for this analysis.

The State of Oregon Water Resources Department (OWRD) measures streamflow at several sites in the upper Walla Walla River basin (Table 3). The North and South Fork Walla Walla River stations are representative of headwater flows prior to diversions into the agricultural ditch system.

In 2002, the WWBWC began flow monitoring in the Walla Walla basin (WWBWC, 2009a). The network has grown to 50 stations, which include small-order streams, source springs, and irrigation ditches. Fifteen of the sites currently monitored are in Washington State. However, these smaller streams most likely differ enough from the larger streams where Ecology monitors streamflow that their usefulness for this analysis is limited.

Hydrologic Modeling

The WWBWC has also been involved with several flow modeling efforts:

- Bower (2007) describes six “seepage runs” conducted in the Walla Walla River from 2002 through 2004. Flows in the river and in tributaries and for diversions were measured, and then summed and subtracted in 26 reaches in Oregon and Washington to get estimates of flow gain or loss in each reach. Channel gains and losses are presumed to be predominantly from groundwater inflows or river bed infiltration.
- Bower et al. (2007) reports on a mass-balance flow model of the Walla Walla River that was developed using the June and August 2002 seepage runs. The flow model was applied to a temperature analysis used for fisheries habitat conservation planning and for an Oregon Total Maximum Daily Load analysis. The model extends from the river’s headwaters in Oregon to the USGS flow station “Walla Walla River near Touchet, WA”.

- Oregon State University has developed a finite element model of the Walla Walla River in Oregon (Petrides Jimenez, 2008). The model is currently being expanded to include the portion of the river in Washington, and is scheduled to be released in June 2010.
- Baker (2009) reports on seasonal seepage run assessments that build off of Bower (2007). These assessments extend the analysis to several additional years of data and to Mill Creek and the Touchet River.
- To support a GIS[1]-based analysis of fisheries, flow, and temperature, a hydrology data model was developed for the Walla Walla River for 2007-2008 based on the seepage run assessments (WWBWC, 2009b).

Streamflow Patterns

To provide a comparison of flows at gages in the watershed, Figures 3 through 6 show distributions of flows at 13 Ecology and USGS continuous stations during Water Years 2003 through 2009.

- Flows in the Walla Walla River (Figure 3) increase steadily for median and higher flows from the Oregon state line (at Pepper bridge) to the downstream station (near Touchet, WA), which is below the confluence of the Touchet River. However, flows between the two downstream stations decrease for the 5th and 25th percentiles, likely the result of diversions in this reach. Median flows range from 82 cfs at Pepper Bridge to 276 cfs at the gage near Touchet, while 95th percentile flows range from over 500 cfs to over 2,000 cfs at these two stations.
- Flows in Mill Creek (Figure 4) increase from the most upstream station (near Walla Walla) to the next station downstream (at Five Mile Road Bridge). But then flows are much lower at Mill Creek at Walla Walla, reflecting diversion upstream of this station into Bennington Lake and Yellowhawk Creek. Median flows range from 29 cfs at Walla Walla to 66 cfs at Five Mile Road Bridge, while 95th percentile flows approach or exceed 300 cfs. The 5th percentile flow at Walla Walla is 0.1 cfs, and at times there is no flow.
- Flows in the Touchet River (Figure 5) increase from the upstream station (at County Line) to the station at Bolles, but then flows decrease downstream to the station at Cummins Road. The seepage runs in Baker (2009) suggest that diversions and infiltration to groundwater can account for this loss. Median flows range from 88 cfs at Cummings Road to 117 cfs at Bolles, while 95th percentile flows range from 551 cfs at County Line to 945 cfs at Bolles.
- Flows in the North Fork Touchet River (Figure 6) increase downstream between the two gaging stations. Flows in Dry Creek (a tributary of the Walla Walla River) and Coppei Creek (a tributary of the Touchet River) are the lowest of any gages. Median flows vary widely: 29 and 81 cfs in the North Fork above Jim Creek and above Dayton, respectively; 9 cfs in Dry Creek and 5 cfs in Coppei Creek. High 95th percentile flows are: 64 cfs in Dry Creek; 75 cfs in Coppei Creek; 128 cfs in the North Fork above Jim Creek, and 381 cfs in the North Fork above Dayton.

[1] Geographic Information System

- Flows in the North and South Fork Walla Walla River and in Mill Creek (Figure 4), along with the Touchet River (Figure 5), represent the principal headwater tributaries to the Walla Walla River system. Flows in the upstream gages of the South Fork Walla Walla River, Mill Creek, and North Fork Touchet River show similar distributions and provide the majority of the flow in the Walla River downstream.

Figures 7 through 10 illustrate seasonal flow patterns at gaging stations for Water Years 2003 through 2009.

- Flows in the Walla River (Figure 7) show a mixture of rain-event and snowmelt runoff flows, with occasional very high runoff events. Summer and early fall flows are relatively low.
- Mill Creek shows a similar pattern to the Walla Walla River (Figure 8). The very low dry season flows at the farthest downstream station (at Walla Walla, WA) are apparent in this figure.
- Touchet River flows are also similar seasonally to the Walla Walla River (Figure 9). This system responds differently to some precipitation events, but low flow patterns are similar.
- The North Fork Touchet River (Figure 10) again tracks the mainstem flow patterns. The two small creeks show less of a snowmelt runoff signal than the other stations.

Figures 7 through 10 also show the difference in flows between water years: 2008-09 was a relatively wet water year, while 2004-05 was relatively dry.

Instream Flow Rule

In 2007, Ecology established minimum instream flows for WRIA 32 in Chapter 173-532 WAC of state regulations (State of Washington, 2007). Flows must be met at specified *control stations* in each designated stream. Those flows are senior in right to any water rights established after the date of the regulation.

Regulatory flow control stations established by WAC 173-532 are shown in Table 4. All control stations correspond to active Ecology or USGS flow monitoring stations (Figure 1, Tables 1 and 2).

Table 1. Ecology flow monitoring stations in WRIA 32.

ID	Station Name	Code	Status	Type[1]	Start	End	No. days	Comment
32A100	Walla Walla R. at East Detour Road	WW_Det	Active	T	18-Jan-2007	present	1093	
32A105	Walla Walla R. at Beet Road	WW_Beet	Active	T	26-Jul-2002	present	2730	
32A120	Walla Walla R. at Pepper Bridge	WW_Pep	Active	T	26-Jun-2002	present	2760	
32B075	Touchet R. at Cummins Road	Tou_Cum	Active	T	28-Jun-2002	present	2758	
32B100	Touchet R. at Bolles	Tou_Bol	Active	T	31-May-2002	present	2786	
32E050	North Fork Touchet R. above Dayton	NFT_Day	Active	T	12-Dec-2002	present	2591	
32G060	Coppei Creek near mouth	Cop_Mou	Active	T	13-Dec-2002	present	2590	
32B110	Touchet R. at County Line	Tou_Cty	Recent	C	14-Aug-2002	30-Sep-2009	2605	
32E150	North Fork Touchet R. above Jim Creek	NFT_Jim	Recent	C	11-Dec-2002	30-Sep-2009	2486	
32F150	Dry Creek at Hwy 125	Dry_125	Recent	C	13-Dec-2002	30-Sep-2009	2484	
32C070	Mill Creek at Swegle Road	Mill_Swe	Recent	M	7-May-2003	13-Jul-2009	272	
32F060	Dry Creek near mouth	Dry_Mou	Recent	M	7-May-2003	15-Jul-2009	258	
32H090	East Prong Little Walla Walla R. at Stateline Road	EPLWW	Recent	M	13-Feb-2003	4-Dec-2009	336	
32J070	Robinson Fork above Wolf Fork Touchet R.	RobFkTou	Recent	M	11-Feb-2003	14-Jul-2009	274	
32K070	Wolf Fork Touchet R. at Mountain Home Park	WolFkTou	Recent	M	11-Feb-2003	14-Jul-2009	282	
32L070	South Fork Touchet R. above Dayton	SFT_Day	Recent	M	10-Apr-2003	14-Jul-2009	295	
32A080	Walla Walla R. below Lowden	--	Historical	C	20-Apr-2005	1-Nov-2005	196	wet season only (1 year)
32G100	Coppei Creek near Coppei	--	Historical	C	17-Sep-2003	2-Nov-2005	367	dry season only (3 yr)
32A090	Walla Walla R. near Lowden	--	Historical	C	18-Sep-2003	1-Nov-2005	328	dry season only (3 yr)
32D060	Yellowhawk Creek near mouth	--	Historical	C	18-Sep-2003	1-Nov-2005	366	dry season only (3 yr)
32M060	Cottonwood Creek near mouth	--	Historical	C	1-Jul-2004	8-Nov-2004	131	dry season only (1 yr)
32M100	Cottonwood Creek at Hood Road	--	Historical	C	16-Sep-2003	8-Nov-2004	174	dry season only (2 yr)
32N070	Russell Creek near Langdon	--	Historical	C	17-Sep-2003	30-Sep-2004	183	dry season only (2 yr)
32D050	Yellowhawk Creek at mouth	--	Historical	C	30-May-2002	20-Nov-2002	175	dry season only (1 yr)
32B090	Touchet R. at Luckenbill Road	--	Historical	C	29-May-2002	20-Nov-2002	176	dry season only (1 yr)
32B140	Touchet R. above Dayton	--	Historical	C	30-May-2002	19-Nov-2002	174	dry season only (1 yr)

[1] T = Telemetry; C = Continuous; MSH = Manual Gage Height.

Table 2. USGS active flow monitoring stations in WRIA 32.

ID	Station Name	Code	Status	Type[1]	Start	End	Number of days
14013700	Mill Creek at Five Mile Road Bridge near Walla Walla, WA	Mill_5mi	Active	RT	24-Dec-1997	Present	3373
14018500	Walla Walla River near Touchet, WA	WW_nrT	Active	RT	1-Oct-1951	Present	21280
14013000	Mill Creek near Walla Walla, WA	Mill_nrWW	Active	RT	1-Oct-1913	Present	26212
14015000	Mill Creek at Walla Walla, WA	Mill_atWW	Active	RT	1-Oct-1982	Present	8654

[1]RT = Real-time (Telemetry)

Table 3. Oregon Water Resources Department flow monitoring stations in the Walla Walla River basin.

ID	Station Name	Code	Type[1]	Status	Start	End	Number of days
14010000	South Fork Walla Walla River near Milton, OR	OR-SFWW	SA	Active	1-Feb-1903	Present minus 6 weeks	28512
14010800	North Fork Walla Walla River near Milton Freewater, OR	OR-NFWW	RT	Active	1-Oct-1969	Present	10402
14012100	Little Walla Walla River near Milton, OR	OR-LWW	RT	Active	19-May-1932	Present	27608
14012300	Hudson Bay D near Freewater, OR	OR-HBD	RT	Active	1-Jun-1929	Present	22009

[1]SA = Stand-alone (Continuous); RT = Real-time (Telemetry)

Table 4. Regulatory flow control stations in WRIA 32.

Stream Management Unit Name	Control Station Gage Name	Control Station Gage No.	River Mile (RM)	Township/ Range/ Section	Latitude Longitude	Stream Management Reach Description
Mill Creek	Mill Creek at Kooskooskie	USGS 14013000	RM 21.2	6N/37E/12	46°00'29"N -118°07'03"W	Mill Creek at confluence with Walla Walla River (Walla Walla River, RM 33) to headwaters, including tributaries.
Walla Walla River	Walla Walla River at Detour Road	Ecology 32A100	RM 32.4	7N/35E/31	46°02'36"N -118°29'24"W	Walla Walla River, RM 32.4 (below confluence of Walla Walla River and Mill Creek) to state line at Walla Walla, including tributaries.
North Fork Touchet River	North Fork Touchet above Dayton	Ecology 32E050	RM 0.5	10N/38E/32	46°17'50"N -117°57'04"W	Mouth of North Fork Touchet River to headwaters, including tributaries.
Touchet River	Touchet River at Bolles	Ecology 32B100	RM 40.4	9N/37E/7	46°16'27"N -118°13'12"W	Touchet River, RM 40.1 to RM 54.9 (confluence of North Fork Touchet River and South Fork Touchet River), including tributaries, excluding North Fork Touchet River and its tributaries.

Project Description

Goals and Objectives

The goals of this project are to:

1. Develop computer modeling tools that can determine streamflows in WRIA 32 for Ecology flow monitoring stations and USGS flow monitoring stations funded by Ecology.
2. Assess the ability of computer modeling tools to support Ecology and the Walla Walla Water Management Partnership in their water management activities in the basin.
3. Support Ecology in making decisions about use of its flow gaging resources statewide.

To meet these goals, this project has the following objectives:

1. Develop statistical and simple hydrologic models that can predict streamflows at Ecology or Ecology-funded flow monitoring stations in WRIA 32 based on relationships with active long-term USGS flow stations or other Ecology flow stations.
2. Evaluate any existing hydrologic models for WRIA 32, determine whether they can be applied to predict flows at Ecology flow monitoring stations at a level of effort within the schedule designated for this project, and if so, develop those applications.
3. Assess the quality of the results of the modeling tools developed for objectives 1 and 2.
4. Provide support in determining a long-term approach to flow discharge assessment that combines direct monitoring of gage height with modeling approaches, thus allowing the total number of flow monitoring stations using continuous stream gage measurements to be reduced.
5. Identify any data gaps found in the modeling analysis, and if warranted, recommend more complex modeling approaches that might reasonably improve the use of models for flow discharge assessment.
6. Provide training and technology transfer of project products to Ecology staff and local partners.

Model Development

The first study objective will be met by an analysis of (1) the streamflow records for the gages in the WRIA 32 basin and (2) other relevant information such as geographical, geological, or meteorological data. The planned approach is to select *reference stations*, such as active long-term USGS flow stations, and then predict flow data at Ecology-funded stations (*study stations)* from one or more of the reference stations. Based on the results of the analysis, one or more Ecology flow stations may also be selected as a reference station.

Several methods will be explored for this analysis, including:

- Simple linear regression or correlation with data transformations such as log-transformation.
- Areal flows (discharge per watershed area) and drainage area ratios.
- Time-lagging of data.

- Hydrograph separation.
- Simple hydrologic routing models.
- Inclusion of meteorological, geographical, and other non-hydrologic data to adjust predictive equations.

This list is provided roughly in order from the simplest to the most complex approach. The analysis will begin with the simplest approach and will only progress to more complex approaches depending on:

- The quality of the results from the simpler approach.
- Whether the available data support a more complex approach.
- The time available in the project schedule to pursue a more complex approach.
- The potential use of the modeling tools.
- The priority of the station to the Walla Walla Partnership and Ecology.

An example of the simplest kind of correlation is provided in Table 5. Correlations were developed[2] between continuous flow time series from the Ecology, USGS, and OWRD stations. This initial analysis shows how some gages will correlate well, while other will have much poorer relationships. These correlations will be used as the starting point to choose reference stations with the closest statistical relationship to each study station.

- One reference station will be the USGS station with the best correlation.
- A second reference station will be the station with the best correlation (other than the first choice) that is either a USGS station or an Ecology station that is also a control station.
- Two more stations will be selected for analysis from the stations with the best correlations (other than the first two choices).

To meet the third study objective, any hydrologic models currently available or under development will be evaluated to determine applicability to predict flows at Ecology gages. Development of a model application to meet study objectives will be pursued if the application can be developed within the schedule and level of effort planned.

[2] The Correlation analysis tool was used from the Excel® Analysis ToolPak.

Table 5. Correlations between flows from gages in the Walla Walla watershed.

	WW_Pep	WW_Beet	WW_Det	WW_nrT	Mill_nrWW	Mill_5mi	Mill_atWW	Dry_125	Tou_Bol	Tou_Cum	Tou_Cty	NFT_Day	NFT_Jim	Cop_Mou	OR-SFWW	OR-NFWW	OR-LWW
WW_Beet	**0.97**																
WW_Det	**0.96**	**0.93**															
WW_nrT	**0.92**	**0.92**	**0.97**														
Mill_nrWW	**0.89**	**0.90**	**0.94**	**0.90**													
Mill_5mi	**0.89**	**0.89**	**0.95**	**0.92**	**0.98**												
Mill_atWW	**0.88**	**0.89**	**0.95**	**0.94**	**0.98**	**0.98**											
Dry_125	**0.80**	**0.79**	**0.84**	**0.90**	**0.84**	**0.88**	**0.90**										
Tou_Bol	**0.83**	**0.80**	**0.91**	**0.96**	**0.88**	**0.92**	**0.94**	**0.91**									
Tou_Cum	**0.83**	**0.84**	**0.92**	**0.96**	**0.86**	**0.88**	**0.90**	**0.87**	**0.97**								
Tou_Cty	**0.83**	**0.83**	**0.79**	**0.88**	**0.86**	**0.85**	**0.87**	**0.84**	**0.79**	**0.85**							
NFT_Day	**0.87**	**0.84**	**0.91**	**0.89**	**0.87**	**0.85**	**0.87**	**0.79**	**0.90**	**0.89**	**0.85**						
NFT_Jim	**0.82**	**0.75**	**0.87**	**0.79**	**0.76**	**0.73**	**0.74**	0.64	**0.77**	**0.75**	**0.74**	**0.91**					
Cop_Mou	0.65	0.67	**0.71**	**0.79**	**0.78**	**0.83**	**0.84**	**0.87**	**0.84**	**0.77**	**0.73**	0.63	0.46				
OR-SFWW	**0.92**	**0.86**	**0.85**	**0.76**	**0.78**	**0.74**	**0.72**	0.62	**0.71**	0.69	**0.71**	**0.84**	**0.89**	0.43			
OR-NFWW	**0.95**	**0.92**	**0.93**	**0.86**	**0.88**	**0.86**	**0.84**	**0.75**	**0.82**	**0.79**	**0.79**	**0.87**	**0.84**	0.62	**0.93**		
OR-LWW	-0.09	-0.14	-0.15	-0.21	-0.06	-0.12	-0.14	-0.19	-0.14	-0.17	-0.07	0.03	0.13	-0.27	0.20	0.08	
OR-HBD	0.10	0.01	0.04	0.01	0.09	0.02	0.04	0.09	0.04	0.04	0.17	0.17	0.23	-0.03	0.30	0.21	**0.74**

USGS
ECY
ORWD
Control Station

Model Quality Assessment

Best practices of computer modeling should be applied to help determine when a model, despite its *uncertainty*, can be appropriately used to inform a decision (Pascual et al., 2003).

Specifically, model developers and users should:

1. Subject their model to credible, objective peer review.
2. Assess the quality of the data they use.
3. Corroborate their model by evaluating how well it corresponds to the natural system.
4. Perform sensitivity and uncertainty analyses.

The study will follow this approach to meet the fourth study objective of assessing the quality of model results.

Study results will undergo a technical peer review by a designated Ecology employee with appropriate qualifications. Review of the study by Ecology staff, local stakeholders, and the public will also ensure quality.

Practices 2 through 4 above are addressed through *Model Evaluation*. This is the process for generating information over the life cycle of the project that helps to determine whether a model and its analytical results are of a quality sufficient to serve as the basis for a decision. Model quality is an attribute that is meaningful only within the context of a specific model application. Evaluating the uncertainty of data from models is conducted by considering the models' accuracy and reliability.

Accuracy Analysis

Accuracy refers to the closeness of a measured or computed value to its *true* value, where the *true* value is obtained with perfect information. Due to the natural heterogeneity and random variability of many environmental systems, this *true* value exists as a distribution rather than a discrete value.

In this project, accuracy is determined from measures of the *bias* and *precision* of the predicted value from model results, as compared to the observed value from flow measurements on the assumption that measured flows are closer to the *true* value. The known precision and bias of flow measurement values will also be taken into account in interpreting results.

Bias describes any systematic deviation between a measured (i.e., observed) or computed value and its *true* value. Bias in this context could result from uncertainty in modeling or from the choice of parameters used in calibration.

Bias will be inferred by the precision statistic of relative percent difference (RPD)[3]. This statistic

[3] RPD commonly uses the absolute value of the error, but a formulation without an absolute value is used in this report to retain the sign, which indicates the bias of the predicted value relative to the observed value.

provides a relative estimate of whether a protocol produces values consistently higher or lower than a different protocol. Bias will be evaluated using RPD values for predicted and observed pairs individually and using the median of RPD values for all pairs of results.

RPD =

$$\frac{(P_i - O_i) * 2}{(P_i + O_i)}$$

where:

P_i = i^{th} prediction
O_i = i^{th} observation

The RPD was chosen over other measures of bias because of the wide range in flows found in hydrologic records. Using residuals or mean error would tend to underemphasize predictive error during critical low-flow periods and overemphasize error during the highest flows. On the other hand, percent error tends to overemphasize error for low flows. RPD provides the most balanced estimate of error over a wide range of flows.

Precision of modeled results will be expressed with percent relative standard deviation (%RSD). Precision will be evaluated using this statistic for predicted and observed pairs individually and using the mean of values for all pairs of results.

The %RSD presents variation in terms of the standard deviation divided by the mean of predicted and observed values.

%RSD = (SD_i * 200) / (P_i + O_i), where
SD_i = standard deviation of the i^{th} predicted (P_i) and observed (O_i) pair.

Percent error measures have been selected for assessment of accuracy because of the wide range of values expected in the flow record. Uncertainty in flow measurements is usually reported as a percentage; the same approach is being adopted for flow modeling.

Reliability Analysis

Reliability is the confidence that potential users have in a model and its outputs such that the users are willing to use the model and accept its results (Sargent, 2000). Specifically, reliability is a function of the performance record of a model and its conformance to best available, practicable science. Reliability can be assessed by determining the robustness and sensitivity.

Robustness is the capacity of a model to perform equally well across the full range of environmental conditions for which it was designed and which are of interest. Model calibration is achieved by adjusting model input parameters until model accuracy measures are minimized. Robustness will then be evaluated by examining the quality of calibration for different seasons and flow regimes. The variation between accuracy measures for model results from different seasons and flow regimes provides a measure of robustness of model performance.

Sensitivity analysis is the study of how the response of a model can be apportioned to changes in a model's inputs (Saltelli et al., 2000). A model's sensitivity describes the degree to which the model result is affected by changes in a selected input parameter. Sensitivity analysis is recommended as the principal evaluation tool for characterizing the most- and least-important sources of uncertainty in environmental models. Uncertainty analysis investigates the lack of knowledge about a certain population or the real value of model parameters.

Sensitivity analysis can be conducted using Morris's one-at-a-time (OAT) approach (Saltelli et al., 2000). With this approach, each input value is perturbed by a given percentage away from the base value while holding all other input variables constant. Morris's OAT sensitivity analysis methods yield local measures of sensitivity that depend on the choice of base case values. Morris's OAT approach provides a measure of the importance of an input factor in generating output variation. While this approach does not quantify interaction effects, it does provide an indication of the presence of interaction. This test will be applied if the complexity of the model, importance of model results, and the need for additional model quality information are sufficient to justify the level of effort needed.

Other approaches may also be explored to evaluate the sensitivity of regression models to changes in instream flows caused by implementing water management programs in the Walla Walla basin.

Quality Characterization

The uncertainty and applicability of model results will be assessed by evaluating model *quality* results on an annual basis and for summer baseflow conditions. The median %RSD value will be used for comparison for each model at each station within the season or range of flow measurements being considered. The following terminology will be used to describe model results:

Median %RSD for annual streamflow and summer baseflow	Characterization
Both less than 5%	Very Good
Summer less than 5% and annual greater than 5%; or both less than 15%	Good
Does not meet either criteria above	Poor

Flow Gaging Assessment

Objectives 4 and 5 will be accomplished by evaluating the results of the model assessments described above for each gaging station. Each Ecology flow monitoring station will have a preferred modeling approach identified and an evaluation of the quality of the model. This information will be provided to Ecology staff and local stakeholders to support decisions about allocation of resources for flow gaging.

Possible recommendations for use of the Ecology flow monitoring stations resulting from this project could include:

- Continuing operation of the gage as a telemetry gage.

- Reallocating the station to a *manual-stage-height* station using modeling combined with spot-flow measurements for confirmation of modeled flows.
- Abandoning the station, possibly with continued spot-flow measurements at the site.
- Transferring the station to another party.

As a result of the analysis, data gaps may be identified that limit the ability to use modeling tools to estimate streamflows. Recommendations for potential changes in data acquisition to fill these gaps will be made where warranted.

In addition, if the analysis in this study points towards other, more complex, models that could improve the quality of flow estimation, recommendations will be made for using those models in possible future work.

Project Report and Public Involvement

During the course of the project, internal review, input, and guidance will be provided by the Gaging Strategy Workgroup (GSW) and other Ecology staff identified in the Organization and Schedule section below. Input from local partners and the public during the project will be through the Walla Walla Partnership. The form and timing of input during the project will be determined by the project and client leads.

A project report will present the results of the study. Review of the draft report will be the primary mechanism for providing input to the final conclusions and recommendations.

Training and Technology Transfer

The final objective will be achieved by providing (1) modeling tools to interested parties through the internet or other means and (2) presentations and training to Ecology staff and local partners. The timing and content of presentations and training during this project will be determined through consultation with project clients and responsible staff and groups.

Organization and Schedule

The people involved in this project are listed in Table 6. All are employees of the Washington State Department of Ecology.

Table 6. Organization of project staff and responsibilities.

Staff (all EAP unless noted otherwise)	Role	Responsibilities
Hedia Adelsman Special Assistant to the Director (360) 407-6222	Client, Policy Advisor for Walla Walla Partnership	Clarifies scopes of the project. Provides internal review of the QAPP and approves the final QAPP. Reviews the project report. Serves as Ecology liaison between the project manager and the Walla Walla Partnership.
Bill Zachmann SEA Program Phone: (360) 407-6548	Client, Statewide Watershed Coordinator	Clarifies scopes of the project. Provides internal review of the QAPP and approves the final QAPP. Reviews the project report. Serves as liaison with Ecology WAG and SEA Program.
Brad Hopkins Freshwater Monitoring Unit Western Operations Section Phone: (360) 407-6686	Client, Manager of Ecology's Statewide Flow Monitoring Network	Clarifies scopes of the project. Provides internal review of the QAPP and approves the final QAPP. Reviews the project report.
Paul J. Pickett MISU Statewide Coordination Section Phone: (360) 407-6882	Project Manager/ Principal Investigator	Writes the QAPP. Organizes, analyzes, and interprets data. Develops model and analyzes quality of data and model. Writes the draft report and final report.
Karol Erickson MISU Statewide Coordination Section Phone: (360) 407-6694	Unit Supervisor for the Project Manager	Provides internal review of the QAPP. Approves the budget and approves the final QAPP. Tracks progress. Reviews and approves the project report.
Will Kendra Statewide Coordination Section Phone: (360) 407-6698	Section Manager for the Project Manager	Reviews the project scope and budget. Reviews the draft QAPP and approves the final QAPP. Approves the project report.
Gary Arnold Eastern Operations Section Phone: (509) 454-4244	Section Manager for the Study Area	Reviews the project scope and budget. Tracks progress. Reviews the draft QAPP and approves the final QAPP.
William R. Kammin Phone: (360) 407-6964	Ecology Quality Assurance Officer	Reviews the draft QAPP and approves the final QAPP.

QAPP - Quality Assurance Project Plan.
SEA - Shorelands and Environmental Assistance Program.
WAG - Watershed Advancement Group.
EAP - Environmental Assessment Program.
MISU - Modeling and Information Support Unit.

As described above, status updates to the Walla Walla Partnership and any internal decision-making will be determined on an as-needed basis by the project manager and clients. Table 7 shows the schedule proposed for completing the report for this study.

Table 7. Author lead and proposed schedule for completing reports.

Final report	
Author lead	Paul Pickett
Schedule	
Draft due to supervisor	August 2010
Draft due to client/peer reviewer	August 2010
Draft due to external reviewer(s)	September 2010
Draft due to publications coordinator	October 2010
Final report due on web	November 2010

Training and technology transfer will begin during the review of draft reports and will continue after the publication of the final report on an as-needed basis.

References

Baker, T.W., 2009. Water Management Initiative Monitoring Program Phase II: Final Report, Seasonal Seepage Assessments (WMI Task 4.2). Walla Walla Basin Watershed Council, Milton-Freewater, OR.

Bower, B., 2007. Walla Walla River Surface Water Budget Assessment. Walla Walla Basin Watershed Council, Milton-Freewater, OR.

Bower, B, D. Butcher, and M.E. Barber, 2007. Habitat Conservation Planning: Evaluating the Thermal Impacts of Streamflow and Irrigation Bypass in the Walla Walla River. Walla Walla Basin Watershed Council, Milton-Freewater, OR.

Ecology, 2007. Quality Assurance Monitoring Plan: Streamflow Gaging Network. Washington State Department of Ecology, Olympia, WA. Publication No. 05-03-204. www.ecy.wa.gov/biblio/0503204.html.

Economic and Engineering Services, 2002. Walla Walla Watershed, WRIA 32, Level I Assessment. Kennewick, Washington. Prepared for Walla Walla County, Walla Walla, WA.

Johnson, A., B. Era-Miller, R. Coots, and S. Golding, 2004. A Total Maximum Daily Load Evaluation for Chlorinated Pesticides and PCBs in the Walla Walla River. Washington State Department of Ecology, Olympia, WA. Publication No. 04-03-032. www.ecy.wa.gov/biblio/0403032.html.

Joy, J., G. Pelletier, and K. Baldwin, 2007. Walla Walla River Basin pH and Dissolved Oxygen Total Maximum Daily Load Study. Washington State Department of Ecology, Olympia, WA. Publication No. 07-03-010. www.ecy.wa.gov/biblio/0703010.html.

Joy, J. and T. Swanson, 2005. Walla Walla River Basin Fecal Coliform Bacteria Total Maximum Daily Load Study. Washington State Department of Ecology, Olympia, WA. Publication No. 05-03-041. www.ecy.wa.gov/biblio/0503041.html.

Lombard, S. and C. Kirchmer, 2004. Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies. Washington State Department of Ecology, Olympia, WA. Publication No. 04-03-030. www.ecy.wa.gov/biblio/0403030.html.

Pascual, P., N. Stiber, and E. Sunderland, 2003. Draft Guidance on the Development, Evaluation, and Application of Regulatory Environmental Models. Council for Regulatory Environmental Modeling. Office of Science Policy. U.S. Environmental Protection Agency. Washington D.C.

Petrides Jimenez, A.C., 2008. Modeling surface water and groundwater interactions near Milton- Freewater, Oregon. Masters Thesis, Oregon State University, Corvallis, OR. http://ir.library.oregonstate.edu/jspui/handle/1957/8583.

Saltelli, A., S. Tarantola, and F. Campolongo, 2000. Sensitivity Analysis as an Ingredient of Modeling. Statistical Science, 2000. 15: 377-395.

Sargent, R.G., 2000. Verification, Validation, and Accreditation of Simulation Models, Proceedings of the 2000 Winter Simulation Conference. J.A. Joines et al. (Eds).

State of Washington, 2007. Chapter 173-532 Washington Administrative Code, Washington State Department of Ecology, Olympia, WA. www.ecy.wa.gov/biblio/wac173532.html.

Stohr, A., M. LeMoine, and G. Pelletier, 2007. Walla Walla River Tributaries Temperature Total Maximum Daily Load Study. Washington State Department of Ecology, Olympia, WA. Publication No. 07-03-014. www.ecy.wa.gov/biblio/0703014.html.

USEPA, 2002. Quality Assurance Project Plans for Modeling. U.S. Environmental Protection Agency. Washington DC. Publication No. EPA QA/G-5M.

USGS, 2009a. USGS Surface-Water Daily Data for Washington. U.S. Geological Survey, Tacoma, WA. http://waterdata.usgs.gov/wa/nwis/.

USGS, 2009b. USGS Surface-Water Daily Data for Oregon. U.S. Geological Survey, Portland, OR. http://waterdata.usgs.gov/or/nwis/.

WWBWC, 2009a. Surface Water Monitoring in the Walla Walla Basin. Walla Walla Basin Watershed Council, Milton-Freewater, OR.

WWBWC, 2009b. Walla Walla Basin Hydrology and Fisheries GIS Project. Slide Presentation. Walla Walla Basin Watershed Council, Milton-Freewater, OR.

Figures

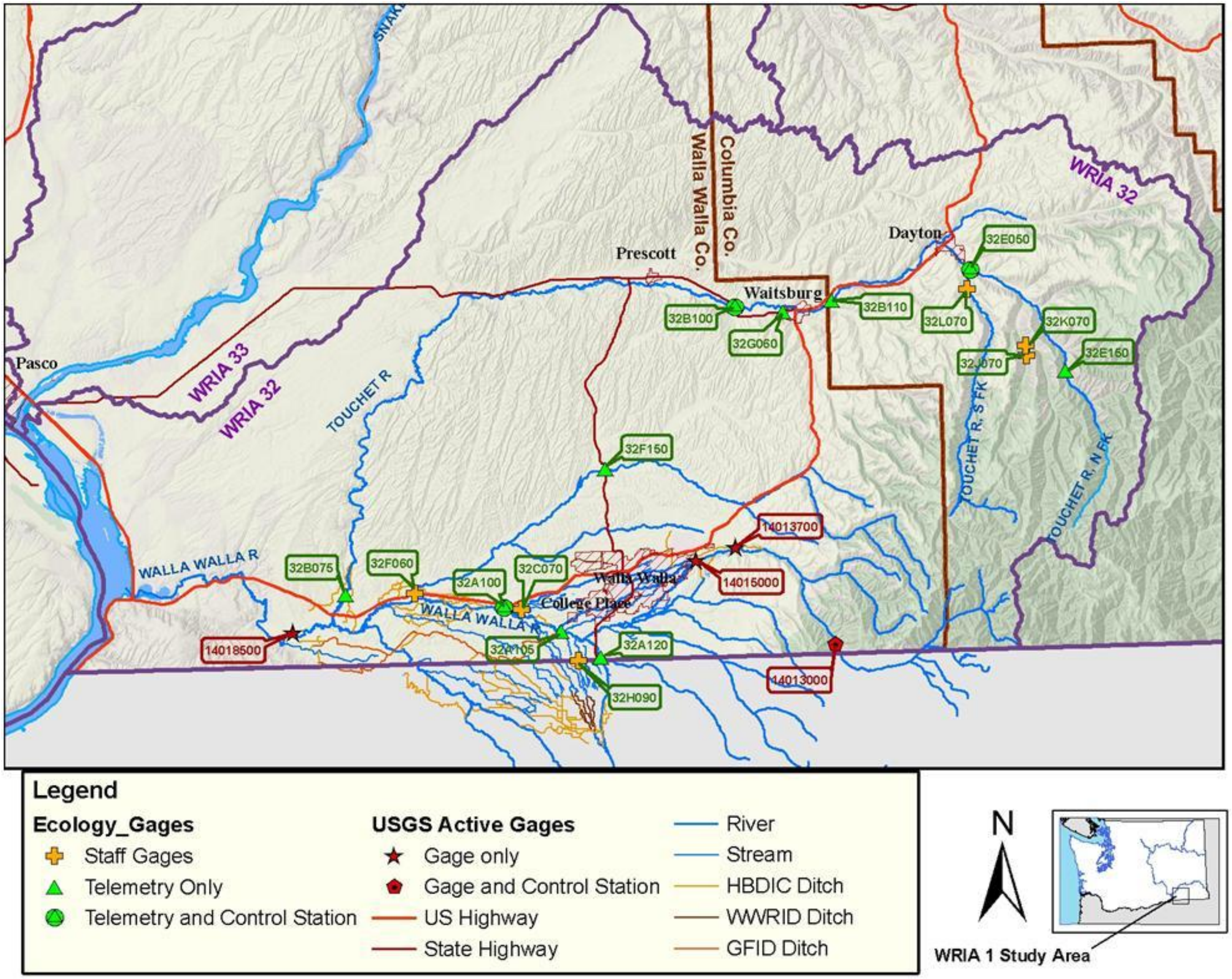

Figure 1. Walla Walla watershed study area (Water Resource Inventory Area 32).

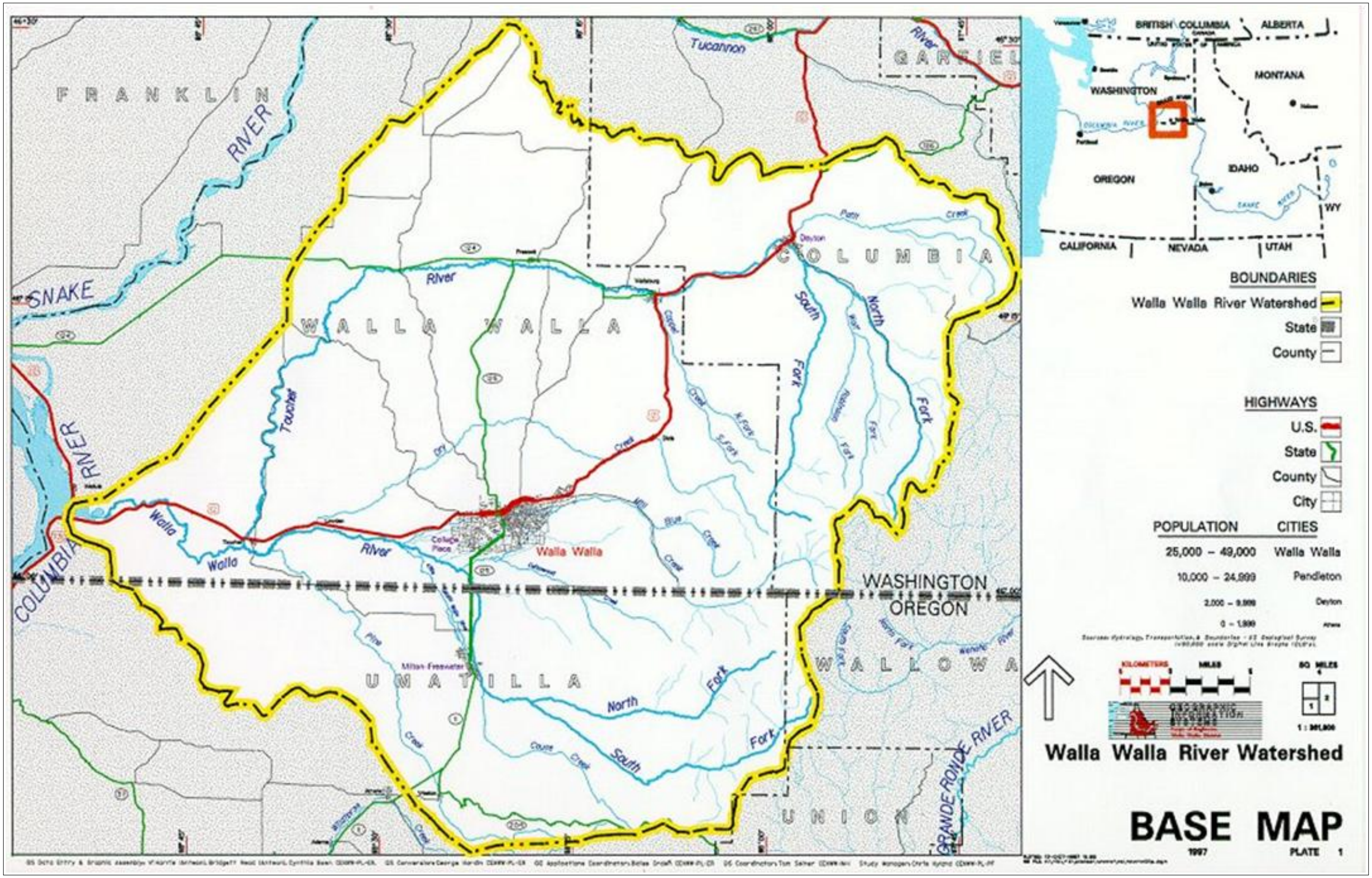

Figure 2. Map of the Walla Walla River watershed.

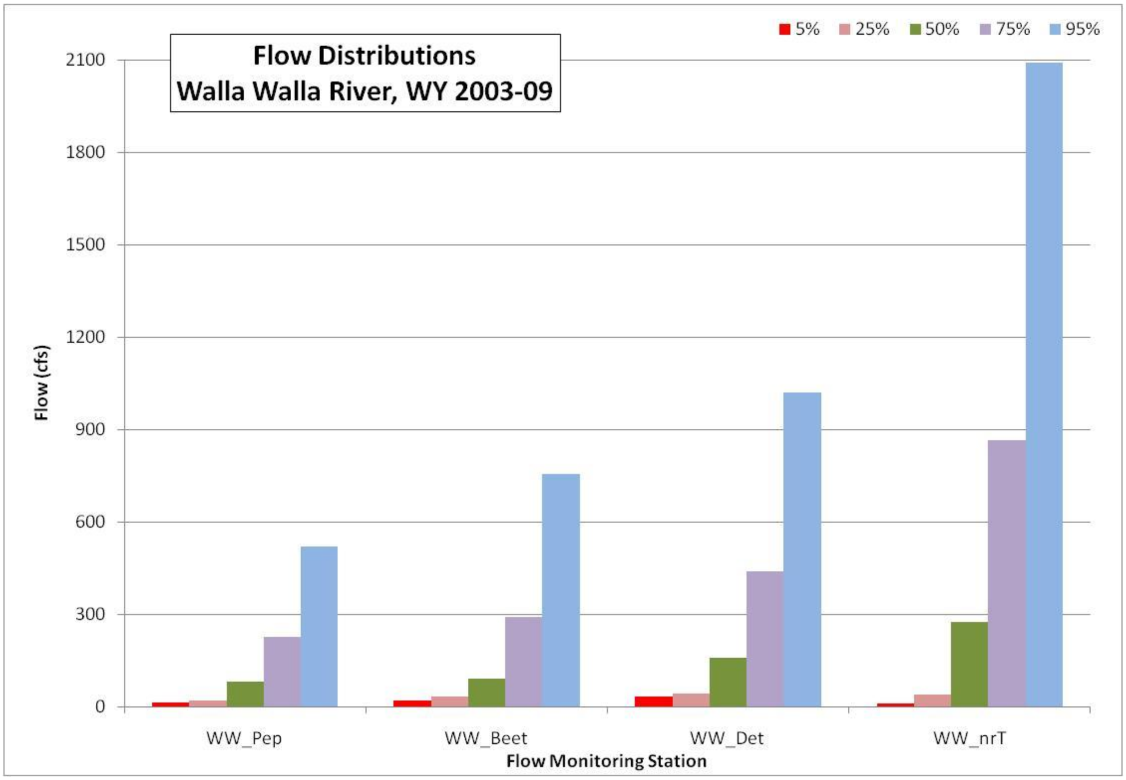

Figure 3. Flow distribution for Walla Walla River gaging stations.

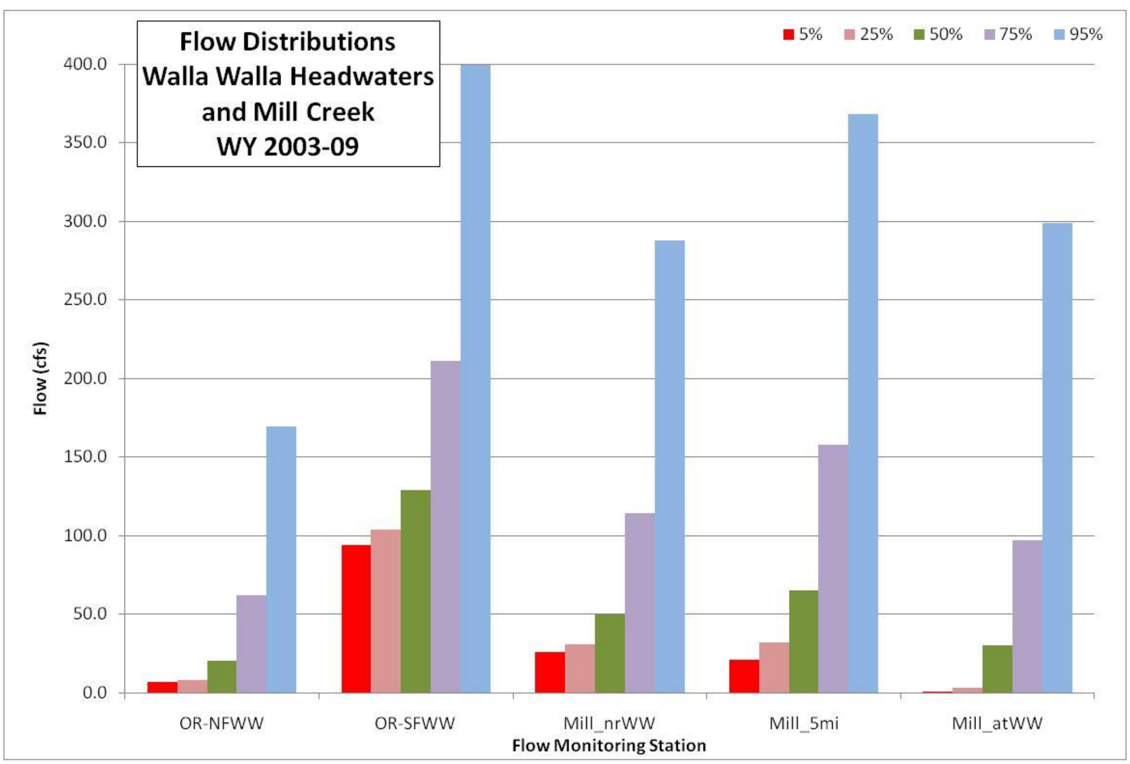

Figure 4. Flow distributions for Walla Walla River headwaters and Mill Creek gaging stations.

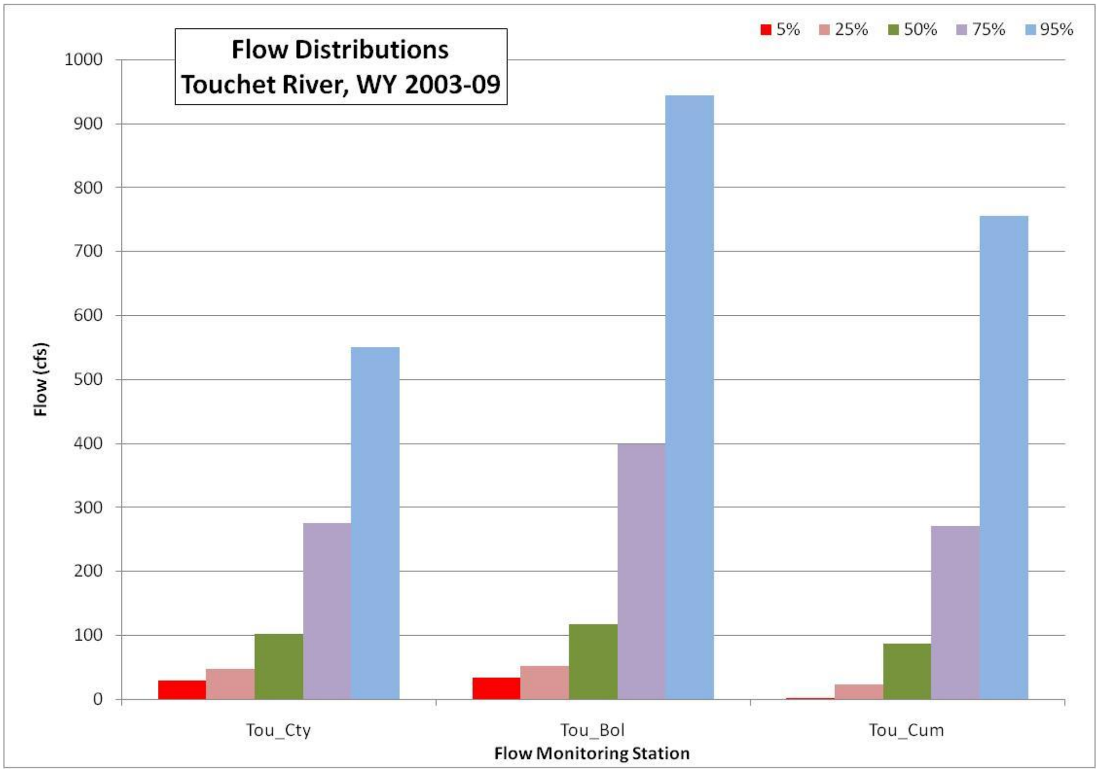

Figure 5. Flow distribution for Touchet River gaging stations.

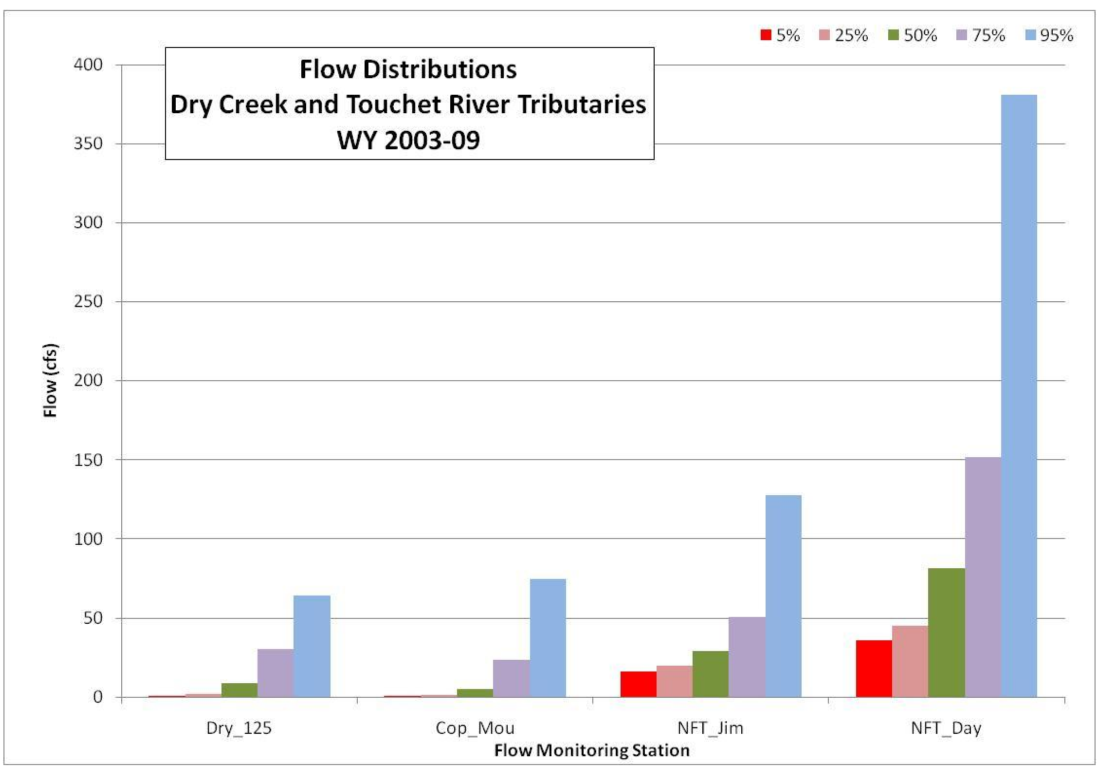

Figure 6. Flow distributions for Dry Creek and Touchet River tributary gaging stations.

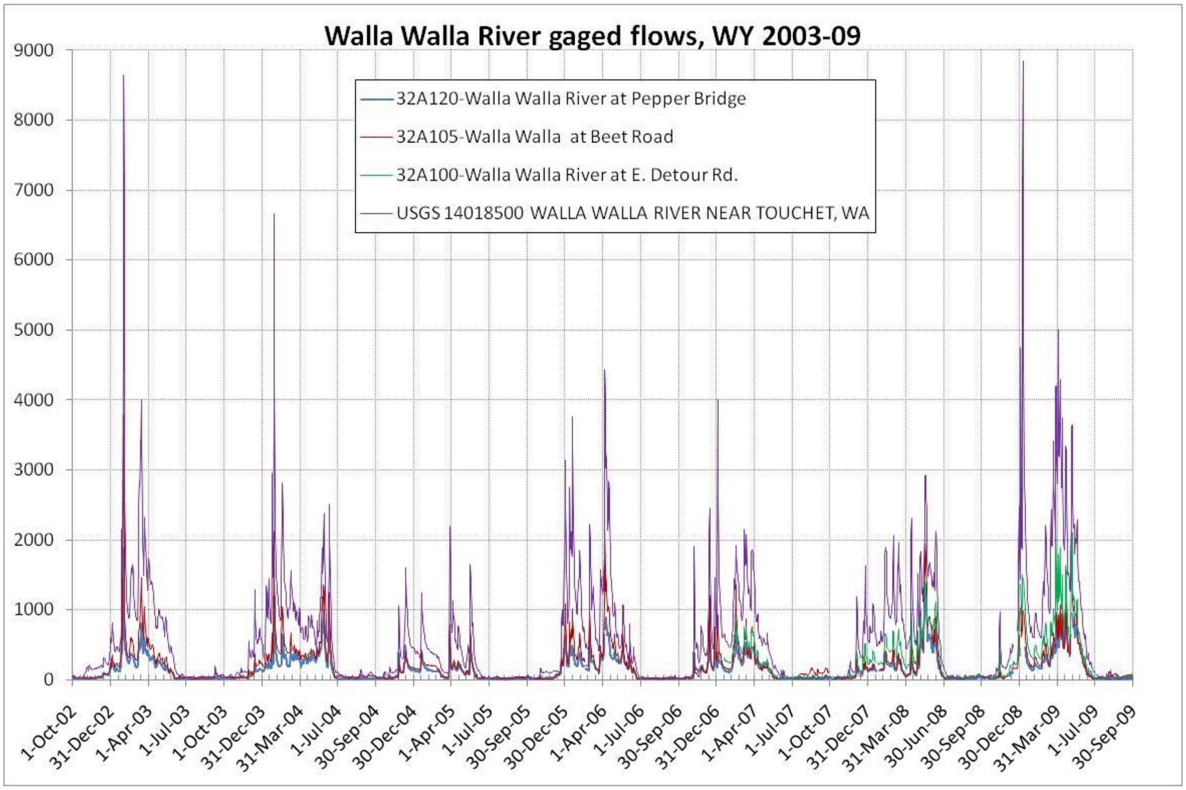

Figure 7. Flow at Walla Walla River gaging stations, October 1, 2002 – September 30, 2009.

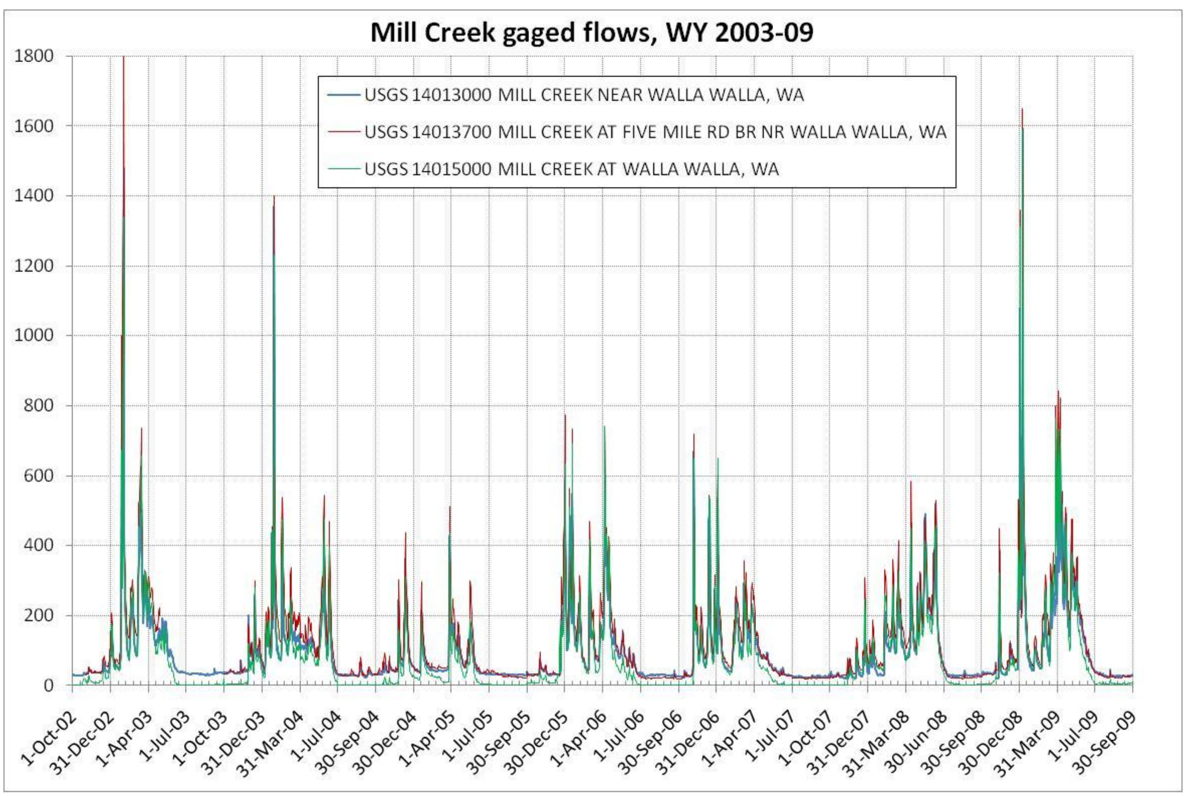

Figure 8. Flow at Mill Creek gaging stations, October 1, 2002 – September 30, 2009.

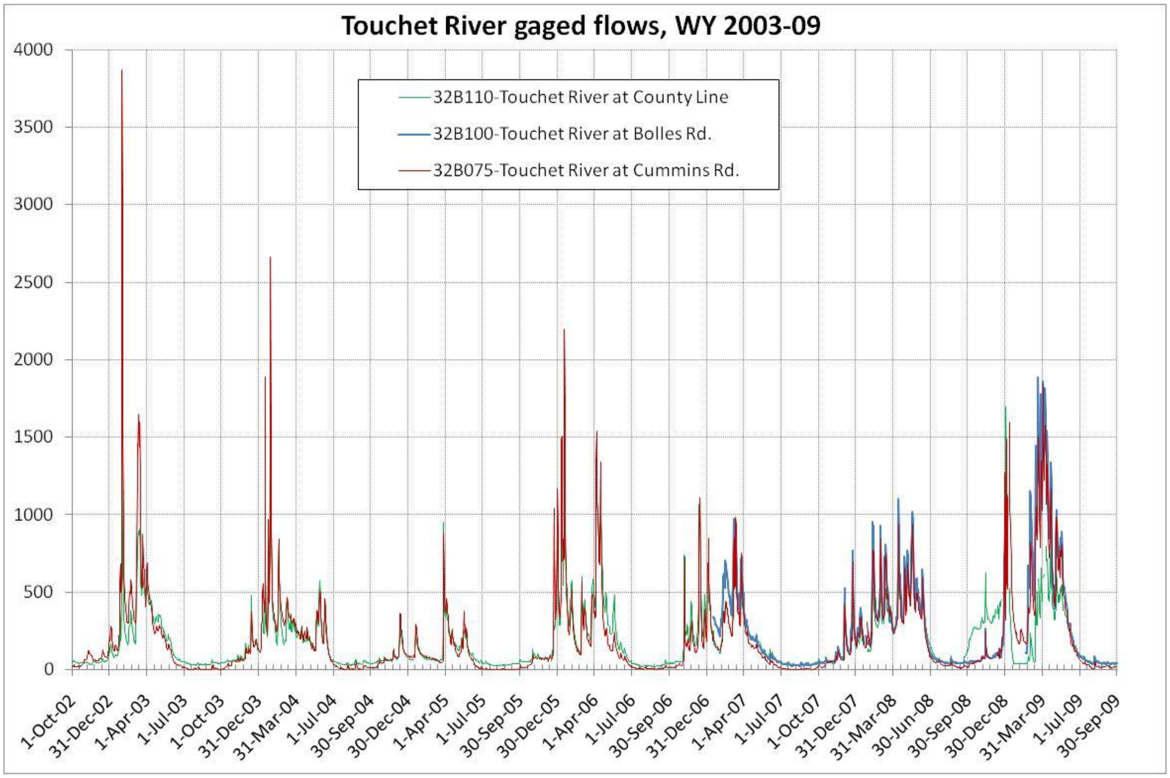

Figure 9. Flow at Touchet River gaging stations, October 1, 2002 – September 30, 2009.

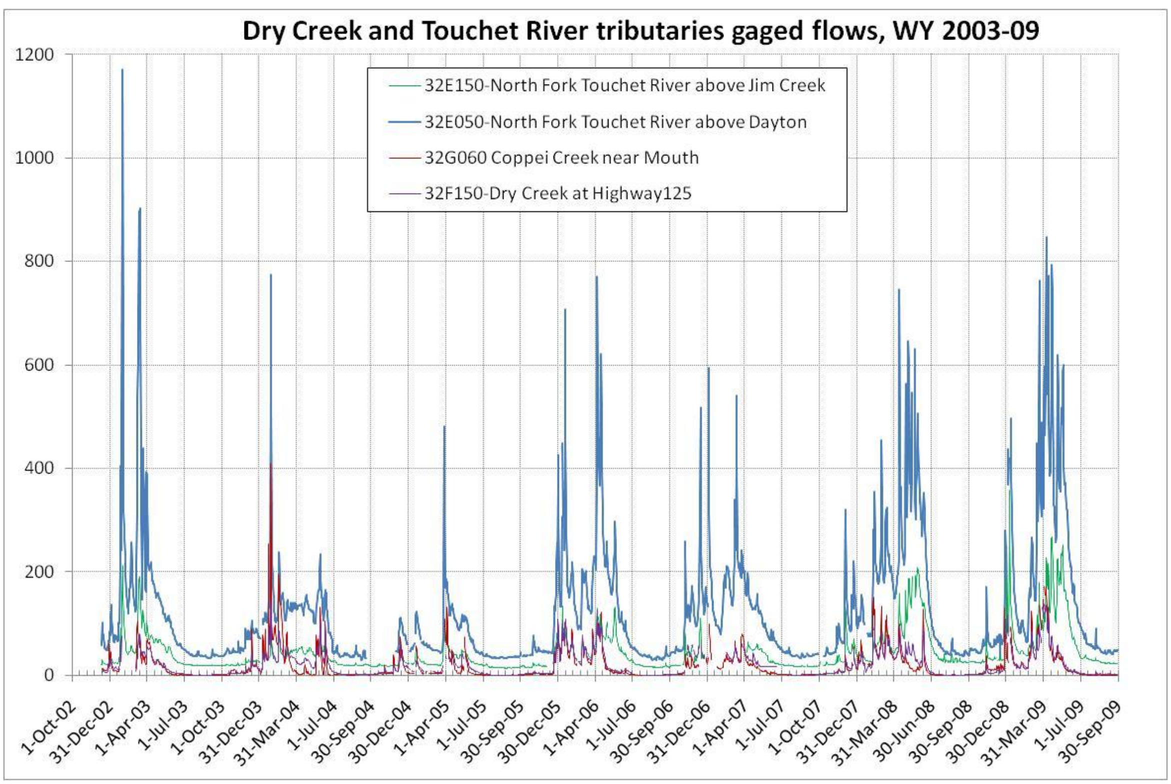

Figure 10. Flow at Touchet River tributary gaging stations, October 1, 2002 – September 30, 2009.

Appendix. Glossary, Acronyms, and Abbreviations

Glossary

Areal flow: Surface water discharge per unit of watershed area, in units of length per time (for example, inches per day).

Baseflow: The component of total streamflow that originates from direct groundwater discharges to a stream.

Hydrologic: Relating to the scientific study of the waters of the earth, especially with relation to the effects of precipitation and evaporation upon the occurrence and character of water in streams, lakes, and on or below the land surface.

Hyporheic zone: The area beneath and adjacent to a stream where surface water and groundwater intermix.

Parameter: A physical chemical or biological property whose values determine environmental characteristics or behavior.

Partnership: The Walla Walla Watershed Management Partnership, a local inter-governmental jurisdiction established by the Washington State legislature.

Reach: A specific portion or segment of a stream.

Seepage run: A study of streamflow that identifies gaining and losing reaches and determines reach-specific magnitudes of groundwater/surface water exchange by calculating a detailed flow balance for the stream from a synoptic series of flow measurements.

Stage height: Water surface elevation.

Stormwater: The portion of precipitation that does not naturally percolate into the ground or evaporate but instead runs off roads, pavement, and roofs during rainfall or snowmelt. Stormwater can also come from hard or saturated grass surfaces such as lawns, pastures, playfields, and from gravel roads and parking lots.

Streamflow: Discharge of water in a surface stream (river or creek).

Surface waters of the state: Lakes, rivers, ponds, streams, inland waters, salt waters, wetlands and all other surface waters and watercourses within the jurisdiction of Washington State.

Telemetry: The automatic transmission of data by wire, radio, or other means from remote sources.

Watershed: A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

Water year (WY): An annual period defined by hydrologic characteristics. The water year used in this study is October 1 through September 30, and the number of the year represents the calendar year at the end of the water year. For example, "WY 2003" describes the water year beginning October 1, 2002 and ending September 30, 2003.

90th percentile: A statistical number obtained from a distribution of a data set, above which 10% of the data exists and below which 90% of the data exists.

Acronyms and Abbreviations

Following are acronyms and abbreviations used frequently in this report.

%RSD	Percent relative standard deviation
Ecology	Washington State Department of Ecology
GFID	Gardena Farms Irrigation District
GIS	Geographic Information System software
HBDIC	Hudson Bay District Improvement Company
No.	Number
OWRD	Oregon Water Resources Department
Partnership	(See Glossary above)
RCW	Revised Code of Washington
RM	River mile
RPD	Relative percent difference
USGS	U.S. Geological Survey
WAC	Washington Administrative Code
WRIA	Water Resources Inventory Area
WWBWC	Walla Walla Basin Watershed Council
WWRID	Walla Walla River Irrigation District
WY	(See Glossary above)

Units of measurement

cfs	cubic feet per second, a unit of flow discharge
cms	cubic meters per second, a unit of flow discharge
ft	feet
g	gram, a unit of mass
in/d	inches per day
kg	kilograms, a unit of mass equal to 1,000 grams
kg/d	kilograms per day
km	kilometer, a unit of length equal to 1,000 meters
l/s	liters per second (0.03531 cubic foot per second)
m	meter
mg	million gallons
mgd	million gallons per day
mg/d	milligrams per day
mg/Kg	milligrams per kilogram (parts per million)
mL	milliliters