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Simulated Runoff at Many Locations in the Methow River Basin, Washington

Open-File Report 2015-1011

U.S. Department of the Interior
U.S. Geological Survey

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SALLY JEWELL, Secretary

U.S. Geological Survey
Suzette M. Kimball, Acting Director

U.S. Geological Survey, Reston, Virginia: 2015

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Conversion Factors

Inch/Pound to International System of Units

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow rate	
inch per day (in/d)	2.54	centimeter per day (cm/d)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

International System of Units to Inch/Pound

Multiply	By	To obtain
	Length	
meter (m)	3.281	foot (ft)

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$°C=(°F-32)/1.8$$

Datums

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Elevation, as used in this report, refers to distance above the vertical datum.

Abbreviations

GIS	geographic information system
GSFLOW	groundwater and surface-water flow model
HRU	hydrologic response unit
PRMS	Precipitation Runoff Modeling System
USGS	U.S. Geological Survey

Simulated Runoff at Many Stream Locations in the Methow River Basin, Washington

By Mark Mastin

Abstract

A collaborative Bureau of Reclamation-U.S. Geological Survey (USGS) team has been brought together to incorporate a conceptual geomorphic-habitat model with a process-based trophic model to understand the processes important to stream habitat for anadromous fish populations. The Methow River Basin was selected as a test basin for this hybrid geomorphic-habitat/trophic model, and one of the required model inputs is long-term daily runoff at reaches with potential habitat. Leveraging the existence of a watershed model that was constructed for the Methow River Basin by the USGS, the team approached the USGS at the Washington Water Science Center to resurrect the original model and to simulate runoff at many locations in the basin to test the trophic model. Thirteen new flow-routing sites were added to the model, creating a total of 61 sites in the basin where daily runoff was simulated and provided as output. The input file that contains observed meteorological data that drives the watershed model and observed runoff data for comparisons with simulated runoff was extended from water year 2001 to water year 2013 using data from 18 meteorological sites and 12 observed runoff sites. The watershed model included simulation of 16 irrigation diversions that simulated 50-percent water loss through canal seepage. Irrigation was simulated as a constant application of 0.2 inches per day to during the irrigation season, May 1–October 7.

Comparisons of the simulated runoff with observed runoff at six selected long-term streamflow-gaging stations showed that the simulated annual runoff was within +15.4 to -9.6 percent of the annual observed runoff. The simulated runoff generally matched the seasonal flow patterns, with bias at some stations indicated by over-simulation of the October–November late autumn season and under-simulation of the snowmelt runoff months of May and June. Sixty-one time series of daily runoff for a 26-year period representative of the long-term runoff pattern, water years 1988–2013, were simulated and provided to the trophic modeling team.

Introduction

The Bureau of Reclamation (Reclamation) and the U.S. Geological Survey (USGS) are collaborating on a project in the Methow River Basin to merge a conceptual geomorphic-habitat model with a process-based trophic model (Bellmore and others, 2014) designed to aid in the understanding of how environmental variables and their relationship to one another influence fish production. The Methow River is one of several rivers selected to test these models at reach and watershed scales. The key hydrodynamic variables for the conceptual geomorphic-habitat model include discharge, changes in water-surface area, depths and velocities associated with discharge, wood and sediment accruals, bed slope, and bed scour. Although streamflow-gaging data are available at about a dozen locations in the basin, daily discharge data are needed at many more stream locations in the basin. The USGS Washington Water Science Center previously developed a rainfall-runoff (watershed) model calibrated to observed runoff (Ely and Risley, 2001; Ely, 2003; Voss and Mastin, 2012); therefore, with some minor alterations to the model and the extension of the meteorological data input files through the end of water year 2013, a daily time series of runoff at many ungaged stream locations on the Methow River network could be simulated.

Purpose and Scope

This report contains background information on the watershed model used to simulate runoff in the Methow River Basin and the results of those simulations. The previous model included input data from water years 1958 to 2001. The input data were updated through water year 2013 for this project. The original model included 48 stream locations where simulated data could be summarized and a daily time series of runoff could be generated. Thirteen new stream locations were added for this project at areas of interest to the team developing the conceptual geomorphic-habitat model and process-based trophic model. All areas of interest were at locations representing small watersheds upstream of existing simulated stream locations. This report also contains summaries of mean monthly and mean annual simulated and observed data. Extensive calibration and parameter sensitivity analysis were done on the watershed model by Ely (2003), so no additional calibration of the model was performed as part of this project.

Basin Description

The Methow River drains 1,820 mi^2 in north-central Washington on the east side of the Cascade Mountains (fig. 1). The headwaters are along the crest of the Cascade Mountains at elevations as high as 8,950 ft, and water generally flows in a southeasterly direction to the mouth at the confluence with the Columbia River near the town of Pateros (elevation 755 ft). Annual precipitation is greatest at the Cascade crest, with more than 70 in. that mostly is in the form of snow, and least near the Methow River mouth, with about 10 in. (climatological normal 1971–2000; Daly and others, 2002).

Water availability in the Methow River Basin is vital for sustaining the local economy and the fragile ecosystem. Irrigation for agriculture accounts for 99 percent of the allocated water use as determined from water rights (Methow Basin Planning, 2005). In 2000, the basin contained 16,730 acres of irrigated land, 77 percent of which were planted in alfalfa, and the remaining acreage primarily was orchards or pasture. Seepage from river channels, irrigated farmland, and unlined irrigation ditches recharges groundwater reservoirs (Konrad and others, 2003) that provide groundwater discharge necessary for maintaining wetlands, riparian habitat, and flows during the late summer and autumn. These summer and autumn flows are vital for supporting the Upper Columbia summer steelhead (*Oncorhynchus mykiss*) and spring Chinook (*Oncorhynchus tshawytscha*) salmon populations (which are both listed as endangered under the Endangered Species Act), as well as bull trout (*Salvelinus confluentus*) populations (listed as a threatened species). Water also is important for the growing tourism industry, which includes Nordic skiing, fishing, boating, and wildland recreation.

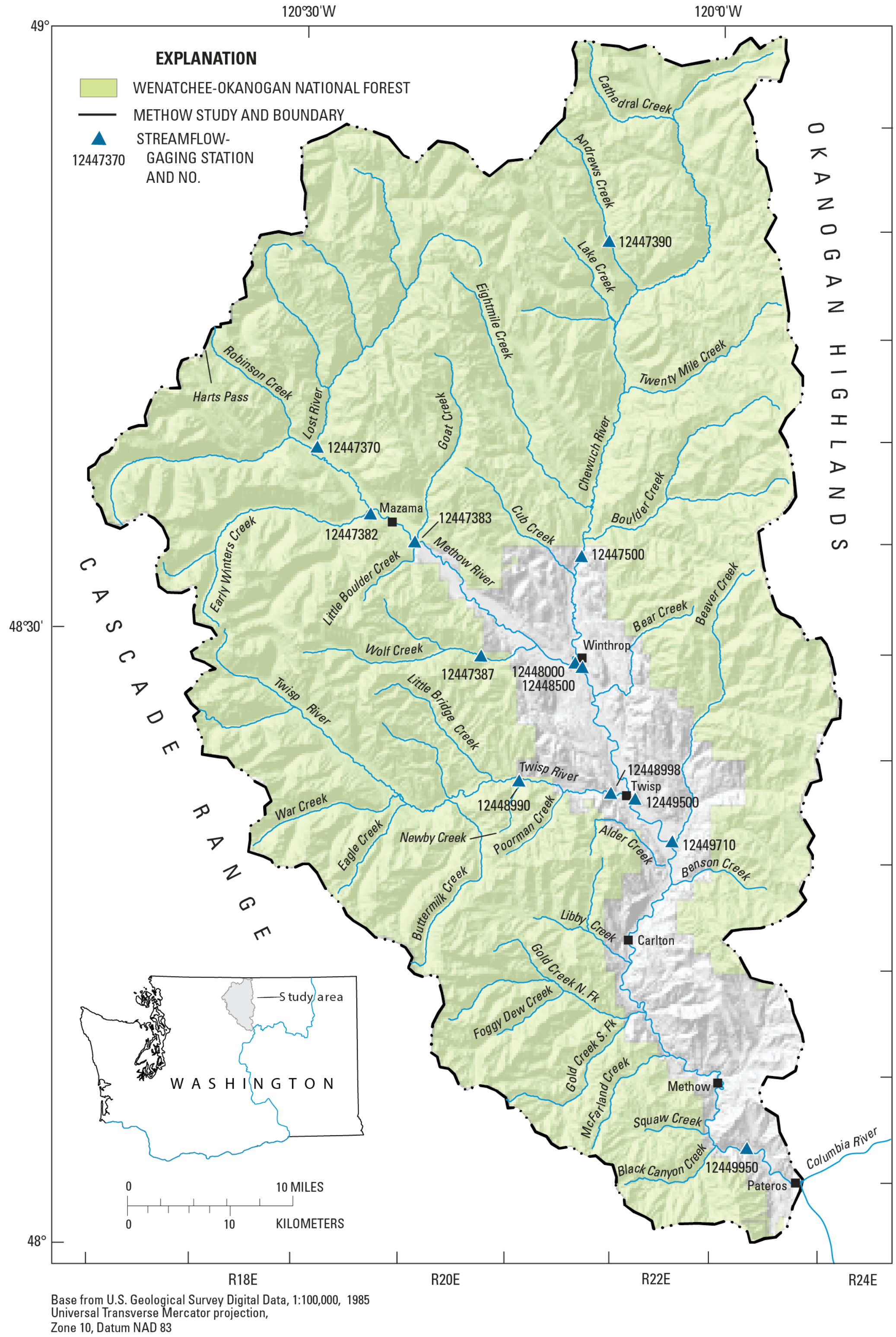


Figure 1. Map showing location of U.S. Geological Survey streamflow-gaging stations in the Methow River Basin, Washington. From Voss and Mastin (2012).

The climate varies from alpine conditions in the Methow River headwaters to semi-arid lowlands. The average annual precipitation for the basin is 31.9 in. (U.S. Geological Survey, 2011). Precipitation mostly is in the form of snow at higher elevations and mostly falls in the winter months. This type of winter-snow precipitation climate results in a hydrology dominated by snowmelt runoff during the spring-early summer season. Two hydrographs are shown in figure 2— Andrews Creek, a small high-elevation watershed (streamflow gaging station is at an elevation of 4,300 ft) with a drainage area of 22.1 mi^2; and Methow River near Pateros, a streamflow-gaging station near the mouth of the Methow River at an elevation of 900 ft with a drainage area of 1,772 mi^2. Andrews Creek has a mean discharge of 32.6 ft^3/s (water years 1969–2013) that is equivalent to an average runoff of 20.03 in. The Methow River near Pateros has a mean discharge (water years 1960–2013) of 1,558 ft^3/s that is equivalent to an average runoff of 11.95 in.. Both streamflow hydrographs show a similar runoff pattern (fig. 2), with highest flows occurring in May and June in response to the snowmelt season.

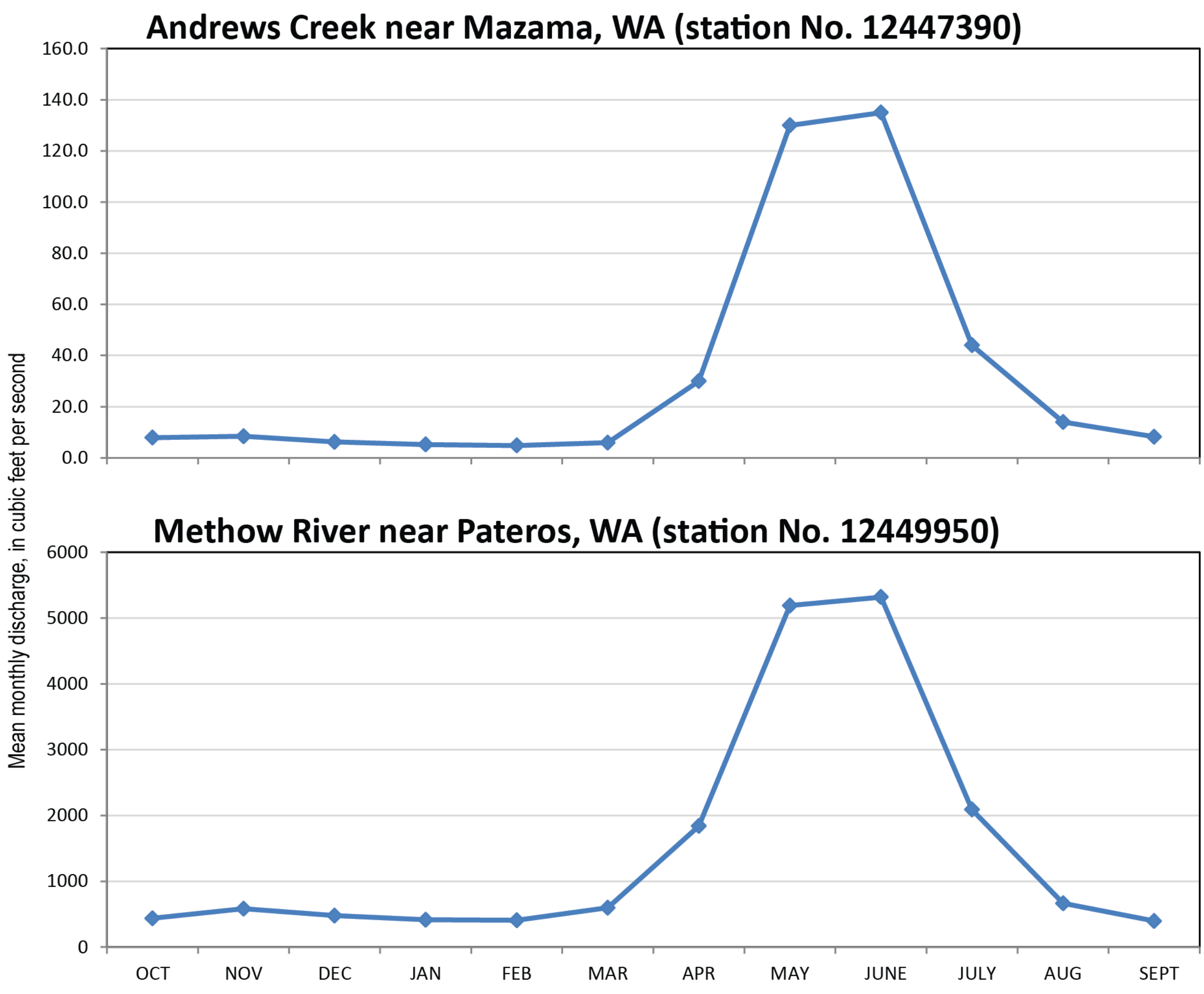


Figure 2. Graphs showing mean monthly discharge for water years 1988–2013 at two streamflow-gaging stations in the Methow River Basin, Washington.

Watershed Model

The watershed model used for this project is the Precipitation Runoff Modular System (PRMS; Leavesley and others, 1983). The model runs on a daily time step and requires daily precipitation and maximum and minimum daily air temperature as input to drive the model. PRMS is a physically based, distributed-parameter model that simulates runoff and snow accumulation and melt. The basin is partitioned into hydrologic response units (HRUs), which sometimes are referred to as model response units (MRUs) or units of land that have similar hydrologic responses to moisture and temperature inputs. A water budget is calculated for each HRU to estimate surface, subsurface, and groundwater outflow. Flow-routing segments (previously referred to as “nodes”) accumulate simulated runoff from the HRUs, route the flows to the next downstream segment, and provide daily simulated runoff to the user as output.

Development of the Model for the Methow River Basin

The original PRMS watershed model was constructed for the Methow River Basin by Ely and Risley (2001) and was updated by Ely (2003). The updated Methow model included the simulation of diversions and applications of irrigation waters. The calibrated parameters and construction of this second version of the model is thoroughly explained by Ely (2003) and closely represents the model used for this project. The second version of the Methow model was developed on a UNIX® computer platform. Since that time, the PRMS model has been updated to run on a Microsoft Windows® operating system and code has been updated to accommodate GSFLOW, a coupled groundwater and surface-water flow model that uses PRMS for the surface-water algorithms (Markstrom and others, 2008). GSFLOW has not been applied to the Methow River Basin. The PRMS updated model for Windows® includes changes in several parameter names and a slight alteration of some of the algorithms. A third version of the Methow model was created using the Windows® version of PRMS by Voss and Mastin (2012). The parameters that were calibrated by Ely (2003) were used in this third version, but as a result of converting to the Windows® PRMS model, the simulations between the two versions of the model did not match exactly. A comparison of the simulated runoff was made by Voss and Mastin (2012) for the two versions of the model at 11 USGS streamflow-gaging stations in the Methow River Basin for water years 1960–2001. The simulated mean annual streamflow for the Windows® version of the Methow model was within 5 percent of the earlier simulations by Ely (2003) for all sites except for Beaver Creek (station 12449710), which was 8.8 percent different. This Windows® version of the Methow model (Voss and Mastin, 2012) is the same as the version used for this project, with the exception of some added stream segments as described in section, “Stream Segments.” The added stream segments do not affect the quantity of runoff simulated by the model. The added segments only provide additional locations where simulated runoff can be reported in the output file.

Construction of the PRMS Model for the Methow River Basin

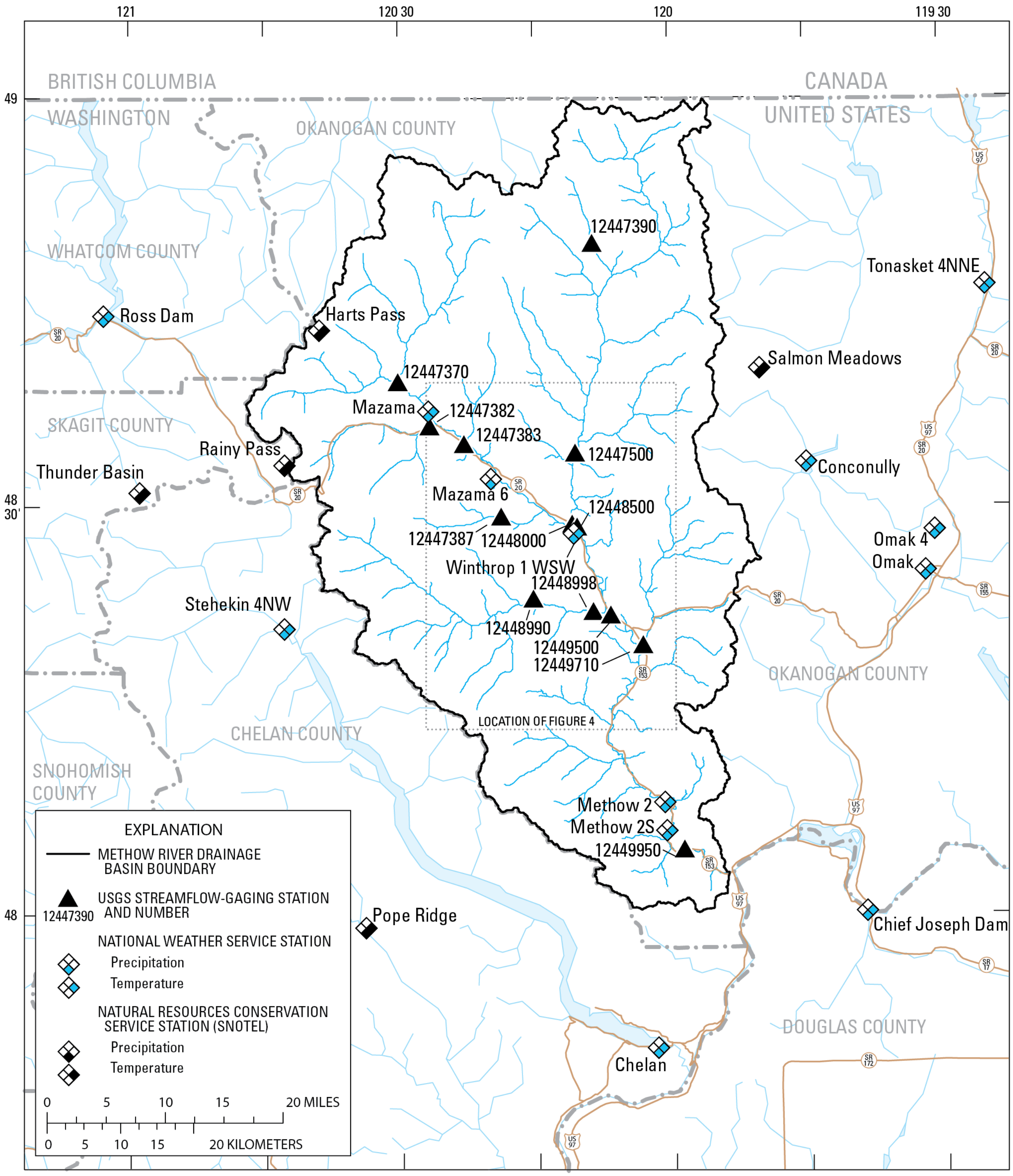
The construction of the PRMS model for the Methow River Basin is thoroughly described by Ely and Riley (2001) and Ely (2003) and in less detail in this section of the report. The drainage network and HRUs were delineated with the geographic information system- (GIS-) based program called Weasel (Viger and others, 1998), with a digital elevation model (DEM) having regularly spaced 30-m cells as the primary input. The delineation of HRUs began with a two-flow-plane process that defined separate irregular polygons on each side of a stream reach. The HRUs were further divided by elevation zones at 1,000-ft intervals. The result was to define 620 HRUs for the entire basin, ranging in size from 1.5 to 2.4 mi^2.

Based on the map of HRUs, a topographic grid, a State Soil Geographic Database (STATSGO) GIS grid of generalized soil-survey data (U.S. Department of Agriculture, 1994), a GIS grid of forest density (Powel and others, 1998), and a GIS grid of land cover/land use (Loveland and others, 1991), the Weasel program computed most of the model parameters for the Methow model. Outside of the Weasel program parameters, such as the groundwater recession coefficients, monthly mean precipitation values for the HRUs and flow-routing parameters were computed or calibrated by comparing simulated and observed runoff.

Input Data File

The PRMS model is driven by input of daily minimum and maximum air temperature and daily precipitation from the input data file (table 1). The model uses an inverse-square distance weighting scheme to distribute the precipitation data from all precipitation inputs to estimate a daily precipitation total for each HRU. Daily minimum and maximum temperatures use a similar inverse-square distance interpolation scheme along with calculated lapse rates to distribute air temperature from all input sites to each of the HRUs (Mastin and Vaccaro, 2002). The input data file for the Methow model also contains daily discharge for 12 streamflow-gaging stations that are used for comparison with simulated discharge and that are not used in the simulations (table 1). After the initial header data, each row of data in the input data file corresponds to 1 day of data for the date provided in the second to fourth columns of data.

The data input file was extended from October 1, 2002 to September 30, 2013 for this project. The locations of the sites represented in the data in the input data file are shown in figure 3.



Base from U.S. Geological Survey Digital Data, 1:100,000, 1985
Universal Transverse Mercator projection,
Zone 10, Datum NAD83

Figure 3. Map showing data-collection network used for the watershed model for the Methow River Basin, Washington. From Ely (2003).

Table 1. Streamflow-gaging and meteorological stations by agency collecting the data, period of record, and the position in the data input file, Methow River Basin, Washington.

[Locations of stations are shown in figure 3. R, runoff; Precip., precipitation; Min., minimum; Max., maximum; Temp., temperature; --, not applicable]

Station name (station No.)	Period of record	Position in each row of data in the input data file			
		R	Precip.	Min.	Max.
U.S. Geological Survey streamflow-gaging stations					
Lost River near Mazama (12447370)	2000–present	1	--	--	--
Early Winters Creek near Mazama (12447382)	2000–present	2	--	--	--
Methow River above Goat Creek near Mazama (12447383)	1991–present	3	--	--	--
Wolf Creek below Diversion near Winthrop (12447387)	2000–2003	4	--	--	--
Andrews Creek near Mazama (12447390)	1968 to present	5	--	--	--
Chewuch River below Boulder Creek near Winthrop (12447500)	No daily record	6	--	--	--
Chewuch River at Winthrop (12448000)	1992–present	7	--	--	--
Methow River at Winthrop (12448500)	1912 –present	8	--	--	--
Twisp R above Newby Creek near Twisp (12448990)	2000–2003	9	--	--	--
Twisp River near Twisp (12448998)	1976–present	10	--	--	--
Methow River near Twisp (12449500)	1919–present	11	--	--	--
Beaver Creek near Mouth near Twisp (12449710)	2000–2001	12	--	--	--
Methow River at Pateros (12449950)	1959–present	13	--	--	--
National Weather Service meteorological stations					
Chelan	1890–present	--	14	32	49
Chief Joseph Dam	1949–present	--	15	33	50
Conconully	1948–present	--	16	34	51
Mazama	1950–present	--	17	35	52
Mazama 6	1948–1976	--	18	--	--
Methow 2	1957–1970	--	19	36	53
Methow 2S	1970–present	--	20	37	54
Omak	1931–1998	--	21	38	55
Omak 4	1980 –1991	--	22	39	56
Ross Dam	1960–present	--	23	40	57
Stehekin 4 NW	1931–present	--	24	41	58
Tonasket 4 NNE	1984–present	--	25	42	59
Winthrop 1 WSW	1931–present	--	26	43	60
Natural Resources Conservation Service meteorological stations					
Harts Pass	1981–1982, 1983–present	--	27	44	61
Pope Ridge	1981–present	--	28	45	62
Rainy Pass	1981–present	--	29	46	63
Salmon Meadows	1981–1982,1983–present	--	30	47	64
Thunder Basin	1989–present	--	31	48	65

Diversions and Applications

Streamflow in most of the lower basin is affected by withdrawals of surface water for irrigation. Water removed from the rivers either is applied to the fields for irrigation or seeps from canals where they are unlined, contributing to the recharge of the local aquifer. The recharge from seepage is simulated by providing a HRU number that directs the seepage from a specified diversion to the simulated groundwater reservoir for that HRU.

Based on discharge measurements documented by Klohn Leonoff, Inc. (1990) and Konrad and others (2003), Ely (2003) estimated that 50 percent of the diverted water is lost from the canal by seepage. This value was used by the Methow model in the simulation of all diversions. Ely (2003) estimated that irrigation was applied at an average rate of 0.2 in/d from May 1 through October 7, totaling 32 in. of water for the 160-day period and approximating the annual water requirement for alfalfa. A time series of 0.2 in/d throughout the irrigation season, May 1–October 7, was developed as a separate data file for simulating irrigation for water years 1988–2013. Another separate data file contains a daily time series of diversions for 16 irrigation canals based on reported values or as determined by Ely (2003) from the change in streamflow at the diversion point (table 2). The Beaver diversion represents a summation of many small diversions in the Beaver Creek area. The data file of daily diversions uses the same values (table 2) for every year of simulation for water years 1988–2013, with the exception of water years 2000 and 2001 when Early Winters and Wolf Creek ditches were shut down early.

Table 2. Simulated irrigation diversions, Methow River Basin, Washington.).

[Data from Ely (2003; table 3). Data position in the diversion data file is shown in parentheses beneath the diversion name. **Abbreviations:** Sept., September; MVID, Methow Valley Irrigation District; TVPI, Twisp Valley Power and Irrigation]

Date	Daily diversion rate, in cubic feet per second							
	Barkley (1)	Beaver (16)	Chewuch (2)	Early winters (3)	Eightmile (4)	Foghorn (5)	Foster (6)	Fulton (7)
May 1–15	12	12	25	14	5	15	5	15
May 16–31	12	12	30	14	5	15	5	15
June 1–15	12	17	30	14	5	15	5	15
June 16–30	12	17	35	14	5	15	5	15
July 1–15	12	17	35	14	7	18	5	18
July 16–31	18	12	30	14	7	18	5	18
August 1–15	18	12	25	14	7	13	5	20
August 16–30	15	12	25	14	7	13	5	20
Sept. 1–15	15	12	25	14	7	10	5	17
Sept. 16–30	9	12	20	14	7	10	5	17
October 1–7	4.5	0	10	7	3.5	5	2.5	8.5
Date	**Kumm-Holloway (8)**	**McKinney Mountain (9)**	**MVID East (10)**	**MVID West (11)**	**Rockview (12)**	**Skyline (13)**	**TVPI (14)**	**Wolf Creek (15)**
May 1–15	4.5	5	39	24	9	20	10	8
May 16–31	4.5	5	39	24	9	20	12	8
June 1–15	4.5	5	41	24	9	22	11	8
June 16–30	4.5	3	41	24	9	22	11	8
July 1–15	4.5	3	42	26	10	17	11	8
July 16–31	4.5	3	42	26	10	17	11	8
August 1–15	4.5	3	37	26	10	20	10	8
August 16–30	4.5	3	37	26	10	20	9	8
Sept. 1–15	4.5	3	39	25	9	15	7	8
Sept. 16–30	4.5	3	39	25	9	15	7	8
October 1–7	2.3	1.5	19.5	10	4.5	7.5	2.5	4

Stream Segments

Stream segments represent the stream reaches, although they can be conceptualized as a point on the stream network that accumulates runoff from an upstream segment and (or) an upstream HRU runoff. A simple algorithm routes water from one segment to the next downstream segment. Model parameters are used to direct runoff from the HRUs to user-specified segments, and the parameters also direct routed streamflows from the segment to the next downstream segment. The segments also allow the user to output daily runoff to an ASCII file for each specified segment. The model was set up with 211 segments, but only 48 segments were active in the sense that they were receiving runoff from HRUs, and the other segments were inactive or were not receiving runoff from HRUs. The inactive segments are simply connected to other segments and they do not affect the simulations. The active segments generally were located at the mouth of major tributaries and at streamflow-gaging stations so that simulated and observed runoff could be compared during the original calibration process. The Reclamation-USGS team developing the trophic-geomorphic model for the Methow River Basin requested additional daily time series of simulated discharge to represent catchments upstream of the existing network of active segments. Thirteen additional segments were activated for this project. Some of the HRUs that were upstream of the new segments and that originally were supplying runoff to an existing active segment now are supplying runoff to a newly activated segment. The runoff accumulated in the newly activated segment is routed downstream to the existing active segment. Thus, all runoff is conserved and tests showed that the resulting runoff hydrograph with the new activated segments is almost identical to the hydrographs simulated by the original model with slight differences (less than 1 percent) owing to changes in travel time. The location and segment number for all segments receiving HRU runoff as point features are shown in figure 4. A total of 61 active segments are in the current watershed model, and a time series of simulated runoff at each of the segments was generated and provided to the Reclamation-USGS team.

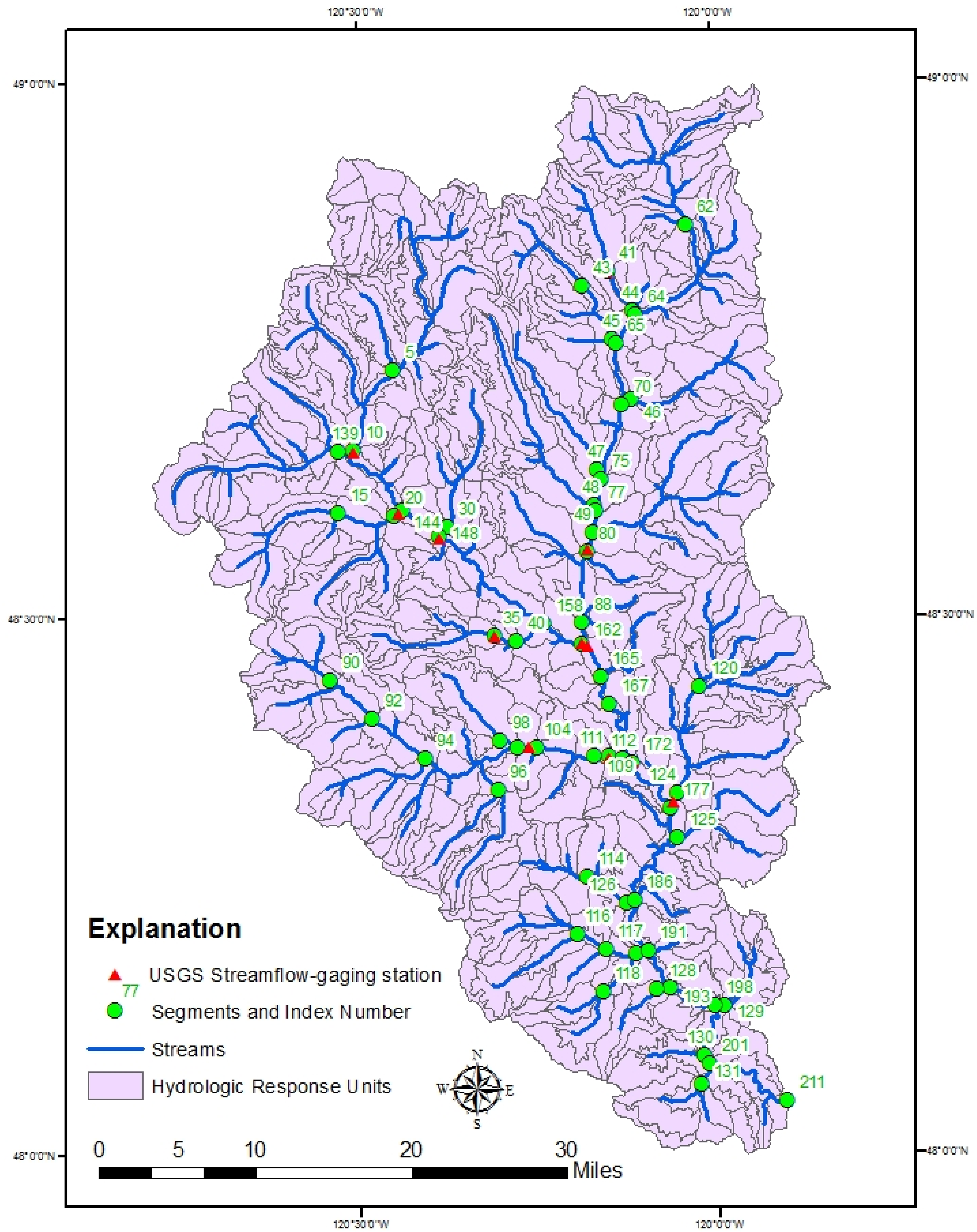


Figure 4. Map showing U.S. Geological Survey (USGS) streamflow-gaging stations, flow-routing segments, and hydrologic response units for the watershed model for the Methow River Basin, Washington.

Simulated Runoff at Stream Locations

The watershed model was run from water years 1986 to 2013. The first two water years were used as a “warm-up” period for the model to allow the various simulated moisture storages and variables to approach a true, stable condition. The effective period of simulation was from the beginning of water year 1988 to the end of water year 2013. This 26-year period seems to be fairly representative of the long-term hydrology of the basin. The annual mean runoff for this period is 1,537 ft^3/s, as recorded at the USGS streamflow-gaging station, Methow River near Pateros, Washington (station No. 12449950), which is similar to the long-term mean runoff of 1,558 ft^3/s at the same streamflow-gaging station (water years 1960–2013, fig. 5).

In order to assess the accuracy of the watershed model in simulating the general hydrology of the basin, mean monthly simulated and observed runoff were compared at six selected streamflow-gaging stations with the longest record of runoff (fig. 6). Several of the comparisons of simulated and observed runoff show a tendency to over-simulate runoff for October and November and under-simulate runoff for May and June. The difference between simulated and observed annual runoff ranged from +15.4 to -9.6 percent (appendix A) for the same stations shown in figure 6. The simulated and observed mean monthly data indicated a larger range of percent difference (appendix A). Ely (2003, p. 33) showed that the watershed model simulations “were less accurate at capturing the magnitude and timing of short-term (1- to 3-day) peak flows.” For this reason and the fact that the model is simulating mean daily flows rather than a shorter time step more suited to simulated instantaneous peak flows, the runoff simulated by the watershed model should not be used for peak-flow analysis.

The simulated runoff output from the watershed model is sent to ASCII files, with each row of data containing 1 day of output. The order of the listed variables (*segment_cfs* in this case) in the header part of the data-output file corresponds to the order of variable value in each row of data to the right of the date information. Following *segment_cfs* is the index number of the variable that relates the values to the specific location on the stream network (fig. 4), and the *tosegment* model variable is the segment downstream that receives the runoff from the indicated segment (table 3). The output file was copied to a spreadsheet and posted on the USGS Washington Water Science Center Methow Project Web site data page (*http://wa.water.usgs.gov/projects/methow/data.htm*).

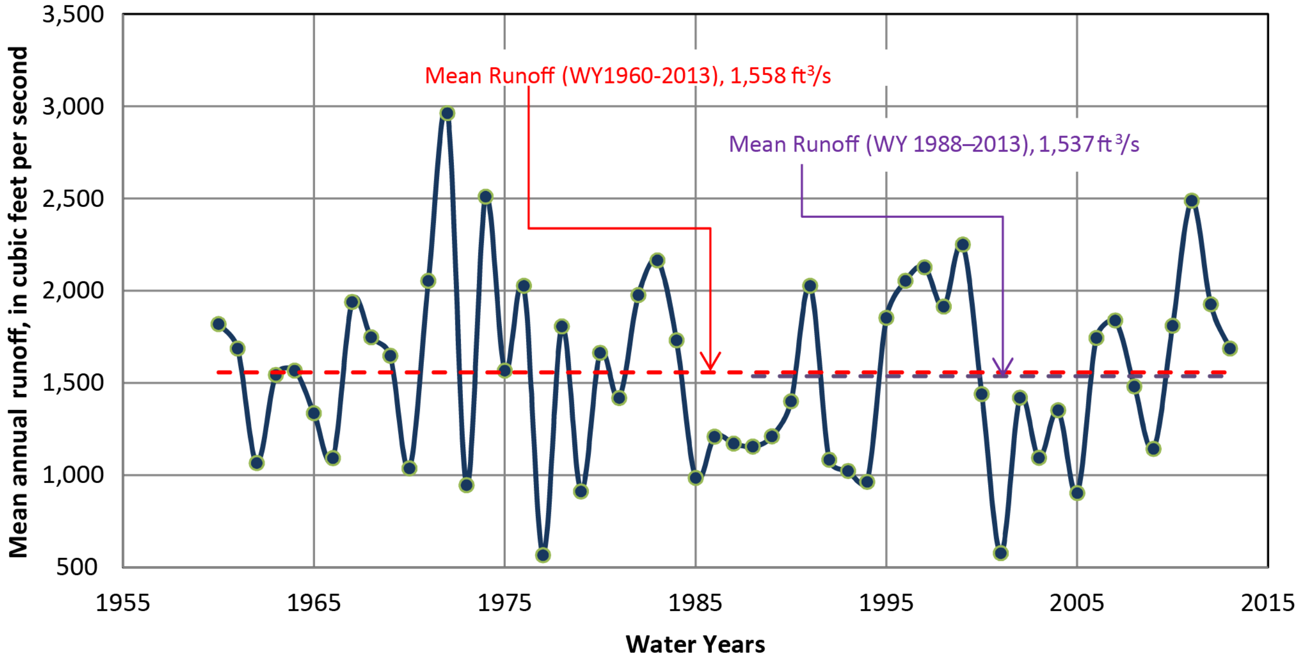


Figure 5. Graph showing annual mean runoff for Methow River near Pateros, Washington (USGS Station No. 12449950).

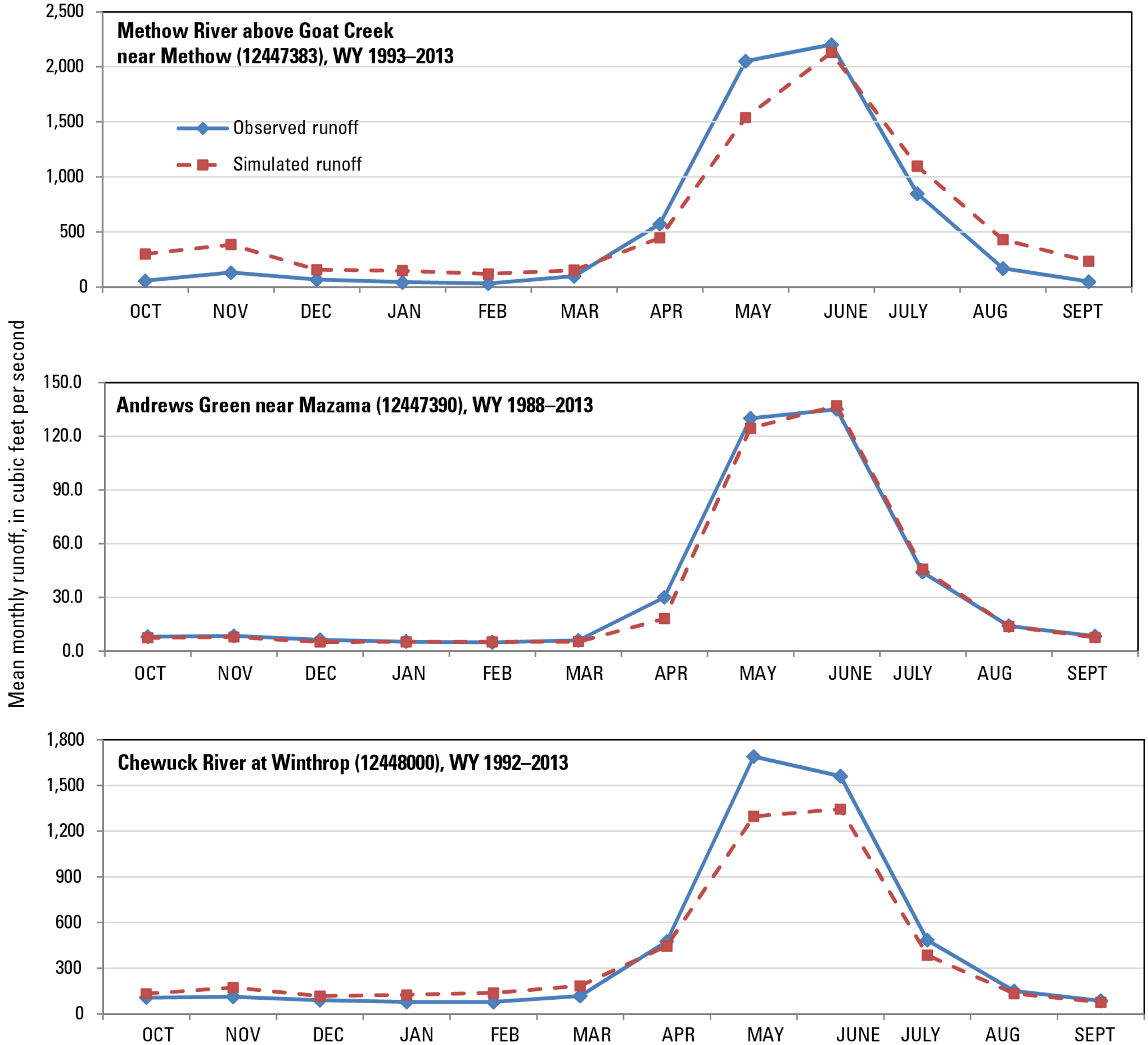


Figure 6. Graphs showing simulated and observed mean monthly runoff for indicated water years (WY) for six selected streamflow-gaging stations in the Methow River Basin, Washington.

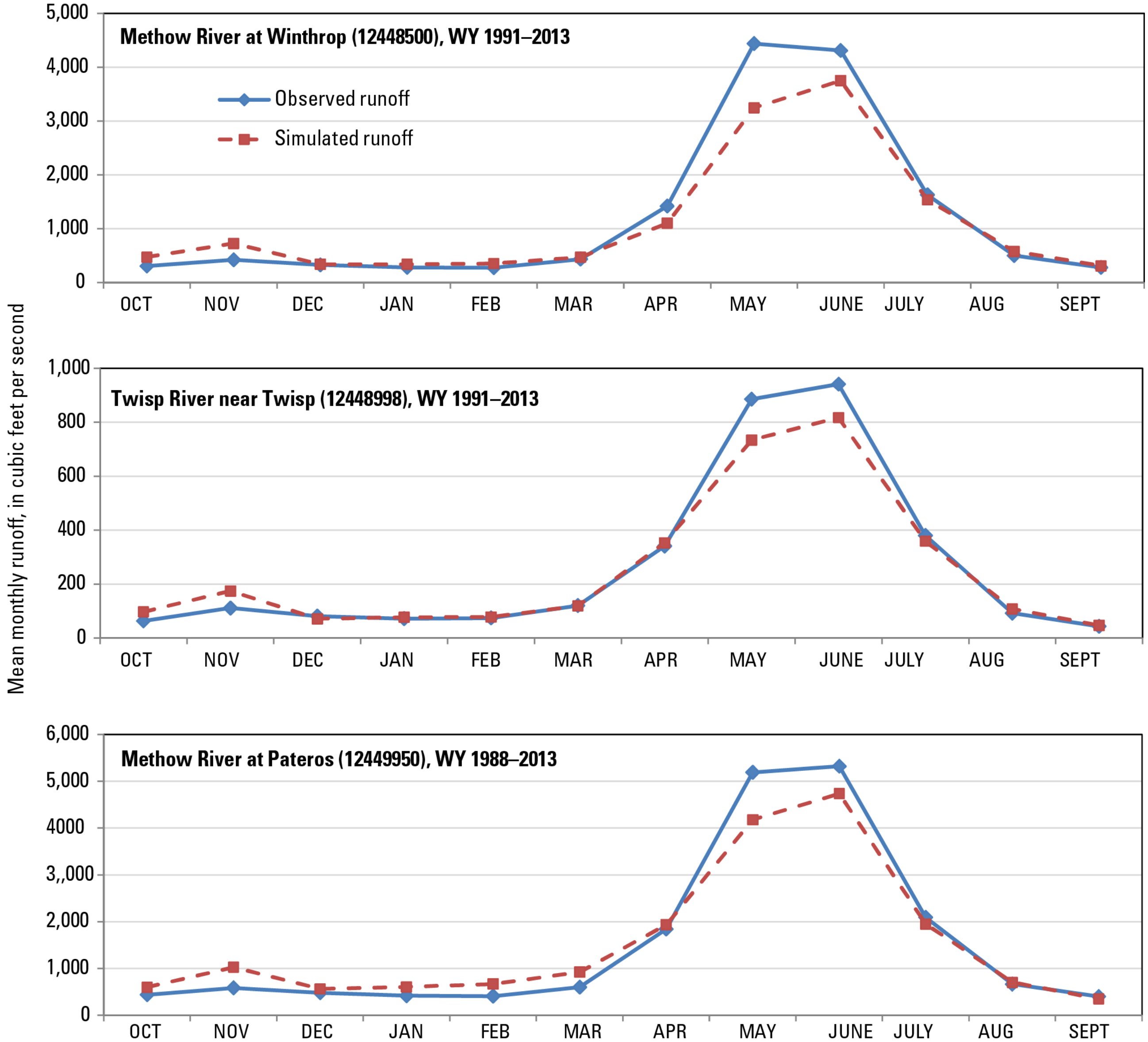


Figure 6—Continued.

Table 3. Index value for the flow-routing variables *segment_cfs* and *tosegment* in the Methow watershed model and the associated streamflow-gaging station and period of record if co-located or the stream location.

[A *tosegment* index value of "0" indicates the final segment. **Abbreviations:** USGS, U.S. Geological Survey; POR, Period of record; Misc. Meas., Miscellaneous discharge measurements; NA, not applicable]

segment_cfs index number	*tosegment* index number	USGS station No.	USGS- streamflow-gaging station (in bold) or stream location	POR, observed record water years
5	10		Lost River above Eurida Creek[1]	NA
10	11	12447370	**Lost River near Mazama**	2001–03
15	20		Early Winters Creek below Varden Creek[1]	NA
20	144	12447382	**Early Winters Creek near Mazama**	2001–03
30	149		Goat Creek	NA
35	36	12447387	**Wolf Creek below Diversion near Winthrop**	2001–03
40	158		Wolf Creek	NA
41	42	12447390	**Andrews Creek near Mazama**	1968–present
43	45		Lake Creek above Disaster Creek[1]	NA
44	64		Andrews Creek at mouth	NA
45	65		Lake Creek at mouth	NA
46	70		Twenty Mile Creek at mouth	NA
47	75		Falls Creek at mouth	NA
48	77		Eightmile Creek at mouth	NA
49	80		Boulder Creek at mouth	NA
62	64		Chewuch River below Meadow Creek[1]	NA
64	65		Chewuch River above Andrews Creek	NA
65	66		Chewuch River above Lake Creek	NA
70	71		Chewuch River below Twenty Mile Creek	NA
75	76		Chewuch River below Falls Creek	NA
77	78		Chewuch River below Eightmile Creek	NA
80	81	12447500	**Chewuch River Below Boulder Creek near Winthrop**	Misc. Meas. only
88	161	12448000	**Chewuch River at Winthrop**	1992–present
90	92		Twisp River above South Creek[1]	NA
92	94		Twisp River above Reynolds Creek[1]	NA
94	100		Twisp River above War Creek[1]	NA
96	100		Buttermilk Creek below West Fork[1]	NA
98	100		Little Bridge Creek near mouth[1]	NA
100	101	12448990	**Twisp River above Newby Creek near Twisp**	2001–03
104	105		Twisp just below 12448990	NA
109	110		Twisp just above 12448998	NA
111	112	12448998	**Twisp River near Twisp**	1976–present
112	171		Twisp River at mouth	NA
114	126		Libby Creek below Hornet Draw[1]	NA
116	117		Gold Creek below Foggy Dew Creek[1]	NA
117	127		Gold Creek below Middle Fork[1]	NA
118	127		South Fork below Rainy Creek[1]	NA

segment_cfs index number	*tosegment* index number	USGS station No.	USGS- streamflow-gaging station (in bold) or stream location	POR, observed record water years
120	121		Beaver Creek below South Fork Beaver Creek	NA
124	177	12449710	**Beaver Creek near Mouth near Twisp**	2001
125	180		Benson Creek at mouth	NA
126	186		Libby Creek at mouth	NA
127	191		Gold Creek at mouth	NA
128	193		McFarland Creek at mouth	NA
129	198		French Creek at mouth	NA
130	201		Squaw Creek at mouth	NA
131	203		Black Canyon Creek	NA
139	140		Methow Headwaters	NA
144	145		Methow River below confluence with Early Winters	NA
148	149	12447383	**Methow River above Goat Creek near Mazama**	1991–present
158	159		Methow below confluence with Wolf Creek	NA
162	163	12448500	**Methow River at Winthrop**	1912–present
165	166		Methow River below Bear Creek	NA
167	168		Methow River. near Airport	NA
172	173	12449500	**Methow River near Twisp**	1919–2013
177	178		Methow River below Beaver Creek	NA
186	187		Methow River above Goat Creek near Mazama	NA
191	192		Methow River below confluence with Gold Creek	NA
193	194		Methow River above McFarland Creek	NA
198	199		Methow River at confluence with French Creek	NA
204	205	12449950	**Methow River near Pateros**	1959–present
211	0		Methow River at mouth	NA

[1]New sites added to the flow-routing network for this report.

Summary

A collaborative Bureau of Reclamation (Reclamation)-U.S. Geological Survey (USGS) effort to incorporate a conceptual geomorphic-habitat model with a process-based trophic model (for a better understanding of the processes important to stream habitat for anadromous fish populations) will be tested in the Methow River Basin, and the effort requires runoff information at many stream locations in the basin. An existing watershed model was available to provide long-term simulated daily discharge data at many stream locations beyond what was available from the network of existing streamflow-gaging stations.

This report documents the changes that were made to the existing watershed model to accommodate the needs of the Reclamation-USGS effort to test the hybrid geomorphic-habitat/trophic model. It also provides some basic descriptions of the model (previous publications provide much more detail about the model). No changes were made to the parameter file of the watershed model that affected the simulation of runoff, except for the "activation" of some streamflow routing segments to augment the number of locations in the basin where runoff information could be simulated. Thirteen new locations were added for a total of 61 sites in the basin where runoff was simulated. The input data file that drives the watershed model was updated to include maximum and minimum daily air temperature and daily precipitation through water year 2013. Time series of simulated daily runoff for each of the 61 sites were generated for the period beginning in water year 1988 through the end of water year 2013 and were provided to the entire modeling team.

Comparisons of the simulated and observed runoff at six selected long-term streamflow-gaging stations showed that the simulated annual runoff was within +15.4 to -9.6 percent of the annual observed runoff. The simulated runoff generally matched the seasonal flow patterns, with bias at some stations indicated by over-simulation of the October–November late autumn season and under-simulation of the snowmelt runoff months of May and June.

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Appendix A. Simulated and Observed Mean Monthly and Annual Runoff for Six Streamflow-Gaging Stations for the Period of Record that the Station Was Active During Water Years 1988–2013

Water years 1993–2013	Methow River above Goat Creek near Methow, station No. 12447383						
	OCT	NOV	DEC	JAN	FEB	MAR	APR
Observed runoff	54	129	66	41	30	96	571
Simulated runoff	299	385	157	147	119	153	446
Percent difference	454.4	198.6	137.6	258.9	296.7	59.3	-22.0
	MAY	JUNE	JULY	AUG	SEPT	ANNUAL	
Observed runoff	2,050	2,200	847	167	47	516	
Simulated runoff	1,539	2,129	1,099	429	235	596	
Percent difference	-24.9	-3.2	29.8	157.0	399.4	15.4	

Water years 1988–2013	Andrews Creek near Mazama, station No. 12447390						
	OCT	NOV	DEC	JAN	FEB	MAR	APR
Observed runoff	7.9	8.4	6.2	5.2	4.8	5.9	30.0
Simulated runoff	7.4	7.8	5	5.1	5.1	5.2	18
Percent difference	-6.3	-7.1	-19.4	-1.9	6.3	-11.9	-40.0
	MAY	JUNE	JULY	AUG	SEPT	ANNUAL	
Observed runoff	130.0	135.0	44.0	14.0	8.2	33.4	
Simulated runoff	124.5	137	45.7	13.7	7.6	31.9	
Percent difference	-4.2	1.5	3.9	-2.1	-7.3	-4.4	

Water years 1992–2013	Chewuch River at Winthrop, station No. 12448000						
	OCT	NOV	DEC	JAN	FEB	MAR	APR
Observed runoff	106	112	89	78	78	117	476
Simulated runoff	132	173	118	124	137	183	445
Percent difference	24.1	54.5	32.1	59.0	76.2	56.7	-6.4
	MAY	JUNE	JULY	AUG	SEPT	ANNUAL	
Observed runoff	1,690	1560	484	150	85	420	
Simulated runoff	1,297	1345	385	133	76	379	
Percent difference	-23.2	-13.8	-20.4	-11.1	-10.0	-9.6	

Water years 1991–2013	Methow River at Winthrop, station No. 12448500						
	OCT	NOV	DEC	JAN	FEB	MAR	APR
Observed runoff	308	424	329	282	275	435	1,420
Simulated runoff	472	727	339	340	354	472	1,102
Percent difference	53.3	71.6	2.9	20.5	28.6	8.5	-22.4
	MAY	JUNE	JULY	AUG	SEPT	ANNUAL	
Observed runoff	4,440	4,310	1,630	500	280	1,202	
Simulated runoff	3,250	3,750	1,540	581	311	1,105	
Percent difference	-26.8	-13.0	-5.5	16.3	11.2	-8.1	

Water years 1988–2013	Twisp River near Twisp, station No. 12448998						
	OCT	NOV	DEC	JAN	FEB	MAR	APR
Observed runoff	63	111	81	72	74	120	341
Simulated runoff	97	174	71	77	78	119	353
Percent difference	54.0	57.0	-12.3	7.2	5.3	-0.8	3.4
	MAY	JUNE	JULY	AUG	SEPT	ANNUAL	
Observed runoff	885	941	380	92	43	267	
Simulated runoff	734	817	359	108	47	253	
Percent difference	-17.0	-13.1	-5.5	17.5	8.1	-5.3	

Water years 1988–2013	Methow River at Pateros, station No. 12449950						
	OCT	NOV	DEC	JAN	FEB	MAR	APR
Observed runoff	437	583	478	415	407	598	1,840
Simulated runoff	597	1,025	563	605	666	922	1,934
Percent difference	36.7	75.8	17.7	45.7	63.6	54.1	5.1
	MAY	JUNE	JULY	AUG	SEPT	ANNUAL	
Observed runoff	5,190	5,320	2,090	665	397	1,515	
Simulated runoff	4,180	4,738	1,948	700	348	1,520	
Percent difference	-19.5	-10.9	-6.8	5.3	-12.3	0.3	

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